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Data Modeling Overview Guide

Release 9.8

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Chapter 1: Introduction

While data modeling can be complex, this *Overview Guide* can help Data Architects understand data modeling and its uses.

Overall, this guide has the following purposes:

- Provide a basic level of understanding of the data modeling method used by erwin® Data Modeler that is sufficient to do real database design.
- Introduce some of the descriptive power and richness of the IDEF1X and IE modeling languages supported, and to provide a foundation for future learning.
- Provide information about the supported features of IDEF1X and IE in erwin® Data Modeler, and the mapping between these methods.

This section contains the following topics

Benefits of Data Modeling (see page 9)
Methods (see page 10)
Typographical Conventions (see page 10)

Benefits of Data Modeling

Regardless of the DBMS you use or the types of data models you want to develop, modeling your database in erwin® Data Modeler has many benefits:

- Enables usage by database and application development staff to define system requirements and to communicate among themselves and with end users.
- Provides a clear picture of referential integrity constraints. Maintaining referential integrity is essential in the relational model where relationships are encoded implicitly.
- Provides a logical RDBMS-independent picture of your database that automated tools can use to generate RDBMS-specific information. This way, you can use a single diagram to generate DB2 table schemas, and schemas for other relational DBMSs.
- Lets you produce a diagram summarizing the results of your data modeling efforts and generate a database schema from that model.

Methods

erwin® Data Modeler supports two methods of data modeling:

IDEF1X

The United States Air Force developed the IDEF1X method. The IDEF1X method is now used in various governmental agencies, in the aerospace and financial industry, and in a wide variety of major corporations.

IE (Information Engineering)

James Martin, Clive Finkelstein, and other IE authorities developed the IE method, which is widely deployed in various industries.

Both methods are suited to environments where large-scale, rigorous, enterprise-wide data modeling is essential.

Typographical Conventions

The following table describes the typographical conventions used in this guide to identify key terms:

Text Item	Convention	Example
Entity Name	All uppercase, followed by the word "entity" in lowercase	MOVIE COPY entity
Attribute Name	All lowercase in quotation marks	"movie name"
Column Name	All lowercase	movie_name
Table Name	All uppercase	MOVIE_COPY
Verb Phrase	All lowercase in angle brackets	<is available for rental as>

Chapter 2: Information Systems, Databases, and Models

This section contains the following topics

Data Modeling (see page 11)
Data Modeling Sessions (see page 13)
Sample IDEF1X Modeling Methodology (see page 15)
Modeling Architecture (see page 16)
Logical Models (see page 17)
Physical Models (see page 19)

Data Modeling

Data modeling

Data modeling is the process of describing information structures and capturing business rules to specify information system requirements. Data models represent a balance between the specific needs of an RDBMS implementation project, and the general needs of the business area that requires it.

When created with the full participation of business and systems professionals, the data model can provide many benefits. These benefits generally fall into the following two classes:

Effort

The staff associated with the process of creating the model.

Product of the Effort

The staff primarily associated with the model.

Examples of Product Benefits

- A data model is independent of implementation, so it does not require that the implementation is in any particular database or programming language.
- A data model is an unambiguous specification of what is wanted.
- The model is business user-driven. The business client controls the content and structure of the model, rather than the system developer. The emphasis is on requirements rather than constraints or solutions.
- The terms used in the model are stated in the language of the business, not that of the system development organization.
- The model provides a context to focus your discussions about what is important to the business.

Examples of Process Benefits

- During early project phases, model development sessions bring together individuals from many parts of the business. The sessions provide a structured forum where business needs and policies are discussed. Business staff typically meets others for the first time, and meets others in different parts of the organization who are concerned with the same needs.
- Sessions lead to development of a common business language with consistent and precise definitions of terms used. Communication among participants is greatly increased.
- Early phase sessions provide a mechanism for exchanging large amounts of information among business participants and transferring much business knowledge to the system developers. Later phase sessions continue that transfer of knowledge to the staff who will implement the solution.
- Session participants are better able to see how their activities fit into a larger context. Also, parts of the project can be seen in the context of the whole. The emphasis is on cooperation rather than separation. Over time, cooperation leads to a shift in values, and the reinforcement of a cooperative philosophy.
- Sessions foster consensus and build teams.

Design of the data structures to support a business area is only one part of developing a system. *Function modeling*, the analysis of processes (function) is equally important. Function models describe how something is done. They can be presented as hierarchical decomposition charts, data flow diagrams, HIPO diagrams, and so on. Developing both your function models and data models at the same time is important. Discussion of the functions that the system performs uncovers the data requirements. Discussion of the data typically uncovers additional function requirements. Function and data are the two sides of the system development coin.

Data Modeling Sessions

Creating a data model involves not only model construction, but also many fact-finding sessions (meetings) to uncover the data and processes used by a business. Running good sessions, like running good meetings of any kind, depends on preparation and real-time facilitation techniques. In general, include the right mix of business and technical experts, and facilitate the modeling sessions. Schedule modeling sessions in advance, carefully plan to cover sets of focused material, and orchestrate it in a way to achieve the results you require.

When possible, it is highly recommended that modeling of function and data be done at the same time. Functional models tend to validate a data model and uncover new data requirements, and helps ensure that the data model supports function requirements.

Session Roles

Formal, guided sessions, with defined roles for participants and agreed upon procedures and rules, are an absolute requirement. The following roles work well:

Facilitator

A facilitator acts as the session guide and is responsible for:

- Arranging the meetings and facilities
- Providing follow-up documentation
- Intervening during sessions, as necessary, to keep sessions on track and to control the scope of the session.

Data Architect

Leads the group through the process of developing and validating the model. A data architect develops the model, in real time if possible, in front of the group. The data architect asks pertinent questions that bring out the important details and records the resulting structure for all to see. The same individual can fill both facilitator and data architect roles, although it can be difficult.

Data Analyst

Acts as the scribe for the session and records the definitions of all the entities and attributes that make up the model. Using the information from the business experts, the data analyst can also begin to package entities and attributes into subject areas. Subject areas are simply manageable and meaningful subsets of the complete data model.

Subject Matter Expert

Provides the business information necessary to construct the model. You can have more than one subject matter expert. They are business experts, not systems experts.

Manager

Participates in the sessions in an assigned role (such as facilitator or subject matter expert) and keeps the process moving. The manager has the responsibility of “breaking ties” but only when necessary. The manager can be from either the systems or business community.

Sample IDEF1X Modeling Methodology

erwin® Data Modeler was developed to support the IDEF1X and IE modeling standards. The use of various levels of models within the IDEF1X method can be helpful in developing a system. General model levels are outlined in the IDEF1X standard. In practice, you can expand or contract the number of levels to fit individual situations.

Model levels generally span from a wide view to a narrow view, depending on project requirements. A wide but not too detailed view can include only the major entities that are important to a business. A narrow view can include a level of precision required to represent the database design in terms understandable by a particular DBMS. At the lowest level of detail, models are technology-dependent. For example, a model for an IMS database looks different from a model for a DB2 database. At higher levels, models are technology independent and can represent information that is not stored in any automated system.

The modeling levels presented are suited to a top-down system development lifecycle approach, where successive levels of detail are created during each project phase.

The highest level models come in two forms:

Entity Relationship Diagram (ERD)

Identifies major business entities and their relationships.

Key-Based (KB)

Sets the scope of the business information requirement (all entities are included) and begins to expose the detail.

The lower-level models also come in two forms:

Fully-Attributed (FA)

Represents a third normal form model that contains all of the detail for a particular implementation effort.

Transformation Model (TM)

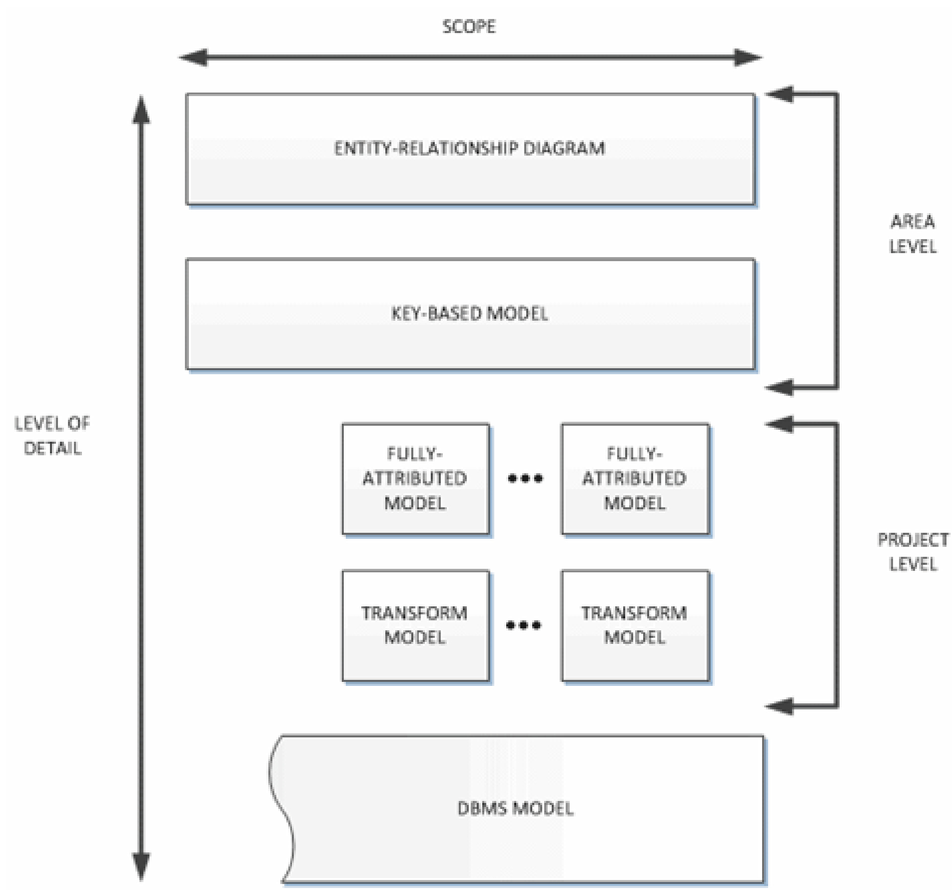
Represents a transformation of the relational model into a structure, which is appropriate to the DBMS chosen for implementation. The TM, in most cases, is no longer in third normal form. The structures are optimized based on the capabilities of the DBMS, the data volumes, and the expected access patterns and rates against the data. In a way, a TM is a picture of the eventual physical database design.

DBMS Model

The database design is contained in the DBMS Model for the system. The DBMS Model can be a project level model or an area level model for the entire integrated system.

Modeling Architecture

Five modeling levels are presented in the following illustration. Notice that the DBMS model can be at either an Area Level scope, or a Project Level scope. It is not uncommon to have single ERD and KB models for a business, and multiple DBMS models. You can have one DBMS model for each implementation environment, and another set within that environment for projects that do not share databases. In an ideal situation, there is a set of Area Level scope DBMS models. One Area Level scope DBMS model for each environment, with complete data sharing across all projects in that environment.



The models fall into two categories:

- Logical
- Physical

Logical Models

There are three levels of logical models that are used to capture business information requirements:

- Entity Relationship diagram
- Key-Based model
- Fully-Attributed model

The Entity Relationship diagram and the Key-Based models are also known as *area data models*. They often cover a wide business area that is larger than the business chooses to address with a single automation project. In contrast, the Fully-Attributed model is a *project data model*. Typically it describes a portion of an overall data structure intended for support by a single automation effort.

Entity Relationship Diagram

The Entity Relationship diagram (ERD) is a high-level data model that shows the major entities and relationships, which support a wide business area. An ERD is primarily a presentation or discussion model.

The ERD objective is to provide a view of business information requirements to satisfy the need for broad planning for development of its information system. These models are not detailed (only major entities are included), and not much detail, if any, on attributes. Many-to-many (nonspecific) relationships are allowed, and keys are generally not included.

Key-Based Model

A key-based (KB) model describes the major data structures, which support a wide business area. All entities and primary keys are included with sample attributes.

The objective of the KB model is to provide a broad business view of data structures and keys required to support the area. A KB model provides a context where detailed implementation level models can be constructed. The model covers the same scope as the Area ERD, but exposes more of the detail.

Fully-Attributed Model

A fully-attributed (FA) model is a third normal form data model that includes all entities, attributes, and relationships required by a single project. The model includes entity instance volumes, access paths and rates, and expected transaction access patterns across the data structure.

Chapter 3: Physical Models

Two levels of physical models exist for an implementation project:

- Transformation model
- DBMS model

The physical models capture all of the information that data architects and database administrators require to implement a logical model as a database system. The Transformation model is also a *project data model* that describes a portion of an overall data structure supported by a single automation effort. Individual projects within a business area are supported, allowing the modeler to separate a larger area model into submodels, or subject areas. Subject areas can be developed, reported on, and generated to the database in isolation from the area model and other subject areas in the model.

This section contains the following topics

Transformation Model (see page 19)
DBMS Model (see page 20)

Transformation Model

The objectives of the Transformation model include:

- Provide the database administrator with sufficient information to create an efficient physical database
- Provide a context for the definition and recording of the data elements
- Hold the records that form the database in the data dictionary
- Help the application team select a physical structure for the programs that will access the data.

During the development effort, the model can also provide the basis for comparing the physical database design against the original business information requirements to:

- Demonstrate that the physical database design adequately supports those requirements.
- Document physical design choices and their implications, such as what is satisfied, and what is not.
- Identify database extensibility capabilities and constraints.

DBMS Model

The Transformation model directly translates into a DBMS model, which captures the physical database object definitions in the RDBMS schema or database catalog. The schema generation function directly supports this model. Primary keys become unique indexes. Alternate keys and inversion entries can also become indexes. Cardinality can be enforced either through the referential integrity capabilities of the DBMS, application logic, or “after the fact” detection and repair of violations.

Chapter 4: Logical Models

This section contains the following topics

Constructing a Logical Model (see page 21)
Entity Relationship Diagram (see page 22)
Logical Model Design Validation (see page 26)
Data Model Example (see page 27)

Constructing a Logical Model

The first step in constructing a logical model is developing the Entity Relationship diagram (ERD), a high-level data model of a wide business area. An ERD is made up of three main building blocks: entities, attributes, and relationships. A diagram can be viewed as a graphical language for expressing statements about your business. Entities are the nouns, attributes are the adjectives or modifiers, and relationships are the verbs. Building a data model is simply a matter of putting together the right collection of nouns, verbs, and adjectives.

The objective of the ERD is to provide a broad view of business information requirements sufficient to plan for development of the business information system. ERD models are not detailed (only major entities are included) and there is not much detail, if any, about attributes. Many-to-many (nonspecific) relationships are allowed and keys are generally not included. An ERD model is primarily a presentation or discussion model.

An ERD can be divided into subject areas, which are used to define business views or specific areas of interest to individual business functions. Subject areas help reduce larger models into smaller, more manageable subsets of entities that can be more easily defined and maintained.

Many methods are available for developing the ERD. These range from formal modeling sessions to individual interviews with business managers who have responsibility for wide areas.

Entity Relationship Diagram

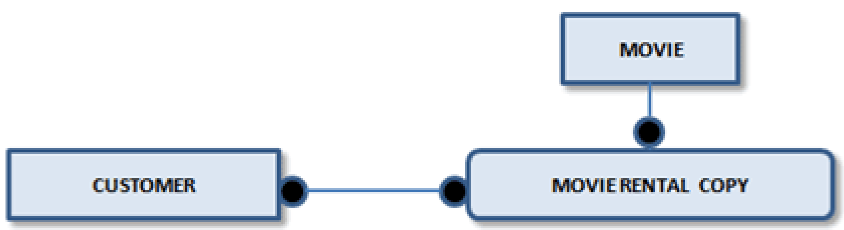
If you are familiar with a relational database structure, you know that the most fundamental component of a relational database is the table. Tables are used to organize and store information. A table is organized in columns and rows of data. Each row contains a set of facts, which is an instance of the table.

In a relational database, all data values must also be atomic, which means that each cell in the table can contain only a single fact. A relationship also exists between the tables in the database. Each relationship is represented in an RDBMS by sharing one or more columns in two tables.

Like the tables and columns that comprise a physical model of a relational database, an ERD (and all other logical data models) includes equivalent components. The components let you model the data structures of the business, rather than the database management system. The logical equivalent to a table is an entity, and the logical equivalent to a column is an attribute.

In an ERD, a box represents an entity, which contains the name of the entity. Entity names are always singular: CUSTOMER not CUSTOMERS, MOVIE not MOVIES, COUNTRY not COUNTRIES. By using singular nouns, you benefit from a consistent naming standard and facilitate reading the diagram as a set of declarative statements about entity instances.

The following illustration depicts a hypothetical video store. The video store must track its customers, movies that can be rented or purchased, and rental copies of movies in the store.



In an ERD, a line drawn between the entities in the model represents a relationship. A relationship between two entities also implies that facts in one entity refer to, or are associated with, facts in another entity. In the preceding example, the video store must track information about CUSTOMERs and MOVIE RENTAL COPYs. The information in these two entities is related, and this relationship can be expressed in a statement: A CUSTOMER rents one or more MOVIE RENTAL COPYs.

Entities and Attributes Defined

An entity is any person, place, thing, event, or concept about which information is kept. More precisely, an entity is a set or collection of like individual objects known as instances. An instance (row) is a single occurrence of a given entity. Each instance must have an identity distinct from all other instances.

