Read Chapter 3

Data Modeling Using the Entity-Relationship (ER) Model

Dr. Hela Chamkhia

Outlines

1. Overview of Database Design Process
2. Entity and Attribute
3. Entity Types, Entity Sets, Keys, and Value Sets
4. Initial Conceptual Design of the COMPANY Database
5. Relationship Types, Relationship Sets, Roles, and Structural Constraints
6. Weak Entity Types

1

Overview of Database Design Process

Overview of Database Design Process

- Two main activities:
  - Database design
  - Applications design
- Focus in this chapter on conceptual database design
  - To design the conceptual schema for a database application
- Applications design focuses on the programs and interfaces that access the database
  - Generally considered part of software engineering

Overview of Database Design Process

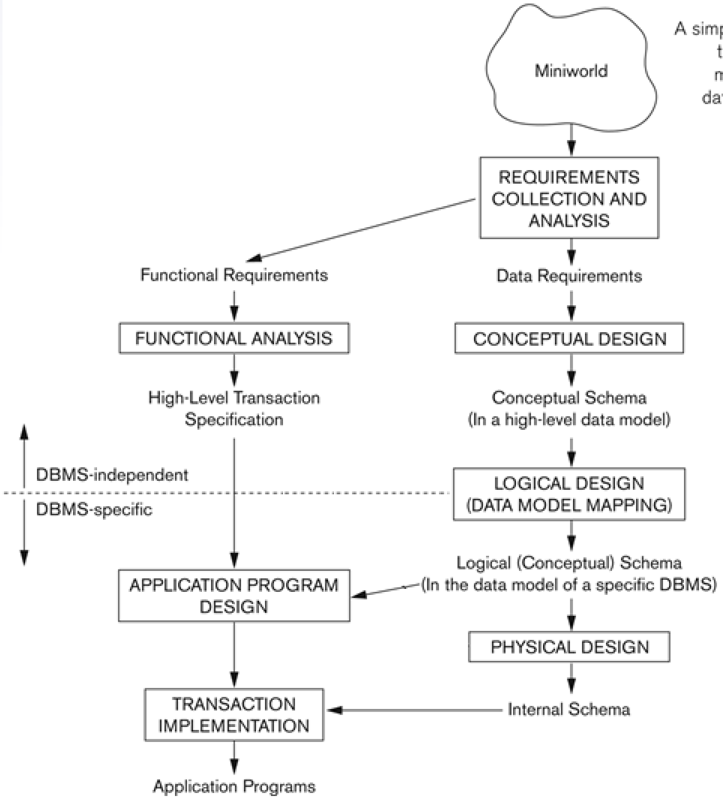

Miniworld
REQUIREMENTS COLLECTION AND ANALYSIS
Functional Requirements
Data Requirements
FUNCTIONAL ANALYSIS
CONCEPTUAL DESIGN
High-Level Transaction Specification
Conceptual Schema (In a high-level data model)
DBMS-independent
DBMS-specific
LOGICAL DESIGN (DATA MODEL MAPPING)
APPLICATION PROGRAM DESIGN
Logical (Conceptual) Schema (In the data model of a specific DBMS)
PHYSICAL DESIGN
TRANSACTION IMPLEMENTATION
Internal Schema
Application Programs

Figure 3.1
A simplified diagram to illustrate the main phases of database design.

Example COMPANY Database

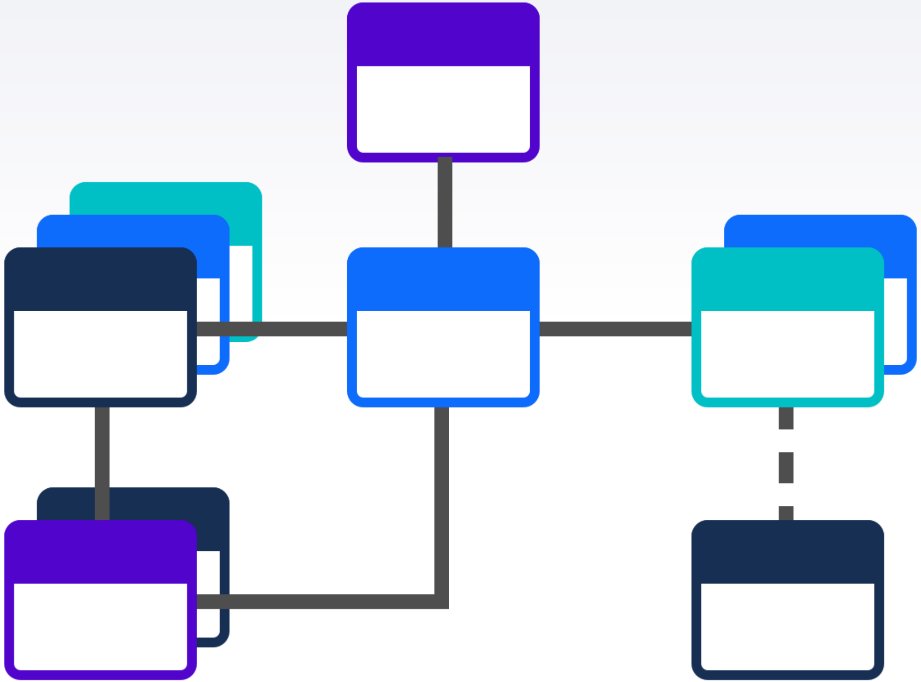
- We need to create a database schema design based on the following (simplified) **requirements** of the COMPANY Database:
    - The company is organized into DEPARTMENTs. Each department has a name, number and an employee who *manages* the department. We keep track of the start date of the department manager. A department may have several locations.
    - Each department *controls* a number of PROJECTs. Each project has a unique name, unique number and is located at a single location.

Example COMPANY Database (Continued)

- The database will store each EMPLOYEE's social security number, address, salary, sex, and birthdate.
  - Each employee *works for* one department but may *work on* several projects.
  - The DB will keep track of the number of hours per week that an employee currently works on each project.
  - It is required to keep track of the *direct supervisor* of each employee.
- Each employee may *have* a number of DEPENDENTs.
  - For each dependent, the DB keeps a record of name, sex, birthdate, and relationship to the employee.

2

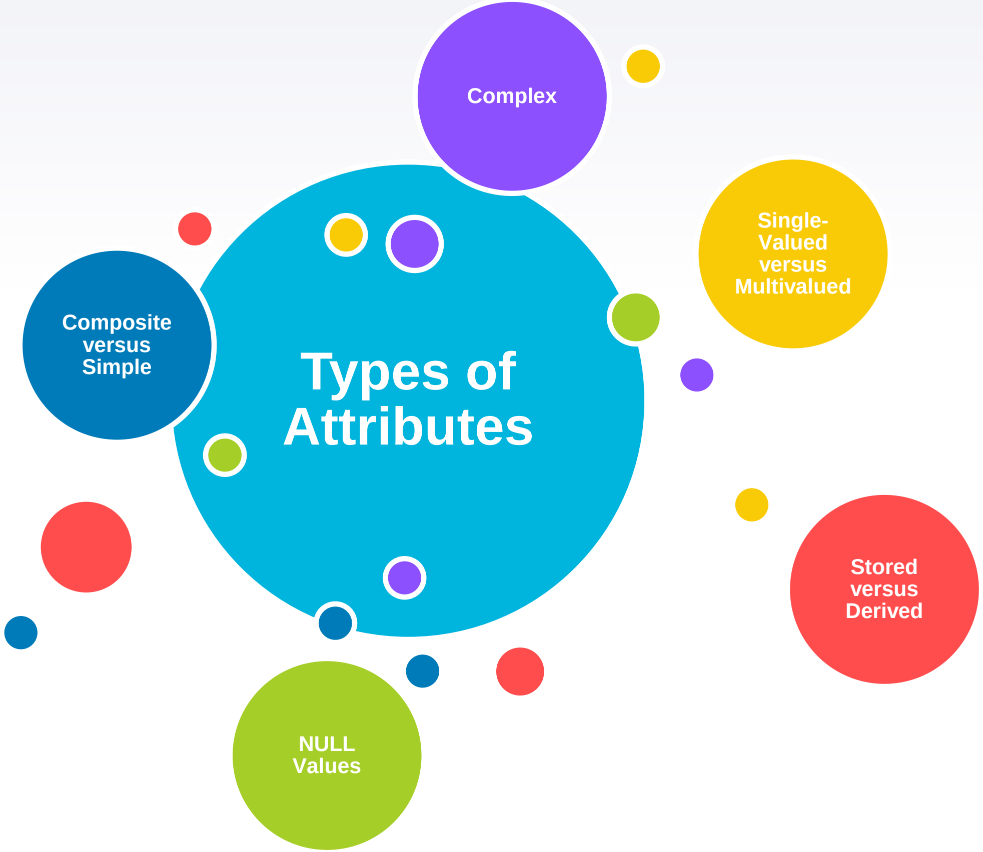
ER Model Concepts



ER Model Concepts

- Entities and Attributes
  - Entity is a basic concept for the ER model. Entities are specific things or objects in the mini-world that are represented in the database.
    - For example the EMPLOYEE John Smith, the Research DEPARTMENT, the ProductX PROJECT
  - Attributes are properties used to describe an entity.
    - For example an EMPLOYEE entity may have the attributes Name, SSN, Address, Sex, BirthDate
  - A specific entity will have a value for each of its attributes.
    - For example a specific employee entity may have Name='John Smith', SSN='123456789', Address ='731, Fondren, Houston, TX', Sex='M', BirthDate='09-JAN-55‘
  - Each attribute has a *value set* (or data type) associated with it – e.g. integer, string, date, enumerated type, …

