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Prototyping the IRDS: An Airport Application

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INTRODUCTION

This report describes a prototype application of an American National Standards Institute/Federal Information Processing Standard to manage information about spatial data. The impetus for this effort emerged from the Information Technology Standards Workshop, March 1990, sponsored by the Geographic Information Systems (GIS) Standards Laboratory at the National Institute of Standards and Technology (NIST). Research and development of the prototype was conducted at the NIST and the Institute for Land Information Management, University of Toronto, an academic participant of the NIST GIS Standards Laboratory.

The Information Resource Dictionary System (IRDS) is a software standard for managing information on data (metadata). An IRDS defines data entities, identifies their locations and formats, establishes and describes the relationships between data entities. The IRDS also provides an extendable structure for accommodating new requirements, as well as an interface supporting the querying and updating of the dictionary contents. In general, the IRDS ensures the data security, maintenance, and integrity of the database it is supporting.

Spatial data refer to locational descriptions of geographic entities and/or their associated attributes. Locational descriptions are expressed by names, geographic codes, or by a coordinate reference system, e.g. latitude/longitude. Issues pertaining to spatial data are not limited to data capture, conversion, format, and exchange. The management of spatial data is also a crucial concern, a very rapid growth in GIS has greatly highlighted this issue.

GIS are computer systems for capturing, manipulating, displaying, and most importantly, analyzing spatial data. Typically, GIS rely on a database management system (DBMS). The IRDS, in support of the DBMS, facilitates the integration of spatial data on a GIS, the sharing of GIS data and applications between GIS, and the integration of a GIS with its own corporate computing environment. GIS are most effective when able to integrate spatial data from various sources. GIS applications and spatial data extend over a broad range of disciplines, consequently GIS users must be able to access and query metadata on a variety of spatial databases on dissimilar computer systems.

The importance of the IRDS to the GIS world is in providing data administration and management functionality. The IRDS is scalable from a data dictionary of a single database, to a data directory of many data dictionaries within an organization such as a federal agency, to a master data catalog of many data directories within the federal government. Potentially, the IRDS has a significant role to play in realizing the National Spatial Database Infrastructure of federal agency databases. This effort is currently envisioned by the Federal Geographic Data Committee (FGDC), consisting of more than 60 federal agencies.

Because much of the social, economic, and demographic data derived from federal sources are spatially referenced, GIS can use the IRDS to access, understand, and use such data more readily, thereby providing new data sources for GIS. To a large degree, the IRDS assists in evaluating spatial data for its fitness for use.

The need for data administration and management in GIS technology is becoming more evident as increasing data sharing occurs in earth science, corporate management, and consumer applications of GIS technology. Software standards, such as the IRDS, will rapidly assume greater and more prominent roles in data sharing. This report, presented in the Integration and GIS technical session at the 1991 Urban Regional Information Systems Association's (URISA) annual meeting, attained immediate acceptance as a milestone in GIS integration. Certainly, this pioneering study demonstrates not only the feasibility, but also, the great value of applying information technology standards to administer and manage geographic information resources.

Henry Tom
NIST GIS Standards Laboratory

ABSTRACT

The management of geographic information resources (GIRs) continues to be plagued by problems of monitoring, locating and controlling the array of geographic information in complex organizations. Software tools to support these functions are fundamental to any effort to maintain the integrity of geographic information as it changes. In addition, such tools are desirable when formalizing, then managing the integration of geographic information resources within an organization. One of the major approaches to this problem in the area of database systems has been development of the information resource dictionary (IRD) which contains meta-data. An Information Resource Dictionary System (IRDS) is a database of meta-data along with software and procedures for the creation and maintenance of the IRD. In 1989 the American National Standards Institute (ANSI) X3.138-1988 IRDS (ANSI-IRDS) was adopted as Federal Information Processing Standard 156 by the United States Government. ANSI-IRDS is intended to support the definition, management and control of mete-data. ***This study presents the first known attempt to actually apply ANSI-IRDS in the geographic information management domain.***

The application of IRDS to technical data management at an airport is used to study the capabilities of IRDS in a geographic data management context. Using the Entity-Relationship-Attribute (E-R-A) model upon which ANSI-IRDS is based, a geographic data model (GDM) of the GIRs involved in the facility alteration permit process was developed. Conversion of the airport GDM to the ANSI-IRDS was carried out at the National Institute of Standards and Technology. Development of the GDM and its conversion to an E-R-A model is discussed. Observations from this modelling effort will be presented. Special consideration is given to the demands that modelling GIRs made upon development of a Geographic-IRDS.

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1. INTRODUCTION

This report describes a cooperative project undertaken as part of a Research Participation Agreement with the Geographic Information Systems Standards Laboratory, National Institute of Standards and Technology, Gaithersburg and the Institute for Land Information Management, University of Toronto for research and development in the area of IRDSs and Geographic Information Systems (GISs).

IRDSs represent a new software tool which has the potential to control, describe and cross reference meta-data within a GIS. Relationships between geographic features may be constrained and integrity rules maintained, leading to efficiency in the storage and processing of geographic data in GISs.

1.1 Purpose

The main purpose of this project is to gain competency in the application of IRDSs to a GIS problem. This problem area is specific to airports. Our goal is to build a prototype Geographic Information Resource Dictionary System (GIRDS) in which it is possible to model:

- the maintenance of geographic data at airports in Canada;
- geographic data located on the Airside and Groundside of an airport;
- geographic data common to both the Airside and Groundside of an airport;

and control and constrain meta-data associated with airport geographic features and the maintenance of these features.

1.2 Scope

The project has seven main parts:

- Reviewing IRDS applications, conceptual modelling tools and the IRDS architecture.
- Identifying the role of IRDS in airport GIS.
- Reviewing the data stored by Canadian airports and the Facility Alteration Permit (FAP) process currently used for geographic data maintenance.
- Building Entity-Relationship models for airport geographic data and the FAP process.
- Converting this integrated GDM to an IRDS E-R-A model.
- Prototyping the GIRDS by building IRD Schema definition tables and IRD definition tables.
- Demonstrating and documenting the results.

1.3 Disclaimers

This project is a research venture in the area of IRDS and its application in GIS. It is to a large extent specific to geographic data management at an airport. Hence, it is driven by the author's view of geographic features on a specific airport. Therefore, this study is not intended to suggest a universally acceptable model.

Certain commercial products are identified in this report in order to adequately specify the procedures being described. In no case does such identification imply recommendation or endorsement by the National Institute of Standards and Technology or the Institute for Land Information Management, nor does it imply that the product identified is necessarily the best for the purpose.

1.4 Acknowledgements

I would like to thank the IRDS experts, Dr. Alan Goldfine and Ms. Thomasin Kirkendall, National Institute of Standards and Technology, for their guidance during the conversion period. Special thanks must also go to Mr. Bruce Rosen, Manager of the Data Administration Group for supporting this project. Many thanks also to Mr. Henry Tom, Manager, Geographic Information Systems Laboratory, National Institute of Standards and Technology, for providing me with the opportunity for working at this Institute.

I would also like to thank Mr. George MacFarlane, Head, Surveys and Mapping, Public Works Canada, Mr. Keith Conner, formerly the Technical Data Centre Manager, Toronto - Lester B. Pearson International Airport and Mr. Larry Monaghan, Northway Map Technology Limited, for providing supporting documentation.

The role of Dr. Vincent Robinson, Director, Institute for Land Information Management, who helped plan and supervise the project and provide the actual problem domain, was critical for the realization of this project.

2. DESCRIPTION OF THE APPLICATION

Airport managers spend millions of dollars each year in an attempt to manage their infrastructure by way of Capital Improvement Programs and Facility Alteration Permits (FAPs) (Robinson and Sani, 1990). Data obtained through these processes are transmitted to Technical Data Centre (TDC) managers for storage and dissemination, yet airports remain data rich and information poor.

In Canada, Federal government policy states that commercialization and self-sufficiency of airports are national objectives. To efficiently carry out their responsibilities and realize these objectives, airport managers must have access to up-to-date information.

Recognizing this, Transport Canada, Headquarters, contracted with the Institute for Land Information Management (ILIM), University of Toronto, to undertake a feasibility study for implementing GISs at airports (Robinson and Sani, 1990). This study, while concluding that GIS is feasible, noted that airports currently lack the ability to handle and analyze geographic relationships. It also noted that it is desirable to integrate information across multiple geographic data sets so that a consistent corporate set of geographic information resources exist at the TDCs which would facilitate on-going geographic data management at Canadian airports.

The concept of an airport GIS (AGIS) is relatively new. To date, this concept has not been extensively employed at North American airports (Robinson and Sani, 1990). However, many airports are now considering this technology in an attempt to manage what may be described as dynamic, complex environments which must address security, emergency, planning, engineering and environmental concerns. In addition, maintenance, commercial leasing and expansion activities must be coordinated and integrated.

A GIS allows managers to input, store, analyze, output and disseminate information. However, while most systems ensure topological consistency of data, a GIS system does not have software tools which design, monitor, locate, protect or control the data stored - a necessary requirement for data integrity. Collectively, these software tools are commonly referred to as an IRDS and are used for information resource management applications.

There have been **no** GIS related IRDS implementations reported to date. Some related efforts include the:

- modelling of the Land-Related Information (LRI) Dictionary/Directory System in Alberta to manage data effectively in the LRI System Network (Alberta Land-Related Information Systems Group, 1989);
- integration of a Dictionary/Directory (D/D) System in a centralized database environment and the necessary software interfaces to the centralized D/D to function as a distributed database management system (DBMS), (Allen et al, 1982);
- integration of a catalogue in the Spatial Data Transfer Standard (SDTS) to identify the location of modules within the transfer and to cross-reference the relationships between modules, spatial domain, maps, map layers and entities (Morrison, 1988).

An integration of technologies - GIS and the ANSI-IRDS - is proposed for this study. To achieve this integration, as a first step, Entity-Relationship models describing airport geographic features and their relationships is required. Entity-Relationship models are also required of the airport geographic database maintenance process currently administered through the use of FAPs, in order that an integrated approach to geographic data management is achieved. This comprehensive airport data model is referred to as the GDM.

Conversion of the airport GDM to the ANSI-IRDS was carried out at the United States Department of Commerce, National Institute of Standards and Technology, Gaithersburg, Maryland, USA. The conversion involved, as a first step, re-defining the E-R data model in terms of the IRDS E-R-A model in order that entity-types and relationship-types are easily identified. Next, an empty IRD had to be created and the IRD Schema defined prior to compiling the ANSI-IRDS commands. Section 11 details this process.

3. INFORMATION RESOURCE DICTIONARY SYSTEM CONCEPTS

Wertz describes a data dictionary system as a computerized database of meta-data (data about data), together with software and procedures used to create and maintain the dictionary database (Wertz, 1989).

An Information Resource Dictionary (IRD) or data dictionary, is a **highly structured type of database** which can be used to design, monitor, locate, protect and control information resources in information systems (Law, 1988).

Data dictionaries are fundamentally different from databases. Databases hold the data values stored for data items, while a data dictionary contains information about data items. Examples of information about a data item that a data dictionary can support are:

- category of the data item;
- relationships of the data item to other data items;
- when and by whom it was defined;
- when and by whom it was modified;
- total number of modifications;
- description of the data item such as its format;
- databases or files in which the data item appears;
- location of the data item in the database or files;
- set or range of valid data items permitted for a data item in the database (Law, 1988).

An IRDS is a software system that allows IRD applications to be developed.

3.1 Need for an IRDS

Today, many organizations have large volumes of data stored in hard copy or on disk. Data is often not validated and may be incorrect or incomplete. Organizations employing geoprocessing systems may suffer from both operating and data related problems. Operating problems may be characterized by redundant data, redundant processing, complexity and interdependence, inflexibility and lack of adequate documentation. Data related problems are characterized by inconsistent data, inconsistent representations and codes, inconsistent timing, lack of understanding among systems, lack of good data and lack of organization. Many of these operating and data related problems are difficult to quantify (Wertz, 1989).

Most organizations concerned with effective information management, data processing, data conversion and communications adopt Information Resource Management (IRM) policies. These policies coordinate the development, operation and maintenance of an organization's information system. An IRDS provides many functions useful for data administration, as shown in Table 1, by providing a medium for meta-data description, cross references and consistency checking (Law, 1988).

TABLE 1 - IRDS applications

APPLICATION	DESCRIPTION
Data Element Standardization	An IRD supports the standardization of data element names, definitions and relationships, which ensures consistent data elements are stored in the database and that files can be accessed by multiple users and programs.
Database Validation (DV)	DV is accomplished by building data integrity rules in an IRD. For example, a range of values may be defined for a particular entity-type that are permissible for any instance of such an entity.
Data Resource Management (DRM)	DRM may be performed by an IRD to describe the use, location and mode of data representation of on-line geographic databases, computer graphic images, archived data on disk and database reports.
System Resource Configuration Management (SRCM)	SRCM involves tracking structures and changes for all resources used in one or more information systems. An IRD can be used as both a directory to locate data or item sources, and as a dictionary to describe configuration item information.
Hardware Configuration Management (HCM)	HCM describes the use, location and structure of computer and communications hardware used to support an information system. An IRD can be designed as a hardware directory to list and locate hardware and peripherals required for computer and communications systems maintenance, replacement and repair.
Software Configuration Management (SCM)	SCM describes the use, location and structure of reusable software items. To support this task, an IRD can be used as a Source Code Directory that lists and locates the programs, subroutines, functions, software utilities and languages available in one or more software libraries (Law, 1988).

4. DATA MODELLING FOR IRDS

A data model is a collection of conceptual tools for describing data, relationships, semantics and constraints (Korth and Silberschatz, 1986). The ANSI-IRDS is based on the Entity-Relationship-Attribute (E-R-A) model which is an extension to the Entity-Relationship (E-R) model.

4.1 Entity-Relationship Model

The E-R model views the world as consisting of entities and relationships. The model achieves a high degree of data independence, which means that applications are immune to changes in storage structure and access strategy (Date, 1986). It is based on set theory and relational theory which formulates the definition of a desired relation in terms of those given relations. It may also be used as the framework from which the Relational and Network models are derived (Chen, 1976).

4.1.1 Mapping Constraints

The connectivity of a relationship specifies the mapping of the associated entity occurrences in the relationship. Values for connectivity are either "one" or "many". The actual number associated with the term many is called the **cardinality** of the connectivity. The basic types of connectivity are one-to-one (1:1), one-to-many (1:N) and many-to-many (N:N) (Chen, 1976). Figures 1-4 illustrate these concepts. Partial relationships between entities are defined by upper and lower cardinalities.

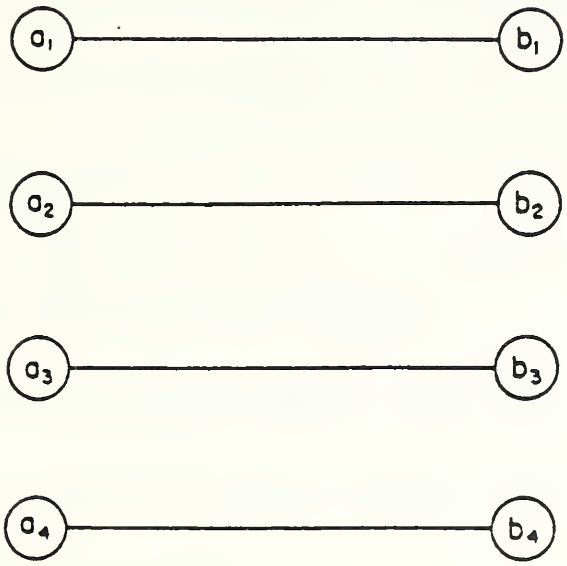

FIGURE 1
ONE-TO-ONE RELATIONSHIP

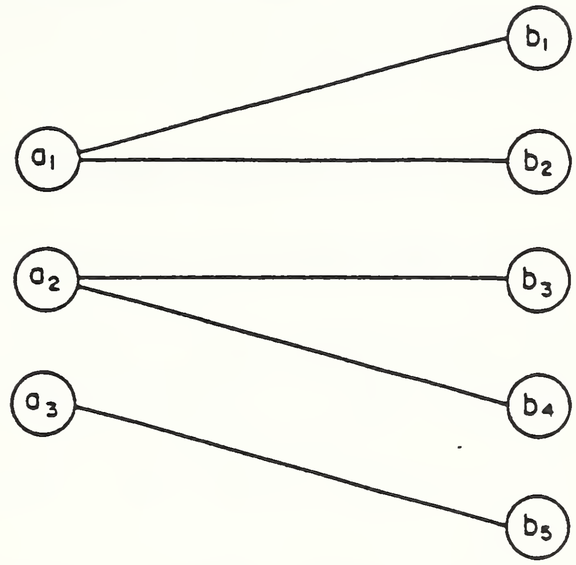

FIGURE 2
ONE-TO-MANY RELATIONSHIP

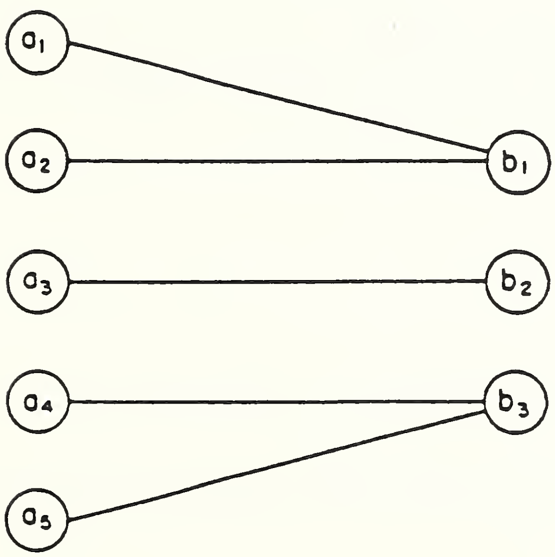

FIGURE 3
MANY-TO-ONE RELATIONSHIP

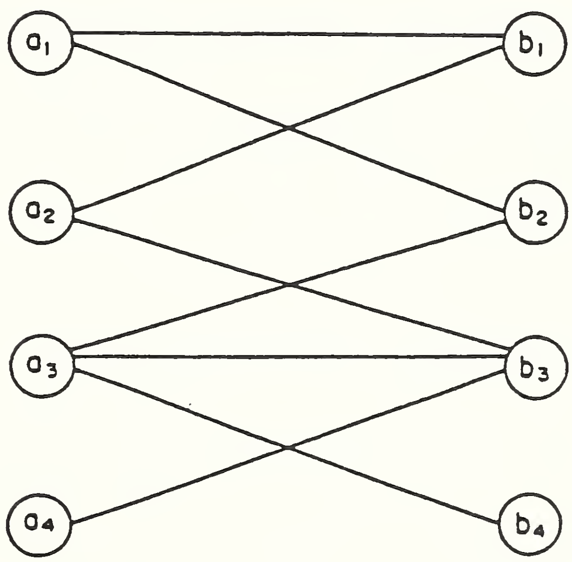

FIGURE 4
MANY-TO-MANY RELATIONSHIP

Figure 1 - 4 - E-R relationships

When the lower bound is one or many, it is a total or obligatory relationship. When the lower bound is zero, it is a partial relationship.

4.2 The Extended-Entity-Relationship Model

The E-R model, although modified and extended by others to provide greater semantics, remains the premier model in conceptual design for communicating fundamental data and relationship definitions with the end user (Teorey et al, 1986). Using the E-R model as a conceptual schema representation, however, has proved difficult because of limitations of the original modelling constructs. For example, data integrity involving null attribute values requires defining relationships such that a null set on either side of the relationship is either allowed or disallowed. Also certain relationships of degree higher than 2 (binary) may be present and are awkward when represented in binary form. The Extended-Entity-Relationship (E-E-R) model provides alternate representations for these commonly used concepts and is compatible with the simplicity of the original E-R model (Teorey et al, 1986). This model is now referred to as the Entity-Relationship-Attribute (E-R-A) model (Rosen and Law, 1990).