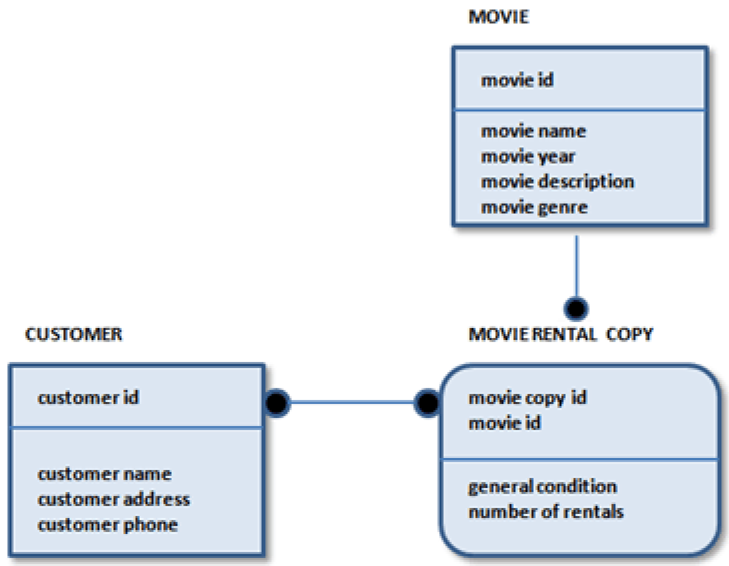
In the preceding illustration, the CUSTOMER entity represents the set of all the possible customers of a business. Each instance of the CUSTOMER entity is a customer. You can list information for an entity in a sample instance table, such as is shown in the following illustration:

CUSTOMER

customer id	**customer name**	**customer address**
10001	Ed Green	Princeton, NJ
10011	Margaret Henley	New Brunswick, NJ
10012	Tomas Perez	Berkeley, CA
17886	Jonathon Walters	New York, NY
10034	Greg Smith	Princeton, NJ

Each instance represents a set of facts about the related entity. In the preceding table, each instance of the CUSTOMER entity includes information about the “customer id,” “customer name,” and “customer address.” In a logical model, these properties are known as the *attributes* of an entity. Each attribute captures a single piece of information about the entity.

You can include attributes in an ERD to describe the entities in the model more fully, as shown in the following illustration:



Logical Relationships

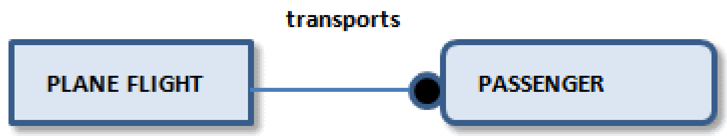
Relationships represent connections, links, or associations between entities. They are the *verbs* of a diagram that show how entities relate to each other. Easy to understand rules help business professionals validate data constraints and ultimately identify relationship cardinality.

Examples of one-to-many relationships:

- A TEAM <has> many PLAYERs
- A PLANE FLIGHT <transports> many PASSENGERs
- A DOUBLES TENNIS MATCH <requires> exactly 4 PLAYERs
- A HOUSE <is owned by> one or more OWNERs
- A SALESPERSON <sells> many PRODUCTs

In all of these cases, the relationships are chosen so that the connection between the two entities is what is known as one-to-many. A one-to-many means that one (and only one instance) of the first entity is related or connected to many instances of the second entity. The entity on the *one-end* is known as the parent entity. The entity on the *many-end* is known as the child entity.

Relationships are displayed as a line connecting two entities, with a dot on one end, and a verb phrase written along the line. In the previous examples, the verb phrases are the words inside the brackets, such as <sells>. The following figure shows the relationship between PLANE FLIGHTs and PASSENGERs on that flight:

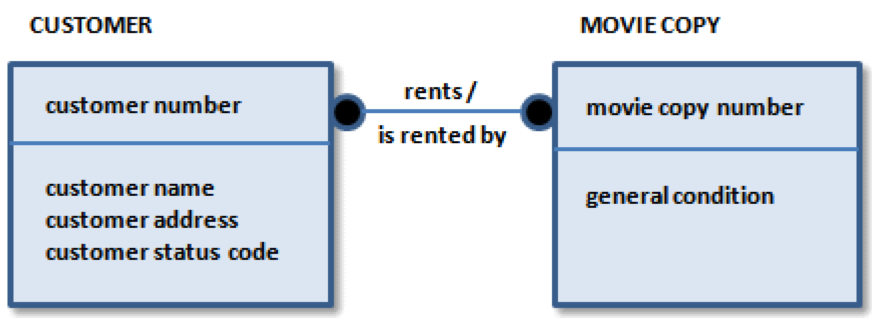


Many-to-Many Relationships

A many-to-many relationship is also known as a nonspecific relationship. A many-to-many relationship represents a situation where an instance in one entity relates to one or more instances in a second entity, and an instance in the second entity also relates to one or more instances in the first entity. In the video store example, a many-to-many relationship occurs between a CUSTOMER and a MOVIE COPY. From a conceptual point of view, this many-to-many relationship indicates that:

- A CUSTOMER <rents> many MOVIE COPYs
- A MOVIE COPY <is rented by> many CUSTOMERs

You typically use many-to-many relationships in a preliminary stage of diagram development, such as in an ERD. Many-to-many relationships are represented in IDEF1X as a solid line with dots on both ends.



Because a many-to-many relationship can hide other business rules or constraints, it is better to explore them later in the modeling process. For example, sometimes a many-to-many relationship identified in early modeling stages is mislabeled, and is actually two one-to-many relationships between related entities. Or, the business must keep additional facts about the many-to-many relationship, such as dates or comments. The result is that an additional entity to keep these facts replaces the many-to-many relationship. Discuss in detail all many-to-many relationships later in the modeling process to help ensure that the relationship is modeled correctly.

Logical Model Design Validation

A data model exposes many of the business rules that describe the area being modeled. Reading the relationships helps you validate that the design of the logical model is correct. Verb phrases provide a brief summary of the business rules embodied by relationships. Although they do not precisely describe the rules, verb phrases do provide an initial sense of how the entities are connected.

If you choose your verb phrases correctly, you can read a relationship from the parent to the child using an *active* verb phrase.

Example:

A PLANE FLIGHT <transports> many PASSENGERs.

Verb phrases can also be read from the perspective of the child entity. You can often read from the child entity perspective using *passive* verb phrases.

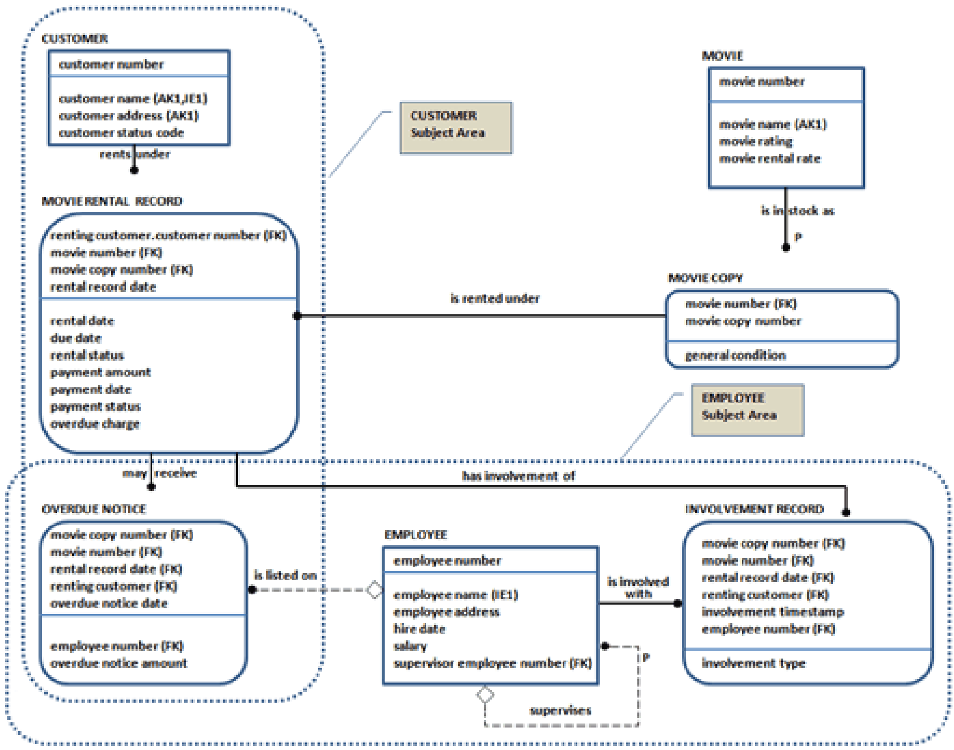
Example:

Many PASSENGERs <are transported by> a PLANE FLIGHT.

Verifying that each verb phrase in the model results in valid statements is a good practice. Reading your model back to the business analysts and subject matter experts is a good way to verify that it correctly captures the business rules.

Data Model Example

The following model of a database was constructed for a hypothetical video store:



The data model of the video store, with definitions of the objects presented on it, makes the following assertions:

- A MOVIE is in stock as one or more MOVIE COPYs. Information recorded about a MOVIE includes its name, a rating, and a rental rate. The general condition of each MOVIE COPY is recorded.
- The store's CUSTOMERs rent the MOVIE COPYs. A MOVIE RENTAL RECORD records the information about the rental of a MOVIE COPY by a CUSTOMER. The same MOVIE COPY can, over time, be rented to many CUSTOMERs.
- Each MOVIE RENTAL RECORD also records a due date for the movie and a status indicating whether it is overdue. Depending on a CUSTOMER's previous relationship with the store, a CUSTOMER is assigned a credit status code that indicates whether the store accepts checks or credit cards for payment, or accepts only cash.
- The store's EMPLOYEEs are involved with many MOVIE RENTAL RECORDs, as specified by an involvement type. There must be at least one EMPLOYEE involved with each record. Because the same EMPLOYEE might be involved with the same rental record several times on the same day, involvements are distinguished with a timestamp.

- An overdue charge is sometimes collected on a rental of a MOVIE COPY. OVERDUE NOTICEs remind a CUSTOMER to return a movie. An EMPLOYEE is sometimes listed on an OVERDUE NOTICE.
- The store keeps salary and address information about each EMPLOYEE. The store may have to look up CUSTOMERs, EMPLOYEEs, and MOVIEs by name, rather than by number.

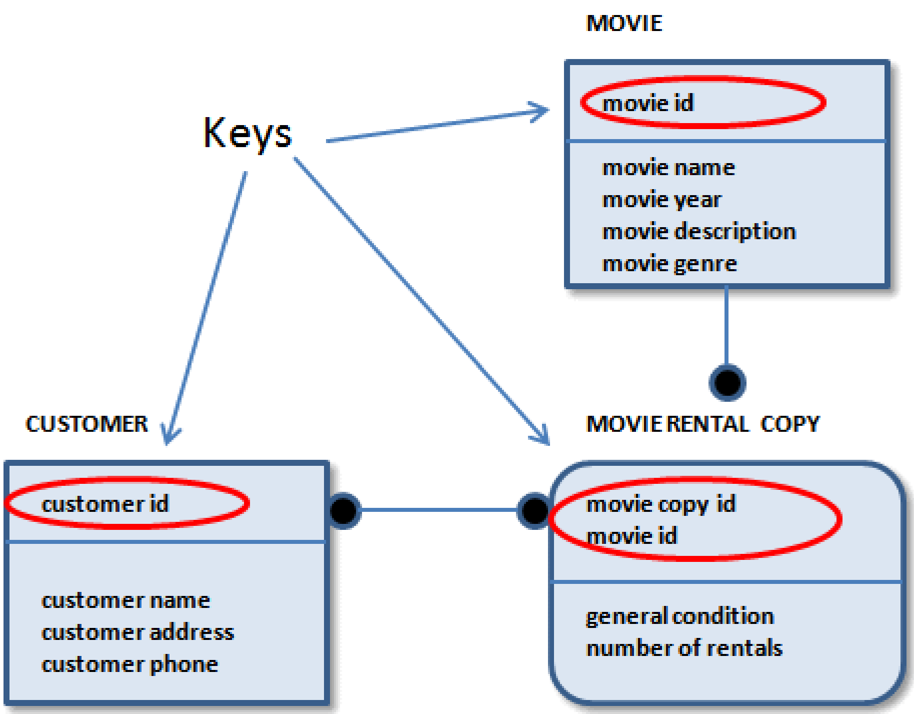
The data model example is relatively small, but it says a lot about the video rental store. You can get an idea of what a database for the business can look like, and a good picture of the business. Several different types of graphical objects are presented in this diagram. The entities, attributes, and relationships, with the other symbols, describe our business rules. The following sections describe what the different graphical objects mean, and how to use erwin® Data Modeler to create your own logical and physical data models.

Chapter 5: The Key-Based Data Model

A key-based (KB) model is a data model that fully describes all of the major data structures that support a wide business area. The goal of a KB model is to include all entities and attributes that are of interest to the business.

As its name suggests, a KB model also includes keys. In a logical model, a *key* identifies unique instances within an entity. When implemented in a physical model, a key provides easy access to the underlying data.

The key-based model basically covers the same scope as the Entity Relationship Diagram (ERD). However, it exposes more of the detail, including the context where detailed implementation level models can be constructed.



This section contains the following topics

Key Types (see page 30)
Primary Key Selection (see page 30)
Alternate Key Attributes (see page 32)
Inversion Entry Attributes (see page 33)
Relationships and Foreign Key Attributes (see page 33)

Key Types

Whenever you create an entity in your data model, one of the most important questions to ask is: “How can a unique instance be identified?” To develop a correct logical data model, you uniquely identify each instance in an entity.

In each entity in a data model, a horizontal line separates the attributes into two groups, key areas and nonkey areas. The area above the line is the key area, and the area below the line is the nonkey area, or data area. The key area of CUSTOMER contains “customer id” and the data area contains “customer name,” “customer address,” and “customer phone.”

Entity and Non-Key Areas

The key area contains the primary key for the entity. The primary key is a set of attributes used to identify unique instances of an entity. The primary key can be comprised of one or more primary key attributes, if the chosen attributes form a unique identifier for each instance in an entity.

An entity usually has many nonkey attributes, which appear below the horizontal line. A nonkey attribute does not uniquely identify an instance of an entity. For example, a database can have multiple instances of the same customer name, which means that “customer name” is not unique. "customer name" would probably be a nonkey attribute.

Primary Key Selection

Choosing the primary key of an entity is an important step that requires serious consideration. Before you actually select a primary key, consider several attributes, which are referred to as candidate key attributes. Typically, the business user who knows the business and business data can help identify candidate keys.

For example, to use the EMPLOYEE entity in a data model (and later in a database) correctly, you uniquely identify instances. In the customer table, you could choose from several potential key attributes including: the employee name, a unique employee number assigned to each instance of EMPLOYEE, or a group of attributes, such as name and birth date.

The rules that you use to select a primary key from the list of all candidate keys are stringent. The rules can be consistently applied across all types of databases and information. The rules state that the attribute or attribute group must:

- Uniquely identify an instance.
- Never include a NULL value.
- Not change over time. An instance takes its identity from the key. If the key changes, it is a different instance.
- Be as short as possible, to facilitate indexing and retrieval. If you must use a key that is a combination of keys from other entities, verify that each part of the key adheres to the other rules.

Example:

Consider which attribute you would select as a primary key from the following list of candidate keys for an EMPLOYEE entity:

- employee number
- employee name
- employee social security number
- employee birth date
- employee bonus amount

If you use the rules in the preceding list to find candidate keys for EMPLOYEE, you could compose the following analysis of each attribute:

- “employee number” is a candidate key because it is unique for all EMPLOYEEs
- “employee name” is probably not a good candidate because multiple employees can have the same name, such as Mary Jones.
- “employee social security number” is unique in most instances, but every EMPLOYEE may not have one.
- The combination of “employee name” and “employee birth date” may work, unless there is more than one John Smith born on the same date and employed by our company. This combination could be a candidate key.
- Only some EMPLOYEEs of our company are eligible for annual bonuses. Therefore, “employee bonus amount” can be expected to be NULL in many cases. As a result, it cannot be part of any candidate key.

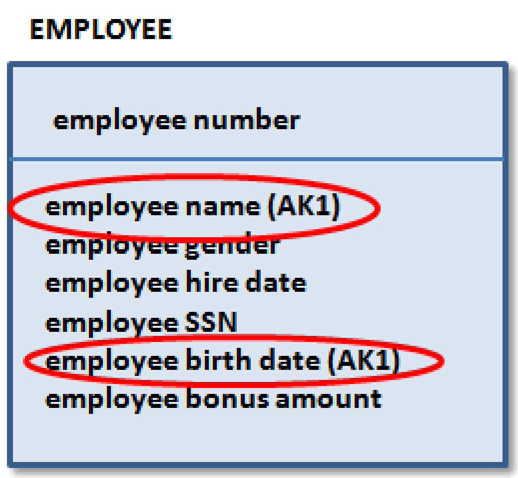
After analysis, there are two candidate keys. One is “employee number” and the other is the group of attributes containing “employee name” and “employee birth date.” “employee number” is selected as the primary key because it is the shortest and helps ensure uniqueness of instances.

When choosing the primary key for an entity, data architects often assign a surrogate key. A surrogate key is an arbitrary number that is assigned to an instance to identify it within an entity uniquely. “employee number” is an example of a surrogate key. A surrogate key is often the best choice for a primary key. A surrogate key is short, can be accessed the fastest, and helps ensure unique identification of each instance. The system can also automatically generate surrogate keys so that numbering is sequential and does not include any gaps.

A primary key chosen for the logical model is not always the primary key used to access the table efficiently in a physical model. The primary key can be changed to suit the needs and requirements of the physical model and database at any point.

Alternate Key Attributes

After you select a primary key from a list of candidate keys, designate some or all of the remaining candidate keys as alternate keys. Alternate keys are often used to identify the different indexes, which are used to access the data quickly. In a data model, an alternate key is designated by the symbol (AK*n*). *n* is a number that is placed after the attributes that form the alternate key group. In the EMPLOYEE entity, “employee name” and “employee birth date” are members of the alternate key group.

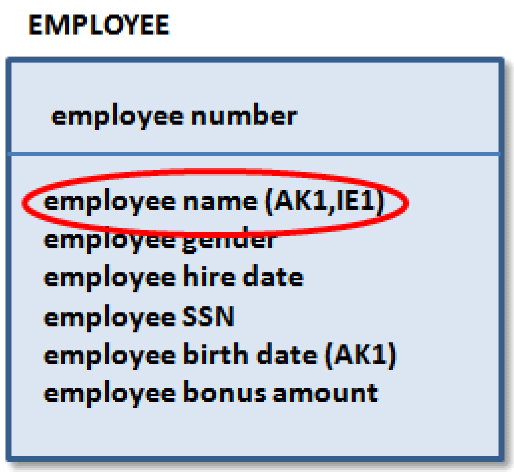


Inversion Entry Attributes

Unlike a primary key or an alternate key, an inversion entry is an attribute or set of attributes that are commonly used to access an entity, but that may not result in finding exactly one instance of an entity. In a data model, the symbol IE*n* is placed after the attribute.