Types of Attributes



Types of Attributes: **Composite versus Simple (Atomic)**

- **Simple**
  - Each entity has a single atomic value for the attribute. For example, SSN or Sex.
- **Composite**
  - The attribute may be composed of several components. For example:
    - Address(Apt#, House#, Street, City, State, ZipCode, Country), or
    - Name(FirstName, MiddleName, LastName).
    - Composition may form a hierarchy where some components are themselves composite.

Example of a composite attribute

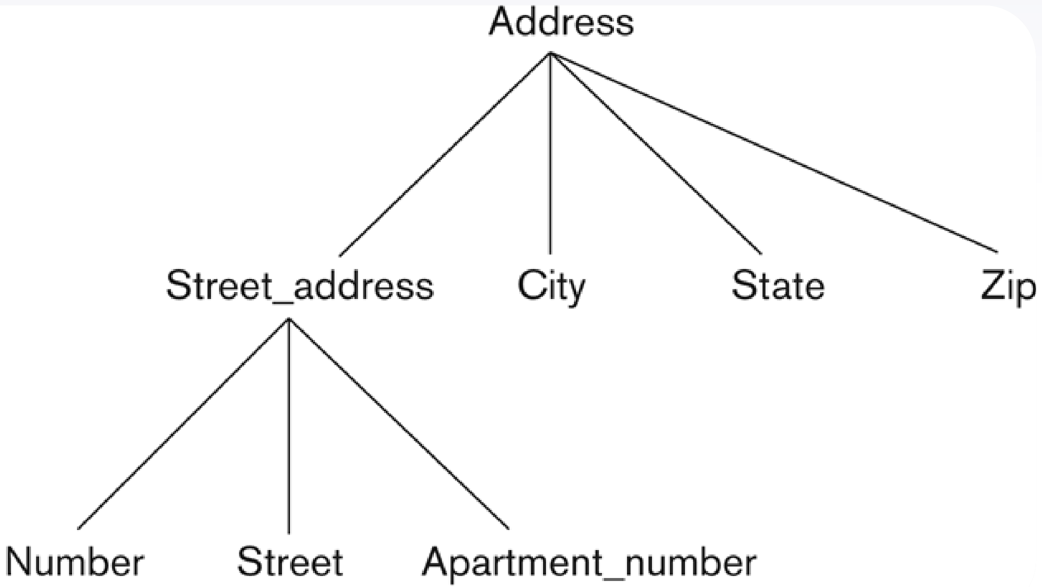


Figure 3.4
A hierarchy of composite attributes.

Types of Attributes: **Single-Valued versus Multivalued**

- **Single-Valued:**
  - Most attributes have a single value for a particular entity; such attributes are called **single-valued**.
    - For example, Age is a single-valued attribute of a person.
- **Multivalued:**
  - In some cases an attribute can have a set of values for the same entity (a Colors attribute for a car, or a College-degrees attribute for a person.
  - A multivalued attribute may have **lower and upper bounds** to constrain the *number of values* allowed for each individual entity.

Types of Attributes: **Stored versus Derived Attributes**

- **Stored**
  - In some cases, two (or more) attribute values are related—for example, the Age and Birth_date attributes of a person. Bith_date is the stored attribute.
- **Derived Attributes.**
  - For a particular person entity, the value of Age can be determined from the current (today's) date and the value of that person's Birth_date. The Age attribute is hence called a **derived attribute** and is said to be **derivable from** the Birth_date attribute.
  - Some attribute values can be derived from *related entities*; for example, an attribute Number_of_employees of a DEPARTMENT entity can be derived by counting the number of employees related to (working for) that department.

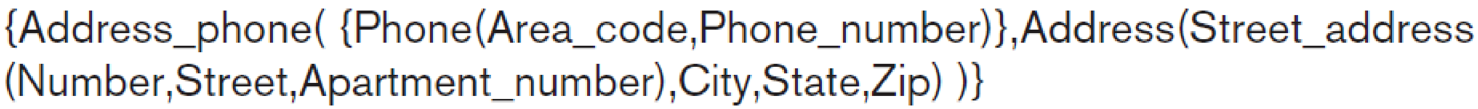
Types of Attributes: **NULL Values.**

NULL Values:

- In some cases, a particular entity may not have an applicable value for an attribute.
  - The Apartment_number attribute of an address applies only to addresses that are in apartment buildings and not to other types of residences, such as single-family homes.
  - A College_degrees attribute applies only to people with college degrees.
- For such situations, a special value called NULL is created.
- NULL can also be used if we do not know the value of an attribute for a particular entity—for example, if we do not know the home phone number of 'John Smith' in Figure 3.3.
- Two meaning of the Null types are : ***not applicable***, and ***unknown.***

Types of Attributes: **Complex attribute**

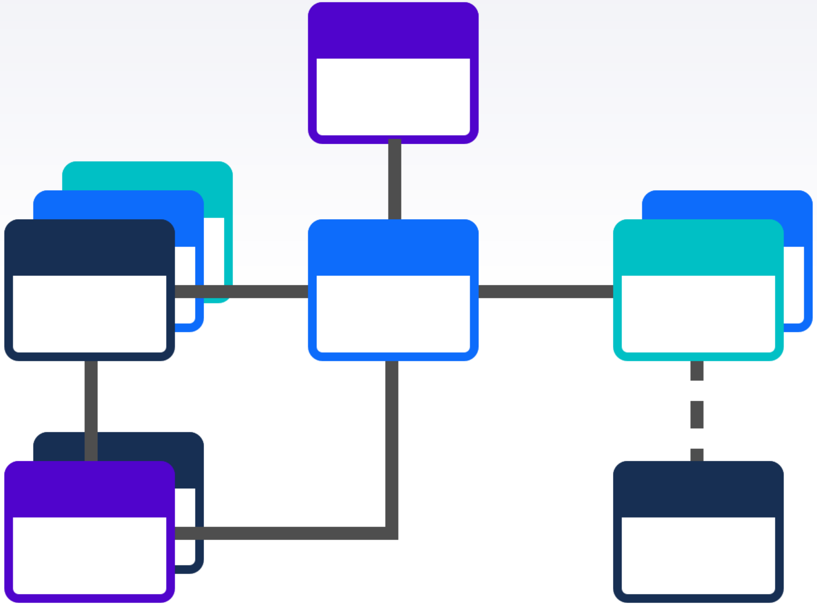
- Composite and multivalued attributes can be nested arbitrarily. We can represent arbitrary nesting by grouping **components of a composite attribute between parentheses ( )** and **separating the components with commas**, and by d**isplaying multivalued attributes between braces { }.**
- Such attributes are called **complex attributes**.
- For example, if a person can have more than one residence and each residence can have a single address and multiple phones, an attribute Address_phone for a person can be specified as shown in Figure 3.5.4 Both Phone and Address are themselves composite attributes.