4.2.1 Degree of Relationship

The degree of relationship is the number of entities associated in the relationship. An n-ary relationship is of degree n. Unary, binary and ternary relationships are special cases where the degree is 1, 2 and 3 respectively.

4.2.2 Connectivity of a Relationship

Constructs for connectivity in the E-R model are 1:1 (unary and binary relationship), 1:N (unary and binary relationships) and N:N (unary and binary relationships). The E-R-A model supports n-ary relationships for $N > 2$.

4.2.3 Diagramming Techniques

The E-R and E-R-A diagrams are graphic portrayals of E-R algebra. Figure 5 illustrates the components of E-R and E-R-A diagrams.

MODEL	CONCEPT	
E-R	ENTITY	
E-R-A	WEAK ENTITY	
	RELATIONSHIP	
	ATTRIBUTE	
	LINKAGES	
E-R	CONNECTIVITY	
E R A	1:1	OBLIGATORY
	1:N	OBLIGATORY
	N:N	OBLIGATORY
	0:1,0:1	PARTIAL
	0:1,0:N	PARTIAL
	0:N,0:N	PARTIAL
E-R-A	MEMBERSHIP CLASS OPTIONAL	
	GENERAL HIERARCHY ISA	

REPRESENTATION

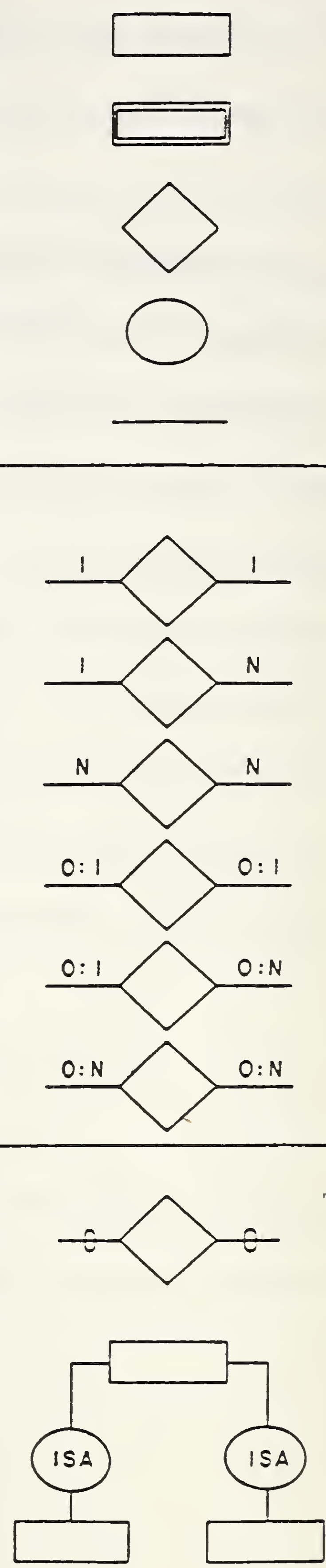

Figure 5 - E-R and E-R-A diagramming techniques

5. THE AMERICAN NATIONAL STANDARDS INSTITUTE INFORMATION RESOURCE DICTIONARY SYSTEM

An IRDS is a set of software specifications for a standard data dictionary system. The ANSI-IRDS Standard establishes the requirements for a software tool, which can be used to control, describe and facilitate the use of an installation's information resources. The description of the information resource is a specific type of information referred to as meta-data. The ANSI-IRDS is intended to support the definition, management, and control of meta-data. It was approved by the American National Standards Institute, Inc. in 1988, and was published as ANSI Standard X3.138-1988. On April 5, 1989, it was adopted as Federal Information Processing Standard 156 (FIPS 156).

5.1 Purpose of the ANSI-IRDS Standard

The purpose of the FIPS ANSI-IRDS Standard is to provide the United States Federal government with a data dictionary to support all phases of the system life- cycle. The ANSI-IRDS Standard is estimated to save the U.S. Federal government over $120 million (in constant 1983 dollars) in benefits by the early 1990's (Chipman and Fiorello, 1983).

5.2 Organization of the ANSI-IRDS Standard

ANSI X3.138-1988 is organized into 7 modules: 1) Core Standard, 2) Basic Functional Schema, 3) IRDS Security, 4) Extensible Life Cycle Phase Facility, 5) Procedure Facility, 6) Application Program Interface and 7) Entity Lists. All the specifications of ANSI X3.138-1988 apply to this standard with one exception: In the chapter "Requirements for a Conformant Implementation" of ANSI X3.138-1988, it is stated that each of Modules 2 through 7 are optional. All implementations of FIPS 156, however, must include the Basic Functional Schema.

5.3 The Architecture of the ANSI-IRDS

As shown in Figure 6 , the ANSI-IRDS Database can be viewed as a four-level architecture in which information specified at one-level describes, and potentially controls, information stored at the next lower level. Thus, one-level defines the types of "objects" which can be described at the next lower level, and that level contains the "instances" of those types.

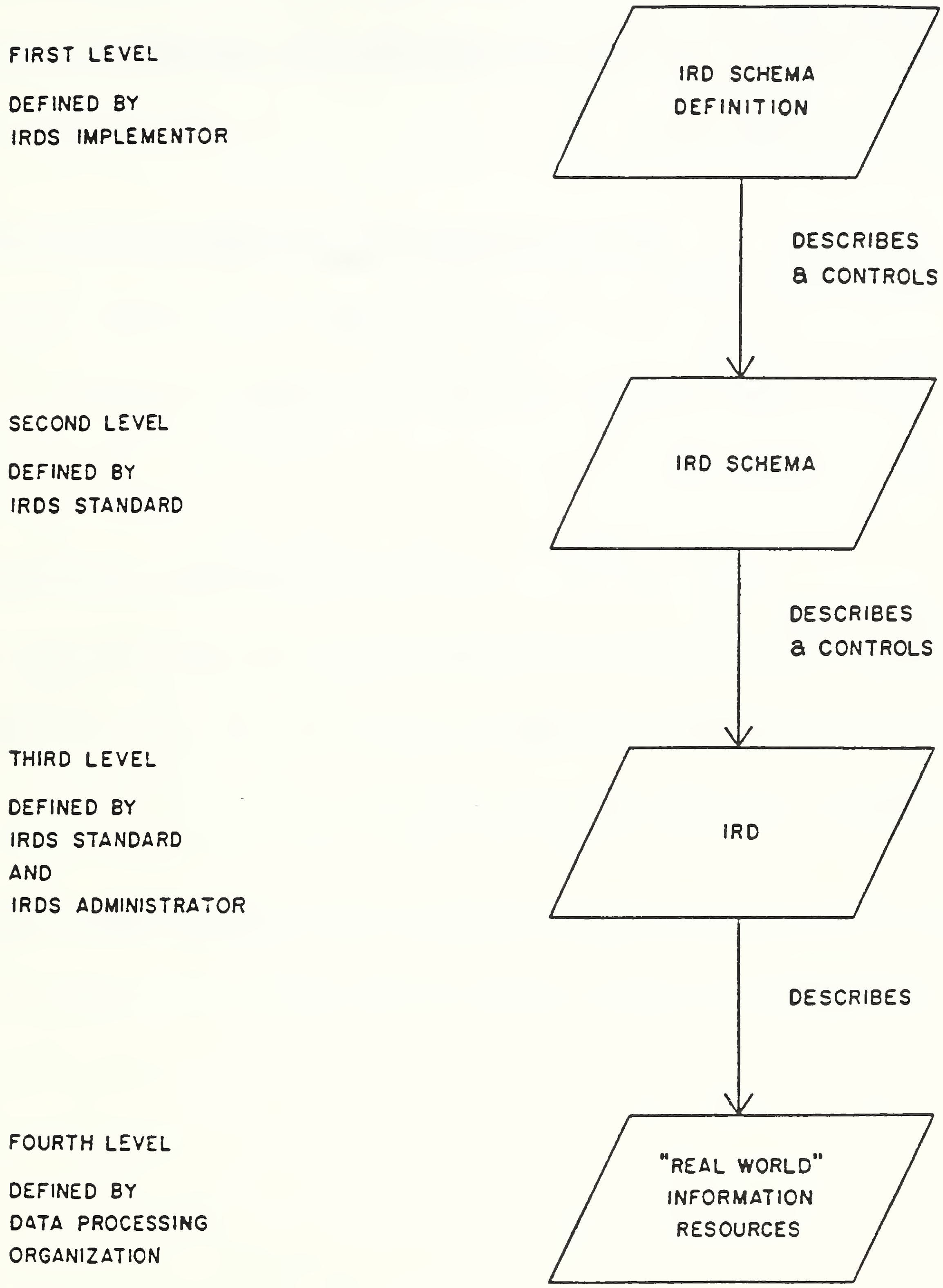

Figure 6 - The four level architecture of the ANSI-IRDS

The top level of the four-level architecture is defined by the ANSI-IRDS implementor. This level contains the types of objects and relationships which can exist and can be defined at the IRD Schema level. These types are referred to as meta-entity-types, meta-relationship-types and meta-attribute-types.

The second level is referred to as the Information Resource Dictionary (IRD) Schema. This level defines the types to be included in the IRD. It also defines various control mechanisms, including naming rules, defaults and validation information for the IRD contents.

The third level, the IRD, describes the environment being modelled by the objects in the environment and the association among these objects; the object descriptions are called entities, and the association descriptions are called relationships. This level also describes the properties of the objects and their associations, i.e. their attributes.

The fourth level, not described in the standard, is the information resources environment. It is the "real world information resources" the descriptions of which exist in the IRD.

5.4 The ANSI-IRDS Data Model

The ANSI-IRDS uses an E-R-A data modelling approach to describe the contents of both the IRD and the IRD Schema. The ANSI-IRDS data model is distinguished by the following characteristics (Table 2):

TABLE 2 - Characteristics of the ANSI-IRDS data model

Characteristics	**Explanation**
Binary E-R-A	Any relationship may connect at most two entities.
Relationships are directed associations	Relationship of entity A → B is not the same as B → A.
Both entities and Relationships may have attributes	The access-name uniquely defines entities and relationships.
Attribute grouping	One level of attribute grouping permitted.
Strongly typed	Entities, relationships and attributes may have one type only.

The typing of entities, relationships and attributes provides the following (American National Standard Institute, Inc. 1988):

- For an entity, the entity type defines how the entity can be named.

- The relationship-type defines:

  (i) whether or not a given pair of entities can be associated.

  (ii) how the relationship can be specified.

  (iii) whether or not there can exist more than one relationship of a given type associating the same two entities.

- For an attribute, the attribute type defines how the attribute is identified and what maintenance operations can be performed against it.

- For an attribute-group, the attribute-group-type defines:

  (i) which types of attributes can be grouped.

  (ii) the ordering of attributes within the group.

  (iii) which attributes can be specified whenever there are multiple entries of the attribute-group-type within a given entity or relationship.

Any given entity, relationship, relationship-class, attribute, or attribute group is called a descriptor. In order to distinguish between those descriptors within the IRD and the IRD Schema, the following terminology is used:

The term IRD descriptor refers to any descriptor which resides in the IRD. The term IRD Schema descriptor refers to any descriptor which resides in the IRD Schema. The terms entity, relationship, relationship-class, attribute and attribute-group are IRD descriptors.

In order to distinguish IRD descriptors from IRD Schema descriptors, the prefix meta is used in reference to the IRD Schema. Thus the terms meta-entity, meta-relationship, meta-relationship-class, meta-attribute and meta-attribute-group are IRD Schema descriptors.

Therefore, every entity-type, relationship-type, attribute-type, and attribute-group-type represented in the IRD must also be represented in the IRD Schema by a meta-entity-type, meta-relationship-type, meta-attribute-type and meta-attribute-group-type. Significant differences between the IRD Schema and the IRD are shown in Table 3.

TABLE 3 - Differences: IRD Schema and IRD

IRD Schema	IRD
Types of meta-entities, meta-relationships and meta-attributes are predetermined by ANSI-IRDS Standard.	Entity-types, relationship-types, and attribute-types are determined by user
Meta-relationship-type is completely defined by a pair of entity-types	Multiple relationship-types involving the same pair of entity-types
Meta-relationship-types constrained to (0,N:0,1), (0,N:2) or (0,N:0,N)	All relationship-types are unconstrained (0,N:0,N)

The ANSI-IRDS use of the E-R-A model is defined in terms of data typing. The structure of each IRDS application, known as an IRD, is defined in terms of entity-types, relationship-types, attribute-types and attribute-group-types. Each entity in the IRD therefore has a unique type referred to as the entity-type of the entity. Similarly, each relationship in the IRD has a unique type called the relationship-type. For a given entity-type or relationship-type, there is a defined set of attribute-types and attribute-group-types associated with the entity-type or relationship-type, and every attribute and attribute-group of an entity or relationship of the particular type must correspond to one of these attribute-types or attribute-group-types. The definition of these types in an IRD Schema provide the framework on which the data contents of the dictionary will be based.

5.5 Definition of the Standard ANSI-IRDS

The ANSI-IRDS is composed of seven modules (American National Standard Institute, Inc., 1988). The Core module consists of the IRD Schema Description, the Minimal IRD Schema, either the Command Language Interface or Panel Interface or both and the IRD. The ANSI-IRDS supports commands for IRD Schema maintenance by allowing the user to add, modify, and delete entities and relationships in the IRD. It also allows output of the IRD, and IRD-IRD interface commands.

5.5.1 The IRD Schema

The IRD Schema describes the structure of the IRD. For every entity, relationship, attribute, and attribute group that can exist in the IRD, the IRD Schema will contain the corresponding entity-type, relationship-type, attribute-type and attribute-group-type. The standard specifies specific entity-types, relationship-types and attribute-group-types. These types are organized into the Minimal Schema of Module 1 and the Basic Functional Schema of Module 2.

The IRD Schema is important because the ANSI-IRDS specifications include facilities to enable an organization to extend the Minimal Schema (Module 1) or Basic Functional Schema (Module 2). This means that an organization can add additional entity-types, relationship-types, attribute-types and attribute-group-types to satisfy its needs.

5.5.2 The Minimal Schema

Software conforming to the ANSI-IRDS specifications must include the Minimal Schema, a collection of entity-types, relationship-types, attribute-types, and other IRD descriptors necessary to establish control over the IRD Schema and the IRD. For example, the Minimal Schema includes the entity-types IRD-USER, IRD-VIEW and IRD-SCHEMA-VIEW, the relationship types IRDS-USER-HAS-IRD-VIEW and IRDS-USER-HAS-IRD-SCHEMA-VIEW, and the attribute-type DEFAULT-VIEW, which are used to control access to the contents of the IRD and the IRD Schema. The attribute-types ADDED-BY, LAST-MODIFIED-BY, and NUMBER-OF-TIMES-MODIFIED, and the attribute-group types. DATE-TIME-ADDED and DATE-TIME-LAST-MODIFIED automatically document information concerning changes to the IRD and its Schema (Goldfine and Konig, 1988).

The relationship-types IRDS-USER-HAS-IRD-VIEW and IRDS-USER-HAS-IRD-SCHEMA-VIEW are associated with the attribute-type DEFAULT-VIEW, which can have, at most, a single attribute per relationship. The Minimal Schema does not contain any attribute-group-types associated with any relationship-type.

Associated with the Minimal Schema are the following meta-entities - Attribute-Type-Validation-Data, Attribute-Type-Validation-Procedure, IRD-Partition, IRDS-Defaults, IRDS-Limits and IRDS-Reserved-Names. The Type-Validation meta-entities validate attributes prior to entry in the IRD. The Defaults meta-entity is used to establish organizational defaults for assigned name-lengths, for the number of occurrences of entities of a particular type, and for attribute-lengths. The Limits meta-entity is used to establish organizationally defined limits and initial values for name-lengths, dates and times, and values of other meta-attribute-types. The Reserved-Names meta-entity specifies the assigned-access-names of those entities and meta-entities that are required by the ANSI-IRDS Specifications.

The Minimal Schema contains one NAMES meta-entity called NAMING-RULES. It is intended for user documentation and contains a description of the rules for naming entities.

5.5.3 Command Language and Panel Interface

An ANSI-IRDS implementation may include either a Command Language or Panel interface. Currently, only a Command Language Interface has been implemented on the prototype developed at National Institute of Standards and Technology (NIST), Gaithersburg (Kirkendall, 1990). It supports user interaction with the ANSI-IRDS in both batch and interactive modes. The Panel Interface provides the ANSI-IRDS user with a set of logical screens or panels. These panels are further structured into panel trees or panel areas.

5.5.4 The IRD

The ANSI-IRDS provides an IRD-IRD interface to: (i) allow movement of data from one standard ANSI-IRDS implementation to another; (ii) create an empty (IRD); (iii) to check compatibilities of Schemas prior to data transfer; and (iv) import a previously exported IRD Schema and an IRD subset into the target environment.

The Core ANSI-IRDS contains four facilities for creating and maintaining the IRD and reporting on its contents. There are facilities for (i) Versioning - the ability to track each revision as a distinct entity in the IRD, (ii) Life Cycle Phases - the ability to document the life cycle of an entity, (iii) Quality Indicators for entities and (iv) IRD-Views for supporting project-oriented activities.

6. INFORMATION RESOURCE DICTIONARY SYSTEM AND GEOGRAPHIC INFORMATION SYSTEM

A GIS is a set of tools for collecting, storing, retrieving, transforming and displaying spatial data for a particular set of purposes (Burrough, 1986). Geographical data describe objects from the real world in terms of:

- their position with respect to a known coordinate system;
- their attributes that are related to position; and
- their geographic relationships.

An AGIS is used to integrate, manage and analyze airport site data. As with any GIS, it consists of three components - computer hardware, application software and a proper organizational context (Burrough, 1986).

Some applications of AGIS include:

- integrating geographically-referenced information and description of available areas for leasing at any given time based on proposed airside and groundside expansions.
- integrating geotechnical, geographical, environmental and capital project information so that an automated, or semi-automated screening procedure can exploit project drawings and surrounding as-built drawings. This integrated information will support timely and complete environmental audits.
- managing changes in the physical boundaries of the airport and relating those changes to responsibilities for land/or buildings for input to Airport Maintenance Management Systems.

- enhancing the consistency and conformance checking process in Planning Departments by ensuring that changes which occur through the FAP process is in accordance with Area Master Planning documents.

- relating ground transportation infrastructure such as roadways, parking lots and curbs to survey data to assist in the design of ground transportation facilities.

- routing of, and determining response times for emergency vehicles.

- locating isolation and staging areas for security purposes (Robinson and Sani, 1990).

6.1 Role of the ANSI-IRDS in Airport GIS

Airports are dynamic environments that serve millions of travellers each year. Information collected and maintained by each site is extensive, both in range and volume. As an example, databases at Toronto - Lester B. Pearson International Airport (LBPIA) concern inventories on site, permitting facilities, enforcement actions and maintenance activities. The inventories database is estimated at one to two hundred megabytes (MB).

Airport databases have not been managed as a corporate resource (Robinson and Sani, 1990). At all large airports, databases have been created by allowing separate departments and systems to collect and handle information independently. Unguided development of databases has led to inconsistent data capture, inconsistent storage of data elements and inadequate definition of non-graphic data. It has also contributed to the fact that data shared across organizational boundaries does not always meet user requirements for consistency. Therefore managers often obtain inconsistent views of various operations in their organization. As a result, little confidence is placed in the data by decision-makers (Robinson and Sani, 1990).