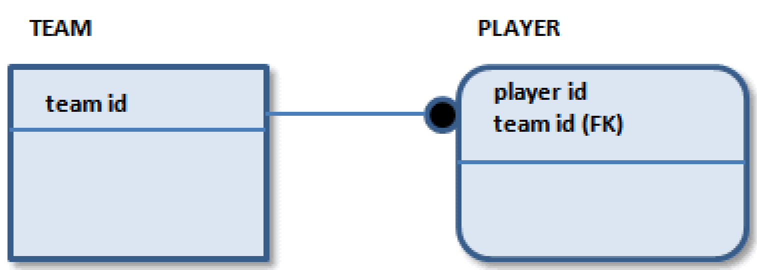
For example, in addition to locating information in an employee database using an employee's identification number, a business may want to search by employee name. Often, a name search results in multiple records, which requires an additional step to find the exact record. By assigning an attribute to an inversion entry group, a non-unique index is created in the database.

Note: An attribute can belong to an alternate key group as well as an inversion entry group.



Relationships and Foreign Key Attributes

A foreign key is the set of attributes that define the primary key in the parent entity. The set of attributes migrates through a relationship from the parent to the child entity. In a data model, a foreign key is designated by the symbol (FK) after the attribute name. Notice the (FK) next to “team id” in the following figure:

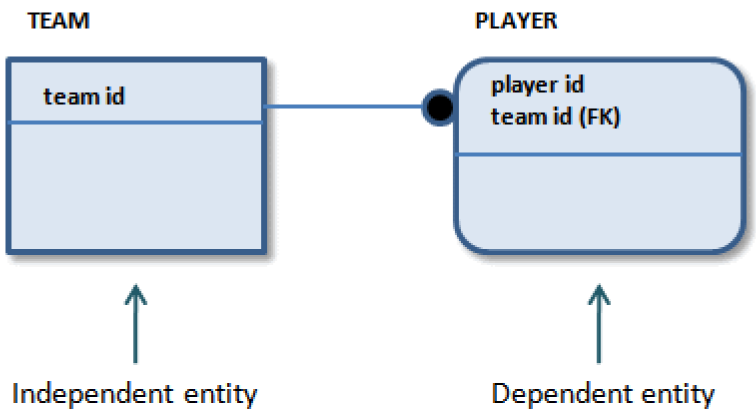


Dependent and Independent Entities

As you develop your data model, you may discover certain entities that depend upon the value of the foreign key attribute for uniqueness. For these entities, the foreign key must be a part of the primary key of the child entity (above the line) to define each entity uniquely.

In relational terms, a child entity that depends on the foreign key attribute for uniqueness is named a dependent entity. In IDEF1X notation, dependent entities are represented as round-cornered boxes.

Entities that do not depend on any other entity in the model for identification are named independent entities. In IE and IDEF1X, independent entities are represented as square-cornered boxes.

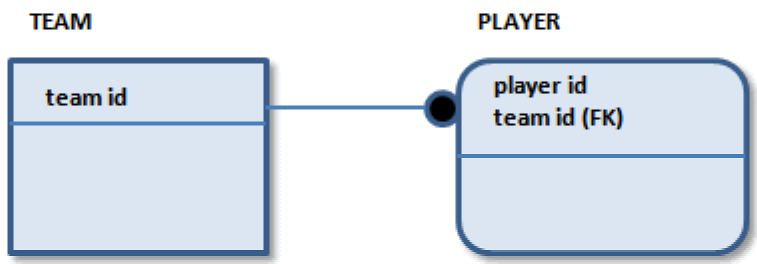


Dependent entities are further classified as existence dependent, which means the dependent entity cannot exist unless its parent does, and identification dependent, which means that the dependent entity cannot be identified without using the key of the parent. Because PLAYERs can exist if they are not on a TEAM, the PLAYER entity is identification-dependent, but not existence-dependent.

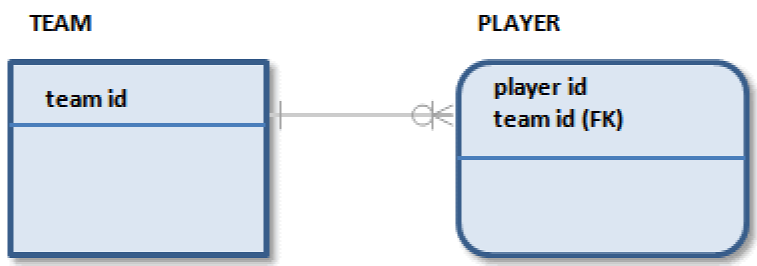
In contrast, there are situations where an entity is existence-dependent on another entity. Consider two entities: ORDER, which a business uses to track customer orders, and LINE ITEM, which tracks individual items in an ORDER. The relationship between these two entities can be expressed as An ORDER <contains> one or more LINE ITEMS. In this case, LINE ITEM is existence-dependent on ORDER, because it makes no sense in the business context to track LINE ITEMS unless there is a related ORDER.

Identifying Relationships

In IDEF1X notation, the type of the relationship that connects two entities enforces the concept of dependent and independent entities. If you want a foreign key to migrate to the key area of the child entity (and create a dependent entity as a result), you can create an identifying relationship between the parent and child entities. A solid line connecting the entities indicates an identifying relationship. In IDEF1X notation, the line includes a dot on the end nearest to the child entity, as shown in the following figure:



In IE notation, the line includes a *crow's foot* at the end of the relationship nearest to the child entity:



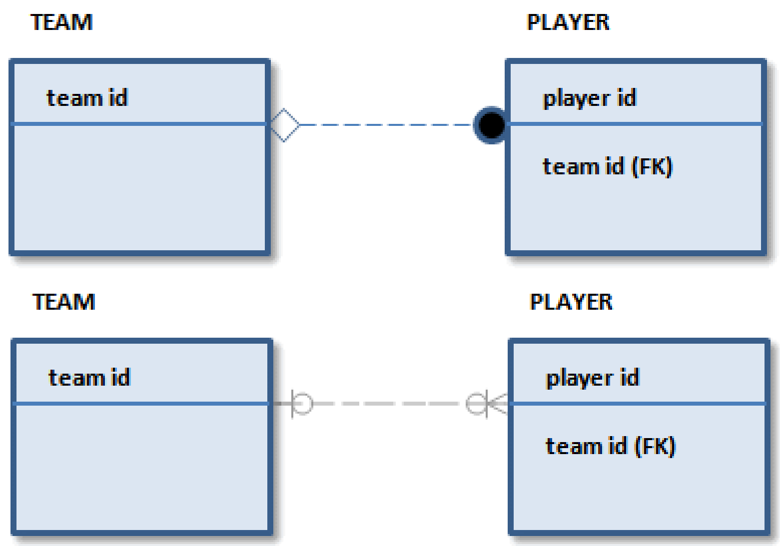
Note: Standard IE notation does not include rounded corners on entities. Rounded entity corners are an IDEF1X symbol included in IE notation to help ensure compatibility between methods.

There are advantages to contributing keys to a child entity through identifying relationships, such as making some physical system queries more straightforward. However, there are also many disadvantages. Some advanced relational theory suggests that contribution of keys not occur in this way. Instead, entity identification is attained through using a logical handle or surrogate key that the system user does not see, in addition to the entity's primary key. Data architects who are interested in this relational theory are encouraged to review the work of E. F. Codd and C. J. Date.

Nonidentifying Relationships

A nonidentifying relationship also connects a parent entity to a child entity. But, when a nonidentifying relationship connects two entities, the foreign key migrates to the nonkey area of the child entity (below the line).

A dashed line connecting the entities indicates a nonidentifying relationship. If you connect the TEAM and PLAYER entities in a nonidentifying relationship, the "team id" migrates to the nonkey as shown in the following figure:



Because the migrated keys in a nonidentifying relationship are not part of the primary key of the child, nonidentifying relationships do not result in any identification dependency. In this case, PLAYER is considered an independent entity, just like TEAM.

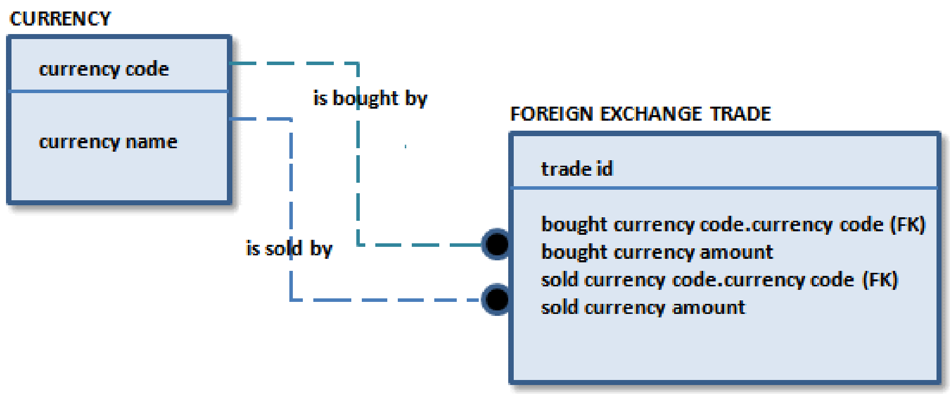
However, the relationship can reflect existence dependency if the business rule for the relationship specifies that the foreign key cannot be NULL (missing). If the foreign key must exist, this implies that an instance in the child entity can only exist if an associated parent instance also exists.

Note: Identifying and nonidentifying relationships are not a feature of the IE methodology. These relationships are included in your diagram as a solid or dashed relationship line to help ensure compatibility between IE and IDEF1X methods.

Rolenames

When a foreign key is contributed to a child entity through a relationship, you can write a new or enhanced definition for the foreign key attributes. The definition explains the foreign key attribute usage in the child entity. Assign a rolename to the definition, especially when the same attribute is contributed to the same entity more than once. Duplicated attributes can appear identical, but because they serve two different purposes, they cannot have the same definition.

Consider the following example where FOREIGN EXCHANGE TRADE has two relationships to CURRENCY.



The key of CURRENCY is "currency code," which is the identifier of a valid CURRENCY that you want to track. You can see from the relationships that one CURRENCY is "bought by" and one is "sold by" a FOREIGN EXCHANGE TRADE.

You also see that the identifier of the CURRENCY (the "currency code") is used to identify each of the two CURRENCYs. The identifier of the one that is bought is named "bought currency code." The identifier of the one that is sold is named "sold currency code." The rolenames show that the attributes are not the same thing as "currency code."

Trading a CURRENCY for the same CURRENCY at the same time and exchange rate is not logical. For a given transaction, such as the instance of FOREIGN EXCHANGE TRADE, "bought currency code" and "sold currency code" must be different. Providing different definitions to the two rolenames captures the difference between the two currency codes.

Attribute/Rolename	Attribute Definition
currency code	The unique identifier of a CURRENCY.
bought currency code	The identifier ("currency code") of the CURRENCY bought by (purchased by) the FOREIGN EXCHANGE TRADE.

sold currency code	The identifier ("currency code") of the CURRENCY sold by the FOREIGN EXCHANGE TRADE.

The definitions and validations of the bought and sold codes are based on "currency code." "currency code" is known as a base attribute.

IDEF1X standard dictates that if two attributes with the same name migrate from the same base attribute to an entity, the attributes must be unified. The result of unification is a single attribute migrated through two relationships. Because of the IDEF1X standard, foreign key attributes are also automatically unified. If you do not want to unify migrated attributes, you can rolename the attributes when you name the relationship, in the Relationship Editor.

Chapter 6: Naming and Defining Entities and Attributes

In data modeling, and in systems development in general, it is important to select clear and well thought out names for objects. The results of your efforts become a clear, concise, and unambiguous model of a business area.

Naming standards and conventions are identical for all types of logical models, including both the Entity Relationship diagrams (ERD) and Key-based (KB) diagrams.

This section contains the following topics

Entity and Attribute Names (see page 39)
Entity Definitions (see page 41)
Attribute Definitions (see page 43)
Rolenames (see page 45)
Definitions and Business Rules (see page 46)

Entity and Attribute Names

The most important rule to remember when naming entities is that entity names are always singular. Singular entity names facilitate reading the model with declarative statements. For example, “A FLIGHT <transports> zero or more PASSENGERs” and “A PASSENGER <is transported by> one FLIGHT.” When you name an entity, you are also naming each instance. For example, each instance of the PASSENGER entity is an individual passenger, not a set of passengers.

Attribute names are also singular. “person name,” “employee SSN,” “employee bonus amount,” for example, are correctly named attributes. Naming attributes in the singular helps to avoid normalization errors, such as representing more than one fact with a single attribute. The attributes “employee child names” or “start or end dates” are plural, and highlight errors in the attribute design.

A good rule to use when naming attributes is to use the entity name as a prefix. The rule here is:

- Prefix qualifies
- Suffix clarifies

Using this rule, you can easily validate the design and eliminate many common design problems. For example, in the CUSTOMER entity, you can name the attributes "customer name," "customer number," "customer address," and so on. Suppose you wanted to name an attribute "customer invoice number." Use the rule to verify that the suffix "invoice number" tells you more about the prefix "customer." Because it does not, move the attribute to a more appropriate location, such as INVOICE.

Sometimes it is difficult to give an entity or attribute a name without first giving it a definition. As a general principle, providing a good definition for an entity or attribute is as important as providing a good name. The ability to find meaningful names comes with experience and a fundamental understanding of what the model represents.

Because the data model is a description of a business, it is best to choose meaningful business names wherever that is possible. If there is no business name for an entity, assign the entity a name that fits its purpose in the model.

Synonyms, Homonyms, and Aliases

Not everyone speaks the same language. Not everyone is always precise in the use of names. Because names identify entities and attributes in a data model, verify that synonyms are resolved so that they do not represent redundant data. Precisely define names so that each person who reads the model can understand which facts are captured in which entity.

Select a name that clearly communicates a sense of what the entity or attribute represents. For example, there is some difference among things named PERSON, CUSTOMER, and EMPLOYEE. Although they can all represent an individual, they have distinct characteristics or qualities. The business user tells you whether PERSON and EMPLOYEE are two different things, or simply synonyms for the same thing.

Select names carefully, and be wary of calling two different things by the same name. For example, if a business area insists on calling its customers "consumers," do not insist on the customer name. Perhaps there is an alias, or there is a new "thing" that is distinct from, although similar to, another "thing." In this case, perhaps CONSUMER is a category of CUSTOMER that can participate in relationships that are not available for other categories of CUSTOMER.

You can enforce unique naming in the modeling environment. Unique naming avoids the accidental use of homonyms, ambiguous names, or duplication of entities or attributes in the model.

Entity Definitions

Defining the entities in your logical model is essential to the clarity of the model and elaborates on the purpose of the entity. Defining entities also clarify which facts you want to include in the entity. Undefined entities or attributes can be misinterpreted in later modeling efforts, and possibly deleted or unified based on the misinterpretation.

Writing a good definition can be difficult. The best definitions are created using the points of view of many different business users and functional groups within the organization. Definitions that can pass the scrutiny of many disparate users provide a number of benefits including:

- Clarity across the enterprise
- Consensus about a single fact having a single purpose
- Easier identification of categories of data

Most organizations and individuals develop their own conventions or standards for definitions. Long definitions tend to take on a structure that helps the reader to understand the “thing” that is being defined. Some of these definitions can go on for several pages (CUSTOMER, for example). Because IDEF1X and IE do not provide standards for definitions, you can adopt the following items as a basic standard for definition structure:

- Description
- Business example
- Comments

Descriptions

A description must be a clear and concise statement that tells whether an object is or is not the thing you are trying to define. Often such descriptions can be fairly short. Be careful, however, that the description is not too general or uses terms that are not defined. Here are a couple of examples, one of good quality and one that is questionable:

Example of good description:

A COMMODITY is something that has a value that can be determined in an exchange.

The preceding example is a good description. Because someone is willing to trade something, you know that something is a COMMODITY. If someone gives you three peanuts and a stick of gum for a marble, then you know that a marble is a COMMODITY.

Example of bad description:

A CUSTOMER is someone who buys something from our company.

The preceding example is not a good description. Because you know that the company also sells products to other businesses, you can misunderstand the word “someone”. The business may also want to track potential CUSTOMERs, not simply customers who have already bought something from the company. You can also define “something” more fully to describe whether the sale is of products, services, or some combination of the two.

Business Examples

Providing typical business examples of the thing being defined is important, because good examples help the reader understand a definition. Comments about peanuts, marbles, or something related to your business can help a reader to understand the concept of a COMMODITY. The definition states that a commodity has value. The example can help to show that value is not always measured in money.

Comments

You can also include general comments for a description. Comments can include the following information:

- The person responsible for the definition
- The source of the information for the definition
- The state of the definition, such as when the definition was last changed

For some entities, also explain how it and a related entity or entity name differ. For example, a CUSTOMER can be distinguished from a PROSPECT.

Definition References and Circularity

An individual definition can look good, but when viewed together they can be circular. Without some care, circularity can happen with entity and attribute definitions.

Example:

- CUSTOMER: Someone who buys one or more of our PRODUCTs
- PRODUCT: Something we offer for sale to CUSTOMERs

When you define entities and attributes in your data model, it is important that you avoid these circular references.

Business Glossary Construction

A business glossary helps you use common business terms when defining an entity or attribute.

Definition example:

"A CURRENCY-SWAP is a complex agreement between two PARTYs where they agree to exchange **cash flows** in two different CURRENCYs over a timeframe. Exchanges can be fixed over the **term** of the swap, or may **float**. Swaps are often used to **hedge** currency and interest **rate risks**."

In the preceding example, defined terms within a definition are highlighted. Using this style makes it unnecessary to define terms each time they are used, because people can look them up whenever needed.

Providing base definitions of common business terms that are not entity or attribute names and referring to these definitions is a good idea. You can use a glossary of commonly used terms separate from the model. Common business terms are highlighted with bold or italic font, as shown in the preceding example.

This strategy seems like it can lead to going back and forth among definitions frequently. The alternative, however, is to define each term completely every time it is used. When internal definitions appear in many places, they must be maintained in many places. The probability that a change is applied to all of them at the same time is small.

Developing a glossary of common business terms can serve several purposes. A glossary can become the base for modeling definitions, and individually it can provide significant value to the business to help people communicate.

Attribute Definitions

Defining all attributes clearly is important, and the same rules apply. When you compare an attribute to a definition, verify whether it fits well and is not incomplete.

Example:

account open date

The date on which the ACCOUNT was opened. A further definition of what "opened" means is needed before the definition is clear and complete.

Define attributes using the same basic structure as entity definitions. Attribute definitions must include a description, examples, and comments. The definitions must also contain, whenever possible, validation rules that specify which facts are accepted as valid values for that attribute.