{Address_phone({Phone(Area_code,Phone_number)},Address(Street_address
(Number,Street,Apartment_number),City,State,Zip))}

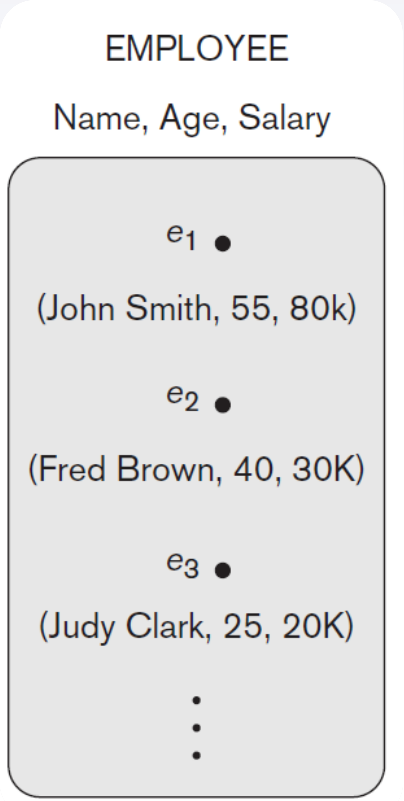
3

Entity Types, Entity Sets, Keys, and Value Sets



Entity Types

- Entities with the same basic attributes are grouped or typed into an entity type.
  - For example, the entity type EMPLOYEE and PROJECT.



EMPLOYEE

Name, Age, Salary

e_1 ●

(John Smith, 55, 80k)

e_2 ●

(Fred Brown, 40, 30K)

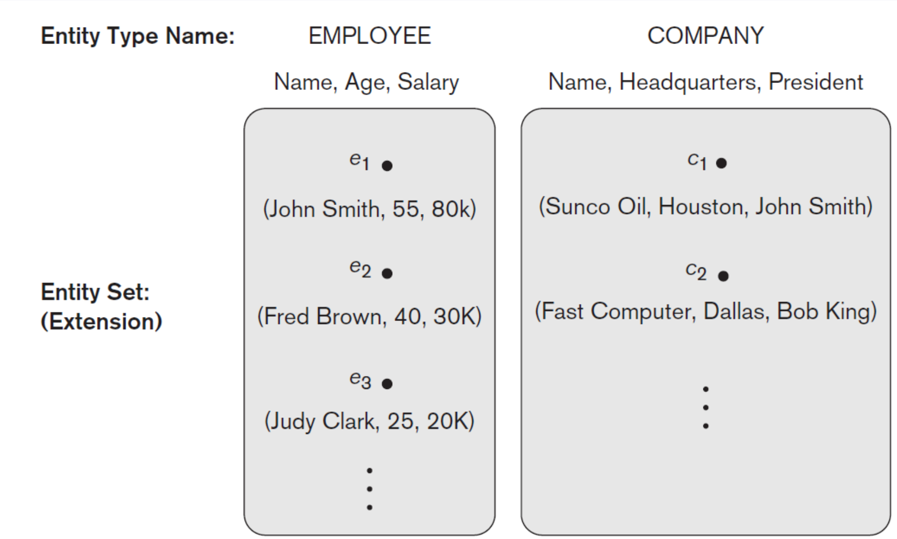
e_3 ●

(Judy Clark, 25, 20K)

⋮

Entity Set

- Each entity type will have **a collection of entities** stored in the database
  - Called the **entity set** or sometimes **entity collection**
- The collection of all entities of a particular entity type in the database at any point in time is called an **entity set** or **entity collection**
- The entity set is usually referred to using the same name as the entity type, even though they are two separate concepts



Entity Type Name: EMPLOYEE COMPANY

Name, Age, Salary

Name, Headquarters, President

Entity Set:
(Extension)

e_1 •

(John Smith, 55, 80k)

e_2 •

(Fred Brown, 40, 30K)

e_3 •

(Judy Clark, 25, 20K)

⋮

c_1 •

(Sunco Oil, Houston, John Smith)

c_2 •

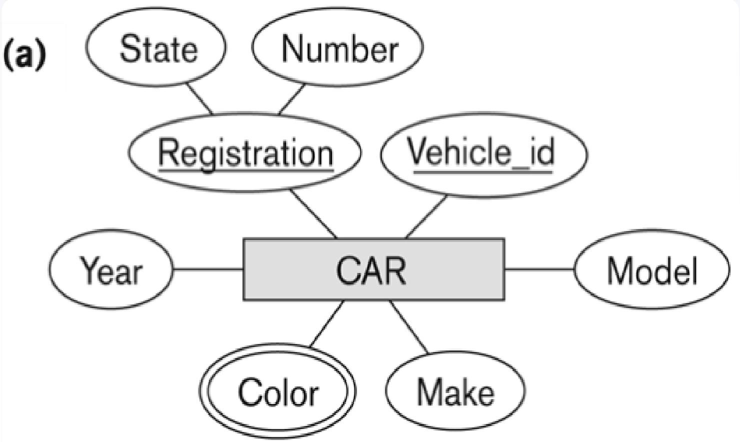
(Fast Computer, Dallas, Bob King)

⋮

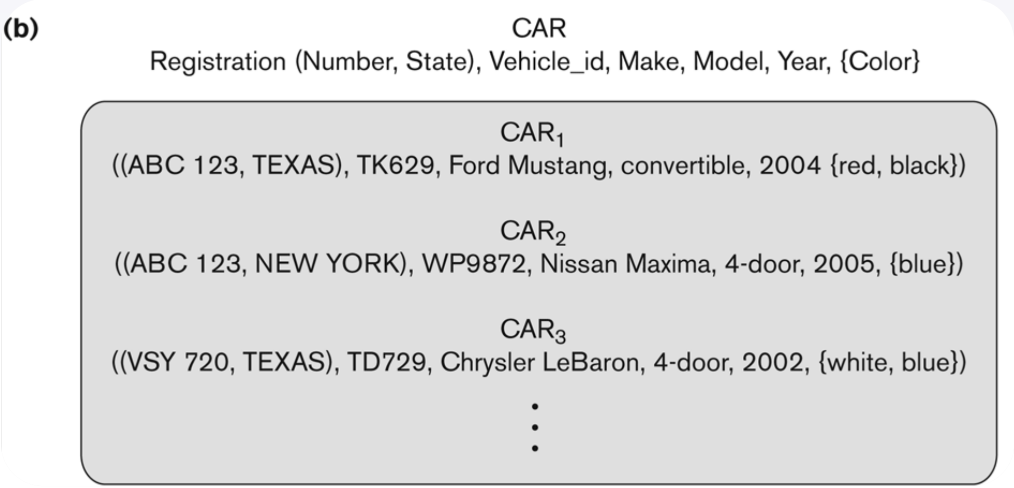
Key Attributes

- An attribute of an entity type for which each entity **must have a unique value** is called a **key attribute** of the entity type.
  - For example, SSN of EMPLOYEE.
- A key attribute may be composite.
  - VehicleTagNumber is a key of the CAR entity type with components (Number, State).
- An entity type may have more than one key.
  - The CAR entity type may have two keys:
    - VehicleIdentificationNumber (popularly called VIN)
    - VehicleTagNumber (Number, State), license plate number.
- Each key is underlined (Note: this is different from the relational schema where only one "primary" key is underlined).

Entity Type CAR with two keys and a corresponding Entity Set



ER diagram notation



(b)

CAR
Registration (Number, State), Vehicle_id, Make, Model, Year, {Color}

CAR_1
((ABC 123, TEXAS), TK629, Ford Mustang, convertible, 2004 {red, black})

CAR_2
((ABC 123, NEW YORK), WP9872, Nissan Maxima, 4-door, 2005, {blue})

CAR_3
((VSY 720, TEXAS), TD729, Chrysler LeBaron, 4-door, 2002, {white, blue})

⋮

Entity set with three entities

Value Sets (Domains) of Attributes

- Each simple attribute is associated with a value set
  - E.g., Lastname has a value which is a character string of up to 15 characters, say
  - Date has a value consisting of MM-DD-YYYY where each letter is an integer
- Similarly, we can specify the value set for the ***Name*** attribute to be the set of strings of alphabetic characters separated by blank characters, and so on.
- A **value set** specifies the set of values associated with an attribute

Attributes and Value Sets

- Value sets are similar to data types in most programming languages – e.g., integer, character (n), real, bit ….
- Mathematically, an attribute **<u>A</u>** for an entity type **<u>E</u>** whose value set is **<u>V</u>** is defined as a function

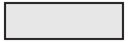
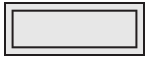
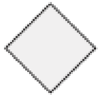
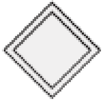
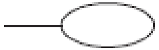
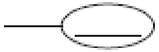
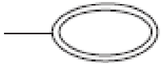
  A : E -> P(V)

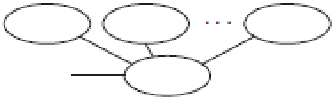
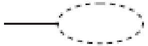
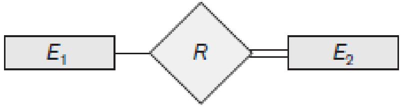
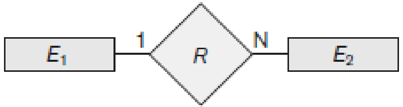
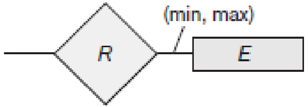
  Where P(V) indicates a power set (which means all possible subsets) of V. The above definition covers simple and multivalued attributes.
- We refer to the value of attribute A for entity **<u>e</u>** as A(e).