6.2 The Role of an ANSI-IRDS/GIS in Airport Geographic Data Management

GISs collect, store, manage and manipulate data, and provide a means for importing and exporting information. Their main function in an organization is to produce information from data. This necessitates data validation and consistency checking. GISs can generally accomplish these tasks in a narrow application domain, but not across an enterprise.

The following roles have been identified for the ANSI-IRDS in an AGIS. They allow TDC managers to build a dictionary of airport facilities which may be cross-referenced and at the same time ensure data security, transfer, maintenance and integrity.

6.2.1 Naming of Data Entities

An airport is composed of telecommunication, navigational and related support equipment which is associated with runways. Examples of these are Instrument Landing Systems (ILS), Glide Path (G/P) and Ceilometer respectively. There are also navigation aids not associated with runways. For example, Area and Airport Surveillance Radar (AASR) and Secondary Surveillance Radar (SSR) - which are located airside. Equipment such as

Approach Slope Indicator Systems (ASIS) which provide a safe minimum wheel clearance over the runway threshold and a safe margin clear of all obstacles when on final approach, may be installed or replaced at airports. For example, Visual ASIS (VASIS) are provided to serve the approach to a runway when one or more of the following conditions exist:

- the runway is not equipped with electronic G/P information and is used on a regular basis for jet carrier operations;
- the pilot of any carrier who may have difficulty judging the approach due to inadequate visual guidance over water or featureless terrain or misleading information produced by deceptive surrounding terrain or runway slopes;
- objects in the approach area which may cause serious hazard to a carrier descending below the normal approach path;
- unusual turbulence occurring in the approach area, and/or physical conditions at either end of the runway which may present a serious hazard to a carrier which undershoots or overshoots the runway (Air Navigation Systems Requirements Branch, 1985).

Two-bar VASIS is being phased out and will cease to be a standard visual approach slope indicator system on January 1, 1995 (Air Navigation Systems Requirements Branch, 1985). In the meantime, Precision Approach Path Indicator Systems (PAPIS) is an alternative to VASIS. This upgrade was carried out progressively at LBPIA from 1987 to 1989. Although they are no longer operational, the VASIS have not been removed from the airside; consequently, their position and attributes are maintained in the geographic database.

An AGIS stores the coordinates and attributes of each piece of equipment. Database queries on the equipment name, its acronym or its replacement name cannot be performed unless each entity in the database is keyed with non-graphic attributes to facilitate its identification; for example, equipment name, alternative name(s) and upgrade name.

The ANSI-IRDS provides a mechanism that allows entities to be given an access name, a descriptive name and alternative names. Naming conventions for the format and content of data entity names can be enforced by the TDC manager to help establish consistency checking of data throughout the organization. This results in greater efficiency through reduced data handling as the number of discrete data elements is reduced. It also reduces confusion among both staff and management, as communication is enhanced (Newton, 1987).

6.2.2 Security

Airports GISs can explicitly store geographic data on the location of airport facilities. These include air terminal buildings (ATBs), underground tunnels, access roads, bomb disposal areas, security locations, etc. They may also store explicit relations between these features and attribute data describing facilities. However, they cannot protect or secure airport data.

Airports have become targets for terrorist activities in recent years. As a result, data on these facilities might be classified as security plans are based thereon. In addition, access to hardware platforms and software tools must be restricted.

The ANSI-IRDS security module allows conventions on assigning security to be defined. For example, a description of what types of personnel should have what types of permissions to read, write, add, modify or delete what types of meta-data can be assigned.

6.2.3 Data Transfer

TDC managers receive and disseminate data from/to airport clientele, consultants, government investigating agencies and adjoining municipalities. Data may be received or transmitted in various formats and may, or may not, be created on systems identical to those of the TDC. Each system has its own commands for representing geometric entities and these commands must be identified and processed for a successful data conversion. GISs provide data conversion packages to handle formats provided by other vendors. However, very few conversion packages, if any, provide a satisfactory solution to the conversion of non-standard geometric entities; for example, ellipses and complex curves. Therefore, most conversions are carried out in an ad hoc manner.

The ANSI-IRDS standard provides mechanisms for documenting non-transferrable geometric elements between systems and alternative commands which are used in their representation. When linked with an AGIS, the ANSI-IRDS could verify the representation of entities in the interchange format prior to conversion or dissemination of data.

6.2.4 Data Management and Maintenance

An AGIS contains relationships between entities which must be preserved if integrity is to be maintained. These relationships may have to be changed in cases where a feature has been removed, replaced or modified. Decisions about data and actions made as a result of these decisions need to be recorded and preserved. The ANSI-IRDS allows these types of decisions to be captured and stored by using the Basic Functional Schema to extend relationships between entities, relationships and elements. The storing of this information can be of value to airports where there is a large turnover in staff or in instances where key personnel resign.

The ANSI-IRDS supports versioning, which permits revision numbers to be assigned to changing versions of each entity as part of the access name. Each entity revision is stored separately in the ANSI-IRDS as a separate entity. This means that in TDC management, an audit trail is provided on updates and the history of an entity can be reviewed, if required. Time stamping of the data entities in the AGIS is also achieved with the IRDS as each entity accessed has meta-attributes of system-time and system-date recorded automatically.

6.2.5 Database Integrity

Most GISs contain a tool box of commands which allow topologic relationships to be established between geometric entities. Typically, they do not provide the capability to automatically constrain relationships or provide for checking their integrity. For example, on an airport, an accessway intersects a taxiway but does not intersect a runway. An IRD provides for data consistency checking rules to be incorporated into an AGIS. For a particular entity type, the user can define data integrity constraints and rules such as direct or associated relationships between an entity or a range of values or a particular set of values that are permissible for any instance of such an entity in the database. An example of a constraint and rule is - storm pipe-links to-storm manhole and overt elevation of storm manhole > invert elevation of storm pipe.

6.2.6 Data Processing

TDCs undertake geographic information processing for various airport groups. Some of these processes are repetitive and include the use of common data sets and the following GIS functions:

- Integration of multiple geographic data sets
- Network analysis - tracing, shortest path
- Proximity distance
- Buffering
- Terrain slope computation
- Point-in-polygon search

Often, in environments such as the LBPIA TDC, where on average 15 requests for information are handled each day, by four or five individuals, it is not uncommon to find duplicated efforts in the processing of geographic data. An AGIS by itself, will not provide the tools to monitor and identify these duplicated efforts.

To maintain efficiency in a data processing environment, it is essential that standardized procedures be developed and maintained. IRD Schemas can be developed to ensure that users perform processes in a certain sequence using specified tolerances.

7. METHODOLOGY

In this Chapter, the concept of a TDC is discussed and the rationale for selecting and modelling the LBPIA-TDC, FAP process and the GIRDS for airport geographic data is presented.

7.1 Concept of a Technical Data Centre

The TDC at airports in Canada grew out of the concept of establishing Technical Drafting Centres for the integration of Architectural and Engineering functions for technical data management. This concept was supported by a feasibility report on Computerized Drafting from the National Facilities Committee on Computer Applications in October 1982 and a pilot project was set up in the Ontario Construction Branch office in Toronto in October 1983 and was completed October 1984 (Airport Facilities Branch, 1985).

The objective of the pilot project was to implement a Technical Drafting Centre which would satisfy client drafting needs through direct lines of communication for data exchange, centralizing regional drafting management, optimizing technology use and application and provide a formal information system for ongoing cost/benefit analyses.

The pilot project proved successful as it showed that the TDC concept was a cost-effective way to satisfy regional drawing production requirements for all regional clients. Based on these results and the realization that this concept could further be expanded to include management for site/regional data as well as site/regional technical resources, TDC Implementation Planning began in January 1986 (Airport Facilities Branch, 1985).

The TDC National Implementation Program (NIP) identified the TDC components as:

- data input and collection
- technical user/management committees
- technical data centre computer aided drafting (CAD) management system
- data storage and retrieval and
- cyclic review and updating programs.

The NIP concluded that the TDC management concept develops for management and site regional users, databases of reliable site data which are cyclically updated (Airport Authority Group, 1988b).

7.2 Technical Data Centre and Geographic Data Management

Table 4 lists the geographic data currently managed by TDCs and updated by the Facility Alteration Permit (FAP) process.

TABLE 4 - Geographic data stored at Technical Data Centres

Storage Medium	Geographic Data
Cronaflexes Microfilm Magnetic Tape Magnetic Disks	Airport Property Boundaries
	Leasehold Property Boundaries
	Zoning and Flight Restrictions
	Planimetric Features - roads, runways, buildings
	Hydrographic Features - rivers, lakes
	Vegetation
	Utility Data Above and Below Ground - poles, hydrants, manholes
	Power and Communication Data - direct buried electrical cables, telephone lines
	Ground and Noise Contours

Geographic data in Table 4 is currently stored in layered drafting files. These files have been found to contain varying levels of accuracy (1-20 centimetres) and content (Robinson and Sani. 1990). In addition, connected features from adjacent files may contain different graphic attributes because data integrity checks cannot be performed with the existing software tools in advance of file loading. Currently, all Major Federal Airports as well as Transport Canada's six operating airports are in the process of establishing or maintaining

TDCs. One of the established centres - Toronto LBPIA TDC is selected as the site for integrating GIS and IRDS for the following reasons:

- The Toronto-LBPIA is a dynamic site located in Mississauga, Ontario, and adjoins the municipalities of Mississauga, Etobicoke and Peel. It is Canada's busiest airport and one that is under constant public scrutiny. Demands for air and land space are immense.

- The Toronto-LBPIA TDC is the most advanced in Canada. It is actively collecting data on its facilities and disseminating data to a wide airport clientele as shown in Figure 7.

- The site employs a full time FAP officer who works in conjunction with the TDC manager.

- The staff at Toronto-LBPIA is highly trained and understands GIS technology.

- The site was one of two studied by ILIM (Robinson and Sani, 1990) and is conveniently located near the University of Toronto, Erindale Campus.

Figure 7 - Typical users of the LBPIA-TDC

7.3 Facility Alteration Permit Process

Updates to geographic data in the TDCs are carried out through FAPs, projects initiated by the Land Use approval process whereby as-built data is supplied to the TDC and by cyclical update programmes using aerial photography. This process although implemented at all Major Federal Airports in Ontario, is operational only at Toronto - LBPIA.

A major function of the FAP system is to ensure that all tenants, including Customs and Immigration, and Health and Welfare, concessionaires and other parties who intend to make alterations on the airport submit a proposal to the Profit Centre Manager (PCM). Four Profit Centres have been established at Toronto - LBPIA; namely, Air Terminal Building 1 (ATB1), ATB2, Airside and Groundside. Proposals include a written request for a FAP and design documents (architectural, civil, structural, mechanical, electrical) prepared by the tenant together with all necessary documentation attached. The exact orientation of the new/altered facility within any airport building or on any airport property, is also required to be shown (e.g. column numbers, distance from existing walls, roadways, and so forth). On major projects, a commitment to provide as-built drawings is required as part of the submission.

Once a FAP is obtained, the tenant proceeds with construction in an agreed upon time frame. On completion, as-built drawings of the new facility, if required, are submitted to the Technical Data Centre (Airport Authority Group, 1988a and Airport Construction Services, 1982).

Database maintenance at airports is not automated. It is a separate task, undertaken by TDC managers when time permits. In many instances, updates may not be undertaken quickly and efficiently with the result that users have begun to question the integrity of the database (Robinson and Sani, 1990).

The FAP process is currently the process for initiating the database maintenance process at Toronto - LBPIA. It is the only mechanism through which TDC managers can maintain their information base.

8. THE TECHNICAL DATA CENTRE COMPUTER ASSISTED DRAFTING DATABASE

The TDC CAD database was developed in 1985 with the objective of providing Transport Canada with current, consistent data at its Major Federal Airports and six operating Regions. Specifications for the database design required flexibility for efficient CAD use and structuring of data elements to facilitate low cost data conversion following GIS system acquisition (Sani, 1988 and McFarlane, 1988). The LBPIA TDC stores geographic data as geometric primitives (GPs) which are organized into one of 10 files (Table 5).

Each GP is assigned graphic attributes of display level, display colour, line thickness and line style and is stored in both a binary graphics format and an American Standard Code for Information Interchange (ASCII) format. GPs in the ASCII format have associated with them the National Topographic Series (NTS) feature code as an attribute, but this attribute is not stored in the binary graphic files (Sani, 1988).

There is limited data structuring in the database. GPs stored are points, lines and to a lesser extent polygons (e.g. buildings and wooded areas) with no connectivity, continuity or spatial relationships explicitly represented in the data structure. This structure, although acceptable for CAD applications, is clearly unacceptable for the management of Transport Canada's information resource.

TABLE 5 - LBPIA geographic data files

File Name	Example of Features Stored
Civil Utility Above Ground	Catch Basin, Manhole, Hydrant
Civil Utility Under Ground	Septic Tank, Storm Pipe
Control and Boundary	Monument, Airport Property Boundary
Electrical Utilities Above Ground	Antenna, Apron light, Electrical manholes
Electrical Utilities Under Ground	Telephone cable, Duct, Transformer
Hydrography	Creek, Ditch, Lake, Swamp
Planimetric	Road, Bridge, Sidewalk
Topographic	Contour, Spot Elevation
Vegetation	Wooded Area, Tree, Scrub
Zoning and Flight Path Restrictions	Registered, ICAO, Restricted

Information resource management relies on current and up-to-date information to be effective. Attempts aimed at keeping databases up-to-date at LBPIA, by means of the FAP process have failed, due to the lack of human resources required to manually input the as-built data (Robinson and Sani, 1990). A more automated approach is required. The GIRDS model provides support for this automation by linking the FAP process to the management of geographic data.

9. THE FACILITY ALTERATION PERMIT DATA MODEL

This Chapter describes the E-R model developed for the FAP process at Toronto Lester B. Pearson International Airport described in Chapter 7. In the following discussion, entities are highlighted and relationships are highlighted and underlined.

The model identifies the **tenant** as commencing the FAP process by **<u>obtain</u>**ing a **TDC Work Request Form** which is completed and **<u>passed to</u>** the TDC (Figure 8). Cardinalities of 1:N and N:1 respectively are assigned, as there is one **work request** per **TDC work request form**.

Work request is modelled as the parent of the children **general information**, **TDC work comments**, **details of request** and **request type** by use of the **<u>isa</u>** relationship with cardinalities of 1:1. An **<u>isa</u>** relationship is also used to link the parent **request type** with children **TDC**, **art** and **FAP**, which describe the type of request. Upper and lower bound cardinalities of 0:1 are assigned respectively indicating that a request may contain a minimum of zero and a maximum of 1 request type. The entity **general information** is further modelled to show that the **name** of the individual making the request is **<u>included</u>** as part of the

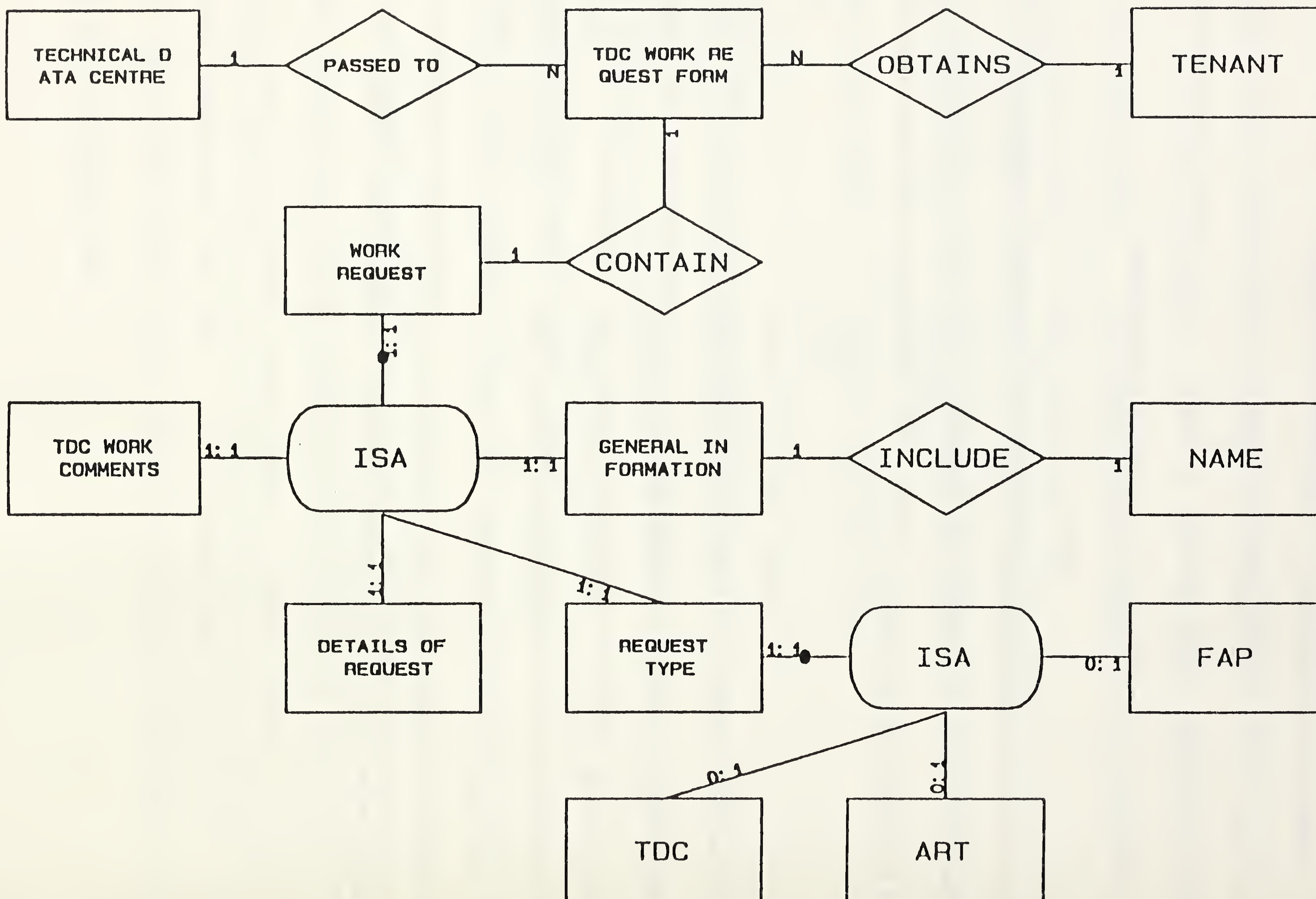

Figure 8 - The FAP process commences with the tenant

Note: Text placement by E-R Designer, (Chen and Associates, 1989)

general information on the work request. A cardinality of 1:1 is assigned.

The **TDC**, having received a Work Request Form from the **tenant**, accesses the **databases** to determine the availability of the data. **Databases** stored by the TDC are **geographic** and **building structure** and are modelled by a parent-child relationship of cardinalities 1:1,0:1. The **Building structure** database may contain **structural, mechanical, utilities, electrical** and **architectural** databases and therefore is linked to the parent **building structure** with an isa relationship of cardinalities 1:1:0:1 (Figure 9).

Databases are used by **data processing** to provide **information** to the tenant. Cardinalities are N:N and 1:1 respectively, as many processes may be run on the databases to produce the requested information set (Figure 9).

Information produced by the TDC is used for preparing **documents** which are submitted with the **FAP Application**. Cardinalities are N:N and N:1 respectively. The **FAP application** is submitted to the tenant's **PCM**, who in turn forwards it (tables request) to a **Technical Review Committee** (TRC).