Validation Rules

A *validation rule* identifies a set of values that an attribute is allowed to take. A validation rule constrains or restricts the domain of values that are acceptable. Values have meanings in both an abstract and a business sense. For example, if "person name," is defined as the preferred form of address chosen by the PERSON, it is constrained to the set of all character strings. You can define any validation rules or valid values for an attribute as a part of the attribute definition. You can assign these validation rules to an attribute using a domain. Supported domains include text, number, datetime, and blob.

Definitions of attributes, such as codes, identifiers, or amounts, often are not good business examples. Including a description of the validation rules or valid values of the attribute is a good idea. When you define a validation rule, it is better to go beyond simply listing the values that an attribute can take. For example, you define the attribute "customer status" as follows:

Customer status: *A code that describes the relationship between the CUSTOMER and our business.* Valid values: *A, P, F, N.*

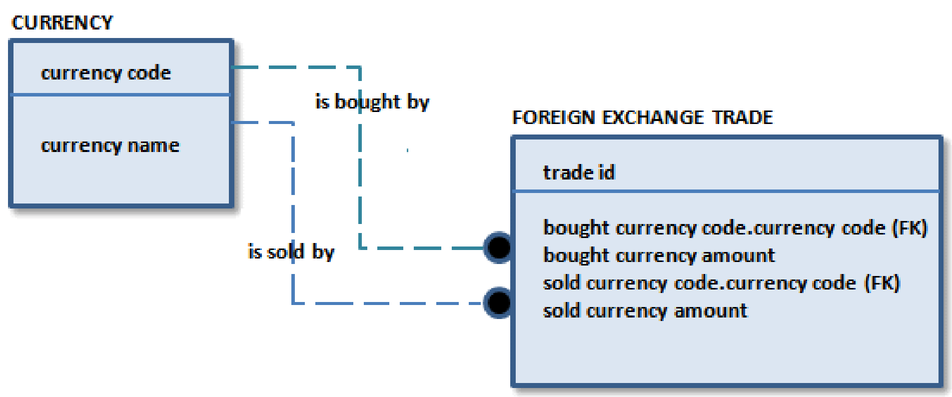
The validation rule specification is not helpful because it does not define what the codes mean. You can better describe the validation rule using a table or list of values, such as is described in the following table:

Valid value	Meaning
A: Active	The CUSTOMER is currently involved in a purchasing relationship with our company.
P: Prospect	Someone with whom we are interested in cultivating a relationship, but with whom we have no current purchasing relationship.
F: Former	The CUSTOMER relationship has lapsed. In other words, there has been no sale in the past 24 months.
N: No business accepted	The company has decided that no business relationships exist with this CUSTOMER.

Rolenames

When a foreign key is contributed to a child entity through a relationship, you can write a new or enhanced definition for the foreign key attributes. The definition explains the foreign key attribute usage in the child entity. Assign a rolename to the definition, especially when the same attribute is contributed to the same entity more than once. Duplicated attributes can appear identical, but because they serve two different purposes, they cannot have the same definition.

Consider the following example where FOREIGN EXCHANGE TRADE has two relationships to CURRENCY.



The key of CURRENCY is “currency code,” which is the identifier of a valid CURRENCY that you want to track. You can see from the relationships that one CURRENCY is “bought by” and one is “sold by” a FOREIGN EXCHANGE TRADE.

You also see that the identifier of the CURRENCY (the “currency code”) is used to identify each of the two CURRENCYs. The identifier of the one that is bought is named “bought currency code.” The identifier of the one that is sold is named “sold currency code.” The rolenames show that the attributes are not the same thing as “currency code.”

Trading a CURRENCY for the same CURRENCY at the same time and exchange rate is not logical. For a given transaction, such as the instance of FOREIGN EXCHANGE TRADE, "bought currency code” and “sold currency code” must be different. Providing different definitions to the two rolenames captures the difference between the two currency codes.

Attribute/Rolename	Attribute Definition
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sold currency code	The identifier (“currency code”) of the CURRENCY sold by the FOREIGN EXCHANGE TRADE.

The definitions and validations of the bought and sold codes are based on “currency code.” “currency code” is known as a base attribute.

IDEF1X standard dictates that if two attributes with the same name migrate from the same base attribute to an entity, the attributes must be unified. The result of unification is a single attribute migrated through two relationships. Because of the IDEF1X standard, foreign key attributes are also automatically unified. If you do not want to unify migrated attributes, you can rolename the attributes when you name the relationship, in the Relationship Editor.

Definitions and Business Rules

Business rules are a critical part of the data model. Business rules take the form of relationships, rolenames, candidate keys, defaults, and other modeling structures. Modeling structures include generalization categories, referential integrity, and cardinality. Business rules are also captured in entity and attribute definitions and validation rules.

For example, a CURRENCY entity can be defined as follows:

The set of all valid currencies recognized anywhere in the world, or a subset of these that our company has decided to use in its day to day business operations.

The entity definition contains a subtle, but important distinction. In the latter case, there is a business rule, or policy statement, involved. This rule manifests itself in the validation rules for “currency code.” This rule restricts the valid values for “currency code” to the values used by the business. Maintenance of the business rule becomes a task of maintaining the table of valid values for CURRENCY. To permit or prohibit trading of CURRENCYs, you simply create or delete instances in the table of valid values.

The attributes “bought currency code” and “sold currency code” are similarly restricted. However, both are further restricted using a validation rule that says “bought currency code” and “sold currency code” cannot be equal. Therefore, each is dependent on the value of the other in its actual use. Validation rules can be addressed in the definitions of attributes, and can also be defined explicitly using validation rules, default values, and valid value lists.

Chapter 7: Relationships

Relationships are a bit more complex than they seem at first. Relationships carry information that describes the rules of the business and the constraints on creating, modifying, and deleting instances. For example, you can use cardinality to define how many instances are involved in both the child and parent entities in the relationship. You can also specify how you want to handle database actions such as INSERT, UPDATE, and DELETE using referential integrity rules.

Data modeling also supports highly complex relationship types. Relationship types let you construct a logical model of your data that is understandable to both business and systems experts.

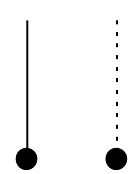
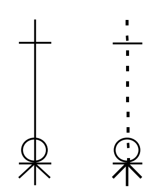
This section contains the following topics

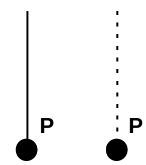
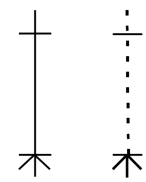
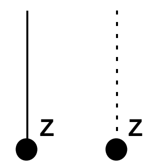
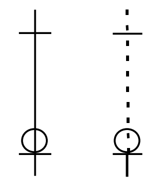
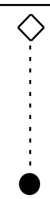
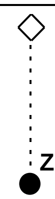
Relationship Cardinality (see page 47)
Referential Integrity (see page 51)
Additional Relationship Types (see page 57)

Relationship Cardinality

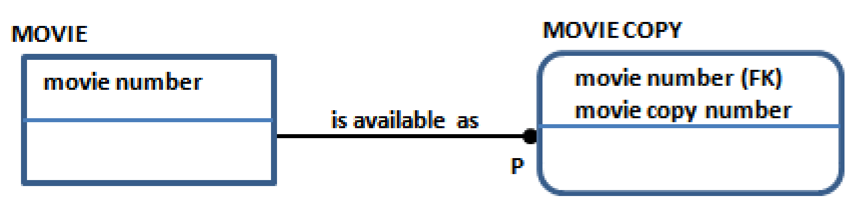
The *many* in a one-to-many relationship does not mean that there must be more than one instance of the child connected to a parent. The *many* in one-to-many really means that there are zero, one, or more instances of the child paired up to the parent.

Cardinality is the relational property that defines exactly how many instances appear in a child table for each corresponding instance in the parent table. IDEF1X and IE differ in the symbols that are used to specify cardinality. However, both methods provide symbols to denote one or more, zero or more, zero or one, or exactly N, as explained in the following table:

Cardinality Description	IDEF1X Notation Nonidentifying	Identifying	IE Notation Nonidentifying	Identifying
One to zero, one, or more				

Cardinality Description	IDEF1X Notation Nonidentifying	Identifying	IE Notation Nonidentifying	Identifying
One to one or more				
One to zero or one				
Zero or one to zero, one, or more (nonidentifying only)				
Zero or one to zero or one (nonidentifying only)				

Cardinality lets you specify additional business rules that apply to the relationship. In the following figure, the business has decided to identify each MOVIE COPY based on both the foreign key “movie-number” and a surrogate key “copy-number.” Also, each MOVIE is available as one or more MOVIE COPYs. The business has also stated that the relationship is identifying, that MOVIE COPY cannot exist unless there is a corresponding MOVIE.



The MOVIE/MOVIE COPY model also specifies the cardinality for the relationship. The relationship line shows that there is exactly one MOVIE, and only one, participating in a relationship. MOVIE is the parent in the relationship.

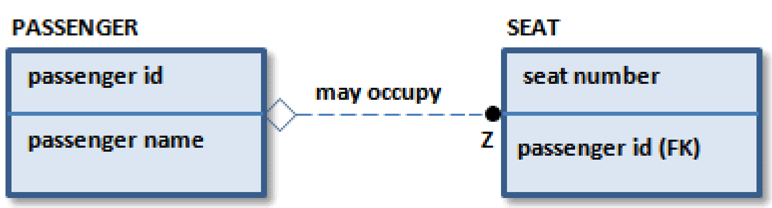
By making MOVIE COPY the child in the relationship, the business defined a MOVIE COPY as one of several rentable copies of a movie title. The business also determined that to be included in the database, a MOVIE must have at least one MOVIE COPY. Therefore, the cardinality of the *is available as* relationship is one-to-one or more. The *P* symbol next to the dot represents cardinality of one or more. As a result, you also know that a MOVIE with no copies is not a legitimate instance in this database.

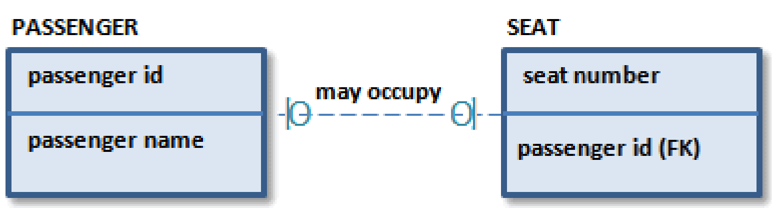
In contrast, the business may want to know about all of the MOVIEs in the world, even MOVIEs for which they have no copies. So their business rule is that for a MOVIE to exist (be recorded in their information system) there can be zero, one, or more copies. To record this business rule, the *P* is removed. When cardinality is not explicitly indicated in the diagram, cardinality is one-to-zero, one, or more.

Cardinality in Nonidentifying Relationships

Nonidentifying relationships contribute keys from a parent to a child entity. However, by definition, some (or all) of the keys do not become part of the key of the child. This means that the child is not identification-dependent on the parent. There can also be situations where an entity at the *many* end of the relationship can exist without a parent, or existence-dependent.

If the relationship is *mandatory* from the perspective of the child, then the child is existence-dependent on the parent. If it is *optional*, the child is neither existence or identification-dependent with respect to that relationship (although it may be dependent in other relationships). To indicate the optional case, IDEF1X includes a diamond at the parent end of the relationship line and IE includes a circle.





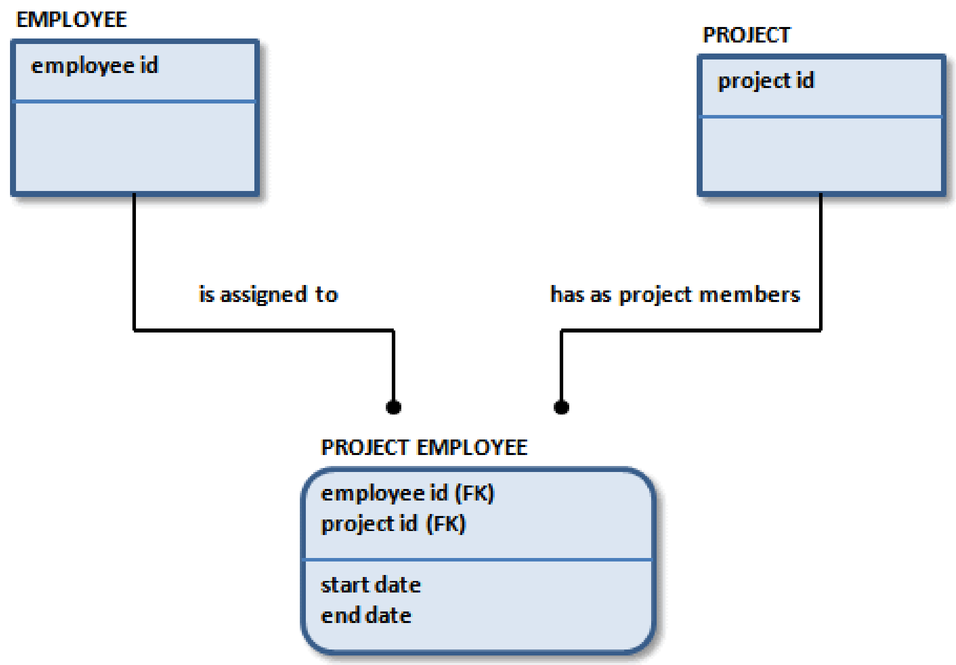
In the preceding examples, the attribute “passenger id” is a foreign key attribute of SEAT. Because the “passenger id” does not identify the SEAT but identifies the PASSENGER occupying the SEAT, the business has determined that the relationship is nonidentifying. The business has also stated that the SEAT can exist without any PASSENGER, so the relationship is optional. When a relationship is optional, the diagram includes either a diamond in IDEF1X, or a circle in IE notation. Otherwise, the cardinality graphics for nonidentifying relationships are the same as for identifying relationships.

The cardinality for the relationship is indicated with a *Z* in IDEF1X and a single line in IE. The cardinality states that a PASSENGER <may occupy> zero or one of these SEATs on a flight. Each SEAT can be occupied, in which case the PASSENGER occupying the seat is identified using “passenger id.” It can also be unoccupied, in which case the “passenger id” attribute is empty (NULL).

Referential Integrity

Because a relational database relies on data values to implement relationships, the integrity of the data in the key fields is important. For example, if you change a value in a primary key column of a parent table, reflect this change in each child table where the column appears as a foreign key. The action that is applied to the foreign key value varies depending on the rules defined by the business.

For example, a business that manages multiple projects might track its employees and projects in a model similar to the one in the following example. The business has determined that the relationship between PROJECT and PROJECT EMPLOYEE is identifying, so the primary key of PROJECT becomes a part of the primary key of PROJECT EMPLOYEE.



The business also decides that for each instance of PROJECT EMPLOYEE there is exactly one instance of PROJECT, which indicates PROJECT EMPLOYEE is existence-dependent on PROJECT.

What would happen if you were to delete an instance of PROJECT? If the business does not want to track instances in PROJECT EMPLOYEE if PROJECT is deleted, delete all instances of PROJECT EMPLOYEE that inherited part of their key from the deleted PROJECT.

The rule that specifies the action taken when a parent key is deleted is known as *referential integrity*. The referential integrity option chosen for this action in this relationship is *Cascade*. Each time an instance of PROJECT is deleted, this *Delete* cascades to the PROJECT EMPLOYEE table. The Delete action also deletes all related instances in PROJECT EMPLOYEE.

Available actions for referential integrity include the following:

Cascade

If an instance in the parent entity is deleted, each related instance in the child entity must also be deleted.

Restrict

Deletion of an instance in the parent entity is prohibited if the following is true:

- One or more related instances in the child entity exist.
- Deletion of an instance in the child entity is prohibited if there is a related instance in the parent entity.

Set Null

If an instance in the parent entity is deleted, the foreign key attributes in each related instance in the child entity are set to NULL.

Set Default

If an instance in the parent entity is deleted, the foreign key attributes in each related instance in the child entity are set to the specified default value.

<None>

No referential integrity action is required. Not every action must have a referential integrity rule associated with it. For example, a business may decide that referential integrity is not required when deleting an instance in a child entity. This business rule is valid where the cardinality is zero, one to zero, or one or more, because instances in the child entity can exist even if there are no related instances in the parent entity.

Although referential integrity is not a formal part of the IDEF1X or IE languages, it does capture business rules that indicate how the completed database works. Referential integrity is a critical part of data modeling and provides a method for both capture and display of referential integrity rules.

Once referential integrity is defined, the facilitator or analyst tests the referential integrity rules defined by the business users. The facilitator or analyst asks questions or works through different scenarios that show the results of the business decision. When the requirements are defined and fully understood, specific referential integrity actions, such as *Restrict* or *Cascade* can be recommended.