Displaying an Entity type

- In ER diagrams, an **entity type** is displayed in a **rectangular** box
- Attributes are displayed in **ovals**
  - Each attribute is connected to its entity type
  - Components of a composite attribute are connected to the oval representing the composite attribute
  - Each key attribute is **underlined**
  - Multivalued attributes displayed in **double ovals**

NOTATION for ER diagrams

Symbol	Meaning
	Entity
	Weak Entity
	Relationship
	Indentifying Relationship
	Attribute
	Key Attribute
	Multivalued Attribute

Symbol	Meaning
	Composite Attribute
	Derived Attribute
	Total Participation of E_2 in R
	Cardinality Ratio 1: N for $E_1 : E_2$ in R
	Structural Constraint (min, max) on Participation of E in R

Entity Type CAR with two keys and a corresponding Entity Set

(a)

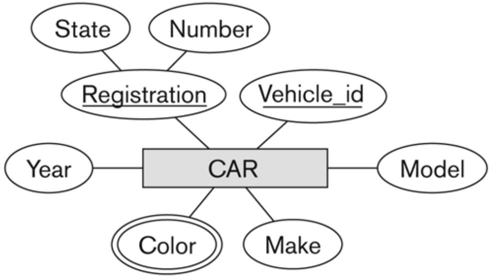


Figure 3.7
The CAR entity type with two key attributes, Registration and Vehicle_id. (a) ER diagram notation. (b) Entity set with three entities.

(b)

CAR
Registration (Number, State), Vehicle_id, Make, Model, Year, {Color}

CAR$_1$
((ABC 123, TEXAS), TK629, Ford Mustang, convertible, 2004 {red, black})

CAR$_2$
((ABC 123, NEW YORK), WP9872, Nissan Maxima, 4-door, 2005, {blue})

CAR$_3$
((VSY 720, TEXAS), TD729, Chrysler LeBaron, 4-door, 2002, {white, blue})

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4

Initial Conceptual Design of the COMPANY Database

Initial Conceptual Design of Entity Types for the COMPANY Database Schema

- Based on the requirements, we can identify four initial entity types in the COMPANY database:
  - DEPARTMENT
  - PROJECT
  - EMPLOYEE
  - DEPENDENT
- Their initial conceptual design is shown on the following slide
- The initial attributes shown are derived from the requirements description

Initial Conceptual Design of Entity Types for the COMPANY Database Schema

1. An entity type DEPARTMENT with attributes Name, Number, Locations, Manager, and Manager_start_date. Locations is the only multivalued attribute. We can specify that both Name and Number are (separate) key attributes because each was specified to be unique.

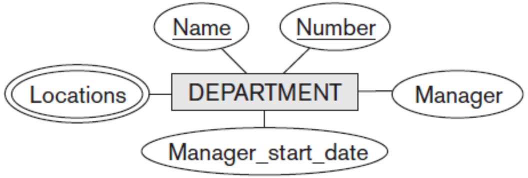
2. An entity type PROJECT with attributes Name, Number, Location, and Controlling_department. Both Name and Number are (separate) key attributes.

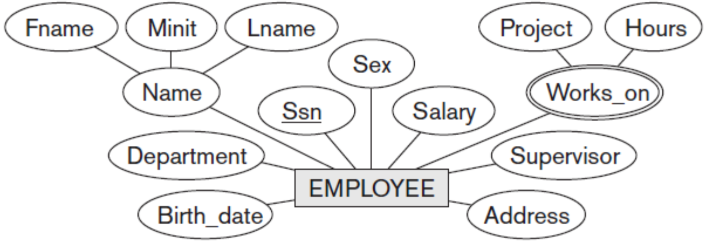
3. An entity type EMPLOYEE with attributes Name, Ssn, Sex, Address, Salary, Birth_date, Department, and Supervisor. Both Name and Address may be composite attributes; however, this was not specified in the requirements. We must go back to the users to see if any of them will refer to the individual components of Name—First_name, Middle_initial, Last_name—or of Address. In our example, Name is modeled as a composite attribute, whereas Address is not, presumably after consultation with the users.

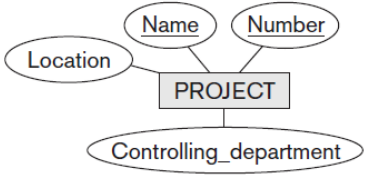
4. An entity type DEPENDENT with attributes Employee, Dependent_name, Sex, Birth_date, and Relationship (to the employee).

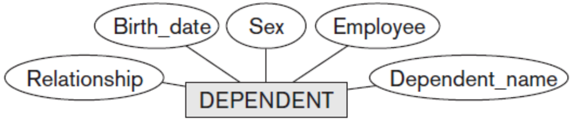
Initial Design of Entity Types:

EMPLOYEE, DEPARTMENT, PROJECT, DEPENDENT









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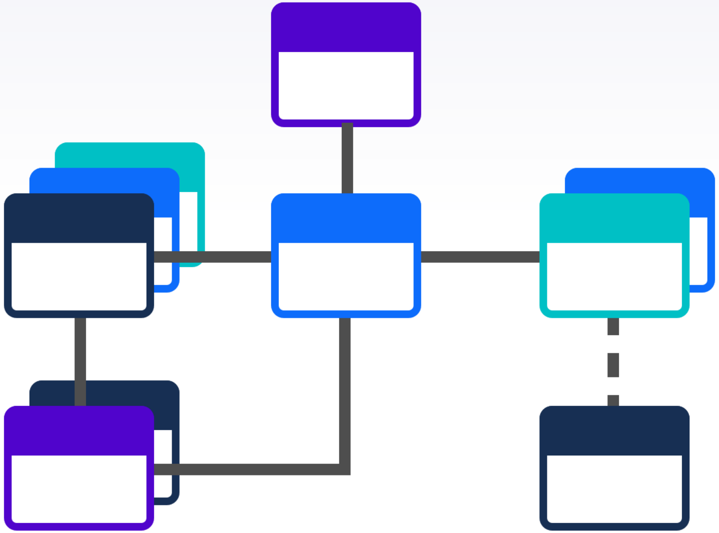
Relationship Types, Relationship Sets, Roles, and Structural Constraints



Refining the initial design by introducing **relationships**

- The initial design is typically not complete
- Some aspects in the requirements will be represented as **relationships**
- ER model has three main concepts:
    - Entities (and their entity types and entity sets)
    - Attributes (simple, composite, multivalued)
    - Relationships (and their relationship types and relationship sets)
- We introduce relationship concepts next

Relationships and Relationship Types (1)

- A **relationship** relates **two or more** distinct entities **with a specific meaning**.
  - For example, EMPLOYEE John Smith ***works on*** the ProductX PROJECT, or EMPLOYEE Franklin Wong ***manages*** the Research DEPARTMENT.
- Relationships of the same type are grouped or typed into a **relationship type**.
  - For example, the WORKS_ON relationship type in which EMPLOYEEs and PROJECTs participate, or the MANAGES relationship type in which EMPLOYEEs and DEPARTMENTs participate.
- The degree of a relationship type is the number of participating entity types.
  - Both MANAGES and WORKS_ON are *binary* relationships.