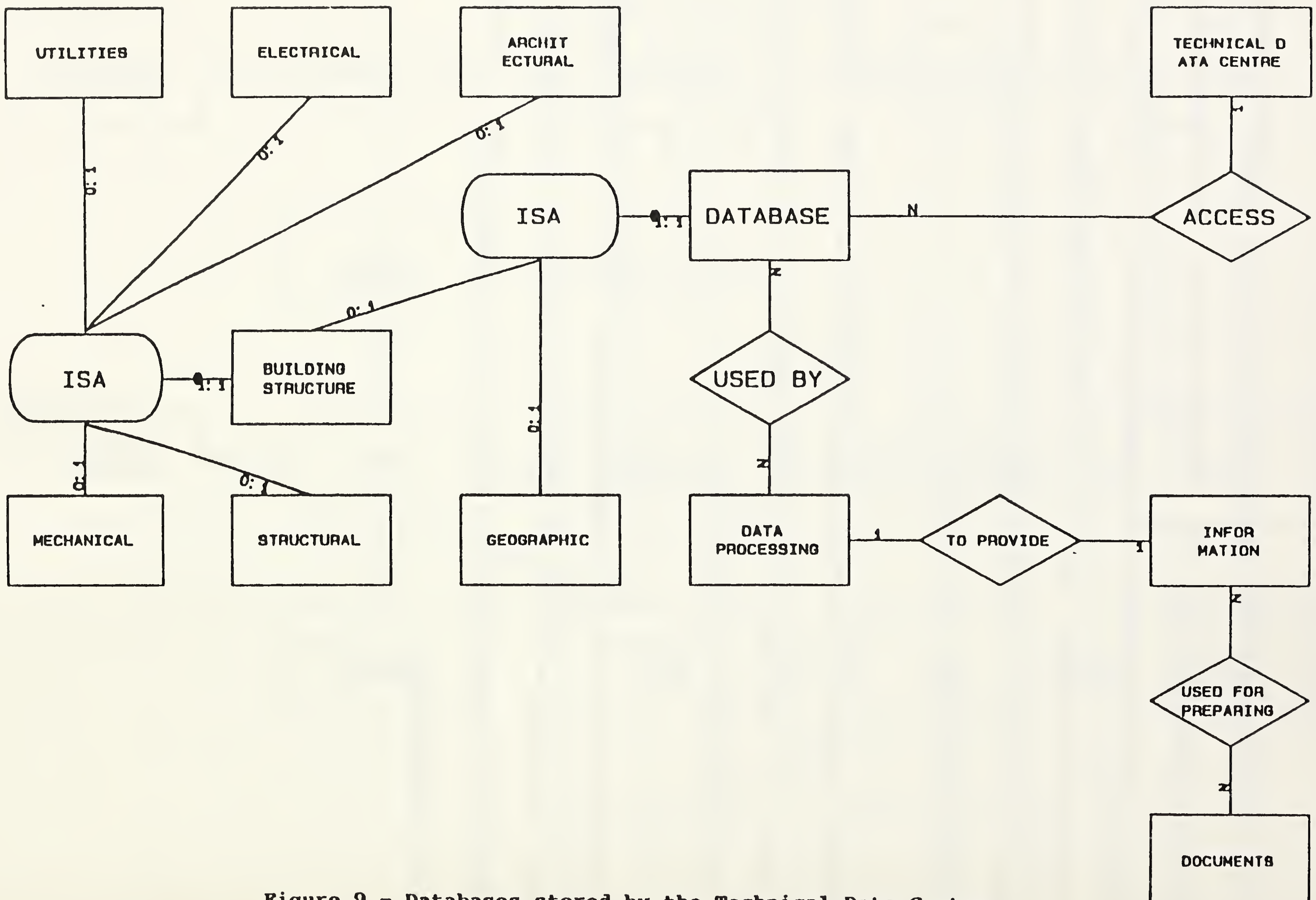

Figure 9 - Databases stored by the Technical Data Centre

Note: Text placement by E-R Designer, (Chen and Associates, 1989)

Assigned cardinalities of 1:1, as shown in Figure 10, indicate that each application is reviewed by a PCM and a TRC.

The application, having been reviewed by the **TRC** is forwarded to the **Manager of Airport Development** who creates a **project file** and identifies a **LBPIA project team** to study the FAP application in detail. Cardinalities of 1:1 are assigned. The **project team** generates **comments** which are delivered to the **TRC**. The **TRC** then makes a **recommendation** which is communicated to the **tenant** (Figure 11). On approval of the FAP the **tenant** prepares an **alteration schedule** which specifies an **alteration period** (Figure 12).

During the **alteration period**, regular inspection is undertaken by the FAP officer to ensure compliance (**IKAP/FAP officer**-issue-**inspection report**) (Figure 12). A cardinality of 1:N is assigned which indicates that several **inspection reports** may be provided to a **contractor-tenant** during the construction period.

On completion of the alteration, the **contractor-tenant** finalize **as-built drawings** which are entered in the **TDC** for the purpose of updating the existing databases (**as-built drawing**-entered in-**TDC**). Since **as-built drawings** contain overlays showing above ground and underground features, electrical distribution and so forth, cardinalities of N:1 are assigned (Figure 12).

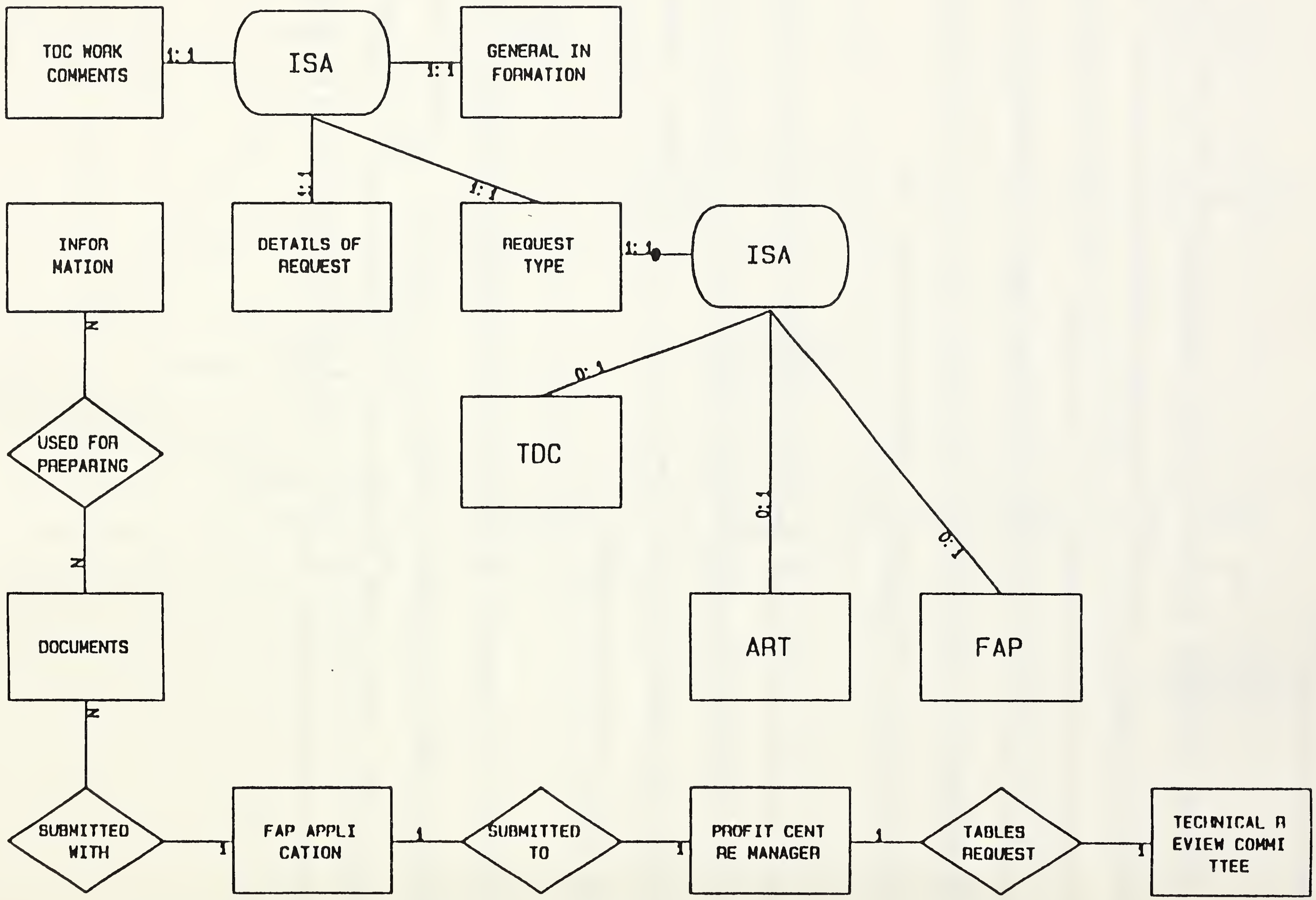

Figure 10 - The FAP application submitted to the Profit Centre Manager

Note: Text placement by E-R Designer, (Chen and Associates, 1989)

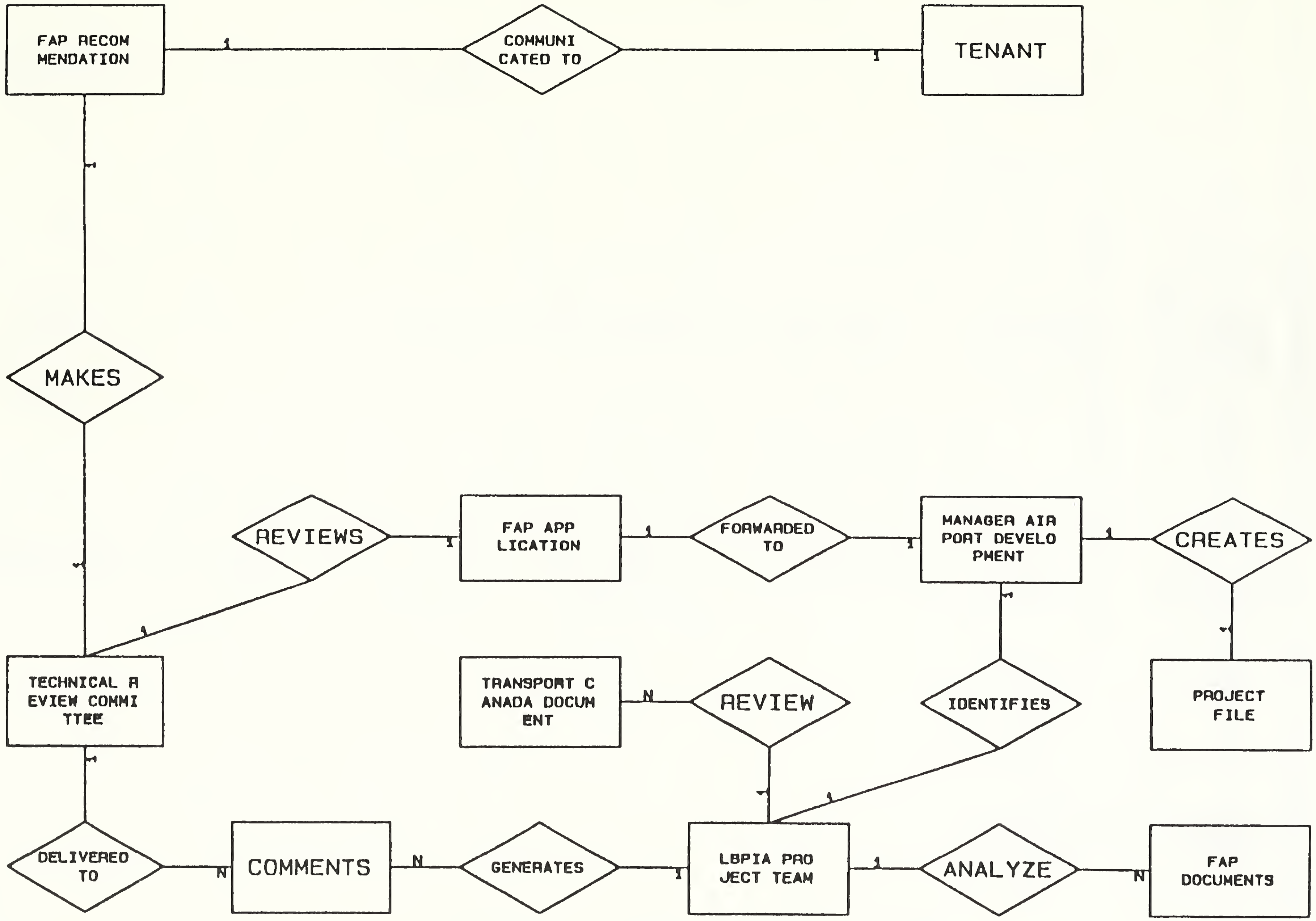

Figure 11 - LBPIA project team formed

Note: Text placement by E-R Designer, (Chen and Associates, 1989)

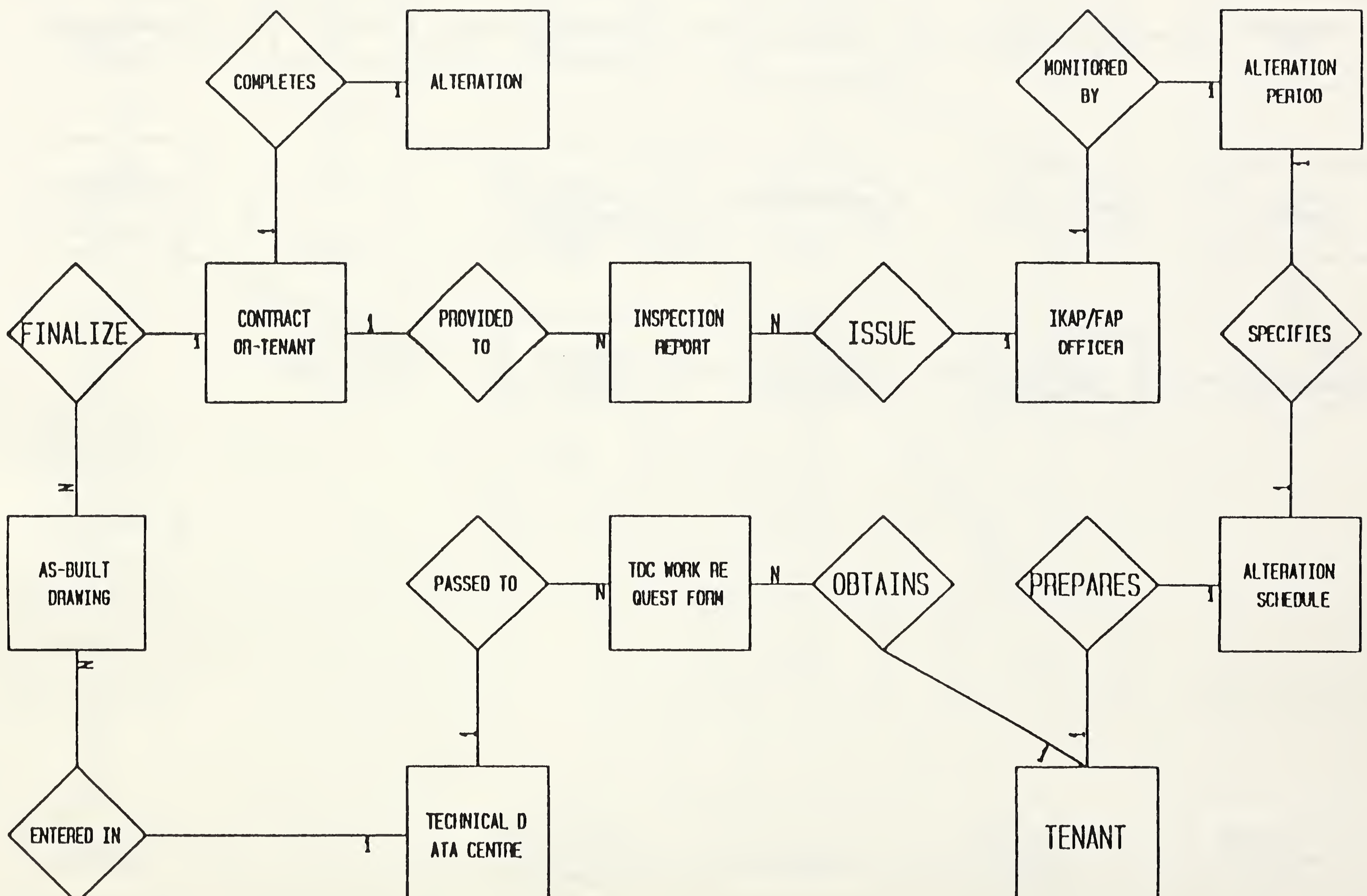

Figure 12 - Inspection by FAP officer

Note: Text placement by E-R Designer, (Chen and Associates, 1989)

9.1 FAP Attributes

A number of attributes were identified for the FAP entities during the modelling process. These attributes, listed in Table 6, indicate that it is possible to select a key identifer, such as a FAP number, to link DBMS attribute tables with spatial data.

TABLE 6 - FAP attributes

Entity Name	Attributes
Details of request	Capital number IKAP number PWC number Required date Drawing number Contract number
TDC work comments	Date sent out Work order number Name of consultant Request completed by Date of completion
General information	Project title Designator Phone number Date
Name	Surname Given name
FAP	FAP number
Profit Centre Manager	Surname Given name

TABLE 6 - FAP attributes (cont.)

Entity Name	Attributes
Airport Development Manager	Surname Given name
Project file	Number
FAP document	Reference number
Transport Canada document	Reference number
Tenant	Surname Given name Address Telephone number
Alteration schedule	Start date End date
Alteration period	Number of months
IKAP officer	Surname Given name Telephone number
Inspection report	FAP number Report number
Contractor/tenant	Surname Given name
Alteration	FAP number

TABLE 6 - FAP attributes (cont.)

Entity Name	Attributes
As-built drawing	Drawing number Consultant agreement number Project date Project number Sheet number Scale Description

10. THE GEOGRAPHIC DATA MODEL

The geographic data model (GDM) is organized to reflect a logical view of systems as they exist at the airport. It is based on the E-R approach to modelling spatial databases which has been successfully adopted by Armstrong and Densham, 1990; Calkins and Marble, 1987; and Robinson and Zhang, 1988. Entities at the highest level in the model are treated as **complex feature systems** which may be decomposed into **feature systems** and then into **features** at the lowest level. Features are represented by their fundamental dimensional (FD) entities (i.e. geometric primitives) consisting of points, nodes, complex lines and polygons, each of which is built from a set of coordinate triplets (Armstrong and Densham, 1990). The model enables high-level entities to obtain their FD representation through hierarchical aggregation.

The GDM views the geographic database as the parent of three distinct types of airport operations - Airside, Groundside and Prosaic (McFarlane, 1990). In turn, these operations are modelled as complex feature systems. This approach can be contrasted to the view of the LBPIA-TDC which is based on the three major airport operating systems - Airside, Groundside and Industrial - in which airport features are not easily represented due to the complexity and overlapping of geographic features within each system. For example, geographic features in the groundside drainage system, such as storm sewers and ditches, cross into the airside system.

In the GDM, airside complex feature systems encompass all geographic features which are common to an airfield feature system, such as, runways, taxiways and aprons. Airport Prosaic Systems are complex feature systems which represent all feature systems common to both Airside and Groundside. These may include storm, utility and boundary feature systems. Groundside complex feature systems include only feature systems that are consistently located on the groundside of airports, such as administrative and catering facilities, fuel farms and power houses.

10.1 Airside

In Figure 13, the complex feature system **airside** is a parent of the **airfield** feature system. An isa relationship exists between the parent entity **airfield** and the children feature entities **runway**, **taxiway**, **apron** and **unpaved area**. Cardinalities of 1:N are assigned as LBPIA **airfield** contains many of the above child entities. **Runways** are connected to many **taxiways** which joins **aprons**. Cardinalities of N:N are assigned for the relationship **apron**-adjacent to -**unpaved area** as is the case at the end of aprons and at intersections of taxiways.