Referential Integrity Options

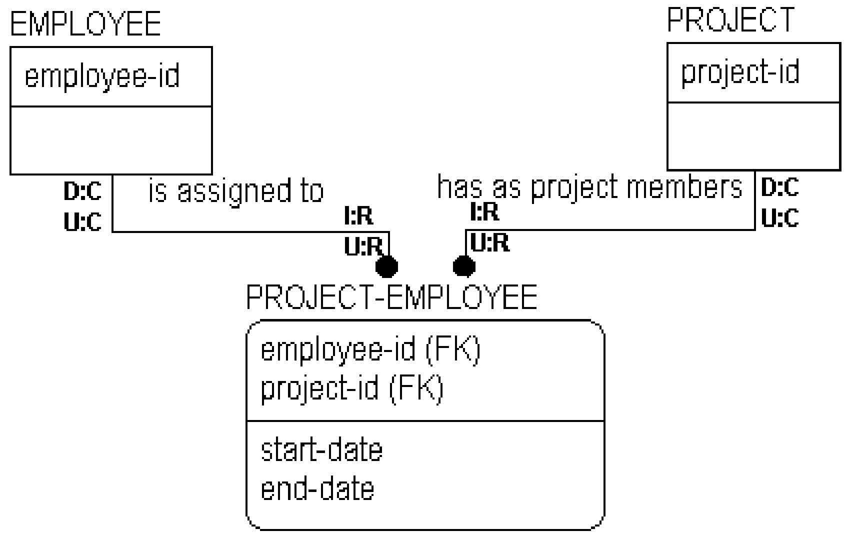
Referential integrity rules vary depending on:

- Whether or not the entity is a parent or child in the relationship
- The database action that is implemented

As a result, in each relationship there are six possible actions for which referential integrity can be defined:

- PARENT INSERT
- PARENT UPDATE
- PARENT DELETE
- CHILD INSERT
- CHILD UPDATE
- CHILD DELETE

The following figure shows referential integrity rules in the EMPLOYEE-PROJECT model:

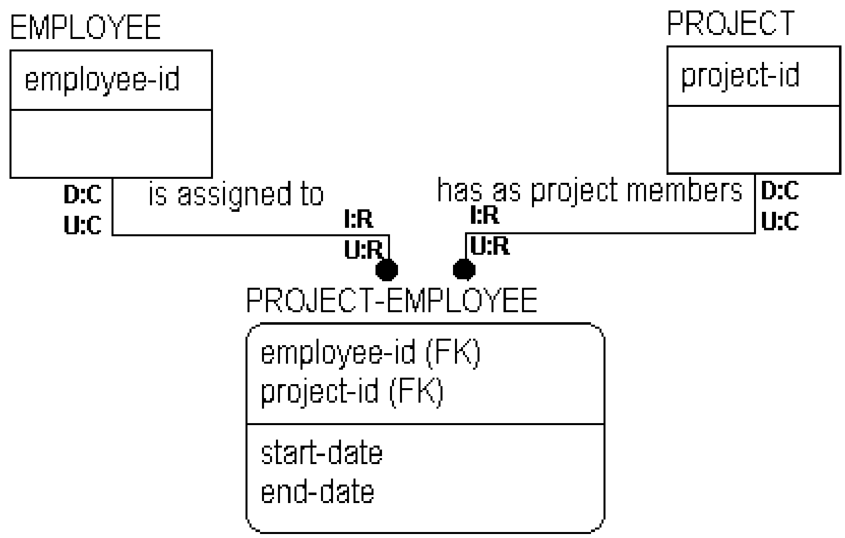


The referential integrity rules captured in the figure show the business decision to cascade all deletions in the PROJECT entity to the PROJECT-EMPLOYEE entity. This rule is called PARENT DELETE CASCADE, and is noted in the figure by the letters *D:C* placed at the parent end of the specified relationship. The first letter in the referential integrity symbol always refers to the database action: I(Insert), U(Update), or D(Delete). The second letter refers to the referential integrity option: C(Cascade), R(Restrict), SN(Set Null), and SD(Set Default).

In the figure, no referential integrity option was specified for PARENT INSERT, so referential integrity for insert (I:) is not displayed on the diagram.

RI, Cardinality, and Identifying Relationships

In the figure below, the relationship between PROJECT and PROJECT-EMPLOYEE is identifying. Therefore, the valid options for referential integrity for the parent entity in the relationship, PROJECT, include Cascade and Restrict:



Cascade indicates that all instances of PROJECT-EMPLOYEE that are affected by the deletion of an instance of PROJECT should also be deleted. Restrict indicates that a PROJECT cannot be deleted until all instances of PROJECT-EMPLOYEE that have inherited its key have been deleted. If there are any left, the Delete is restricted.

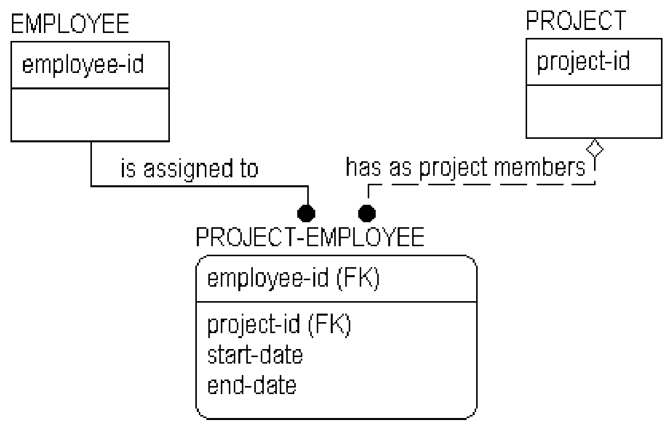
One reason to restrict the deletion might be that the business needs to know other facts about a PROJECT-EMPLOYEE such as the date started on the project. If you Cascade the Delete, you lose this supplementary information.

When you update an instance in the parent entity, the business has also determined that the updated information should cascade to the related instances in the child entity.

As you can see in the example, different rules apply when an instance is inserted, updated, or deleted in the child entity. When an instance is inserted, for example, the action is set to Restrict. This rule appears as *I:R* placed next to the child entity in the relationship. This means that an instance can be added to the child entity *only* if the referenced foreign key matches an existing instance in the parent entity. So, you can insert a new instance in PROJECT-EMPLOYEE only if the value in the key field matches a key value in the PROJECT entity.

RI, Cardinality, and Non-Identifying Relationships

If the business decides that PROJECT-EMPLOYEEs are not existence- or identification-dependent on PROJECT, you can change the relationship between PROJECT and PROJECT-EMPLOYEE to optional, non-identifying. In this type of relationship, the referential integrity options are very different:



Since a foreign key contributed across a non-identifying relationship is allowed to be NULL, one of the referential integrity options you can specify for PARENT DELETE is Set Null. Set Null indicates that if an instance of PROJECT is deleted, then any foreign key inherited from PROJECT in a related instance in PROJECT-EMPLOYEE should be set to NULL. The Delete does not cascade as in our previous example, and it is not prohibited (as in Restrict). The advantage of this approach is that you can preserve the information about the PROJECT-EMPLOYEE while effectively breaking the connection between the PROJECT-EMPLOYEE and PROJECT.

Use of Cascade or Set Null should reflect business decisions about maintaining the historical knowledge of relationships, represented by the foreign keys.

Additional Relationship Types

As you develop a logical model, you may find some parent/child relationships that do not fall into the standard, one-to-many relationships. These relationship exceptions include:

Many-to-many relationships

A relationship where one entity <owns> many instances of a second entity, and the second entity also <owns> many instances of the first entity. For example, an EMPLOYEE <has> one or more JOB TITLEs, and a JOB TITLE <is applied to> one or more EMPLOYEEs.

N-ary relationships

A simple one-to-many relationship between two entities is termed binary. When a one-to-many relationship exists between two or more parents and a single child entity, it is termed an *n-ary relationship*.

Recursive relationships

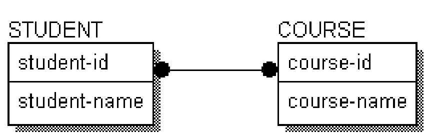
Entities that have a relationship to themselves take part in recursive relationships. For example, for the EMPLOYEE entity, you could include a relationship to show that one EMPLOYEE <manages> one or more EMPLOYEEs. This type of relationship is also used for bill-of-materials structures, to show relationships between parts.

Subtype relationships

Related entities are grouped together so that all common attributes appear in a single entity, but all attributes that are not in common appear in separate, related entities. For example, the EMPLOYEE entity could be subtyped into FULL-TIME and PART-TIME.

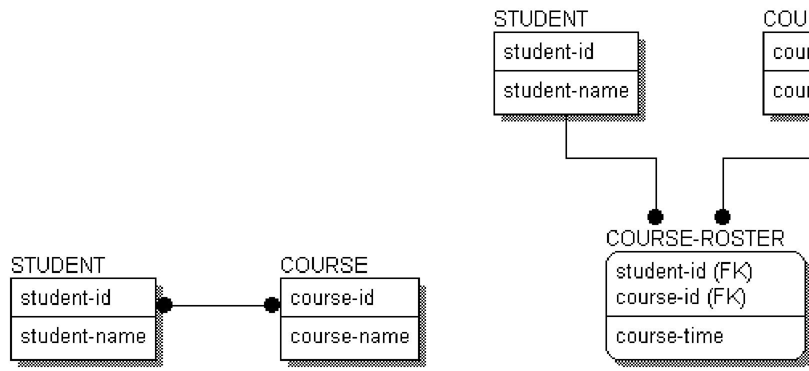
Many-to-Many Relationships

In key-based and fully-attributed models, relationships must relate zero or one instances in a parent entity to a specific set of instances in a child entity. As a result of this rule, many-to-many relationships that were discovered and documented in an ERD or earlier modeling phase must be broken down into a pair of one-to-many relationships.



This figure shows a many-to-many relationship between STUDENTs and COURSEs. If you did not eliminate the many-to-many relationship between COURSE and STUDENT, the key of COURSE would be included in the key of STUDENT, and the key of STUDENT would be included in the key of COURSE. Since COURSEs are identified by their own keys, and likewise for STUDENTs this, creates an endless loop.

You can eliminate a many-to-many relationship by creating an associative entity. In the following figure, the many-to-many relationship between STUDENT and COURSE is resolved by adding the COURSE-ROSTER entity.

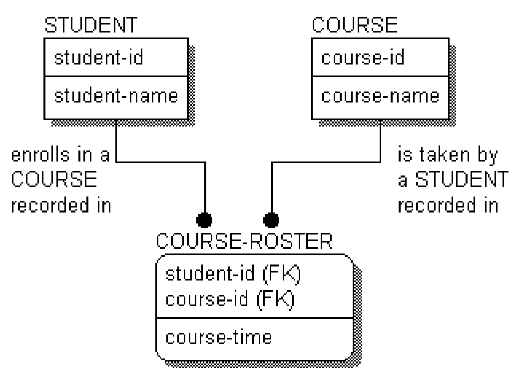


COURSE-ROSTER is an associative entity, which means it is used to define the association between two related entities.

Many-to-many relationships often hide meaning. In the diagram with a many-to-many relationship, you know that a STUDENT enrolls in many COURSEs, but no information is included to show how. When you resolve the many-to-many relationship, you see not only how the entities are related, but uncover additional information, such as the "course-time," which also describes facts about the relationship.

Once the many-to-many relationship is resolved, you are faced with the requirement to include relationship verb phrases that validate the structure. There are two ways to do this: construct new verb phrases or use the verb phrases as they existed for the many-to-many relationship. The most straightforward way is to continue to read the many-to-many relationship, through the associative entity. Therefore, you can read A STUDENT <enrolls in> many COURSEs and A COURSE <is taken by> many STUDENTs. Many modelers adopt this style for constructing and reading a model.

There is another style, which is equally correct, but a bit more cumbersome. The structure of the model is exactly the same, but the verb phrases are different, and the model is read in a slightly different way:

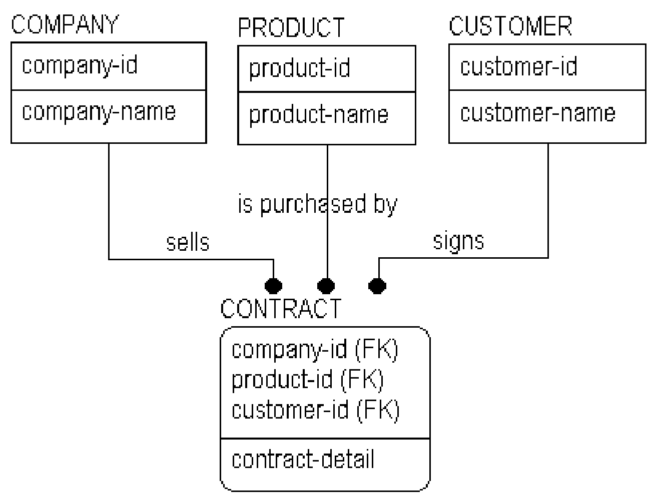


You would read: A STUDENT <enrolls in a COURSE recorded in> one or more COURSE-ROSTERs, and A COURSE <is taken by a STUDENT recorded in> one or more COURSE-ROSTERs.Although the verb phrases are now quite long, the reading follows the standard pattern; reading directly from the parent entity to the child.

Whichever style you choose, be consistent. Deciding how to record verb phrases for many-to-many relationships is not too difficult when the structures are fairly simple, as in these examples. However, this can become more difficult when the structures become more complex, such as when the entities on either side of the associative entities are themselves associative entities, which are there to represent other many-to-many relationships.

N-ary Relationships

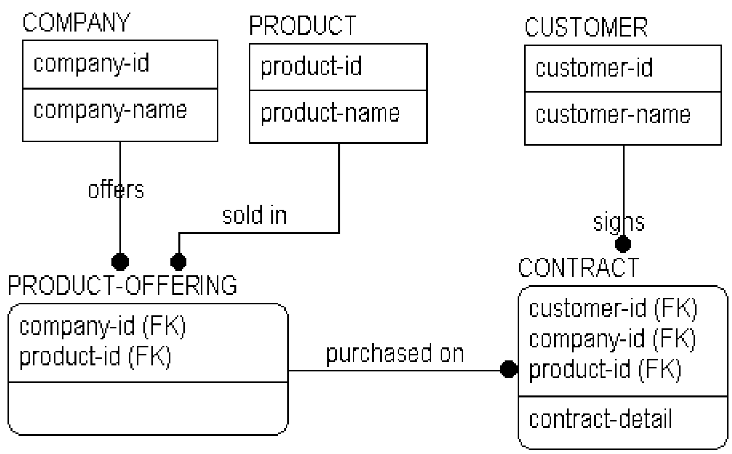
When a single parent-child relationship exists, the relationship is called binary. All of the previous examples of relationships to this point have been binary relationships. However, when creating a data model, it is not uncommon to come across n-ary relationships, the modeling name for relationships between two or more parent entities and a single child table. An example of an n-ary relationship is shown in the following figure:



Like many-to-many relationships, three-, four-, or n-ary relationships are valid constructs in entity relationship diagrams. Also like many-to-many relationships, n-ary relationships should be resolved in later models using a set of binary relationships to an associative entity.

If you consider the business rule stated in the figure, you can see that a CONTRACT represents a three-way relationship among COMPANY, PRODUCT, and CUSTOMER. The structure indicates that many COMPANYs sell many PRODUCTs to many CUSTOMERs. When you see a relationship like this, however, there are business questions that should be answered. For example, “Must a product be offered by a company before it can be sold?” “Can a customer establish a single contract including products from several different companies?” and, “Do you need to keep track of which customers 'belong to' which companies?” Depending on the answers, the structures may change.

For example, if a product must be offered by a company before it can be sold, then you would have to change the structure as follows:



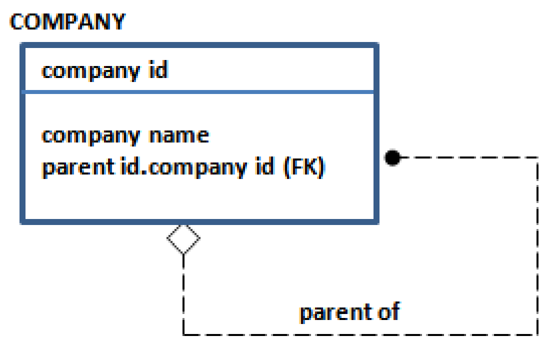
Since PRODUCTs must be offered by COMPANYs, you can create an associative entity to capture this relationship. As a result, the original three-way relationship to CONTRACT is replaced by two, two-way relationships.

By asking a variety of business questions, it is likely that you will find that most n-ary relationships can be broken down into a series of relationships to associative entities.

Recursive Relationships

An entity can participate in a recursive relationship (also called *fishhook*) where the same entity is both the parent and the child. This relationship is an important one when modeling data originally stored in legacy DBMSs such as IMS or IDMS that use recursive relationships to implement bill of materials structures.

For example, a COMPANY can be the parent of other COMPANYs. As with all non-identifying relationships, the key of the parent entity appears in the data area of the child entity. See the following figure:



The recursive relationship for COMPANY includes the diamond symbol to indicate that the foreign key can be NULL, such as when a COMPANY has no parent. Recursive relationships must be both optional (diamond) and non-identifying.

The “company-id” attribute is migrated through the recursive relationship, and appears in the example with the rolename “parent-id.” There are two reasons for this. First, as a general design rule, an attribute cannot appear twice in the same entity under the same name. Thus, to complete a recursive relationship, you must provide a rolename for the migrated attribute.

Second, the attribute “company-id” in the key, which identifies each instance of COMPANY, is not the same thing as the “company-id” migrated through the relationship, which identifies the parent COMPANY. You cannot use the same definition for both attributes, so the migrated attribute must be rolenamed. An example of possible definitions follows:

company-id

The unique identifier of a COMPANY.

parent-id

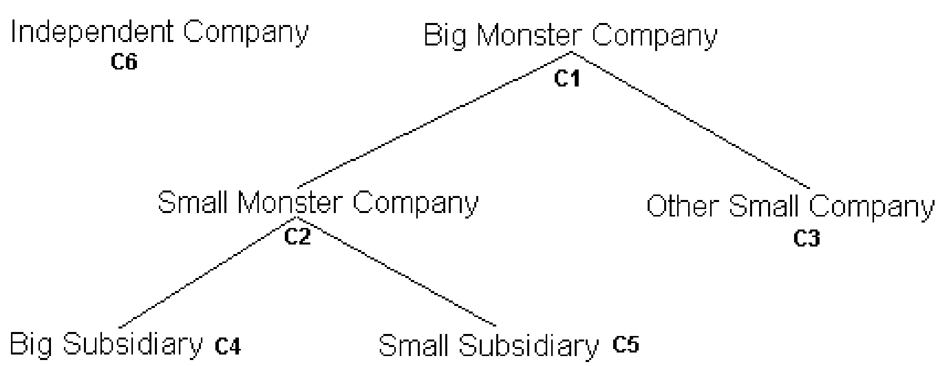
The “company-id” of the parent COMPANY. Not all COMPANYs have a parent COMPANY.

If you create a sample instance table, such as the one that follows, you can test the rules in the relationship to ensure that they are valid.