Relationship instances of the WORKS_FOR (N:1) relationship between EMPLOYEE and DEPARTMENT

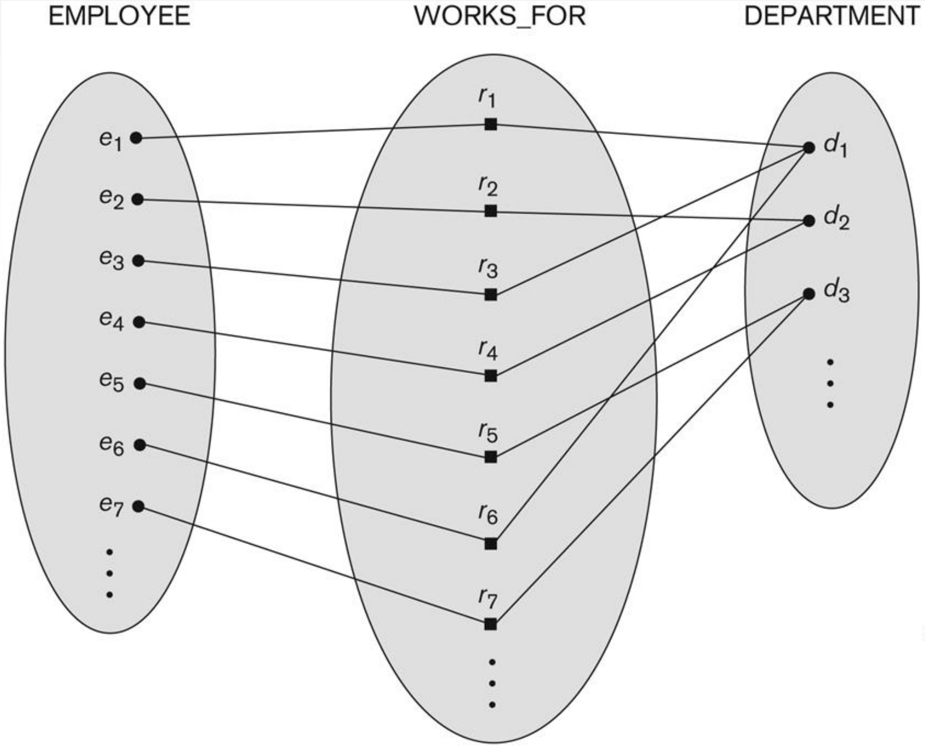


Figure 3.9
Some instances in the WORKS_FOR relationship set, which represents a relationship type WORKS_FOR between EMPLOYEE and DEPARTMENT.

Relationship instances of the (M:N) WORKS_ON relationship between EMPLOYEE and PROJECT

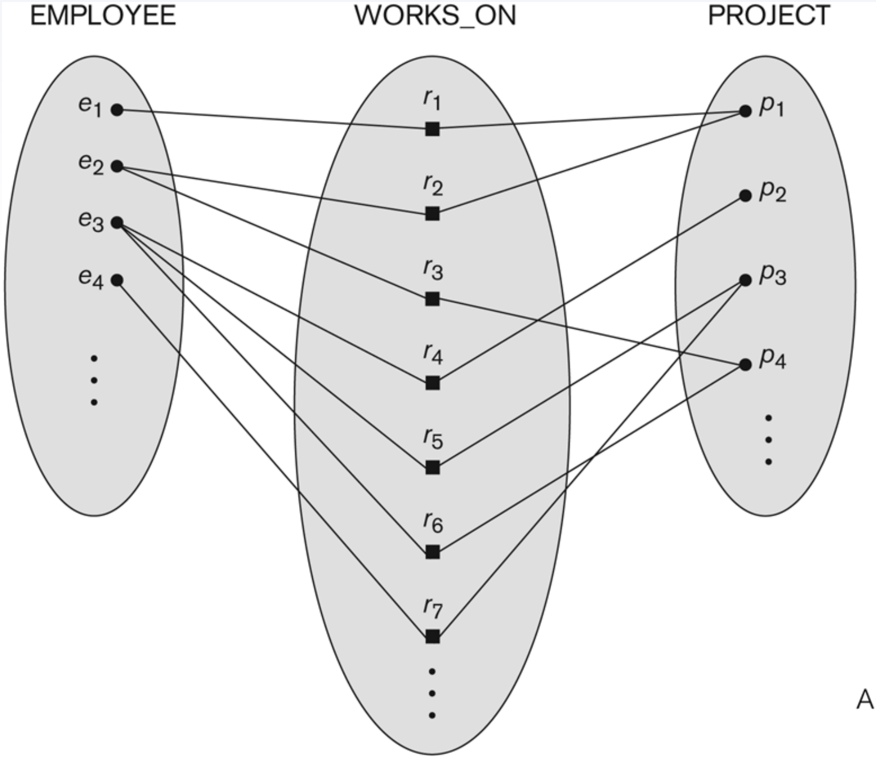


Figure 3.13
An M:N relationship, WORKS_ON.

Relationship type vs. relationship set (1)

- **Relationship Type:**
  - Is the schema description of a relationship
  - Identifies the relationship **name** and the **participating entity type**s
  - Also identifies certain relationship **constraints**
- **Relationship Set:**
  - The current set of relationship instances represented in the database
  - The current *state* of a relationship type

Relationship type vs. relationship set (2)

- Previous figures displayed the relationship sets
- Each instance in the set relates individual participating entities – one from each participating entity type
- In ER diagrams, we represent the *relationship type* as follows:
  - **Diamond-shaped box** is used to display a relationship type
  - Connected to the participating entity types via straight lines
  - Note that the relationship type is not shown with an arrow. The name should be typically readable from left to right and top to bottom.

Refining the COMPANY database schema by introducing relationships

- By examining the requirements, **six relationship types** are identified
- All are *binary* relationships(degree 2)
- Listed below with their participating entity types:
  - WORKS_FOR (between EMPLOYEE, DEPARTMENT)
  - MANAGES (also between EMPLOYEE, DEPARTMENT)
  - CONTROLS (between DEPARTMENT, PROJECT)
  - WORKS_ON (between EMPLOYEE, PROJECT)
  - SUPERVISION (between EMPLOYEE (as subordinate), EMPLOYEE (as supervisor))
  - DEPENDENTS_OF (between EMPLOYEE, DEPENDENT)

ER DIAGRAM – Relationship Types are:

WORKS_ FOR, MANAGES, WORKS_ ON, CONTROLS, SUPERVISION, DEPENDENTS_ OF

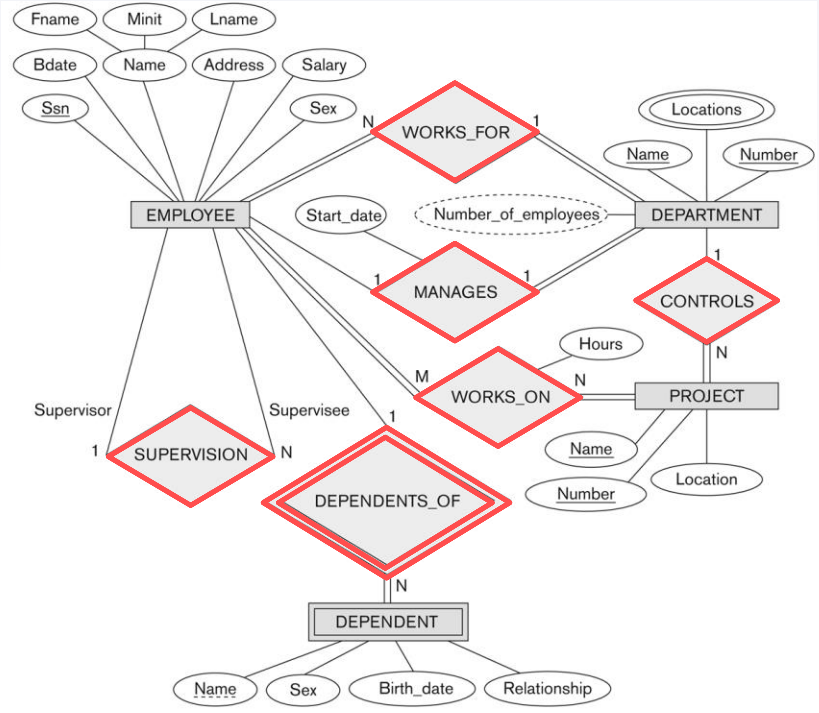


Figure 3.2
An ER schema diagram for the COMPANY database. The diagrammatic notation is introduced gradually throughout this chapter.

Discussion on Relationship Types

- In the refined design, some attributes from the initial entity types are refined into relationships:
  - Manager of DEPARTMENT -> MANAGES
  - Works_on of EMPLOYEE -> WORKS_ON
  - Department of EMPLOYEE -> WORKS_FOR
  - Etc…
- In general, more than one relationship type can exist between the same participating entity types
  - MANAGES and WORKS_FOR are distinct relationship types between EMPLOYEE and DEPARTMENT
  - Different meanings and different relationship instances.