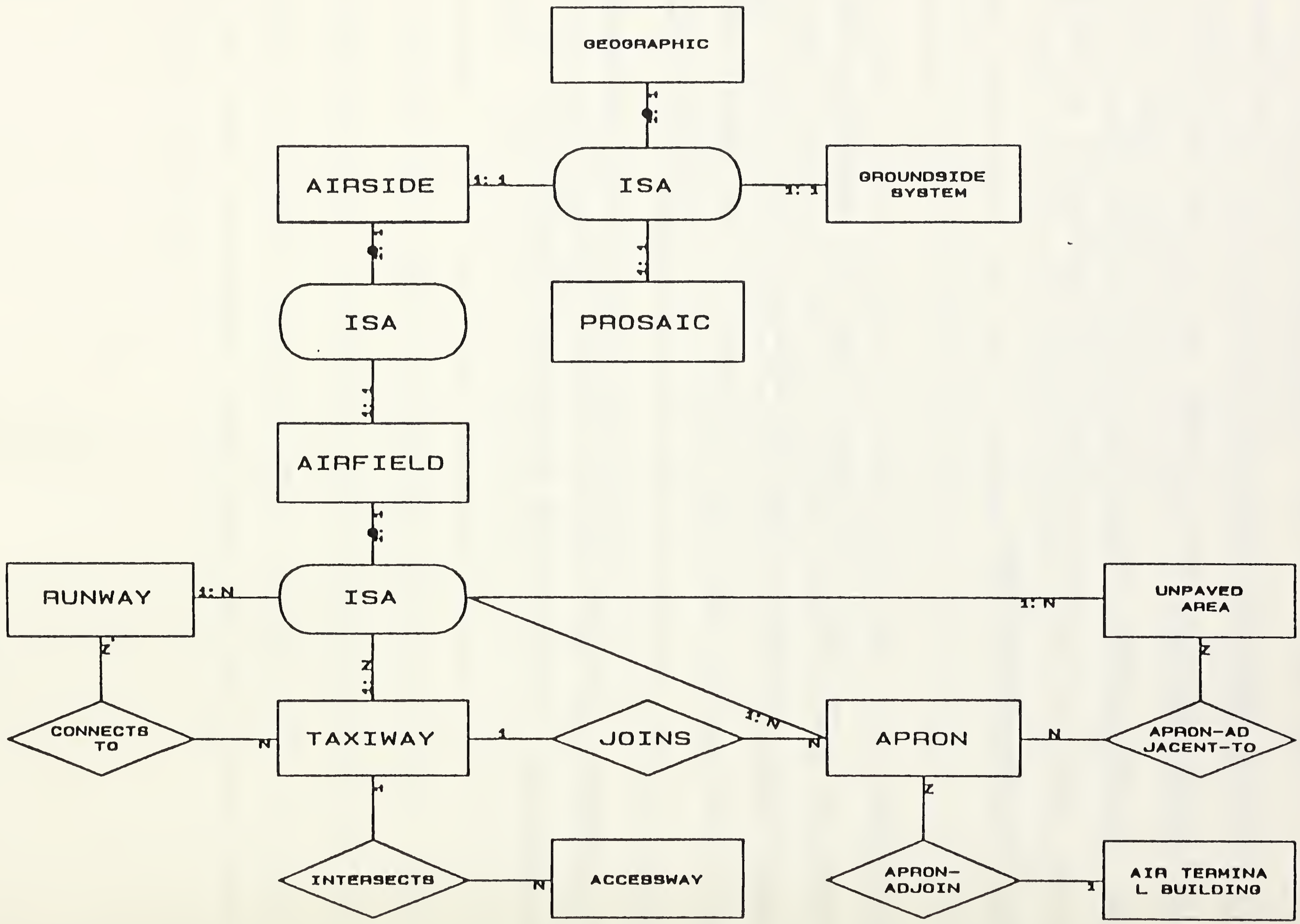

Figure 13 - Airside

Note : Text placement by E-R Designer, (Chen and Associates, 1989)

10.1.1 Runway Linkages

At airports, each **runway** is zoned. There are four types of zoning, namely, **restrictive**, **registered**, **operational** and **ICAO** (the International Civil Aviation Organization). Cardinalities of 1:1,0:1 indicate as illustrated in Figure 14 that the existence of a runway does not imply the existence of one or more types of zoning.

Registered zoning defines the **runway strip**, **take off and approach surface**, **obstacle limitation surface** and the **transitional surface**. A parent-child relationship is used to model the **registered** zoning. Each child is linked to its parent with cardinalities of 1:1,0:N indicating that both runway ends may have registered zoning.

The restrictive feature entity is modelled as parent of **navigational aids** and **waste disposal area** by use of the isa relationship with cardinalities of 1:1,0:N respectively. **Navigational aids** is further decomposed by modelling it as the parent of **VASIS**, **PAPIS**, **low intensity light bars**, **high intensity light bars** and **instrument landing system** with cardinalities of 1:1,0:1. Each **Navigational Aid** is linked to the **centre-line** of the runway which is contained in the runway **approach path**. The **centre-line** of the runway is defined by two **threshold points** as shown in Figure 14, hence the cardinality of 1:N, where N=2. **Instrument Landing System** is modelled as the parent of a number of feature entities, namely, **outer marker**, **middle marker**, **glide path**, **back beam marker** and **back beam antenna** with cardinalities of 1:1. Each of these feature entities are associated with their children - **building** and **antenna** - through isa relationships, each with a 1:1 cardinality.

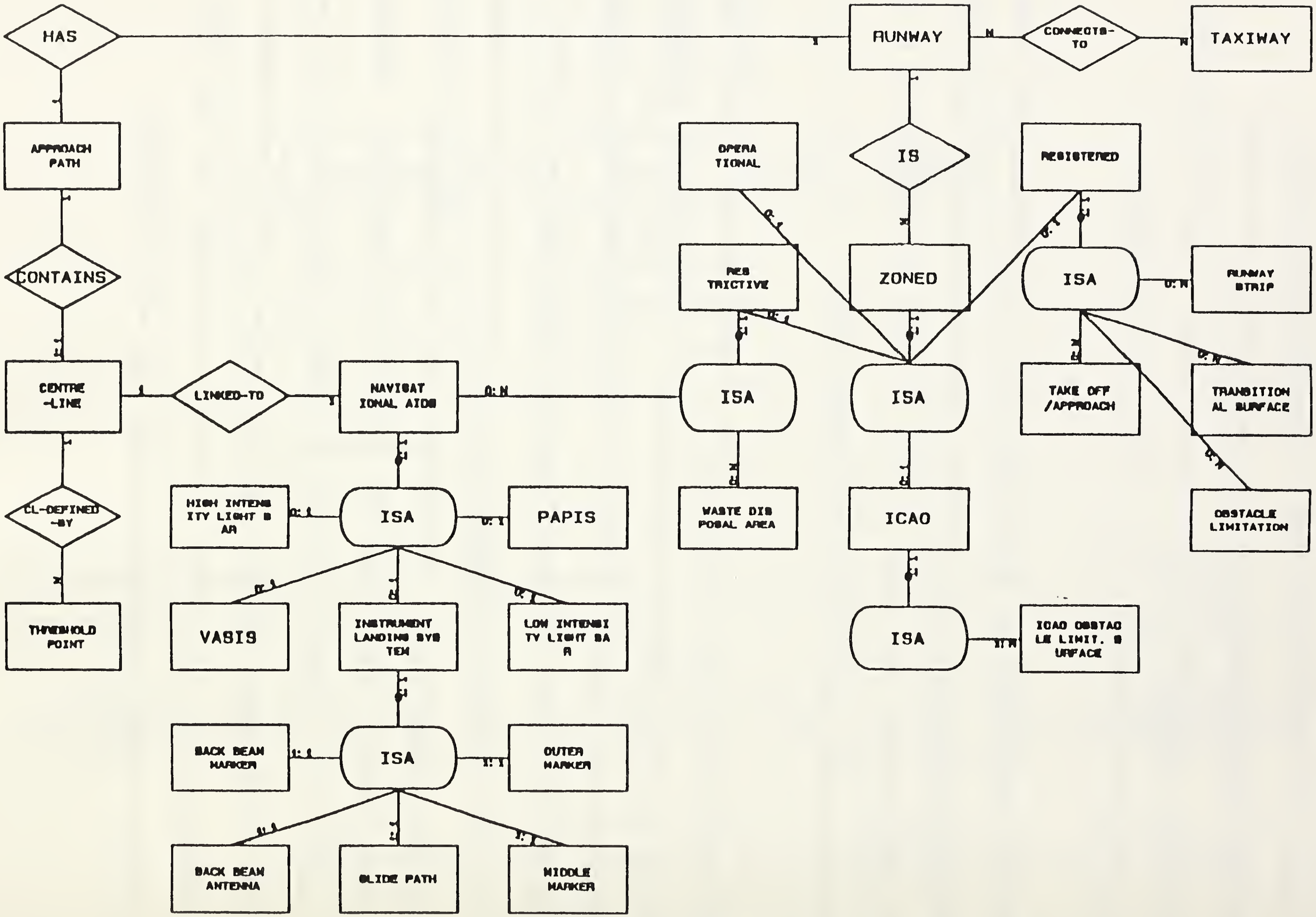

Figure 14 - Runway centre-line definition

Note: Text placement by E R Designer, (Chen and Associates, [illegible])

The **ICAO** zoning is viewed as the parent of **ICAO obstacle limitation surface**. A relation of 1:N is established indicating that this zoning is applicable to both ends of the runway, as changes in weather conditions may determine which end of a runway is used for take-off and landing. **ICAO obstacle limitation surfaces** prevent obstacles from intruding into **approach path**. Relationships as shown in Figure 15 are expressed as 1:N and N:1 respectively.

An **Obstacle** isa **vegetation**, **topography**, **building**, **pole** and **antenna**. Both **vegetation** and **topography** are represented individually as an aggregation of child entities (in the case of **topography** not shown in the GDM) and hence the cardinalities of 1:1,0:1. Entities **building**, **pole** and **antenna** are assigned cardinalities of 1:1,0:N as many of these features are located airside. **Vegetation**, as shown in Figure 15, is the parent of feature entities **scrub**, **wooded area** and **tree** while **topography** is described by **contours** with cardinalities of 1:N.

Operational zoning which exists only in the absence of **registered** zoning, does not occur at LBPIA. Therefore, this feature entity is not decomposed in the GDM.

Runway is associated with many **lighting** systems. These **lighting** systems are parents of **edge**, **inset** and **approach**. Lower and upper bound cardinalities of 0:N are established for

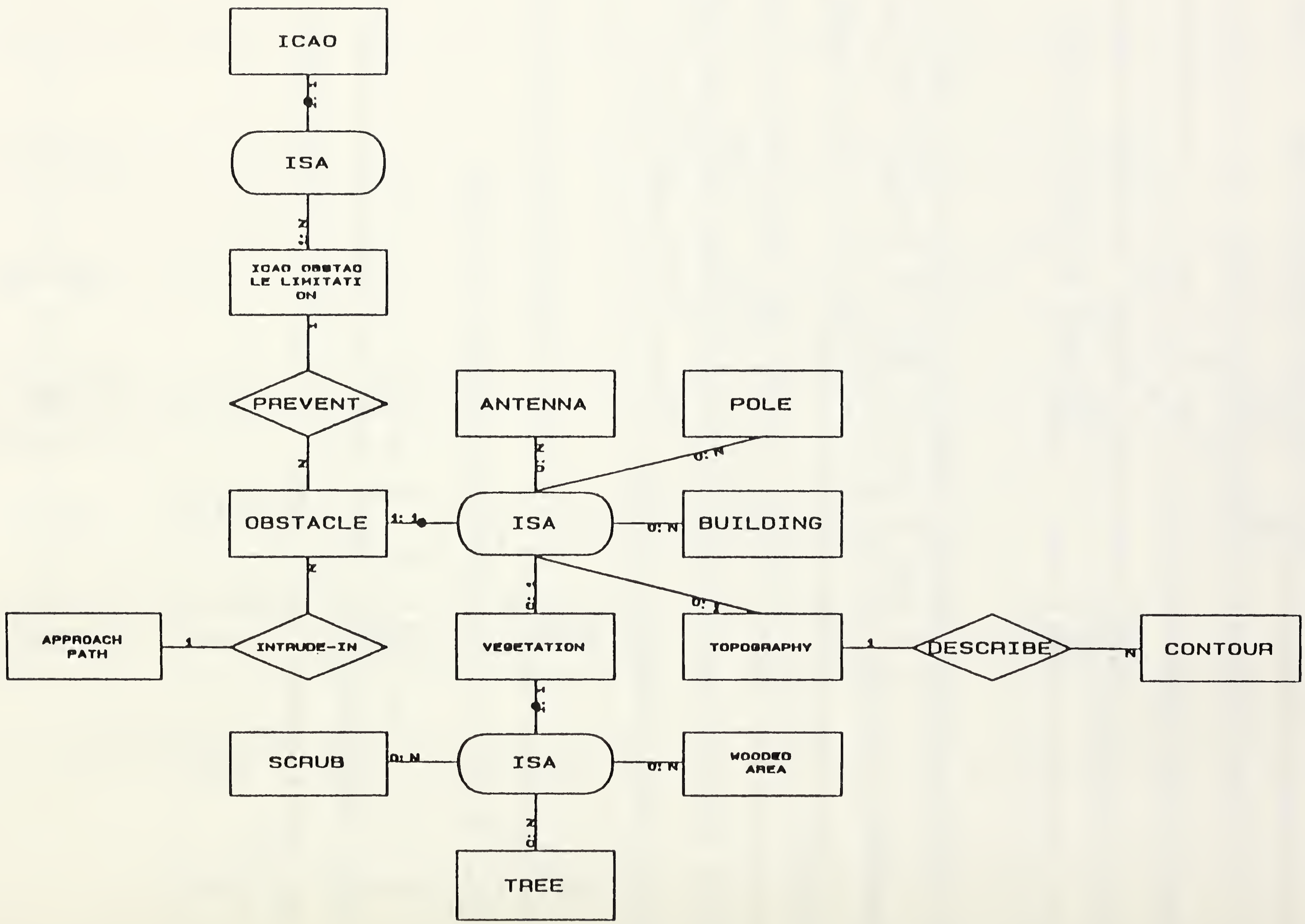

Figure 15 - Airside vegetation

Note: Text placement by E-R Designer, (Chen and Associates, 1989)

edge and inset as shown in Figure 16, as some airports do not have these lighting systems for the following reasons:

- only local commercial airports licensed for night operations are equipped with edge lighting; for example, the turf runway at Muskoka airport does not have edge lighting.
- only runways with category II status are equipped with inset lighting which allow operation under adverse weather conditions. In Ontario, LBPIA is the only airport which has inset lighting on runways.

Both **edge** and **inset** lighting systems are represented as feature entities in the model. A lower and upper bound cardinality of 1:1 is assigned to **approach** lights as these exist at all airports. **Approach** lights are further decomposed through an isa relationship to link existing feature entities - **high intensity approach bars** and **low intensity approach bars** - with 1:N relationships. These feature entities are defined in Figure 14 through parent-child linkages with the entities **navigational aids** and **restrictive zoning**.

10.1.2 Taxiway Linkages

As shown earlier in Figure 13, the model describes **taxiways** as connected to **runways** with a 1:N cardinality. **Taxiways** are also viewed as joining **aprons** and intersecting **accessways** with cardinalities of 1:N. Many **accessways** are linked with each **road**, hence a cardinality of N:1.

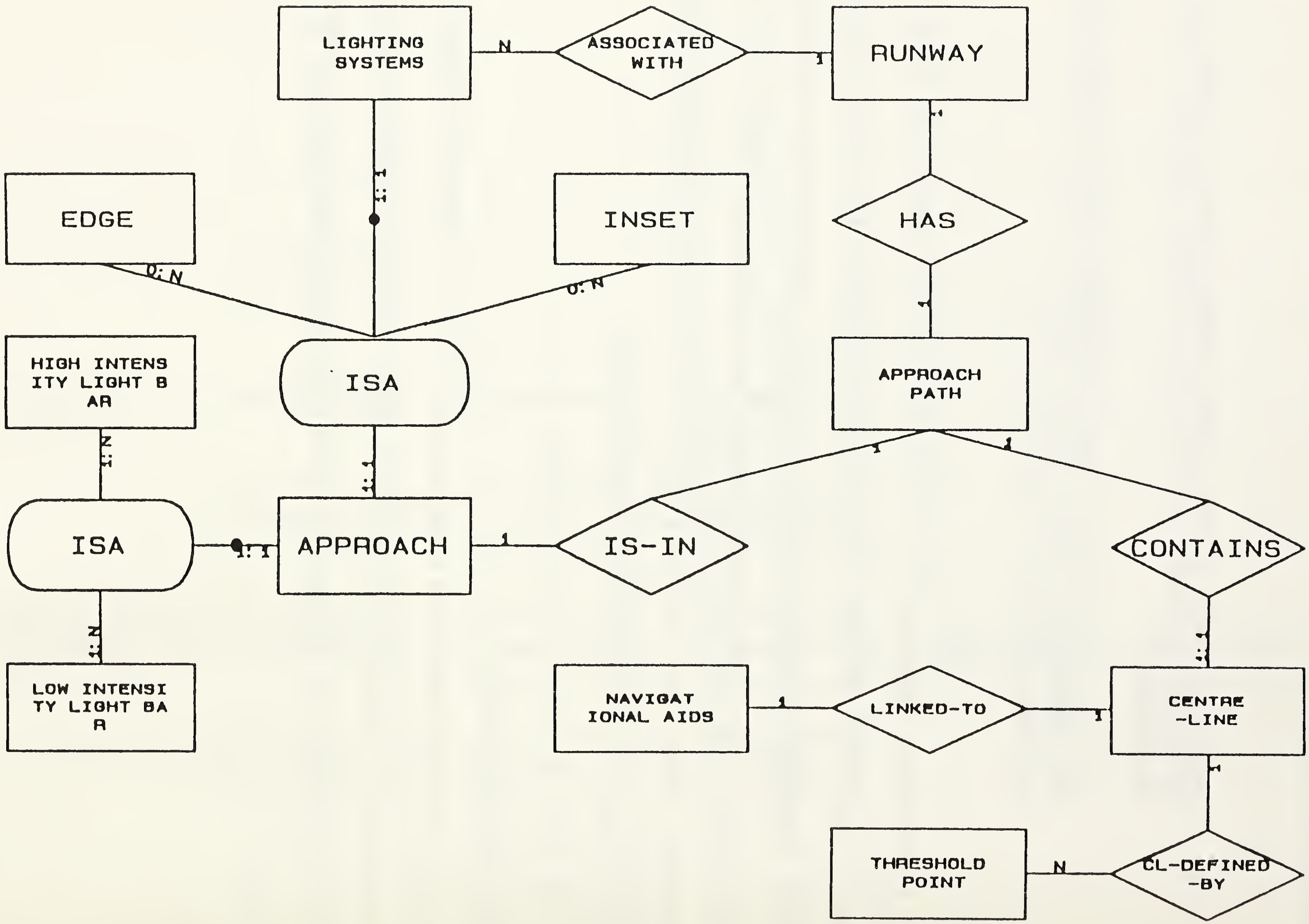

Figure 16 - Runway lighting system

Note: Text placement by E-R Designer, (Chen and Associates, 1989)

10.1.3 Apron Linkages

Aprons are represented in the model as joining taxiways (Figure 13). They are also viewed as adjoining **air terminal buildings** and therefore a relationship connection of N:1 is assigned.

10.1.4 Unpaved Area Linkages

Unpaved area is modelled as adjacent to aprons with N:N cardinality. No further decomposition of this feature entity is undertaken in the model.