COMPANY

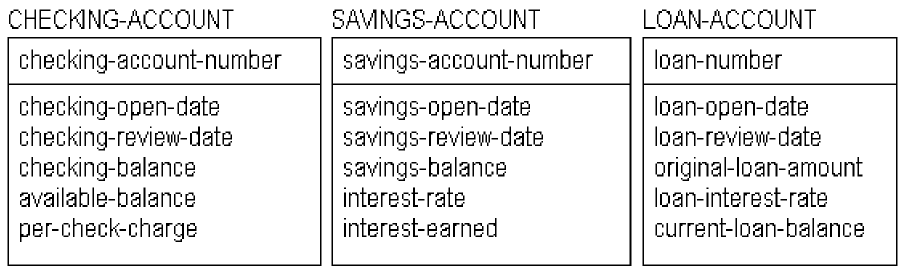
company-id	parent-id	company-name
C1	NULL	Big Monster Company
C2	C1	Smaller Monster Company
C3	C1	Other Smaller Company
C4	C2	Big Subsidiary
C5	C2	Small Subsidiary
C6	NULL	Independent Company

The sample instance table shows that Big Monster Company is the parent of Smaller Monster Company and Other Smaller Company. Smaller Monster Company, in turn, is the parent of Big Subsidiary and Small Subsidiary. Independent Company is not the parent of any other company and has no parent. Big Monster Company also has no parent. If you diagram this information hierarchically, you can validate the information in the table, as shown in the figure below:



Subtype Relationships

A subtype relationship, also referred to as a generalization category, generalization hierarchy, or inheritance hierarchy, is a way to group a set of entities that share common characteristics. For example, you might find during a modeling effort that several different types of ACCOUNTs exist in a bank such as checking, savings, and loan accounts, as shown in the figure below:

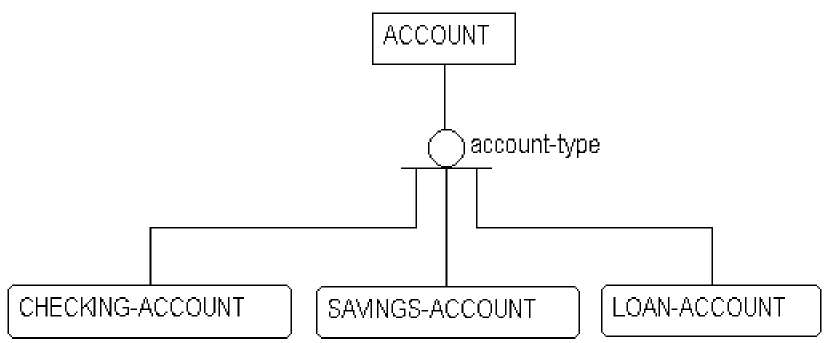


When you recognize similarities among the different independent entities, you may be able to collect attributes common to all three types of accounts into a hierarchical structure.

You can move these common attributes into a higher level entity called the *supertype entity* (or *generalization entity*). Those that are specific to the individual account types remain in the subtype entities. In this example, you can create a supertype entity called ACCOUNT to represent the information that is common across the three types of accounts. The supertype ACCOUNT includes a primary key of “account-number.”

Three subtype entities, CHECKING-ACCOUNT, SAVINGS-ACCOUNT, and LOAN-ACCOUNT, are added as dependent entities that are related to ACCOUNT using a subtype relationship.

The result is a structure like the one shown in the figure below:



In this figure, an ACCOUNT is either a CHECKING-ACCOUNT, a SAVINGS-ACCOUNT, or a LOAN-ACCOUNT. Each subtype entity is an ACCOUNT and inherits the properties of ACCOUNT. The three different subtype entities of ACCOUNT are mutually exclusive.

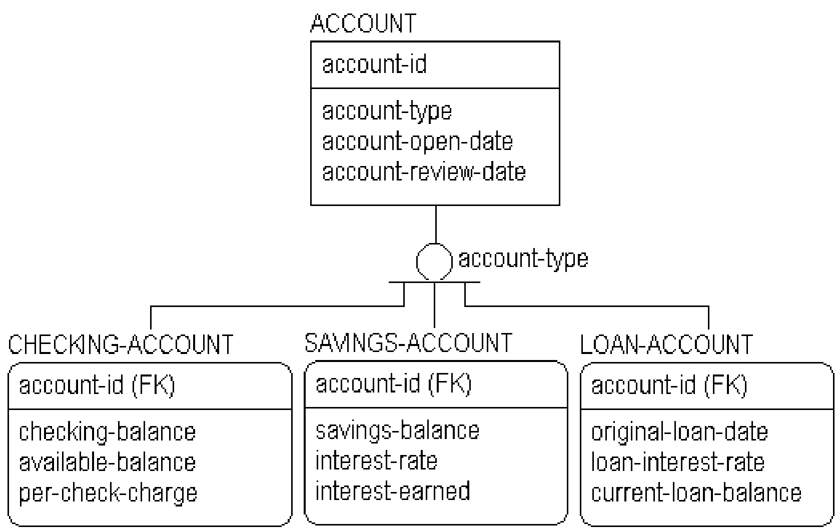
In order to distinguish one type of ACCOUNT from another, you can add the attribute "account-type" as the subtype discriminator. The subtype discriminator is an attribute of the category supertype (ACCOUNT) and its value will tell you which type of ACCOUNT it is.

Once you have established the subtype relationship, you can examine each attribute in the original model, in turn, to determine if it should remain in the subtype entities, or move to the supertype. For example, each subtype entity has an "open-date." If the definitions of these three kinds of "open-date" are the same, you can move them to the supertype, and drop them from the subtype entities.

You must analyze each attribute in turn to determine if it remains in the subtype entity or moves to the supertype entity. In those cases where a single attribute appears in only some of the subtype entities, you face a more difficult decision. You can either leave the attribute with the subtype entities or move the attribute up to the supertype. If this attribute appears in the supertype, the value of the attribute in the supertype will be NULL when the attribute is not included in the corresponding subtype entity.

Which alternative to choose depends on how many of the subtype entities share the common attribute. If most do, it is good practice, at higher level models, to move them up. If few subtype entities share the attribute, it is best to leave them where they are. In lower level models, depending on the purpose, it is often appropriate to leave the attributes in their subtype entity.

After analysis, the resulting model might appear as follows:

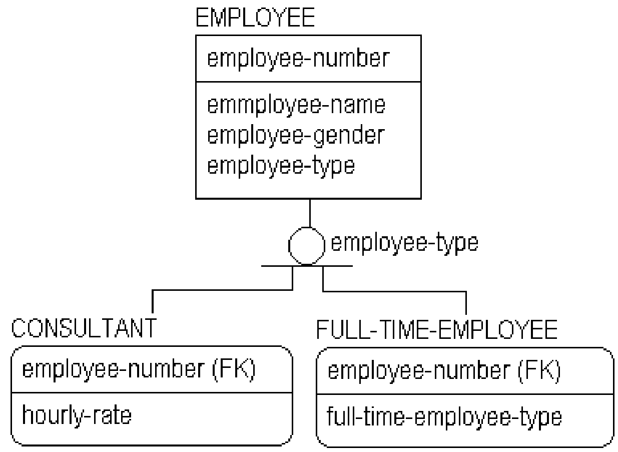


When developing a subtype relationship, you must also be aware of any specific business rules that you need to impose at the subtype level that are not pertinent to other subtypes of the supertype. For example, LOAN accounts are deleted after they reach a zero balance. You would not want to delete CHECKING and SAVINGS accounts under the same conditions.

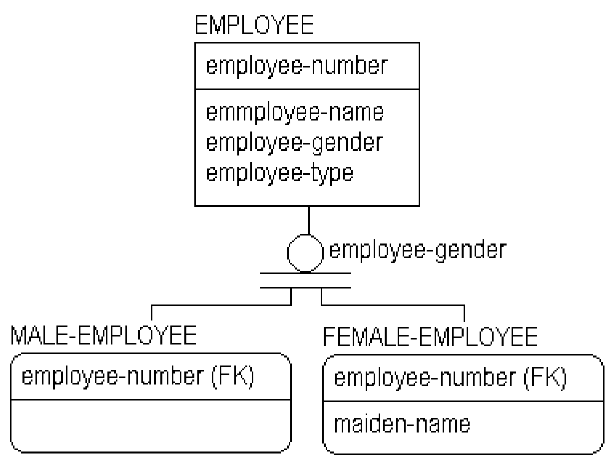
There can also be relationships that are meaningful to a single subtype and not to any other subtype in the hierarchy. For example, the LOAN entity needs to be examined, to ensure that any previous relationships to records of customer payments or assets are not lost because of a different organizational structure.

Complete Compared to Incomplete Subtype Structures

In IDEF1X, different symbols are used to specify whether or not the set of subtype entities in a subtype relationship is fully defined. An incomplete subtype indicates that the modeler feels there may be other subtype entities that have not yet been discovered. An incomplete subtype is indicated by a *single line* at the bottom of the subtype symbol, as shown in the figure below:



A complete subtype indicates that the modeler is certain that all possible subtype entities are included in the subtype structure. For example, a complete subtype could capture information specific to male and female employees, as shown in the figure below. A complete subtype is indicated by *two lines* at the bottom of the subtype symbol.



When you create a subtype relationship, it is a good rule to also create a validation rule for the discriminator. This helps to ensure that all subtypes have been discovered. For example, a validation rule for "account-type" might include: C=checking account, S=savings account, L=loans. If the business also has legacy data with account types of "O," the validation rule uncovers the undocumented type and lets you decide if the "O" is a symptom of poor design in the legacy system or a real account type that you forgot.

Inclusive and Exclusive Relationships

Unlike IDEF1X, IE notation does not distinguish between complete and incomplete subtype relationships. Instead, IE notation documents whether the relationship is *exclusive* or *inclusive*. However, IDEF1X notation distinguishes between complete and incomplete; exclusive and inclusive.

In an exclusive subtype relationship, each instance in the supertype can relate to one and only one subtype. For example, you might model a business rule that says an employee can be either a full-time or part-time employee but not both. To create the model, you can include an EMPLOYEE supertype entity with FULL-TIME and PART-TIME subtype entities and a discriminator attribute called “employee-status.” In addition, you can constrain the value of the discriminator to show that valid values for it include *F* to denote full-time and *P* to denote part-time.

In an inclusive subtype relationship, each instance in the supertype can relate to one or more subtypes. In our example, the business rule might now state that an employee could be full-time, part-time, or both. In this example, you can constrain the value of the discriminator to show that valid values for it include *F* to denote full-time, *P* to denote part-time, and *B* to denote both full-time and part-time.

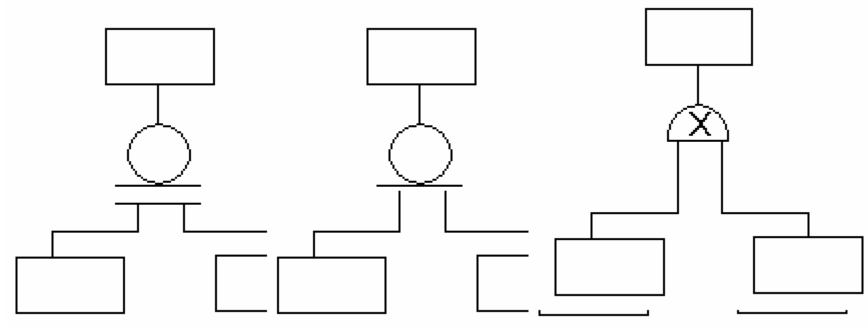
Note: In IDEF1X notation, you can represent inclusive subtypes by drawing a separate relationship between the supertype entity and each subtype entity.

IDEF1X and IE Subtype Notation

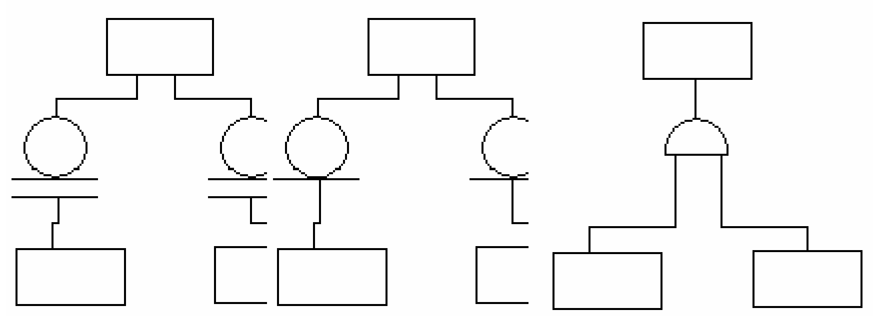
The following illustrates subtype notation in IDEF1X and IE:

IDEF1X Subtype Notation		IE Subtype Notation
Complete	**Incomplete**	

Exclusive Subtype



Inclusive Subtype



When to Create a Subtype Relationship

You should create a subtype relationship when:

- Entities share a common set of attributes. This was the case in our previous examples.
- Entities share a common set of relationships. This has not been explored but, referring back to the account structure, you can, as needed, collect any common relationships that the subtype entities had into a single relationship from the generic parent. For example, if each account type is related to many CUSTOMERs, you can include a single relationship at the ACCOUNT level, and eliminate the separate relationships from the individual subtype entities.
- Business model demands that the subtype entities should be exposed in a model (usually for communication or understanding purposes) even if the subtype entities have no attributes that are different, and even if they participate in no relationships distinct from other subtype entities. Remember that one of the major purposes of a model is to assist in communication of information structures, and if showing subtype entities assists communication, then show them.

Chapter 8: Normalization Problems and Solutions

This section contains the following topics

Normalization (see page 69)
Overview of the Normal Forms (see page 70)
Common Design Problems (see page 71)
Unification (see page 81)
How Much Normalization Is Enough (see page 82)
Support for Normalization (see page 84)

Normalization

Normalization, in relational database design, is the process by which data in a relational construct is organized to minimize redundancy and non-relational constructs. Following the rules for normalization, you can control and eliminate data redundancy by removing all model structures that provide multiple ways to know the same fact.

The goal of normalization is to ensure that there is only one way to know a fact. A useful slogan summarizing this goal is:

ONE FACT IN ONE PLACE!

Overview of the Normal Forms

The following are the formal definitions for the most common normal forms.

Functional Dependence (FD)

Given an entity E, attribute B of E is functionally dependent on attribute A of E if and only if each value of A in E has associated with it precisely one value of B in E (at any one time). In other words, A uniquely determines B.

Full Functional Dependence

Given an entity E, an attribute B of E is fully functionally dependent on a set of attributes A of E if and only if B is functionally dependent on A and not functionally dependent on any proper subset of A.

First Normal Form (1NF)

An entity E is in 1NF if and only if all underlying values contain only atomic values. Any repeating groups (that might be found in legacy COBOL data structures, for example) must be eliminated.

Second normal Form (2NF)

An entity E is in 2NF if it is in 1NF and every non-key attribute is fully dependent on the primary key. In other words, there are no partial key dependencies-dependence is on the entire key K of E and not on a proper subset of K.

Third Normal Form (3NF)

An entity E is in 3NF if it is in 2NF and no non-key attribute of E is dependent on another non-key attribute. There are several equivalent ways to express 3NF. Another way is: An entity E is in 3NF if it is in 2NF and every non-key attribute is non-transitively dependent on the primary key. A final way is: An entity E is in 3NF if every attribute in E carries a fact about all of E (2NF) and only about E (as represented by the entity's entire key and only by that key). One way to remember how to implement 3NF is using the following quip: “Each attribute relies on the key, the whole key, and nothing but the key, so help me Codd!”

Beyond 3NF lie three more normal forms, Boyce-Codd, Fourth, and Fifth. In practice, third normal form is the standard. At the level of the physical database design, choices are usually made to *denormalize* a structure in favor of performance for a certain set of transactions. This may introduce redundancy in the structure, but it is often worth it.

Common Design Problems

Many common design problems are a result of violating one of the normal forms. Common problems include:

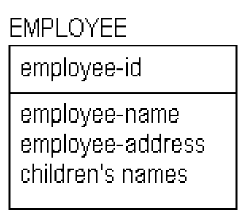
- Repeating data groups
- Multiple use of the same attribute
- Multiple occurrences of the same fact
- Conflicting facts
- Derived attributes
- Missing information

When you work on eliminating design problems, the use of sample instance data can be invaluable in discovering many normalization errors.

Repeating Data Groups

Repeating data groups can be defined as lists, repeating elements, or internal structures inside an attribute. This structure, although common in legacy data structures, violates first normal form and must be eliminated in an RDBMS model. An RDBMS cannot handle variable-length repeating fields because it offers no ability to subscript through arrays of this type. The entity below contains a repeating data group, “children's-names.” Repeating data groups violate first normal form, which basically states that an entity is in first normal form if each of its attributes has a single meaning and not more than one value for each instance.

Repeating data groups, as shown below, present problems when defining a database to contain the actual data. For example, after designing the EMPLOYEE entity, you are faced with the questions, “How many children's names do you need to record?” “How much space should you leave in each row in the database for the names?” and “What will you do if you have more names than remaining space?”

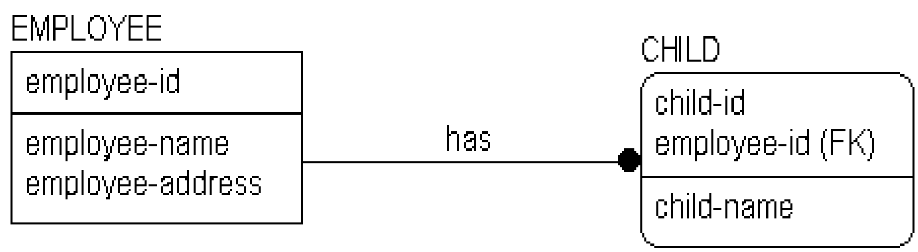


The following sample instance table might clarify the problem:

EMPLOYEE

emp-id	emp-name	emp-address	children's-names
E1	Tom	Berkeley	Jane
E2	Don	Berkeley	Tom, Dick, Donna
E3	Bob	Princeton	-
E4	John	New York	Lisa
E5	Carol	Berkeley	-

In order to fix the design, it is necessary to somehow remove the list of children's names from the EMPLOYEE entity. One way to do this is to add a CHILD table to contain the information about employee's children, as follows:



Once that is done, you can represent the names of the children as single entries in the CHILD table. In terms of the physical record structure for employee, this can resolve some of your questions about space allocation, and prevent wasting space in the record structure for employees who have no children or, conversely, deciding how much space to allocate for employees with families.

The following tables are the sample instance tables for the EMPLOYEE-CHILD model:

EMPLOYEE

emp-id	emp-name	emp-address
E1	Tom	Berkeley
E2	Don	Berkeley
E3	Bob	Princeton
E4	Carol	Berkeley

CHILD

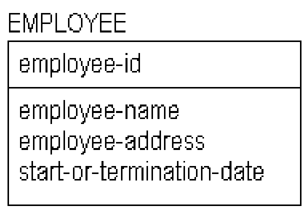
emp-id	child-id	child-name
E2	C1	Tom

E2	C2	Dick
E2	C3	Donna
E4	C1	Lisa

This change makes the first step toward a normalized model; conversion to first normal form. Both entities now contain only fixed-length fields, which are easy to understand and program.