Constraints on Relationships

- Constraints on Relationship Types
  - (Also known as ratio constraints)
  - Cardinality Ratio (specifies *maximum* participation)
    - One-to-one (1:1)
    - One-to-many (1:N) or Many-to-one (N:1)
    - Many-to-many (M:N)
  - Existence Dependency Constraint (specifies *minimum* participation) (also called participation constraint)
    - zero (optional participation, not existence-dependent)
    - one or more (mandatory participation, existence-dependent)

Many-to-one (N:1) Relationship

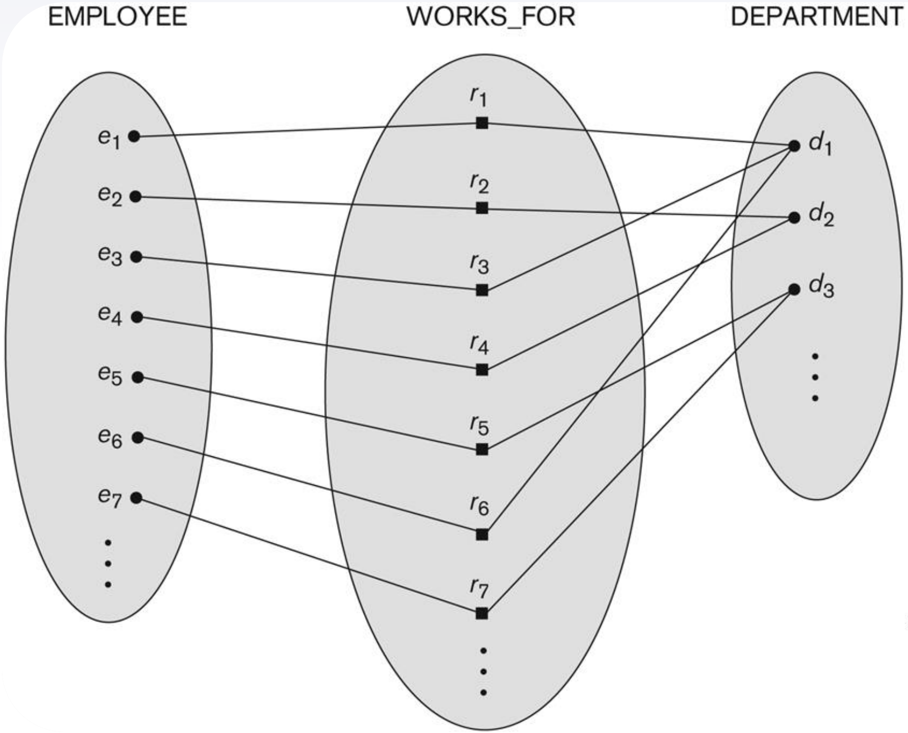


Figure 3.9
Some instances in the WORKS_FOR relationship set, which represents a relationship type WORKS_FOR between EMPLOYEE and DEPARTMEN

Many-to-many (M:N) Relationship

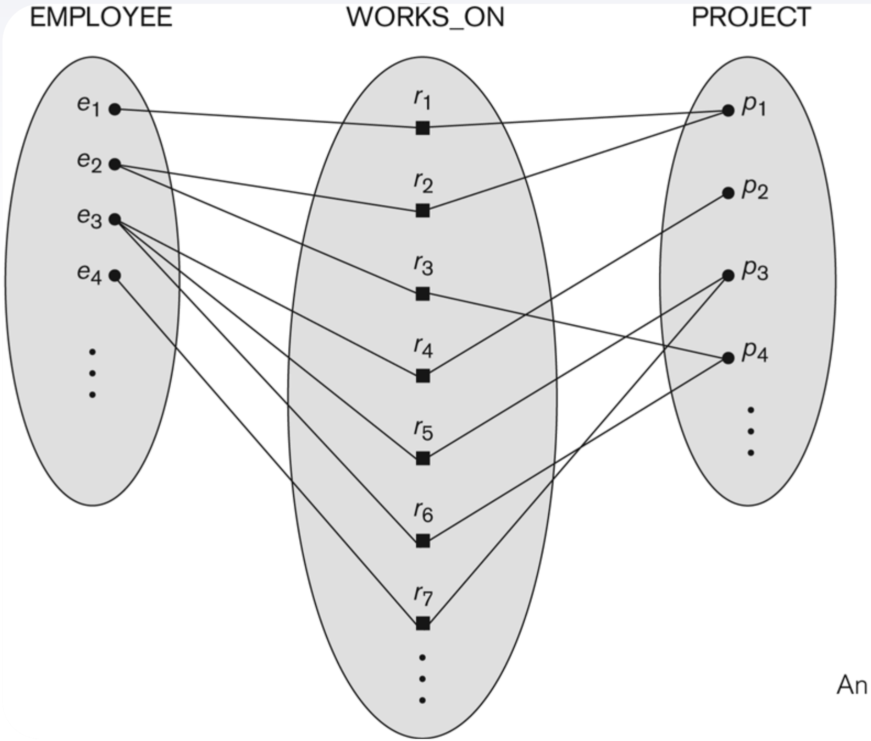


Figure 3.13
An M:N relationship, WORKS_ON

Recursive Relationship Type

- A relationship type between the same participating entity type in **distinct roles**
- Also called a **self-referencing** relationship type.
- Example: the SUPERVISION relationship
- EMPLOYEE participates twice in two distinct roles:
  - supervisor (or boss) role
  - supervisee (or subordinate) role
- Each relationship instance relates two distinct EMPLOYEE entities:
  - One employee in *supervisor* role
  - One employee in *supervisee* role

Displaying a recursive relationship

- In a recursive relationship type.
  - Both participations are same entity type in different roles.
  - For example, SUPERVISION relationships between EMPLOYEE (in role of supervisor or boss) and (another) EMPLOYEE (in role of subordinate or worker).
- In following figure, first role participation labeled with 1 and second role participation labeled with 2.
- In ER diagram, need to display role names to distinguish participations.

A Recursive Relationship Supervision

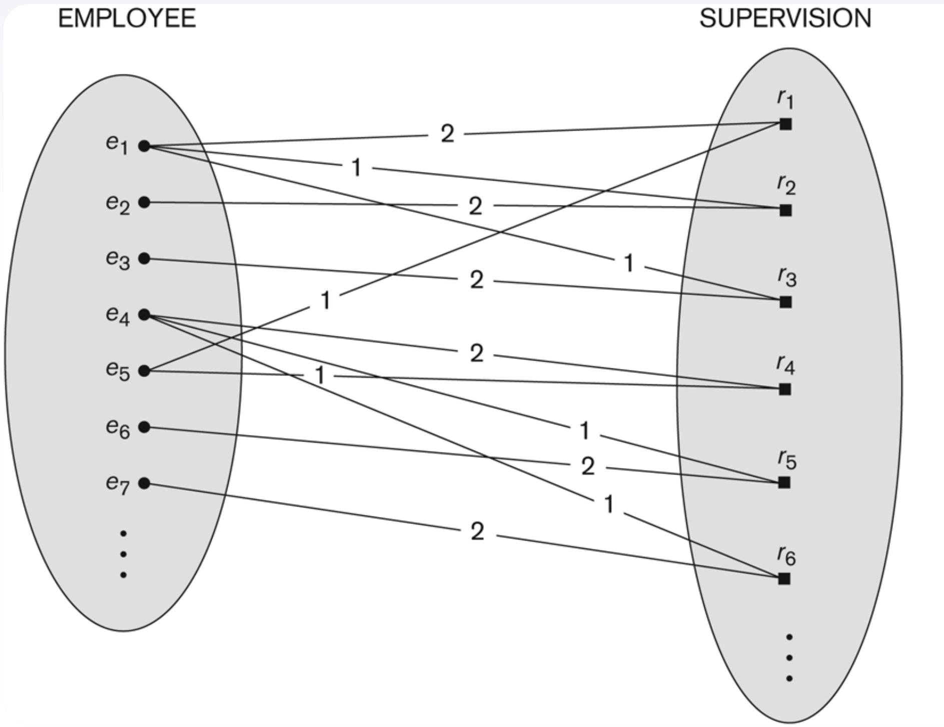


Figure 3.11
A recursive relationship SUPERVISION between EMPLOYEE in the *supervisor* role (1) and EMPLOYEE in the *subordinate* role (2).