10.2 Prosaic System

A **Prosaic system** on the airport is viewed as a parent complex feature system with children **Storm Drain**, **Transportation**, **Utility** and **Land Related Information** which may or may not be represented at all airports. Upper and lower bound cardinalities assigned to this isa relationship are 1:1,0:1 as illustrated in Figure 17.

10.2.1 Storm Drain Linkages

The feature system **Storm Drain** is the parent of the feature entities **ditch** and **storm sewer** with cardinalities of 1:1,0:N. **Ditch** drains-into **storm culvert** which connects-with **storm pipe**. Cardinalities of N:1 and 1:1 are assigned respectively. Linkages between **storm culvert** and **storm pipe** with **storm sewer** are obtained through the isa relationship with cardinalities of 1:1, with **storm sewer** as parent. A **storm pipe** is viewed as providing a linkage to a **storm manhole**. Many **storm manholes** are required for draining a **road**, hence

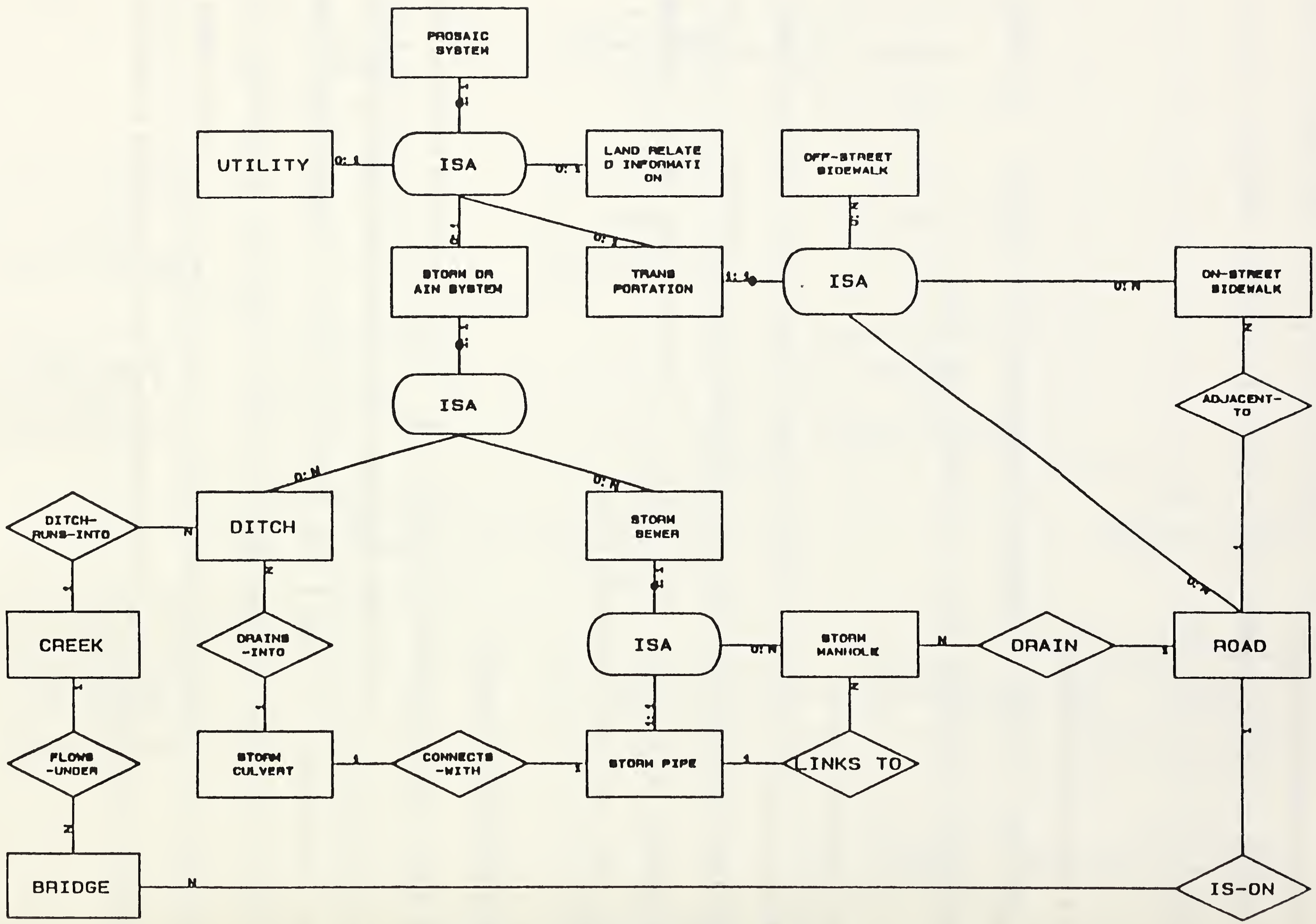

Figure 17 - Prosaic system

Note: Text placement by E-R Designer, (Chen and Associates, 1989)

a N:1 cardinality.

A N:1 relationship - **ditch-runs-into** - is established between the feature entities **ditch** and **creek**. A **creek** is viewed as **flowing-under** many **bridges** and **bridges** are located on (is-on) **roads** (Figure 17). There is no further decomposition of the feature entities **ditch**, **creek**, **bridge**, **storm manhole**, and **storm pipe**. Therefore, they are linked directly to their fundamental dimensional entities (FDEs) through isa relationships with cardinalities of 1:1.

10.2.2 Transportation Linkages

The **transportation** feature system is composed of **off-street sidewalk**, **on-street sidewalk** and **road** feature entities as shown in Figure 17. **On-street sidewalks** are **adjacent-to** **roads** with a cardinality of N:1. Since many **roads** are viewed as crossing many **Ontario Hydro power lines**, a cardinality of N:N is assigned.

10.2.3 Utility Linkages

The high-level system entity **utility** is decomposed into feature entities **gas**, **water**, **power**, and **communication** through an isa relationship with cardinalities of 1:1,0:1. The entity **Utility** is related to **building** by the relationship **connected-to** with a cardinality of 1:1. A **building** on an airport is viewed as **adjoining** many **parking areas** (1:N) which are **accessed-by** a **road** (N:1). An example of this may be seen at the LBPIA Administration building. The entities **gas** and **communication** are not modelled further due to the complexity of the model in its present form. Relationships are established however for the entities **water** and power.

Water is distributed-by **water pipes** which are viewed as linked to **hydrants**. Cardinalities of 1:N are assigned as shown in Figure 18.

Power is provided-by **Ontario Hydro power lines** with a cardinality of 1:N. **Ontario Hydro power line** is the parent of feature entities **pole** and **power cable** with cardinalities of 1:1,0:N and 1:1 respectively. The former lower bound cardinality indicates that power lines could exist without poles as is the case on the airside. The entity **pole** was earlier described in Figure 15 as a child of the feature entity **obstacle** associated with the airside.

Power cables are accessed-through a **cable manhole** and are also buried-adjacent-to **Bell Canada cables** on the airport. **Bell Canada Cables** are buried in a **cable duct** which run into **cable manholes** with cardinalities of N:1 and 1:N respectively. Finally, a **Bell Canada cable** is identified by many **cable markers** and therefore a cardinality of 1:N is assigned as shown in Figure 18.

10.2.4 Land Related Information Linkages

The GDM describes the feature entity **boundary** as a child of the feature system entity **land related information.** As LBPIA has a defined **boundary**, a 1:1 cardinality is assigned.

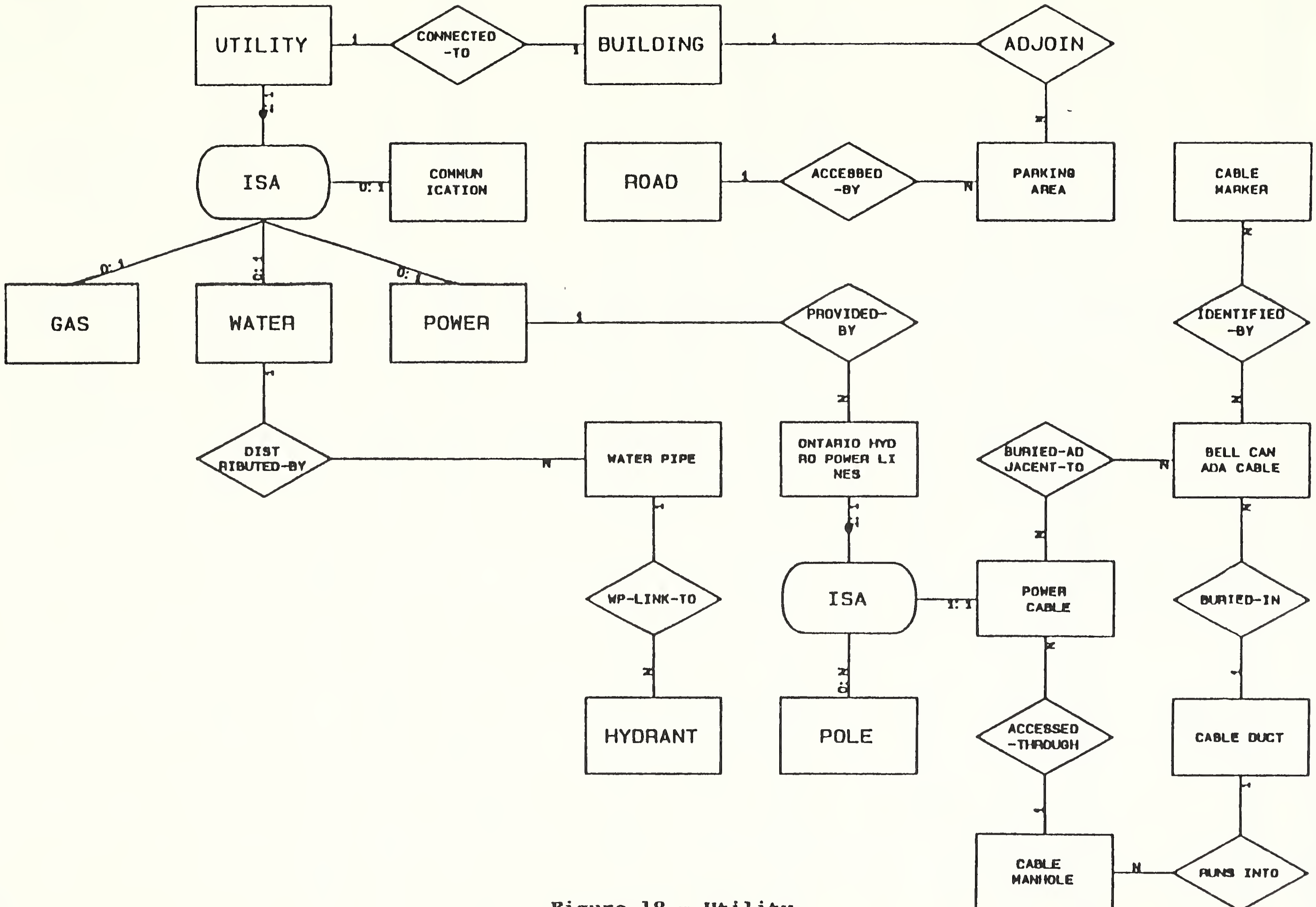

Figure 18 - Utility

Note: Text placement by E-R Designer, (Chen and Associates, 1989)

Boundary is the parent of feature entities **international**, **field**, **lease-property**, **municipal**, and **airport property** with a cardinality of 1:1,0:1 on the first four entities and 1:1 on the latter (Figure 19).

Lease-property boundaries are connected to form **lots**. Cardinalities of N:1 are assigned. **Lots** are leased by **tenants** which is an entity in the FAP process described earlier. A **Lot** encloses **buildings** and a cardinality of 1:N is assigned as many buildings may be on a single **lot**, but a single building cannot occupy more than one lot.

Airport property boundary is viewed as being defined by **boundary segments** which are defined by **survey bars**. On all airport boundary surveys, these **survey bars** are coordinated from the **airport control network**. The **airport control network** is composed of a **horizontal** and **vertical** network. A parent-child relationship with cardinalities of 1:1,0:1 are assigned.

10.3 Groundside

On the **groundside** of an airport, the following complexes exist - **administrative facilities**, **power house** and **fuel farm**. These are modelled as feature entities and children of the complex feature system entity **groundside**.

Administrative facilities are further decomposed through the isa relationship into

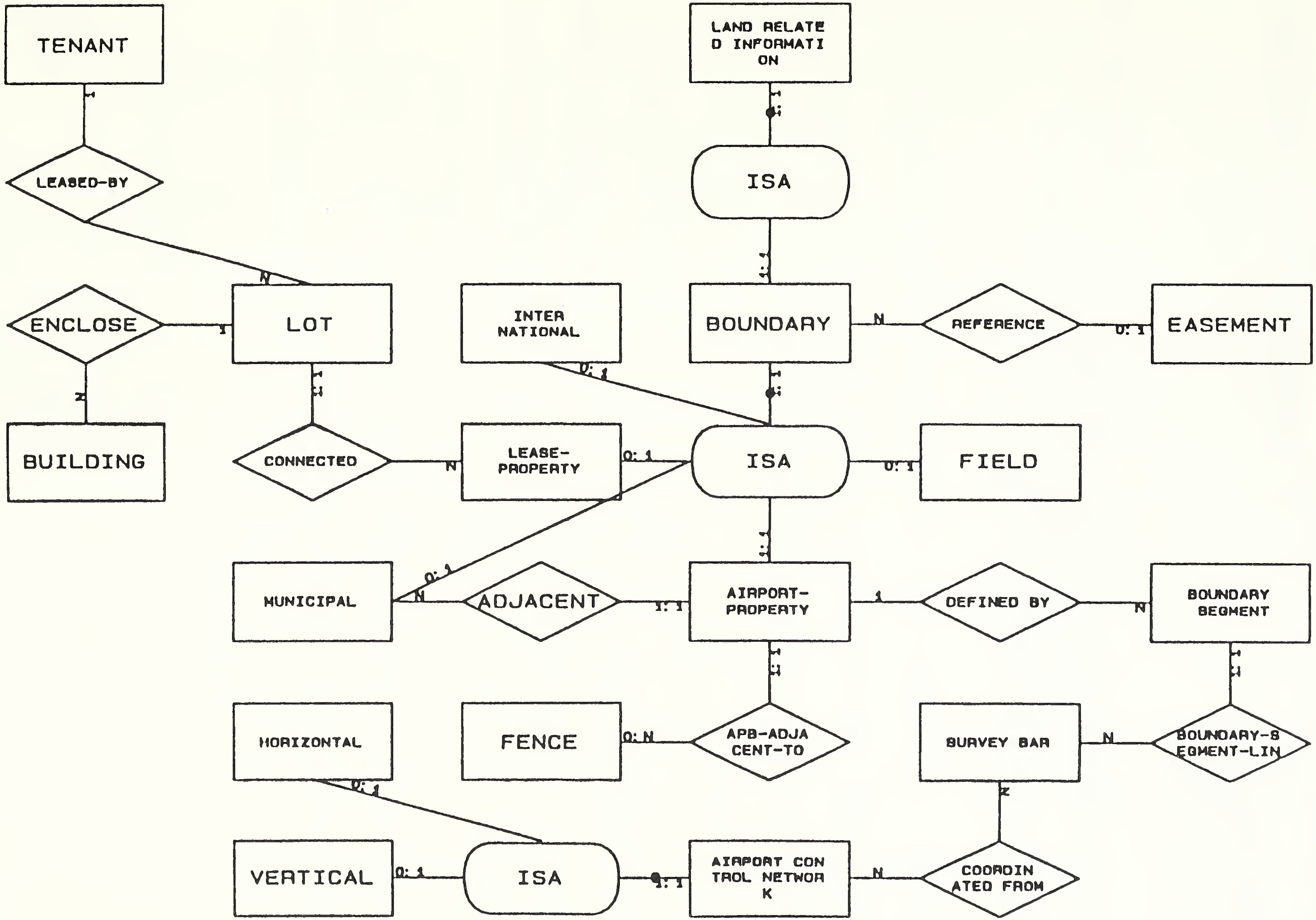

Figure 19 - Land related information
Note: Text placement by E-R Designer, (Chen and Associates, 1989)

catering facilities, **administrative building** and **maintenance garage** (Figure 20). All feature entities are then linked with cardinalities of 1:1 to their FD representations through parent-child relationships.

The feature entity **power house** is modelled as being adjacent to many **transformers** which connect-to many **power cables**, hence cardinalities of 1:N and N:N respectively.

Fuel farms are decomposed through an isa relationship into a **fuel farm complex** which store **fuel tanks**. Cardinalities of 1:1 and 1:N are assigned respectively. **Fuel tanks** are linked to **fuel lines** and are also surrounded by **dikes**, hence the cardinalities of N:N and N:1 respectively.

10.4 The Spatial Model

Each feature entity is mapped to a FDE of point, node, line, complex line or polygon (Armstrong and Densham, 1990). Figure 21 shows the relationships between these entities.

The spatial model describes a **coordinate triplet** as the parent of **point** and **node**. **Points** represent features which are cartographically displayed as symbols. Many **nodes** connect to form many **complex lines**. A cardinality of N:N is assigned. **Complex line** is the parent of line, **curve** and **approximate curve**.