Multiple Use of the Same Attribute

It is also a problem when a single attribute can represent one of two facts, and there is no way to understand which fact it represents. For example, the EMPLOYEE entity contains the attribute “start-or-termination-date” where you can record this information for an employee as follows:



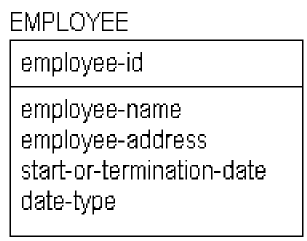
The following sample instance table shows start-or-termination date:

EMPLOYEE

emp-id	emp-name	emp-address	start-or-termination-date
E1	Tom	Berkeley	January 10, 2004
E2	Don	Berkeley	May 22, 2002
E3	Bob	Princeton	March 15, 2003
E4	John	New York	September 30, 2003
E5	Carol	Berkeley	April 22, 2000
E6	George	Pittsburgh	October 15, 2002

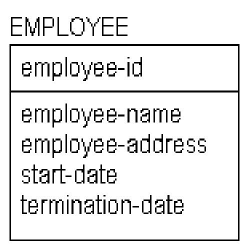
The problem in the current design is that there is no way to record both a start date, *the date that the EMPLOYEE started work*, and a termination date, *the date on which an EMPLOYEE left the company*, in situations where both dates are known. This is because a single attribute represents two different facts. This is also a common structure in legacy COBOL systems, but one that often resulted in maintenance nightmares and misinterpretation of information.

The solution is to allow separate attributes to carry separate facts. The following figure is an attempt to correct the problem. It is still not quite right. To know the start date for an employee, for example, you have to derive what kind of date it is from the “date-type” attribute. While this may be efficient in terms of physical database space conservation, it creates confusion with query logic.



In fact, this solution actually creates a different type of normalization error, since “date-type” does not depend on “employee-id” for its existence. This is also poor design since it solves a technical problem, but does not solve the underlying business problem-how to store two facts about an employee.

When you analyze the data, you can quickly determine that it is a better solution to let each attribute carry a separate fact, as in the following figure:



The following table is a sample instance table showing “start-date” and “termination-date”:

EMPLOYEE

emp-id	emp-name	emp-address	start-date	termination-date
E1	Tom	Berkeley	January 10, 2004	-
E2	Don	Berkeley	May 22, 2002	-
E3	Bob	Princeton	March 15, 2003	-
E4	John	New York	September 30, 2003	-

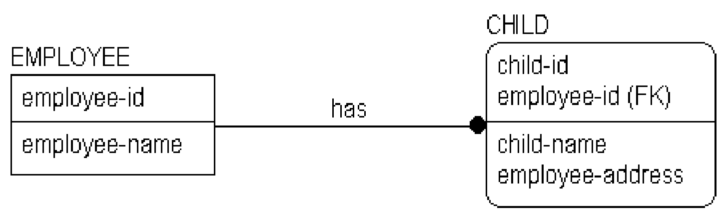
E5	Carol	Berkeley	April 22, 2000	-
E6	George	Pittsburgh	October 15, 2002	Nov 30, 2003

Each of the two previous situations contained a first normal form error. By changing the structures, an attribute now appears only once in the entity and carries only a single fact. If you make sure that all the entity and attribute names are singular and that no attribute can carry multiple facts, you have taken a large step toward assuring that a model is in first normal form.

Multiple Occurrences of the Same Fact

One of the goals of a relational database is to maximize data integrity. To do so, it is important to represent each fact in the database once and only once, otherwise errors can begin to enter into the data. The only exception to this rule (one fact in one place) is in the case of key attributes, which can appear multiple times in a database. The integrity of keys, however, is managed using referential integrity.

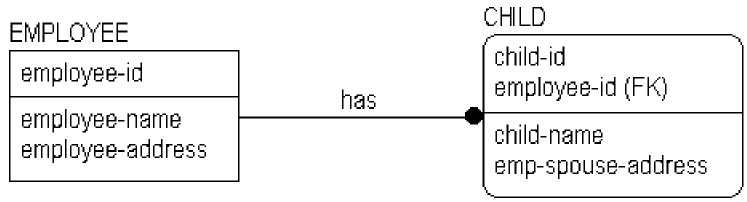
Multiple occurrences of the same fact often point to a flaw in the original database design. In the following figure, you can see that including “employee-address” in the CHILD entity has introduced an error in the database design. If an employee has multiple children, the address must be maintained separately for each child.



“employee-address” is information about the EMPLOYEE, not information about the CHILD. In fact, this model violates second normal form, which states that each fact must depend on the entire key of the entity in order to belong to the entity. The example above is not in second normal form because “employee-address” does not depend on the entire key of CHILD, only on the “employee-id” portion, creating a partial key dependency. If you place “employee-address” back with EMPLOYEE, you can ensure that the model is in at least second normal form.

Conflicting Facts

Conflicting facts can occur for a variety of reasons, including violation of first, second, or third normal forms. An example of conflicting facts occurring through a violation of second normal form is shown in the following figure:



The following two tables are sample instance tables showing “emp-spouse-address”:

EMPLOYEE

emp-id	emp-name	emp-address
E1	Tom	Berkeley
E2	Don	Berkeley
E3	Bob	Princeton
E4	Carol	Berkeley

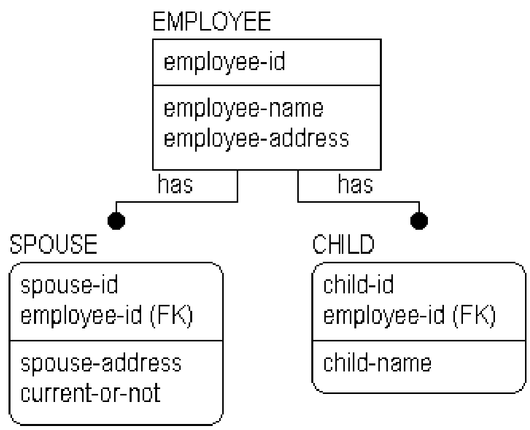
CHILD

emp-id	child-id	child-name	emp-spouse-address
E1	C1	Jane	Berkeley
E2	C1	Tom	Berkeley
E2	C2	Dick	Berkeley
E2	C3	Donna	Cleveland
E4	C1	Lisa	New York

The attribute named “emp-spouse-address” is included in CHILD, but this design is a second normal form error. The instance data highlights the error. As you can see, Don is the parent of Tom, Dick, and Donna but the instance data shows two different addresses recorded for Don's spouse. Perhaps Don has had two spouses (one in Berkeley, and one in Cleveland), or Donna has a different mother from Tom and Dick. Or perhaps Don has one spouse with addresses in both Berkeley and Cleveland. Which is the correct answer? There is no way to know from the model as it stands. Business users are the only source that can eliminate this type of semantic problem, so analysts need to ask the right questions about the business to uncover the correct design.

The problem in the example is that “emp-spouse-address”is a fact about the EMPLOYEE's SPOUSE, not about the CHILD. If you leave the structure the way it is now, then every time Don's spouse changes address (presumably along with Don), you will have to update that fact in multiple places; once in each CHILD instance where Don is the parent. If you have to update multiple places, you might miss some and get errors.

Once it is recognized that “emp-spouse-address” is a fact not about a child, but about a spouse, you can correct the problem. To capture this information, you can add a SPOUSE entity to the model, as shown in the following figure:



The following three tables are sample instance tables reflecting the SPOUSE Entity:

EMPLOYEE

emp-id	emp-name	emp-address
E1	Tom	Berkeley
E2	Don	Berkeley
E3	Bob	Princeton
E4	Carol	Berkeley

CHILD

emp-id	child-id	child-name
E1	C1	Jane
E2	C1	Tom
E2	C2	Dick
E2	C3	Donna
E4	C1	Lisa

SPOUSE

emp-id	spouse-id	spouse-address	current-spouse
E2	S1	Berkeley	Y
E2	S2	Cleveland	N
E3	S1	Princeton	Y
E4	S1	New York	Y
E5	S1	Berkeley	Y

In breaking out SPOUSE into a separate entity, you can see that the data for the address of Don's spouses is correct. Don has two spouses, one current and one former.

By making sure that every attribute in an entity carries a fact about *that* entity, you can generally be sure that a model is in at least second normal form. Further transforming a model into third normal form generally reduces the likelihood that the database will become corrupt; in other words, that it will contain conflicting information or that required information will be missing.

Derived Attributes

Another example of conflicting facts occurs when third normal form is violated. For example, if you included both a “birth-date” and an “age” attribute as non-key attributes in the CHILD entity, you violate third normal form. This is because “age” is *functionally dependent* on “birth-date.” By knowing “birth-date” and the date today, you can *derive* the “age” of the CHILD.

Derived attributes are those that may be computed from other attributes, such as totals, and therefore you do not need to directly store them. To be accurate, derived attributes need to be updated every time their derivation sources are updated. This creates a large overhead in an application that does batch loads or updates, for example, and puts the responsibility on application designers and coders to ensure that the updates to derived facts are performed.

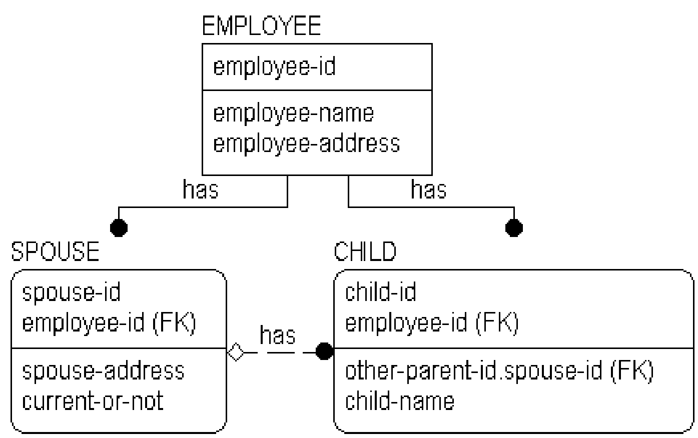
A goal of normalization is to ensure that there is only one way to know each fact recorded in the database. If you know the value of a derived attribute, and you know the algorithm by which it is derived and the values of the attributes used by the algorithm, then there are two ways to know the fact (look at the value of the derived attribute, or derive it by manual calculation). If you can get an answer two different ways, it is possible that the two answers will be different.

For example, you can choose to record both the “birth-date” and the “age”for CHILD. And suppose that the “age” attribute is only changed in the database during an end of month maintenance job. Then, when you ask the question, “How old is this CHILD?” you can directly access “age” and get an answer, or you can subtract “birth-date” from “today's-date.” If you did the subtraction, you would *always* get the right answer. If “age” was not recently updated, it might give you the wrong answer, and there would *always* be the *potential for conflicting answers*.

There are situations, where it makes sense to record derived data in the model, particularly if the data is expensive to compute. It can also be very useful in discussing the model with those in the business. Although the theory of modeling says that you should never include derived data or do so only sparingly, break the rules when you must and at least record the fact that the attribute is derived and state the derivation algorithm.

Missing Information

Missing information in a model can sometimes result from efforts to normalize the data. In the example, adding the SPOUSE entity to the EMPLOYEE-CHILD model improves the design, but destroys the implicit relationship between the CHILD entity and the SPOUSE address. It is possible that the reason that “emp-spouse-address” was stored in the CHILD entity in the first place was to represent the address of the other parent of the child (which was assumed to be the spouse). If you need to know the other parent of each of the children, then you must add this information to the CHILD entity.



The following three tables are sample instance tables for EMPLOYEE, CHILD, and SPOUSE:

EMPLOYEE

emp-id	emp-name	emp-address
E1	Tom	Berkeley
E2	Don	Berkeley
E3	Bob	Princeton
E4	Carol	Berkeley

CHILD

emp-id	child-id	child-name	other-parent-id
E1	C1	Jane	-
E2	C1	Tom	S1
E2	C2	Dick	S1
E2	C3	Donna	S2
E4	C1	Lisa	S1

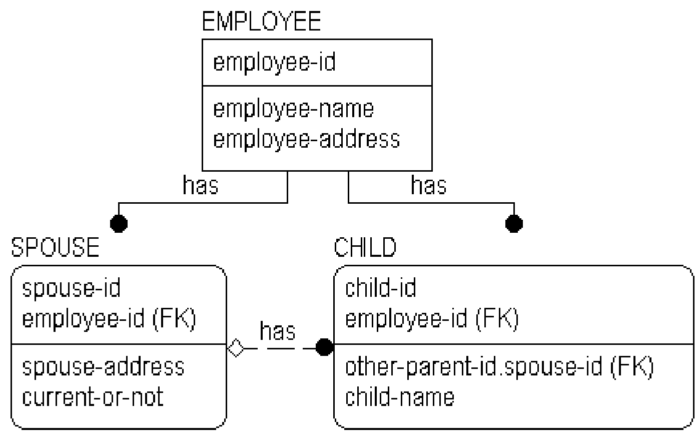
SPOUSE

emp-id	spouse-id	spouse-address	current-or-not
E2	S1	Berkeley	Y
E2	S2	Cleveland	N
E3	S1	Princeton	Y
E4	S1	New York	Y
E5	S1	Berkeley	Y

However, the normalization of this model is not complete. In order to complete it, you must ensure that you can represent all possible relationships between employees and children, including those where both parents are employees.

Unification

In the following example, the “employee-id” attribute migrates to the CHILD entity through two relationships: one with EMPLOYEE and the other with SPOUSE. You might expect that the foreign key attribute would appear twice in the CHILD entity as a result. Since the attribute “employee-id” was already present in the key area of CHILD, it is not repeated in the entity even though it is part of the key of SPOUSE.



This combining of two identical foreign key attributes migrated from the same base attribute through two or more relationships is called *unification*. In the example, “employee-id”was part of the primary key of CHILD (contributed by the “has” relationship from EMPLOYEE) and was also a non-key attribute of CHILD (contributed by the “has” relationship from SPOUSE). Since both foreign key attributes are the identifiers of the same EMPLOYEE, it is better that the attribute appears only once. Unification is implemented automatically when this situation occurs.

The rules used to implement unification include:

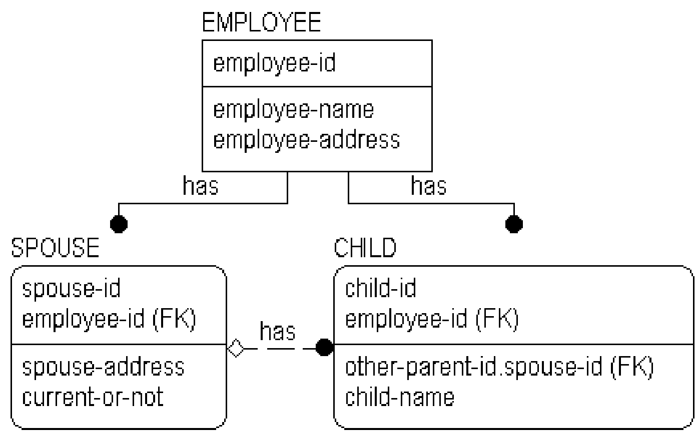
- If the same foreign key is contributed to an entity more than once, without the assignment of rolenames, then all occurrences unify.
- If the occurrences of the foreign key are given different rolenames, then unification does not occur.
- If different foreign keys are assigned the same rolename, and these foreign keys are rolenamed back to the same base attribute, then unification occurs. If they are not rolenamed back to the same base attribute, there is an error in the diagram.
- If any of the foreign keys that unify are part of the primary key of the entity, then the unified attribute remains as part of the primary key.
- If none of the foreign keys that unify are part of the primary key, then the unified attribute is not part of the primary key.

Accordingly, you can override the unification of foreign keys, when necessary, by assigning rolenames. If you want the same foreign key to appear two or more times in a child entity, you can add a rolename to each foreign key attribute.

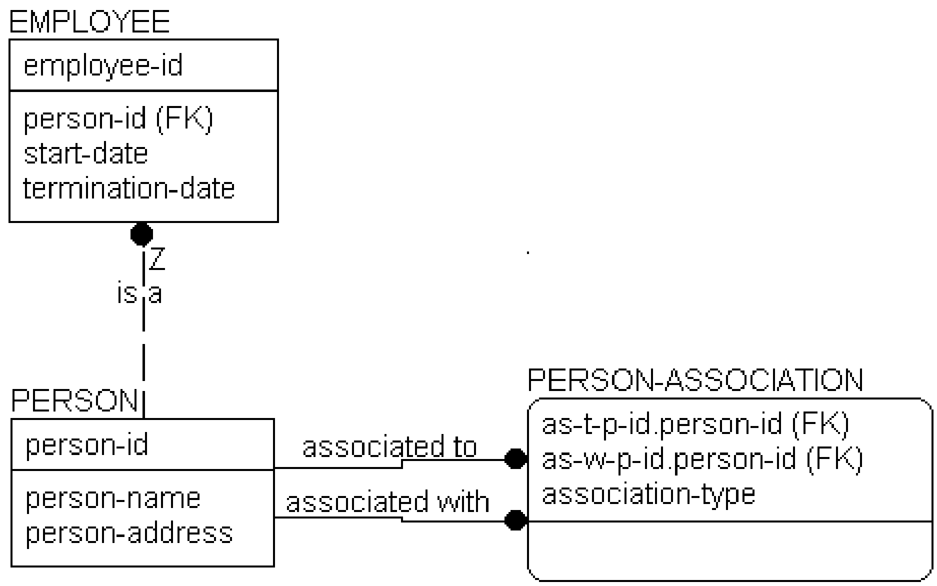
How Much Normalization Is Enough

From a formal normalization perspective (what an algorithm would find solely from the shape of the model, without understanding the meanings of the entities and attributes) there is nothing wrong with the EMPLOYEE-CHILD-SPOUSE model. However, just because it is normalized does not mean that the model is complete or correct. It still may not be able to store all of the information that is needed or it may store the information inefficiently. With experience, you can learn to detect and remove additional design flaws even after the pure normalization is finished.

Using the following EMPLOYEE-CHILD-SPOUSE model example, you see that there is no way of recording a CHILD whose parents are both EMPLOYEEs. Therefore, you can make additional changes to try to accommodate this type of data.