Recursive Relationship Type is: SUPERVISION (participation role names are shown)

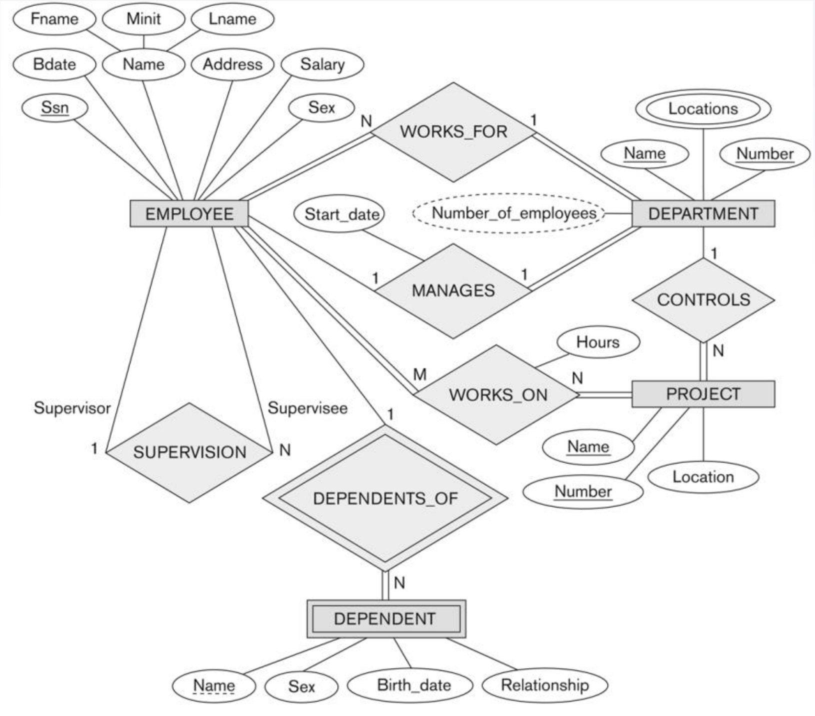
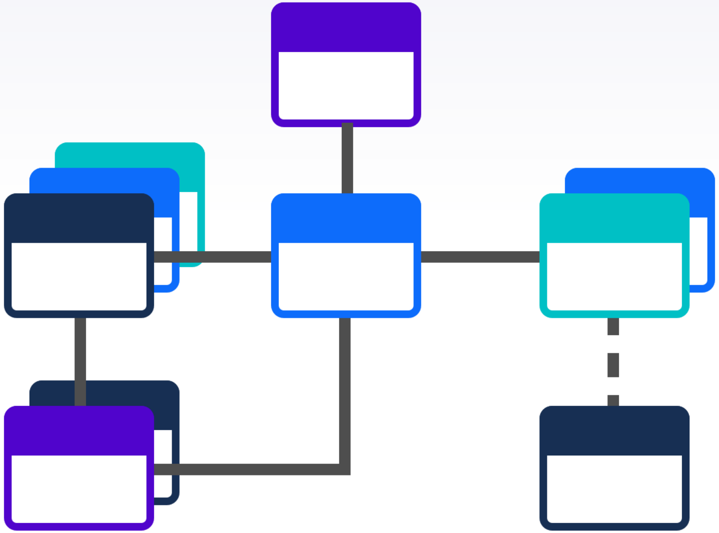


Figure 3.2
An ER schema diagram for the COMPANY database. The diagrammatic notation is introduced gradually throughout this chapter.

6 Weak Entity Types



Weak Entity Types

- An entity that does not have a key attribute and that is identification-dependent on another entity type.
- A weak entity must participate in an identifying relationship type with an owner or identifying entity type
- Entities are identified by the combination of:
  - A partial key of the weak entity type
  - The particular entity they are related to in the identifying relationship type
- **Example:**
  - A DEPENDENT entity is identified by the dependent's first name, *and* the specific EMPLOYEE with whom the dependent is related
  - Name of DEPENDENT is the *partial key*
  - DEPENDENT is a *weak entity type*
  - EMPLOYEE is its identifying entity type via the identifying relationship type DEPENDENT_OF

Attributes of Relationship types

- A relationship type can have attributes:
  - For example, HoursPerWeek of WORKS_ON
  - Its value for each relationship instance describes the number of hours per week that an EMPLOYEE works on a PROJECT.
    - A value of HoursPerWeek depends on a particular (employee, project) combination
  - Most relationship attributes are used with M:N relationships
    - In 1:N relationships, they can be transferred to the entity type on the N-side of the relationship

Example Attribute of a Relationship Type: Hours of WORKS_ON

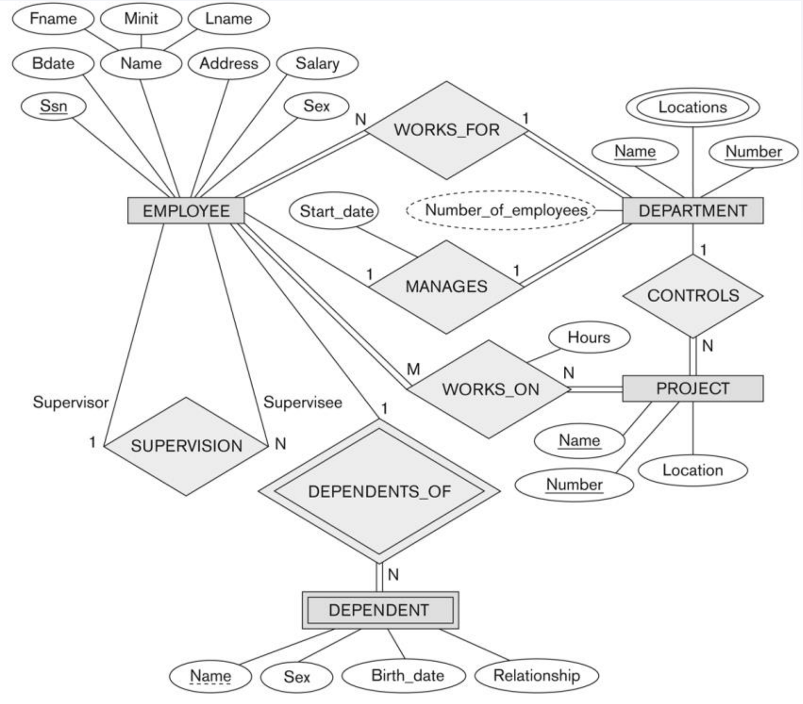


Figure 3.2
An ER schema diagram for the COMPANY database. The diagrammatic notation is introduced gradually throughout this chapter.

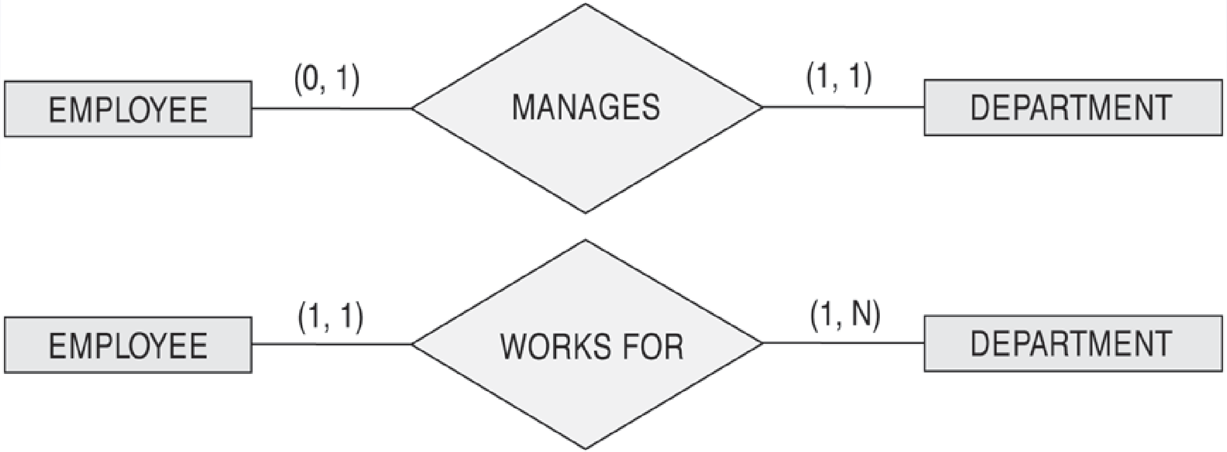
Notation for Constraints on Relationships

- Cardinality ratio (of a binary relationship): 1:1, 1:N, N:1, or M:N
  - Shown by placing appropriate numbers on the relationship edges.
- Participation constraint (on each participating entity type): total (called existence dependency) or partial.
  - Total shown by double line, partial by single line.
- NOTE: These are easy to specify for Binary Relationship Types.