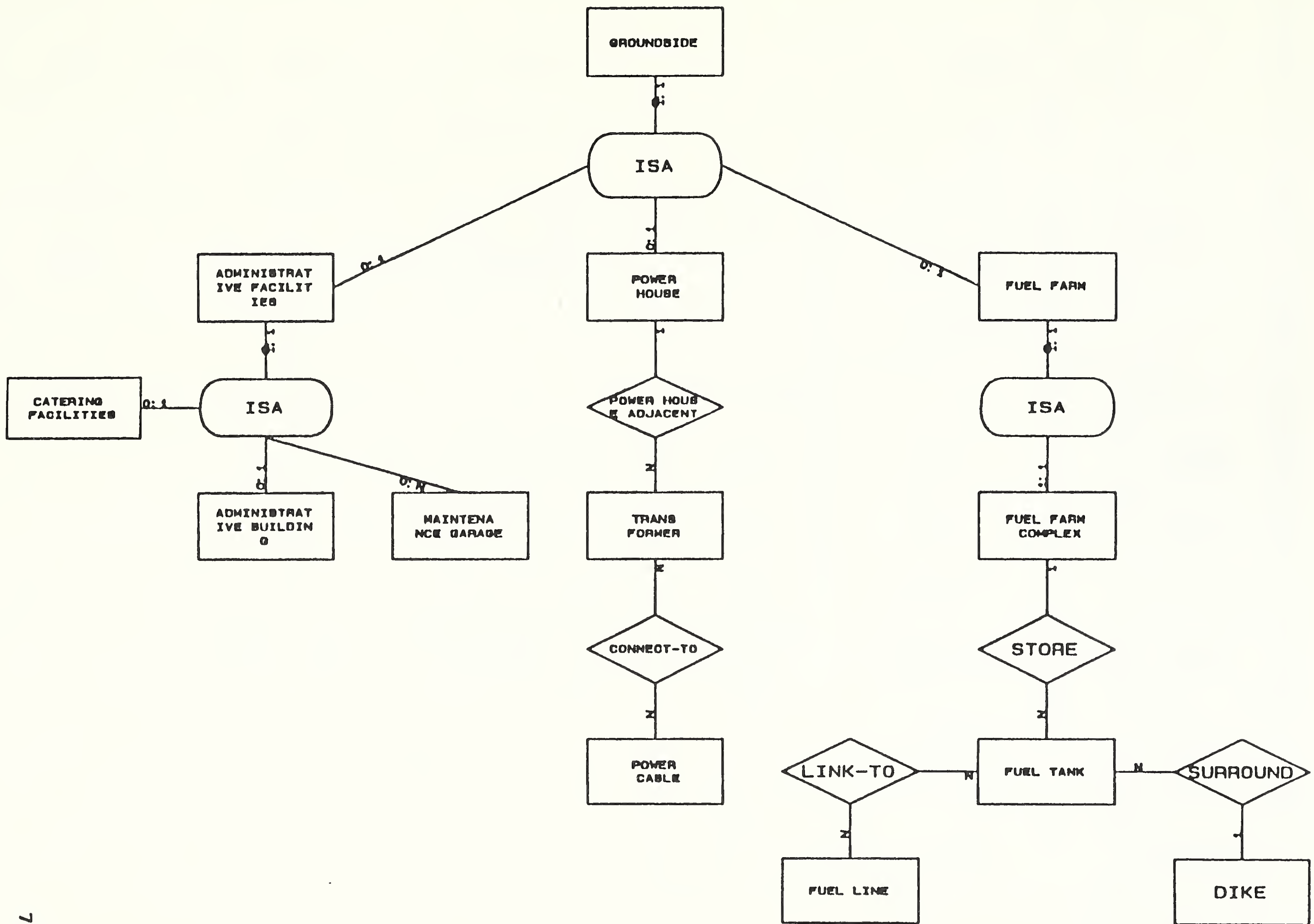

Figure 20 - Groundside

Note: Text placement by E-R Designer, (Chen and Associates, 1989)

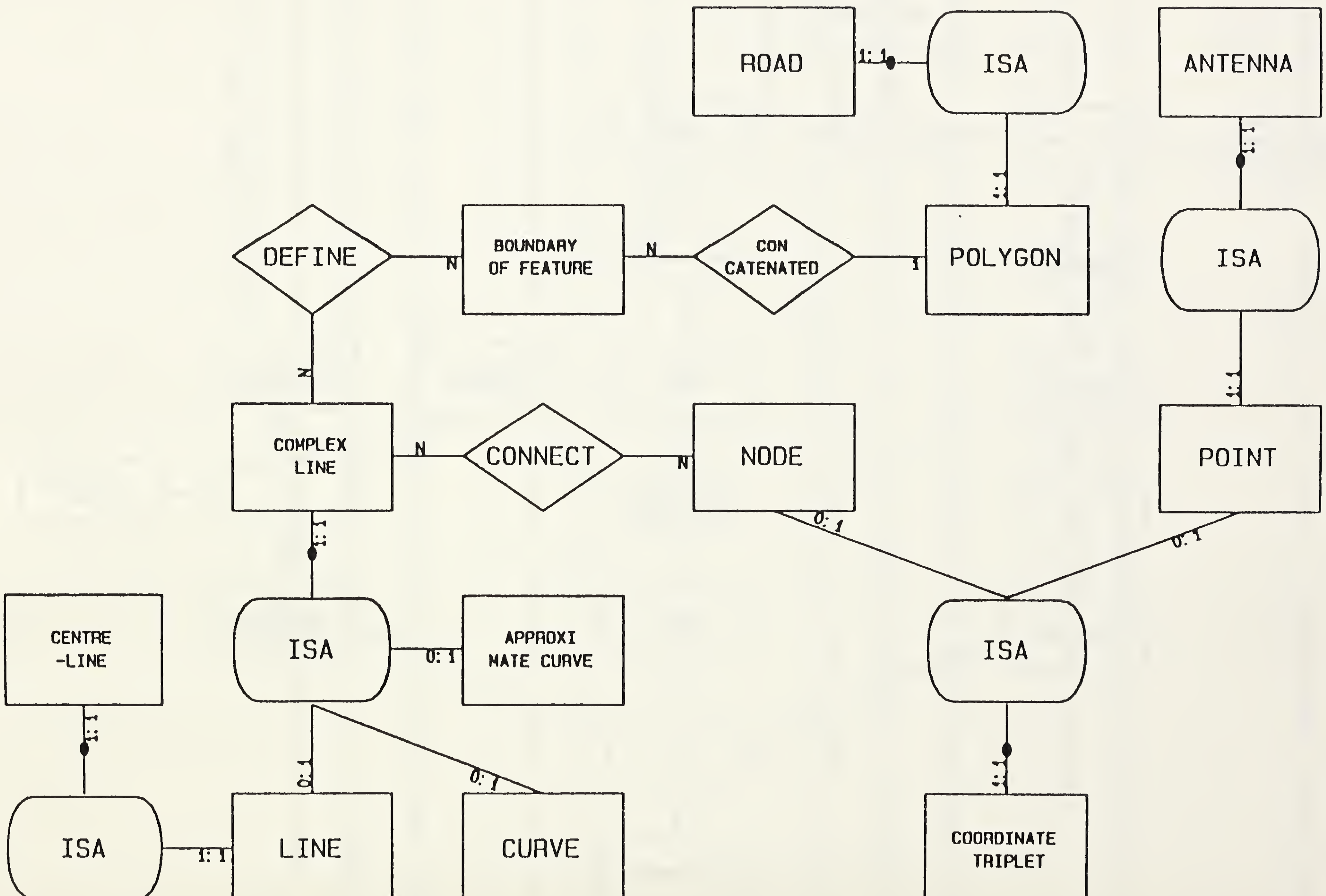

Figure 21 - The spatial model

Note: Text placement by E-R Designer, (Chen and Associates, 1989)

Cardinalities of 1:1,0:1 indicate that a complex line could be built from any child or combination of children. Attributes associated with FDEs are given in Table 7.

Many complex lines define a boundary of a feature. These boundary of features are then concatenated to form polygons. Cardinalities of N:N are assigned. Examples of feature entities mapped as polygons are runway, taxiway, apron and so forth.

Table 7 - Attributes of fundamental dimensional entities

Fundamental Dimensional Entity	Attribute
Point	Point-Identification (ID)
Node	Node-ID
Line	From-Node To-Node
Curve	Radius Centre
Approximate Curve	Deflection angle Chord length
Complex line	Left Right
Polygon	Area

10.5 Attributes

Attributes are associated with each entity. A complete listing of these could not be presented due to the volume of information; consequently, only attributes of one feature entity from each category of complex feature systems is presented in Table 8.

Table 8 - Example of feature entity attributes

Complex System Name	Entity Name	Attributes
Airside	Runway	Bearing Classification Construction date Declination Length Pavement load Rating Surface type Width
Prosaic	Storm pipe	Diameter Flow direction Invert elevation Length Material Overt elevation Width
Groundside	Administrative Building	Address Heating, ventilation and air conditioning (HVAC) system type Material Number of storeys Occupancy Security system

10.6 Spatial Relationships

Table 9 lists spatial relationships identified during conceptual modelling. These spatial relationships confirm that geographic information system processing is a necessary requirement at airports. For example, the relationships **is-in** and **intersect** suggest that point-in-polygon and polygon overlay processing are required for solving complex queries or forming the database to be consistent with the model and subsequent updates.

Table 9 - List of spatial relationships

Spatial Relationships	Symmetric Relationships
connected-to linked-to	
is-in is-on	outside
encloses	enclosed-by
contain	
intersect cross	
adjacent-to adjoin	

10.7 The GIRDS Data Model

Two connections are possible to link the FAP and GDMs to form the GIRDS data model. One connection is through the parent-child relationship established for **database** in which the entity **geographic** was a child of the entity **database**. The second link occurs in modelling the high-level entity **land related information**. Here the entity **lot** is <u>**leased by**</u> **tenant** in the FAP model.

10.8 Statistics on the GIRDS Data Model

Table 10 provides statistics on the GIRDS data model. It shows that of the 378 constructs used in the model, approximately 66% are represented by entities and relationships. A further 34% comprise parent-child relationships.

Table 10 - GIRDS statistics

Description	Number
Constructs	378
Entities	167
Geographic entities	126
Relationships	84
ISA	127

Table 11 provides statistics on the FDEs. These numbers show that 91 entities are mapped directly to the FDEs of which approximately 44% are polygons and 29% complex lines.

Table 11 - FDE statistics

Description	Number
Point	16
Nodes	5
Lines	4
Complex Lines	26
Polygons	40

10.9 Observations: Spatial Data Representations with E-R Models

A couple of observations can be made while modelling spatial data on airports. Firstly, the parent-child relationship (isa), an extension of the E-R model, is a necessary construct for the modelling of spatial relationships. For example, the FDE coordinate triplet is the parent of node and point. Nodes connect to form a complex line which is the parent of FDEs line, curve and approximate curve. These FDEs are then linked to geographic features through <u>isa</u> relationships. It is evident therefore that the linking of geographic features to spatial relationships could not be accomplished in E-R modelling without the isa construct. The parent-child relationship also allows greater flexibility in modelling relationships and permitted hierarchical aggregation.

Secondly, two entities require special consideration when mapped to FDEs. These are runways and contours. Runways are usually identified by a number. For example runway

15L-33R indicates that one end of the runway is at an azimuth of 150° while the other is at 330°. L and R, left and right indicates that this is one of two parallel runways. 15L therefore is the left hand runway to the aircraft on a 150° heading. As such, it was desirable to assign the cardinality between runway and polygon as N:1 where N=2. Contours provide a slightly different problem. Normally, contours when modelled from a cartographic view-point are viewed as complex lines. However, contours by their definition are lines of constant elevation and in fact close on themselves. In most surveying applications, contours are used as polygons in volume computations and cut and fill analysis. As information, rather than data, is the primary requirement at airports, it is natural to model contours as polygons.

11. THE GEOGRAPHIC INFORMATION RESOURCE DICTIONARY SYSTEM

Conversion of the airport GDM to the ANSI-IRDS involved, as a first step, re-defining the data model in terms of an E-R-A model in order that entity-types and relationship-types are easily identified. Next, an empty IRD had to be created and the IRD Schema defined prior to compiling the ANSI-IRDS commands.

11.1 Populating the IRD

The IRD is populated in a top-down manner. As a first step, this requires converting the E-R diagram to an E-R-A, GIRDS diagram (Law, 1988).

11.1.1 Conversion to an E-R-A, GIRDS Diagram

The E-R-A, GIRDS diagram, unlike the E-R diagram identifies:

- the direction of flow between entities,
- the hierarchy of entities,
- entity-types and relationship-types associated with each entity and relationship; and
- entities and relationships used in describing the IRD.

Figures 22 and 23 illustrate these concepts.

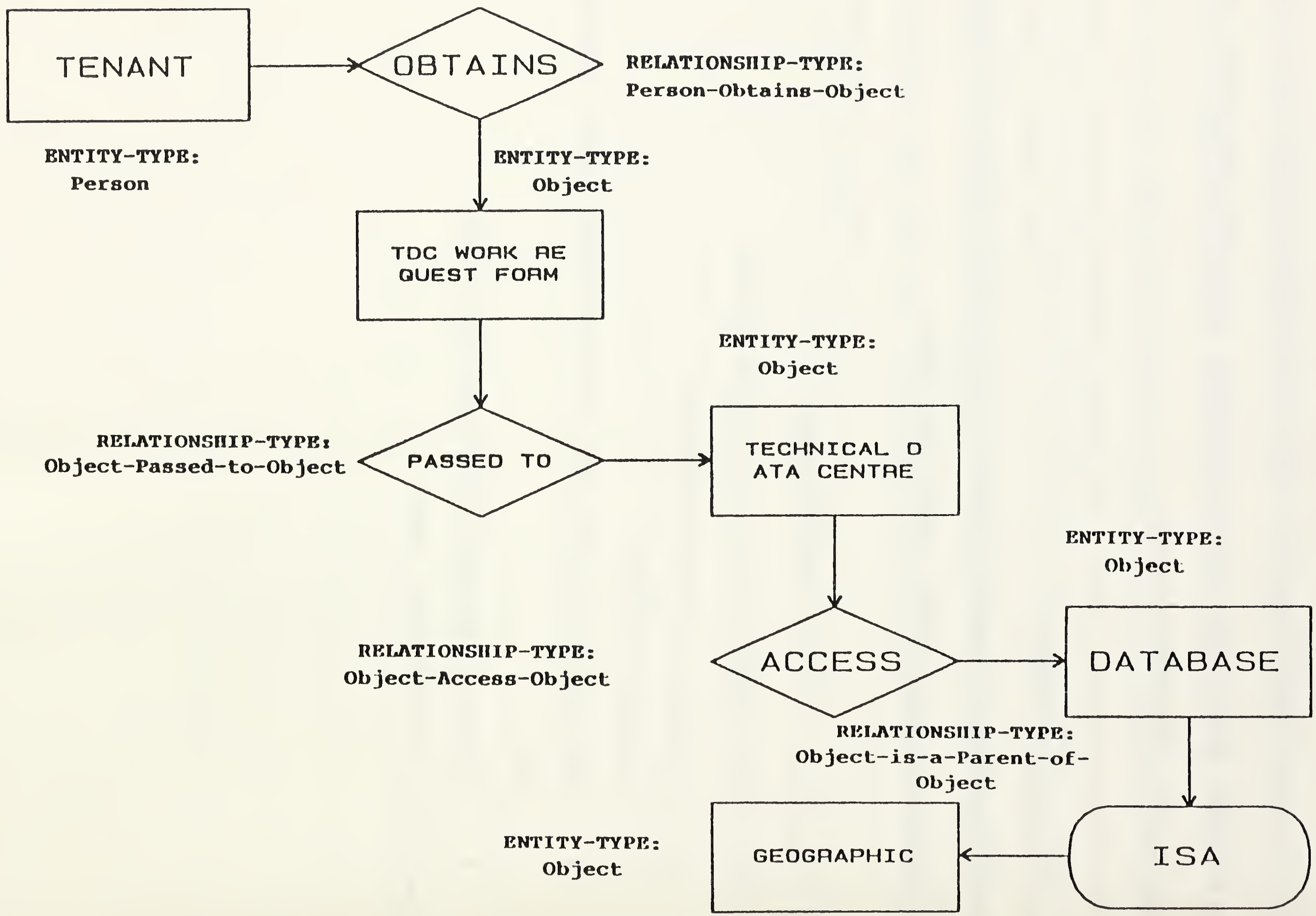

Figure 22 - Example of the FAP E-R-A

Note: Text placement by E-R Designer, (Chen and Associates, 1989)

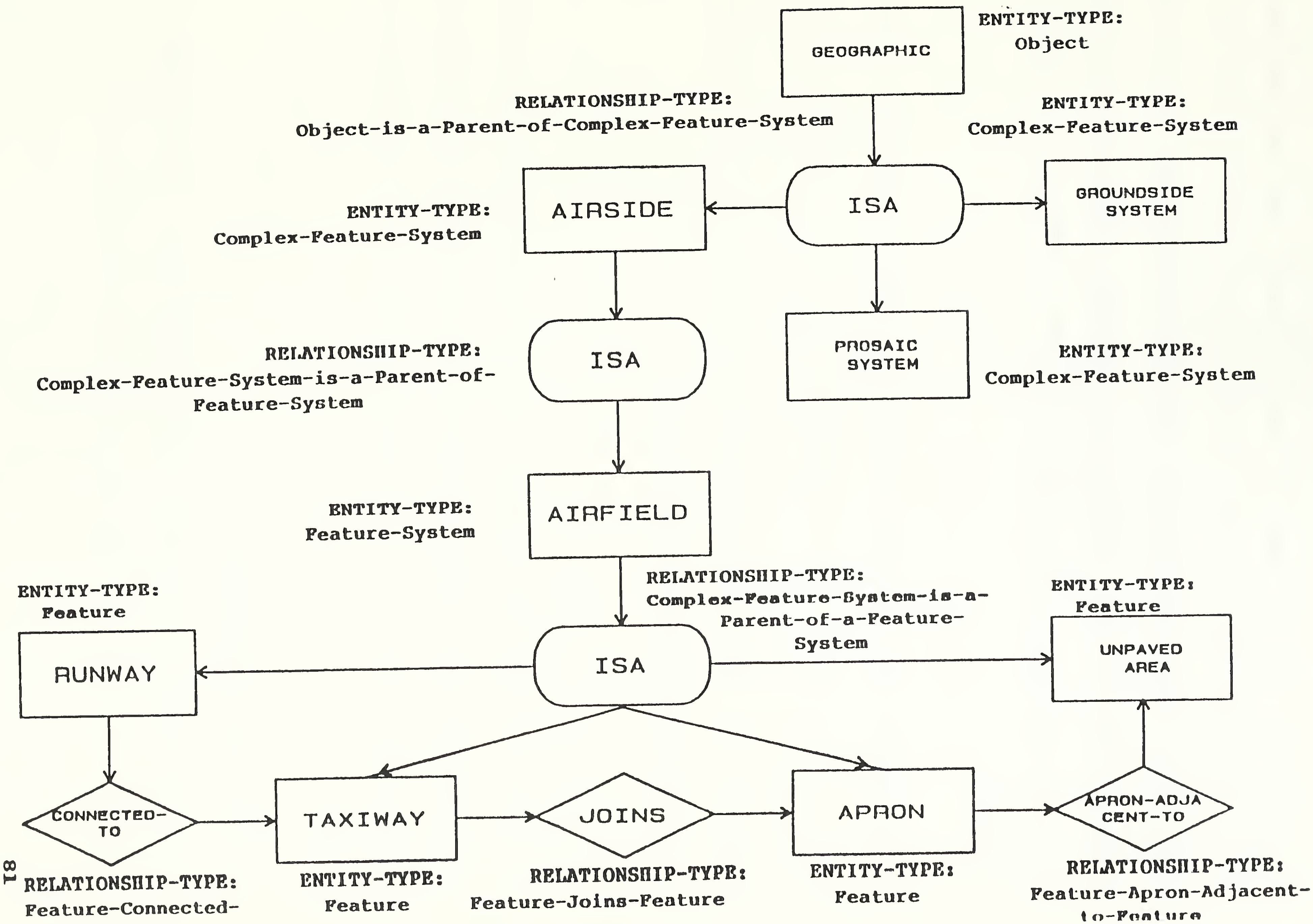

Figure 23 - Example of the Geographic E-R-A

Note: Text placement by E-R Designer, (Chen and Associates, 1989)

At the FAP level, (Figure 22), there is no hierarchy of entities. Each entity is assigned a entity type, **person** or **object**. Meta-entity type **person** refers to entities such as tenant, TRC, project manager and so forth. Meta-entity type **object** is used to identify entities such as alteration schedule, documents, as-built drawings and so forth. Relationship-types person-obtains-object and object-is-a-parent-of-object are established for the entities - **database** and **geographic**.

At the Geographic level, the hierarchy of entities are described as complex feature systems, feature systems and features. The entity, **geographic** (Figure 23), which is assigned an entity-type, object, is the parent of the complex feature systems - airside, prosaic system and groundside. Entity-types are therefore assigned to these entities as well as a relationship-type of object-is-a-parent-of-complex-feature-system.

11.1.2 Creating an Empty IRD

Once the E-R to E-R-A model conversion is complete, the next step is to create an empty IRD and associate with it the Basic Functional Schema. This process could be carried out either interactively or through batch processing using the IRD commands to create the IRD Schema and define the IRD.

11.1.3 GIRDS Schema Definition

This section provides an example of the Schema definition used to support meta-data for the GIRDS. It should be noted that within the IRD, each entity-type name and entity name must be unique.

Table 12 lists the ANSI-IRDS commands used to define the IRD Schema for the section of the airport GDM shown in Figure 23. These commands provide for the definition of entity-types and relationship-types in the IRD Schema.