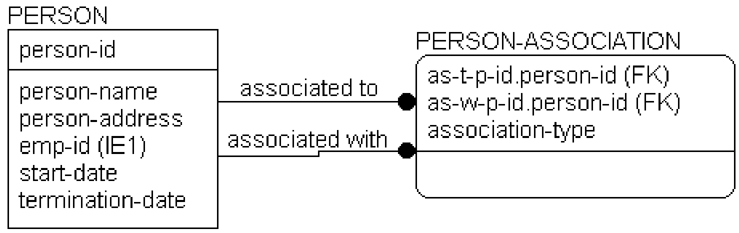
If you noticed that EMPLOYEE, SPOUSE, and CHILD all represent instances of people, you may want to try to combine the information into a single table that represents facts about people and one that represents facts about relationships. To fix the model, you can eliminate CHILD and SPOUSE, replacing them with PERSON and PERSON-ASSOCIATION. This lets you record parentage and marriage through the relationships between two PERSONs captured in the PERSON-ASSOCIATION entity.



In this structure, you can finally record any number of relationships between two PERSONs, as well as a number of relationships you could not previously record in the first model, such as adoption. The new structure automatically covers it. To represent adoption you can add a new value to the “person-association-type” validation rule to represent adopted parentage. You can also add legal guardian, significant other, or other relationships between two PERSONs later, if needed.

EMPLOYEE remains an independent entity, since the business chooses to identify EMPLOYEEs differently from PERSONs. However, EMPLOYEE inherits the properties of PERSON by virtue of the *is a* relationship back to PERSON. Notice the *Z* on that relationship and the absence of a diamond. This is a one-to-zero or one relationship that can sometimes be used in place of a subtype when the subtype entities require different keys. In this example, a PERSON either *is an* EMPLOYEE or *is not an* EMPLOYEE.

If you wanted to use the same key for both PERSON and EMPLOYEE, you can encase the EMPLOYEE entity into PERSON and allowed its attributes to be NULL whenever the PERSON is not an EMPLOYEE. You still can specify that the business wanted to look up employees by a separate identifier, but the business statements would be a bit different. This structure is shown in the following figure:



This means that a model may normalize, but still may not be a correct representation of the business. Formal normalization is important. Verifying that the model means something, perhaps with sets of sample instance tables as done here, is no less important.

Support for Normalization

Support for normalization of data models is supported, but does not currently contain a full normalization algorithm. If you have not used a real time modeling tool before, you will find the standard modeling features quite helpful. They will prevent you from making many normalization errors.

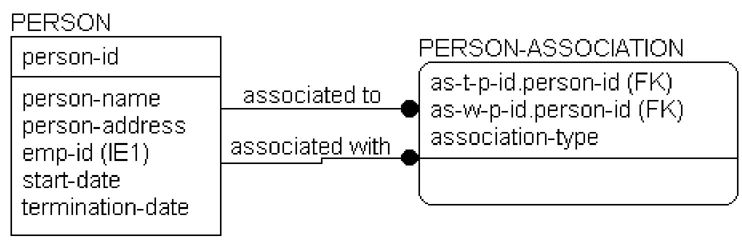
First Normal Form Support

In a model, each entity or attribute is identified by its name. Any name for an object is accepted, with the following exceptions:

- A second use of an entity name (depending on your preference for unique names) is flagged.
- A second use of an attribute name is flagged, unless that name is a rolename. When rolenames are assigned, the same name for an attribute may be used in different entities.
- You cannot bring a foreign key into an entity more than once without unifying the like columns.

By preventing multiple uses of the same name, you are prompted to put each fact in exactly one place. However, there may still be second normal form errors if you place an attribute incorrectly, but no algorithm would find that without more information than is present in a model.

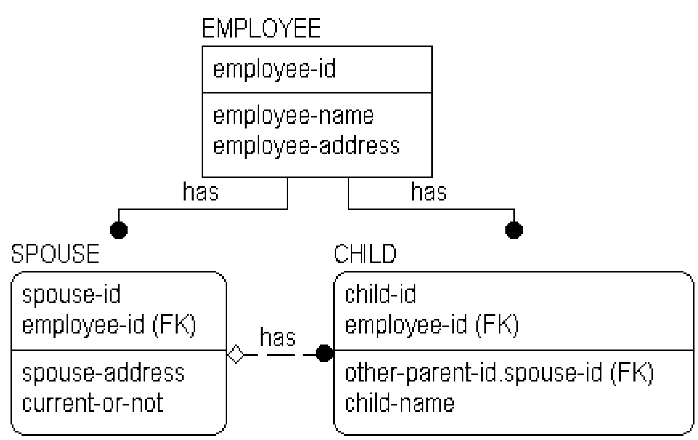
In a data model, erwin® Data Modeler cannot know that a name you assign to an attribute can represent a list of things. In the following example, erwin® Data Modeler accepts “children's-names” as an attribute name. So erwin® Data Modeler does not directly guarantee that every model is in first normal form.



However, the DBMS schema function does not support a data type of *list*. Since the schema is a representation of the database in a physical relational system, first normal form errors are also prevented at this level.

Second and Third Normal Form Support

erwin® Data Modeler does not currently manage functional dependencies, but it can help to prevent second and third normal form errors. For example, if you reconstruct the examples below, you will find that once “spouse-address” is defined as an attribute of SPOUSE, you cannot also define it as an attribute of CHILD. (Again, depending on your preference for unique names.)



By preventing the multiple occurrence of foreign keys without rolenames, you are reminded to think about what the structure represents. If the same foreign key occurs twice in the same entity, there is a business question to ask: Are we recording the keys of two separate instances, or do both of the keys represent the same instance?

When the foreign keys represent different instances, separate rolenames are needed. If the two foreign keys represent the same instance, then it is very likely that there is a normalization error somewhere. A foreign key appearing twice in an entity without a rolename means that there is a redundant relationship structure in the model. When two foreign keys are assigned the same rolename, unification occurs.

Chapter 9: Physical Models

Two levels of physical models exist for an implementation project:

- Transformation model
- DBMS model

The physical models capture all of the information that data architects and database administrators require to implement a logical model as a database system. The Transformation model is also a *project data model* that describes a portion of an overall data structure supported by a single automation effort. Individual projects within a business area are supported, allowing the modeler to separate a larger area model into submodels, or subject areas. Subject areas can be developed, reported on, and generated to the database in isolation from the area model and other subject areas in the model.

This section contains the following topics

Objective (see page 87)
Support for the Roles of the Physical Model (see page 88)
Denormalization (see page 89)

Objective

The objective of a physical model is to provide a database administrator with sufficient information to create an efficient physical database. The physical model also provides a context for the definition and recording (in the data dictionary) of the data elements that form the database, and assists the application team in choosing a physical structure for the programs that will access the data. To ensure that all information system needs are met, physical models are often developed jointly by a team representing the data administration, database administration, and application development areas.

When it is appropriate for the development effort, the model can also provide the basis for comparing the physical database design against the original business information requirements to:

- Demonstrate that the physical database design adequately supports those requirements.
- Document physical design choices and their implications, such as what is satisfied, and what is not.
- Identify database extensibility capabilities and constraints.

Support for the Roles of the Physical Model

Support is provided for both roles of a physical model:

- Generating the physical database
- Documenting physical design against the business requirements

For example, in a logical/physical model, you can create a physical model from an ERD, key-based, or fully attributed model simply by changing the view of the model from Logical Model to Physical Model. Each option in the logical model has a corresponding option in the physical model. Therefore, each entity becomes a relational table, attributes become columns, and keys become indices.

Once the physical model is created, you can generate all model objects in the correct syntax for the selected target server directly to the catalog of the target server, or indirectly as a schema DDL script file.

Summary of Logical and Physical Model Components

The following table summarizes the relationship between objects in a logical and a physical model:

Logical Model	Physical Model
Entity	Table
Dependent entity	Foreign Key is part of the child table's Primary Key
Independent entity	Parent table or, if it is a child table, Foreign Key is NOT part of the child table's Primary Key
Attribute	Column
Logical datatype (text, number, datetime, blob)	Physical datatype (valid example varies depending on the target server selected)
Domain (logical)	Domain (physical)
Primary key	Primary key, Primary Key Index
Foreign key	Foreign key, Foreign Key Index
Alternate key (AK)	Alternate Key Index-a unique, non-primary index

Logical Model	Physical Model
Inversion entry (IE)	Inversion entry Index-a non-unique index created to search table information by a non-unique value, such as customer last name.
Key group	Index
Business rule	Trigger or stored procedure
Validation rule	Constraint
Relationship	Relationship implemented using Foreign Keys
Identifying relationship	Foreign Key is part of the child table's Primary Key (above the line)
Non-identifying relationship	Foreign Key is NOT part of the child table's Primary Key (below the line)
Subtype relationship	Denormalized tables
Many-to-many relationship	Associative table
Referential Integrity relationship (Cascade, Restrict, Set Null, Set Default)	INSERT, UPDATE, and DELETE Triggers
Cardinality relationship	INSERT, UPDATE, and DELETE Triggers
N/A	View or view relationship
N/A	Prescript or postscript

Referential integrity is a part of the logical model, since the decision about how to maintain a relationship is a business decision. Referential integrity is also a physical model component, since triggers or declarative statements appear in the schema. Referential integrity is supported as a part of both the logical and physical models.

Denormalization

You can also *denormalize* the structure of the logical model, or allow data redundancy in a table to improve query performance so that you can build a related physical model that is designed effectively for the target RDBMS. Features supporting denormalization include:

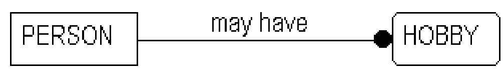
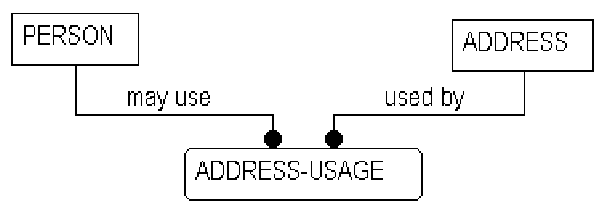
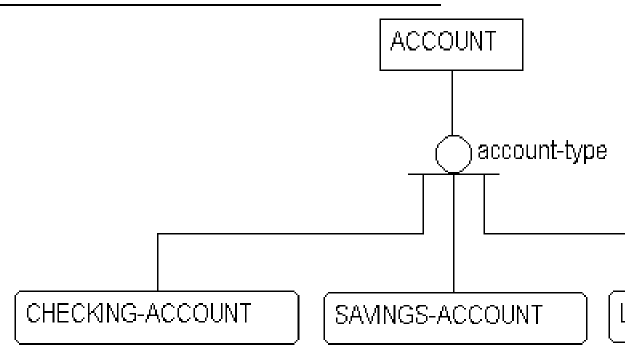
- *Logical only* properties for entities, attributes, key groups, and domains. You can mark any item in the logical model logical only so that it appears in the logical model, but does not appear in the physical model. For example, you can use the logical only settings to denormalize subtype relationships or support partial key migration in the physical model.

- *Physical only* properties for tables, columns, indexes, and domains. You can mark any item in the physical model physical only so that it appears in the physical model only. This setting also supports denormalization of the physical model since it enables the modeler to include tables, columns, and indexes in the physical model that directly support physical implementation requirements.
- Resolution of many-to-many relationships in a physical model. Support for resolving many-to-many relationships is provided in both the logical and physical models. If you resolve the many-to-many relationship in the logical model, the associative entity is created and lets you add additional attributes. If you choose to keep the many-to-many relationship in the logical model, you can still resolve the relationship in the physical model. The link is maintained between the original logical design and the new physical design, so the origin of the associative table is documented in the model.

Appendix A: Dependent Entity Types

Classification of Dependent Entities

The following table lists the types of dependent entities that may appear in an IDEF1X diagram:

Dependent Entity Type	Description	Example
Characteristic	A characteristic entity represents a group of attributes that occur multiple times for an entity, and is not directly identified by any other entity. In the example, HOBBY is a characteristic of PERSON.	
Associative or Designative	Associative and designative entities record multiple relationships between two or more entities. If the entity carries only the relationship information, it is termed a designative entity. If it also carries attributes that further describe the relationship, it is called an associative entity. In the example, ADDRESS-USAGE is an associative or designative entity.	
Subtype	Subtype entities are the dependent entities in a subtype relationship. In the example, CHECKING-ACCOUNT, SAVINGS-ACCOUNT, and LOAN-ACCOUNT are subtype entities.	

Appendix B: Glossary

This section contains the following topics:

alternate key (see page 93)
attribute (see page 93)
basename (see page 94)
binary relationship (see page 94)
BLOB (see page 94)
cardinality (see page 94)
complete subtype cluster (see page 94)
dependent entity (see page 94)
denormalization (see page 94)
discriminator (see page 94)
domain (see page 94)
entity (see page 95)
foreign key (see page 95)
identifying relationship (see page 95)
incomplete subtype cluster (see page 95)
independent entity (see page 95)
inversion entry (see page 95)
logical model (see page 95)
logical/physical model (see page 95)
non-key attribute (see page 95)
non-identifying relationship (see page 95)
non-specific relationship (see page 96)
normalization (see page 96)
physical model (see page 96)
primary key (see page 96)
referential integrity (see page 96)
rolename (see page 96)
schema (see page 96)
specific relationship (see page 96)
subtype entity (see page 97)
subtype relationship (see page 97)

alternate key

An attribute or attributes that uniquely identify an instance of an entity.
If more than one attribute or group of attributes uniquely identify an instance of an entity, the alternate keys are those attributes or groups of attributes not selected as the primary key. A unique index for each alternate key is generated.

attribute

Represents a type of characteristic or property associated with a set of real or abstract things (people, places, events, and so on).

basename

The original name of a rolenamed foreign key.

binary relationship

A relationship where exactly one instance of the parent is related to zero, one, or more instances of a child. In IDEF1X, identifying, non-identifying, and subtype relationships are all binary relationships.

BLOB

A dbspace that is reserved for storage of the byte and text data that makes up binary large objects, or BLOBs, stored in table columns. The BLOB dbspace can hold images, audio, video, long text blocks, or any digitized information.

cardinality

The ratio of instances of a parent to instances of a child. In IDEF1X, the cardinality of binary relationships is 1:n, where n can be one of the following:

- Zero, one, or more (signified by a blank space)
- One or more (signified by the letter P)
- Zero or one (signified by the letter Z)
- Exactly n (where n is some number)

complete subtype cluster

If the subtype cluster includes all of the possible subtypes (every instance of the generic parent is associated with one subtype), then the subtype cluster is complete. For example, every ACCOUNT is either a checking, savings, or loan account and therefore the subtype cluster of CHECKING-ACCOUNT, SAVINGS-ACCOUNT, or LOAN-ACCOUNT is a complete subtype cluster.

dependent entity

An entity whose instances cannot be uniquely identified without determining its relationship to another entity or entities.

denormalization

To allow data redundancy in a table to improve query performance.

discriminator

The value of an attribute in an instance of the generic parent determines to which of the possible subtypes that instance belongs. This attribute is known as the discriminator. For example, the value in the attribute “account-type” in an instance of ACCOUNT determines to which particular subtype (CHECKING-ACCOUNT, SAVINGS-ACCOUNT, or LOAN-ACCOUNT) that instance belongs.

domain

A group of predefined logical and physical property characteristics that can be saved, selected, and then attached to attributes and columns.

entity

An entity represents a set of real or abstract things (people, places, events, and so on) that have common attributes or characteristics. Entities can be either independent or dependent.

foreign key

An attribute that has migrated through a relationship from a parent entity to a child entity. A foreign key represents a secondary reference to a single set of values; the primary reference is the owned attribute.

identifying relationship

A relationship where an instance of the child entity is identified through its association with a parent entity. The primary key attributes of the parent entity become primary key attributes of the child.

incomplete subtype cluster

If the subtype cluster does not include all of the possible subtypes (every instance of the generic parent is not associated with one subtype), then the subtype cluster is incomplete. For example, if some employees are commissioned, a subtype cluster of SALARIED-EMPLOYEE and PART-TIME EMPLOYEE is incomplete.

independent entity

An entity whose instances can be uniquely identified without determining its relationship to another entity.

inversion entry

An attribute or attributes that do not uniquely identify an instance of an entity, but are often used to access instances of entities. A non-unique index for each inversion entry is generated.

logical model

The data modeling level where you create a conceptual model that contains objects such as entities, attributes, and key groups.

logical/physical model

A model type created where the logical and physical models are automatically linked.

non-key attribute

Any attribute that is not part of the entity's primary key. Non-key attributes can be part of an inversion entry or alternate key, and can also be foreign keys.

non-identifying relationship

A relationship where an instance of the child entity is not identified through its association with a parent entity. The primary key attributes of the parent entity become non-key attributes of the child.

non-specific relationship

Both parent-child connection and subtype relationships are considered specific relationships since they define precisely how instances of one entity relate to instances of another. However, in the initial development of a model, it is often helpful to identify non-specific relationships between two entities. A non-specific relationship, also referred to as a many-to-many relationship, is an association between two entities where each instance of the first entity is associated with zero, one, or many instances of the second entity and each instance of the second entity is associated with zero, one, or many instances of the first entity.

normalization

The process by which data in a relational construct is organized to minimize redundancy and non-relational constructs.

physical model

The data modeling level where you add database and database management system (DBMS) specific modeling information such as tables, columns, and datatypes.

primary key

An attribute or attributes that uniquely identify an instance of an entity. If more than one attribute or group of attributes can uniquely identify each instance, the primary key is chosen from this list of candidates based on its perceived value to the business as an identifier. Ideally, primary keys should not change over time and should be as small as possible. A unique index for each primary key is generated.

referential integrity

The assertion that the foreign key values in an instance of a child entity have corresponding values in a parent entity.

rolename

A new name for a foreign key. A rolename is used to indicate that the set of values of the foreign key is a subset of the set of values of the attribute in the parent, and performs a specific function (or role) in the entity.

schema

The structure of a database. Usually refers to the DDL (data definition language) script file. DDL consists of CREATE TABLE, CREATE INDEX, and other statements.

specific relationship

A specific relationship is an association between entities where each instance of the parent entity is associated with zero, one, or many instances of the child entity, and each instance of the child entity is associated with zero or one instance of the parent entity.

subtype entity

There are often entities which are specific types of other entities. For example, a SALARIED EMPLOYEE is a specific type of EMPLOYEE. Subtype entities are useful for storing information that only applies to a specific subtype. They are also useful for expressing relationships that are only valid for that specific subtype, such as the fact that a SALARIED EMPLOYEE qualifies for a certain BENEFIT, while a PART-TIME-EMPLOYEE does not. In IDEF1X, subtypes within a subtype cluster are mutually exclusive.

subtype relationship

A subtype relationship (also known as a categorization relationship) is a relationship between a subtype entity and its generic parent. A subtype relationship always relates one instance of a generic parent with zero or one instance of the subtype.