Table 12 - Schema definition

```
/* entity type definition */

add meta-entity object meta-entity-type = entity-type;
add meta-entity complex-feature-system
    meta-entity-type = entity-type;
add meta-entity feature-system
    meta-entity-type = entity-type;
add meta-entity feature meta-entity-type = entity-type;

/* relationship-class-type-definition */

add meta-entity is-a-parent-of
    meta-entity-type = relationship-class-type;

/* relationship type definition: parent-child */

add meta-entity object-is-a-parent-of-complex-feature-system
    meta-entity-type = relationship-type;
add meta-entity
complex-feature-system-is-a-parent-of-feature-system
    meta-entity-type = relationship-type;
add meta-entity feature-system-is-a-parent-of-feature
    meta-entity-type = relationship-type;
add meta-entity feature-is-a-parent-of-feature
    meta-entity-type = relationship-type;

/* relationship type definition: feature-feature */

add meta-entity feature-connected-to-feature
    meta-entity-type = relationship-type;
add meta-entity feature-joins-feature
    meta-entity-type = relationship-type;
add meta-entity feature-apron-adjacent-to-feature
    meta-entity-type = relationship-type;

/* relationship-type associated with
   relationship-class-type */

add meta-relationship
    object-is-a-parent-of-complex-feature-system
    member-of is-a-parent-of;
```

Table 12 - Schema definition (cont.)

```
add meta-relationship
   complex-feature-system-is-a-parent-of-feature-system
   member-of  is-a-parent-of;

add meta-relationship
   feature-system-is-a-parent-of-feature
   member-of  is-a-parent-of;

add meta-relationship
   feature-is-a-parent-of-feature
   member-of  is-a-parent-of;

/* relationship-type  positional  definition */

add meta-relationship
   object-is-a-parent-of-complex-feature-system
   connects object  position  =  1;

add meta-relationship
   object-is-a-parent-of-complex-feature-system
   connects complex-feature-system  position  =  2;

add meta-relationship
   complex-feature-system-is-a-parent-of-feature-system
   connects complex-feature-system  position  =  1;

add meta-relationship
   complex-feature-system-is-a-parent-of-feature-system
   connects feature-system  position  =  2;

add meta-relationship
   feature-system-is-a-parent-of-feature
   connects feature-system  position  =  1;

add meta-relationship
   feature-system-is-a-parent-of-feature
   connects feature  position  =  2;
```

11.1.4 GIRDS: IRD Definition

Once the IRD Schema is created, all entities and relationships can be defined at the IRD level as shown in Table 13.

Table 13 - IRD definition

```
/* ird level - define entities */

add entity geographic entity-type = object;
add entity airside entity-type = complex-feature-system;
add entity prosaic-system
   entity-type = complex-feature-system;
add entity groundside entity-type = complex-feature-system;
add entity airfield entity-type = feature-system;
add entity runway entity-type = feature;
add entity taxiway entity-type = feature;
add entity apron entity-type = feature;
add entity unpaved-area entity-type = feature;

/* add parent-child relationships */

add relationship geographic is-a-parent-of airside;
add relationship geographic is-a-parent-of prosaic-system;
add relationship geographic is-a-parent-of groundside-system;
add relationship airside is-a-parent-of airfield;
add relationship airfield is-a-parent-of runway;
add relationship airfield is-a-parent-of taxiway;
add relationship airfield is-a-parent-of apron;
add relationship airfield is-a-parent-of unpaved-area;

/* add relationships for features */

add relationship runway feature-connected-to-feature taxiway;
add relationship taxiway feature-joins-feature apron;
add relationship apron feature-apron-adjacent-to-feature
   unpaved-area;
```

11.2 Compiling the ANSI-IRDS Commands

The ANSI-IRDS prototype program (AIRDSPP) developed at NIST translates ANSI-IRDS commands into Structured Query Language (SQL) commands and sends these to the Oracle DBMS, where the database representing the IRD is maintained (Oracle Corporation, 1989a). AIRDSPP performs various consistency checks, some of which include calls to the DBMS to access data. Formatting of the output and some of the entity selection is done at the AIRDSPP level. The remainder of the selection is done through the DBMS facility (Goldfine and Kirkendall, 1988).

When the ANSI-IRDS prototype is executed, the AIRDSPP looks for the Oracle table DICTIONARY_NAMES to get a list of available IRDs. If this table exists, then the user is asked to name the IRD. If not, AIRDSPP calls subroutines SET_DICT and MK_DICT to create the necessary tables. Preliminary parsing of each ANSI-IRDS command is performed by the subroutines GETCOM, READCOM, INDEXCOMM, DO_COMMAND, CK_SYNTAX and MATCH_TEMPLATE.

After a command has been read in and parsed, the list of values from the parse is passed by the subroutine DO_COMMAND to the subroutine for that command. Each command has a corresponding subroutine, and each subroutine has, as its name, an abbreviation of the name of the command. The subroutines do the required consistency checking and translate the command into SQL commands. The SQL commands may then be executed against an Oracle database by using the Oracle Call Interface (OCI) subroutines supplied with the Oracle DBMS (Oracle Corporation, 1989b).

11.2.1 GIRDS: IRD Output Command

Information on entities, relationships, meta-entities and meta-relationships, as well as system generated meta-attributes and attributes may be obtained from the IRD by use of the Output IRD and Output IRD Schema commands. These commands may be issued interactively or in the batch file as shown in Table 14.

Table 14 - IRD output commands

```
/* ird output */

output ird-schema select object,
complex-feature-system,feature-system,feature,
        complex-feature-system-is-a-parent-of-feature-system,
        feature-system-is-a-parent-of-feature,
        feature-is-a-parent-of-feature,
        object-is-a-parent-of-complex-feature-system,
        feature-connected-to-feature,feature-joins-feature,
        feature-apron-adjacent-to-feature,
```

11.3 GIRDS: Output

The output from the ANSI-IRDS compilation provides a listing of all entities and relationships added to the IRD along with any error messages. In addition, the IRD output command issued in Section 10.2.5 provides information on entities, relationships, meta-entities, meta-relationships, meta-attributes and meta-attribute-groups as depicted in Table 16 and explained in Table 15.

Table 15 - Explanation of GIRDS output

OUTPUT	EXPLANATION
added-by	assigned access-name of the effective IRDS user
connectable	identifies whether or not the specified entity-type meta-entity can participate in any user-defined relationship-types
implementation-lock	identifies those meta-entities which are required for an implementation.
origin	identifies the source of this object type. Default is IXsuffix, where suffix is an installation-defined suffix.
maximum entity assigned descriptive name length	defines the maximum number of characters allowed by the implementation for an entity-descriptive-name.
maximum entity assigned access name length	defines the maximum characters allowed by the implementation for a meta-entity assigned-access-name.
maximum entity assigned descriptive name length	define the maximum number of characters allowed by the implementation for a meta-entity assigned-descriptive-name.
number of instances	identifies how many entities of the corresponding type exist in the IRD.
number of times modified	number of times a particular meta-entity or meta-relationship has been modified.
system-generated	identifies whether or not an entity-type has system-generated entity assigned-access-names.
system-lock	identifies whether or not a given meta-entity or meta-relationship can be deleted from the IRD Schema by the installation.
system-date	identifies the current date

Table 15 - Explanation of GIRDS output (cont.)

OUTPUT	EXPLANATION
system-time	identifies the current time of day
position	of an entity-type with respect to a relationship-type

Table 16 - GIRDS output data

```
META_ENTITY = COMPLEX_FEATURE_SYSTEM
META_ENTITY_TYPE= ENTITY_TYPE

META-ATTRIBUTES:
                     ADDED_BY  = tony
                   CONNECTABLE  = YES
              IMPLEMENTATION_LOCK   = OFF
                        ORIGIN  = IX
MAXIMUM_ENTITY_ASSIGNED_DESCRIPTIVE_NAME_LENGTH     = 64
MAXIMUM_ENTITY_ASSIGNED_ACCESS_NAME_LENGTH    = 32
MINIMUM_ENTITY_ASSIGNED_DESCRIPTIVE_NAME_LENGTH     = 1
              NUMBER_OF_INSTANCES   = 3
           NUMBER_OF_TIMES_MODIFIED    = 0
                SYSTEM_GENERATED   = NO
                   SYSTEM_LOCK  = ON

META-ATTRIBUTE-GROUPS:
   DATE_TIME_ADDED
                   SYSTEM_DATE  = 19900823
                   SYSTEM_TIME  = 151629

META-RELATIONSHIPS:

COMPLEX_FEATURE_SYSTEM_IS_A_PARENT_OF_FEATURE_SYSTEM
RELATIONSHIP_TYPE_CONNECTS_ENTITY_TYPE
COMPLEX_FEATURE_SYSTEM

              IMPLEMENTATION_LOCK   = OFF
                        ORIGIN  = IX
                      POSITION  = 1
                   SYSTEM_LOCK  = ON

OBJECT_IS_A_PARENT_OF_COMPLEX_FEATURE_SYSTEM
RELATIONSHIP_TYPE_CONNECTS_ENTITY_TYPE
COMPLEX_FEATURE_SYSTEM

              IMPLEMENTATION_LOCK   = OFF
                        ORIGIN  = IX
                      POSITION  = 2
                   SYSTEM_LOCK  = ON
```

Table 16 - GIRDS output data (cont.)

Entity = AIRSIDE
Entity Descriptive-Name =
Entity Type = COMPLEX_FEATURE_SYSTEM

Attributes
ADDED_BY = tony
NUMBER_OF_TIMES_MODIFIED = 0

Attribute Groups
DATE_TIME_ADDED
SYSTEM_DATE = 19900823
SYSTEM_TIME = 154953

Relationships
AIRSIDE
COMPLEX_FEATURE_SYSTEM_IS_A_PARENT_OF_FEATURE_SYSTEM
AIRFIELD
GEOGRAPHIC OBJECT_IS_A_PARENT_OF_COMPLEX_FEATURE_SYSTEM
AIRSIDE

Entity = AIRFIELD
Entity Descriptive-Name =
Entity Type = FEATURE_SYSTEM

Attributes
ADDED_BY = tony
NUMBER_OF_TIMES_MODIFIED = 0

Attribute Groups
DATE_TIME_ADDED
SYSTEM_DATE = 19900823
SYSTEM_TIME = 155901

Relationships
AIRSIDE
COMPLEX_FEATURE_SYSTEM_IS_A_PARENT_OF_FEATURE_SYSTEM
AIRFIELD
AIRFIELD FEATURE_SYSTEM_IS_A_PARENT_OF_FEATURE APRON
AIRFIELD FEATURE_SYSTEM_IS_A_PARENT_OF_FEATURE RUNWAY
AIRFIELD FEATURE_SYSTEM_IS_A_PARENT_OF_FEATURE TAXIWAY
AIRFIELD FEATURE_SYSTEM_IS_A_PARENT_OF_FEATURE
UNPAVED_AREA

Table 16 - GIRDS output data (cont.)

Entity = RUNWAY
Entity Descriptive-Name =
Entity Type = FEATURE

Attributes
ADDED_BY = tony
NUMBER_OF_TIMES_MODIFIED = 0

Attribute Groups
DATE_TIME_ADDED
SYSTEM_DATE = 19900823
SYSTEM_TIME = 172838

Relationships
RUNWAY FEATURE_ASSOCIATED_WITH_FEATURE LIGHTING_SYSTEMS
RUNWAY FEATURE_CONNECTS_TO_FEATURE TAXIWAY
RUNWAY FEATURE_HAS_FEATURE APPROACH_PATH
RUNWAY FEATURE_IS_A_PARENT_OF_FUND_DIMEN_ENTITY POLYGON
RUNWAY FEATURE_IS_FEATURE ZONED
AIRFIELD FEATURE_SYSTEM_IS_A_PARENT_OF_FEATURE RUNWAY

12. CONCLUSIONS AND RECOMMENDATIONS

A number of conclusions follow from this modelling effort. These are summarized and presented under the headings of Spatial E-R Modelling, Spatial Relations, Resources Needed for Modelling and the Integration of IRDS and GIS.

12.1 Spatial E-R Modelling

12.1.1 Parent-child (isa) relationships, an extension of the E-R model, provide a means of representing spatial relationships. It should be considered a mandatory construct for E-R modelling of geographic features and their representations. The isa relationship also permits hierarchical aggregation. A total of 127 isa relationships occurred in the model, accounting for approximately 34% of all constructs.

12.1.2 Cardinalities describing relationships between geographic features are predominantly 1:N and N:N. This indicates that a DBMS is required to manage the many tables containing non-geographic data and their linkages to geographic features.

12.1.3 Airports features are modelled as belonging to three types of complex-feature-systems; namely, airside, prosaic and groundside. These complex-feature-systems are decomposed through isa relationships into feature-systems and then features. All features are related to their respective FDEs through isa relationships.

12.1.4 Of the 126 geographic features modelled, 44% are polygons, 29% are complex lines and 18% are points. The remaining 9% is almost equally divided between nodes and lines. This is significant because polygons are concatenated from boundaries of features which are defined by complex lines; consequently, additional hardware and software is required at airports to process the large number of geographic features represented as polygons. These results also indicate that a methodical and extensive database design is required for maintaining an airport geographic database. This is due to the complexity of polygon features which makes maintenance of an airport geographic database a difficult task.

12.2 Spatial Relations

12.2.1 Twelve spatial relationships (operators) are derived in the modelling process (see Table 9, Section 10.6). These spatial relationships confirm that geoprocessing is a necessary requirement at airports. For example, the relationships is-in and intersect suggest that point-in-polygon and polygon overlay processing requirements are necessary.

12.2.2 Of the twelve spatial relationships identified in the GDM, two are considered symmetric. These are - outside and enclosed by - and are listed in Table 9, Section 10.6. Both spatial and symmetric relationships correspond closely to those identified by the Association for Geographic Information, SQL Working Party (The Association for Geographic Information, 1990). These operators, if standardized, would enable GIS applications to be ported more easily and allow vendors to optimize the implementation of these operators.

12.3 Resources Needed for Modelling

12.3.1 The GIRDS modelling task requires approximately 200 man-hours of effort. This is significant as only a small subset of an airport geographic database is modelled. It is also significant that the GIS community realise the effort required to produce this model and understand its necessity. If beneficial results are to be achieved in the management and maintenance of airport geographic databases, airport managers should also realize that meaningful commitments and support should be given to staff and consultants contracted to undertake these tasks.

12.3.2 The GIRDS modelling effort also requires significant computing resources. The conversion from the GDM to the GIRDS takes 50 hours to write 1350 lines of code. Compilation of this code is done on a Digital Equipment Corporation VAX 11/785 with 16 MB of random access memory (RAM) and then on a personal computer (PC), 386 model with 2 MB of RAM and a clock speed of 20 megahertz (MHZ). Compilation times are 12 hours and 23 hours respectively.

12.4 Integration of IRDS and GIS

12.4.1 Output from the GIRDS demonstrates that airport entities, relationships and their attributes can be maintained and monitored with the GIRDS. This is beneficial to TDC managers where equipment is being added or upgraded on the airport; consequently, there is a requirement that new facilities be referenced by name to those being replaced or currently being maintained.

12.4.2 GIRDS demonstrates that it can be used for geographic data maintenance as all entities are time-stamped by the system and the number of times modified is recorded. This implies that non-geographic data may be time-stamped because of the established linkages to the geographic entities which are monitored by the ANSI-IRDS. However, time-stamping of geographic entities occurs only when these entities are changed.

12.4.3 No extensions are required to the ANSI-IRDS for it to be applied to the management of geographic data. Commands provided by the standard implementation of the ANSI-IRDS are adequate to define geographic entities and their relationships in the IRD Schema and the IRD.

12.5 Recommendations

12.5.1 Cardinalities identified in the modelling effort are not included in the conversion as they do not have a direct influence on the GIRDS. However, as cardinalities define the number of tables to be opened by a DBMS for each entity, they should be recorded. It is therefore recommended that the ANSI-IRDS Schema be extended to include cardinalities as attributes of relationships.

12.5.2 The GIRDS conversion did not include the controlling of meta-data on the entities and further work is required in dealing with this issue. For example, feature attributes on the entity runway may be thought of as entities in the ANSI-IRDS having attributes. This is easily demonstrated by considering the relationship **runway-has-length** and attaching attributes to the entity length of metres and centimetres.

12.5.3 The IRDS Standard has demonstrated the ability to manage geographic information resources. The Canadian General Standards Board Committee on Geomatics, has Working Group 4 assigned to the development of a Cataloguing/Data Dictionary Standard. Based on the results of this report, Working Group 4 should consider IRDS as a candidate for a standard in support of the sharing of geomatic data.

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ACRONYMS

Acronym	Definition
AASR	Area and Surveillance Radar
AGIS	Airport Geographic Information System
AIRDSPP	American National Standard Institute Information Resource Dictionary System Prototype Program
ANSI	American National Standards Institute
ASCII	American Standard Code for Information Interchange
ASIS	Approach Slope Indicator System
ATB	Air Terminal Building
CAD	Computer Aided Drafting
DBMS	Database Management System
D/D	Directory/Dictionary
DRM	Data Resource Management
DV	Database Validation
E-E-R	Extended-Entity-Relationship
E-R	Entity-Relationship
E-R-A	Entity-Relationship-Attribute
FAP	Facility Alteration Permit
FD	Fundamental Dimensional
FDE	Fundamental Dimensional Entity
FIPS	Federal Information Processing Standard

ACRONYMS (cont.)

Acronym	Definition
GDM	Geographic Data Model
GIR	Geographic Information Resource
GIRDS	Geographic Information Resource Dictionary System
GIS	Geographic Information System
GP	Geometric Primitive
G/P	Glide Path
HCM	Hardware Configuration Management
HVAC	Heating, Ventilation and Air Conditioning
ICAO	International Civil Aviation Organization
IKAP	Transport Canada Internal Designator
ILIM	Institute for Land Information Management
ILS	Instrument Landing Systems
IRD	Information Resource Dictionary
IRDS	Information Resource Dictionary System
IRM	Information Resource Management
ISA	Generalization hierarchy occurring when an entity is partitioned by different values of the same entity
LBPIA	Lester B. Pearson International Airport
LRI	Land-Related Information
MB	Megabytes

ACRONYMS (cont.)

Acronym	Definition
MHZ	Megahertz
NIP	National Implementation Plan
NIST	National Institute of Standards and Technology
NTS	National Topographic Series
OCI	Oracle Call Interface
PAPIS	Precision Approach Path Indicator System
PC	Personal Computer
PCM	Profit Centre Manager
PWC	Public Works Canada
RAM	Random Access Memory
SCM	Software Configuration Management
SRCM	System Resource Configuration Management
SDTS	Spatial Data Transfer Standard
SQL	Structured Query Language
SSR	Secondary Surveillance Radar
TDC	Technical Data Centre
TRC	Technical Review Committee
VASIS	Visual Approach Slope Indicator System

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11. ABSTRACT (A 200-WORD OR LESS FACTUAL SUMMARY OF MOST SIGNIFICANT INFORMATION. IF DOCUMENT INCLUDES A SIGNIFICANT BIBLIOGRAPHY OR LITERATURE SURVEY, MENTION IT HERE.)

The management of geographic information resources (GIRS) continues to be plagued by problems of monitoring, locating and controlling the array of geographic information in complex organizations. Software tools to support these functions are fundamental to any effort to maintain the integrity of geographic information as it changes. In addition, such tools are desirable when formalizing, then managing the integration of geographic information resources within an organization. One of the major approaches to this problem in the area of database systems has been the development of the information resource dictionary (IRD) which contains meta-data. An Information Resource Dictionary System (IRDS) is a database of meta-data along with software and procedures for the creation and maintenance of the IRD. In 1989 the American National Standards Institute (ANSI) X3.138-1988 IRDS (ANSI-IRDS) was adopted as Federal Information Processing Standard 156 by the United States Government. ANSI-IRDS is intended to support the definition, management and control of mete-data. This study presents the first known attempt to actually apply ANSI-IRDS in the geographic information management domain.

12. KEY WORDS (6 TO 12 ENTRIES; ALPHABETICAL ORDER; CAPITALIZE ONLY PROPER NAMES; AND SEPARATE KEY WORDS BY SEMICOLONS)
geographic information systems; GIS; information resource dictionary system; meta-data; data management; GIS standard

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