Alternative (min, max) notation for relationship structural constraints:

- Specified on each participation of an entity type E in a relationship type R
- Specifies that each entity e in E participates in at least *min* and at most *max* relationship instances in R
- Default(no constraint): min=0, max=n (signifying no limit)
- Must have min≤max, min≥0, max ≥1
- Derived from the knowledge of mini-world constraints
- Examples:
  - A department has exactly one manager and an employee can manage at most one department.
    - Specify (0,1) for participation of EMPLOYEE in MANAGES
    - Specify (1,1) for participation of DEPARTMENT in MANAGES
  - An employee can work for exactly one department but a department can have any number of employees.
    - Specify (1,1) for participation of EMPLOYEE in WORKS_FOR
    - Specify (0,n) for participation of DEPARTMENT in WORKS_FOR

The (min,max) notation for relationship constraints



Read the min,max numbers next to the entity type and looking **away from** the entity type

COMPANY ER Schema Diagram using (min, max) notation

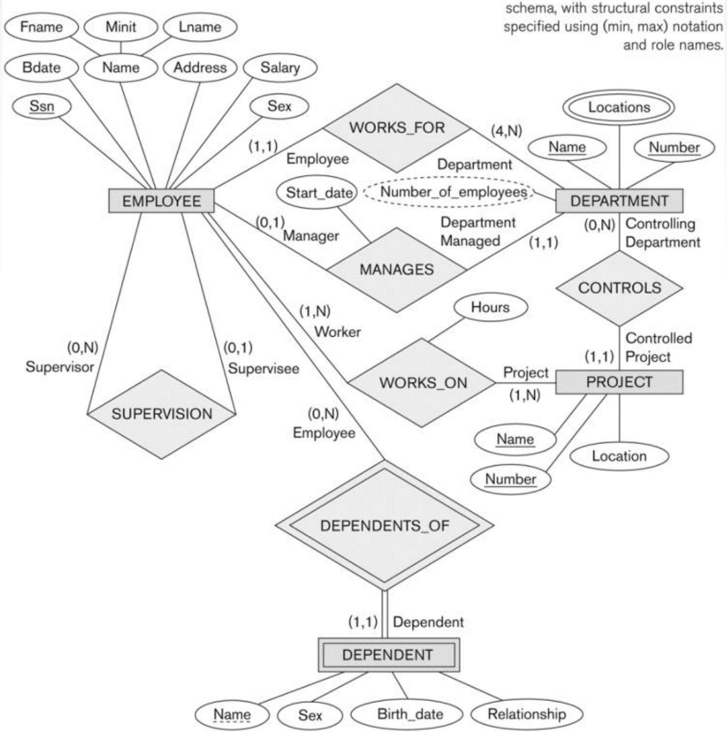


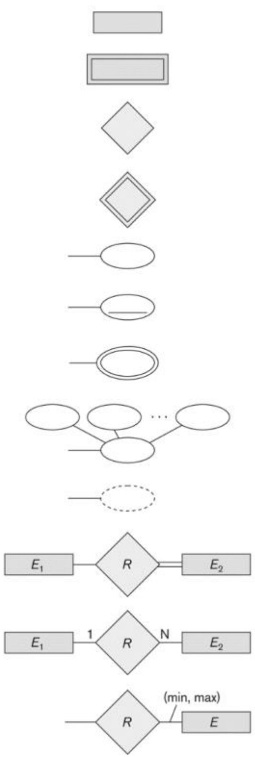
Figure 3.15
ER diagrams for the company schema, with structural constraints specified using (min, max) notation and role names.

Alternative diagrammatic notation

- ER diagrams is one popular example for displaying database schemas
- Many other notations exist in the literature and in various database design and modeling tools
- UML class diagrams is representative of another way of displaying ER concepts that is used in several commercial design tools

Summary of notation for ER diagrams

Figure 3.14
Summary of the notation for ER diagrams.



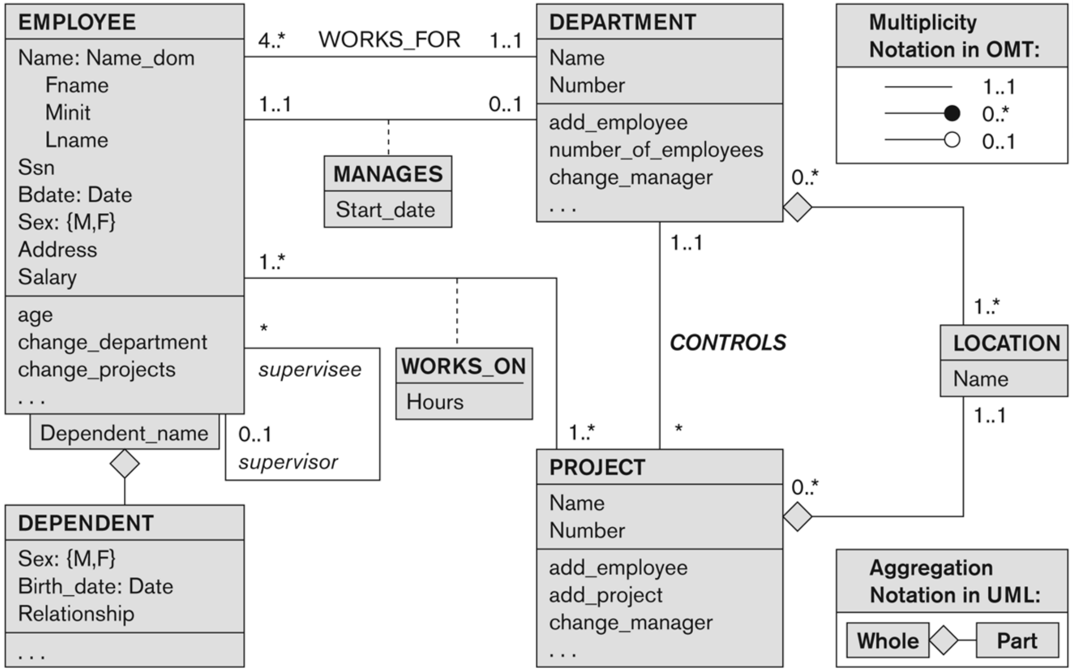
Symbol	Meaning
	Entity
	Weak Entity
	Relationship
	Indentifying Relationship
	Attribute
	Key Attribute
	Multivalued Attribute
	Composite Attribute
	Derived Attribute
E_1 R E_2	Total Participation of E_2 in R
E_1 1 R N E_2	Cardinality Ratio 1: N for E_1:E_2 in R
R (min, max) E	Structural Constraint (min, max) on Participation of E in R

UML class diagrams

- Represent classes (similar to entity types) as large rounded boxes with three sections:
  - Top section includes entity type (class) name
  - Second section includes attributes
  - Third section includes class operations (operations are not in basic ER model)
- Relationships (called associations) represented as lines connecting the classes
  - Other UML terminology also differs from ER terminology
- Used in database design and object-oriented software design
- UML has many other types of diagrams for software design

UML class diagram for COMPANY database schema

Figure 3.16
The COMPANY conceptual schema in UML class diagram notation.



Relationships of Higher Degree

- Relationship types of degree 2 are called binary
- Relationship types of degree 3 are called ternary and of degree n are called n-ary
- In general, an n-ary relationship is not equivalent to n binary relationships
- Constraints are harder to specify for higher-degree relationships (n > 2) than for binary relationships

Discussion of n-ary relationships (n > 2)

- In general, 3 binary relationships can represent different information than a single ternary relationship (see Figure 3.17a and b on next slide)
- If needed, the binary and n-ary relationships can all be included in the schema design (see Figure 3.17a and b, where all relationships convey different meanings)
- In some cases, a ternary relationship can be represented as a weak entity if the data model allows a weak entity type to have multiple identifying relationships (and hence multiple owner entity types)(see Figure 3.17c)

Example of a ternary relationship

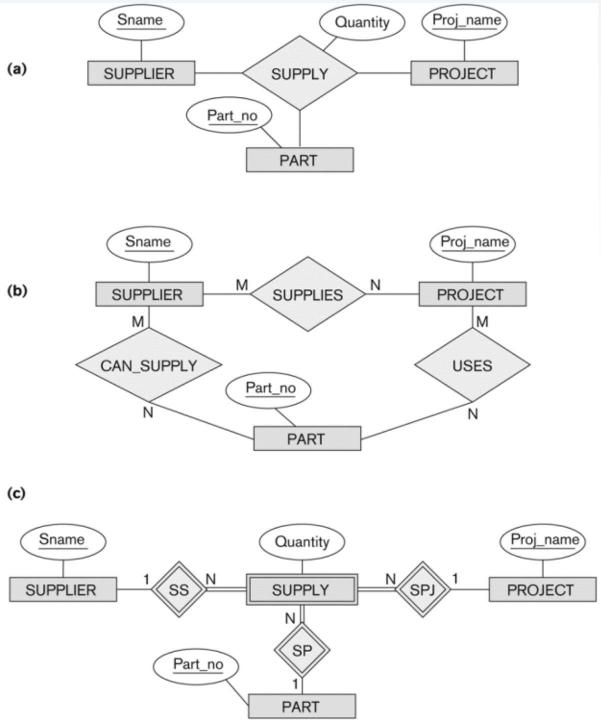


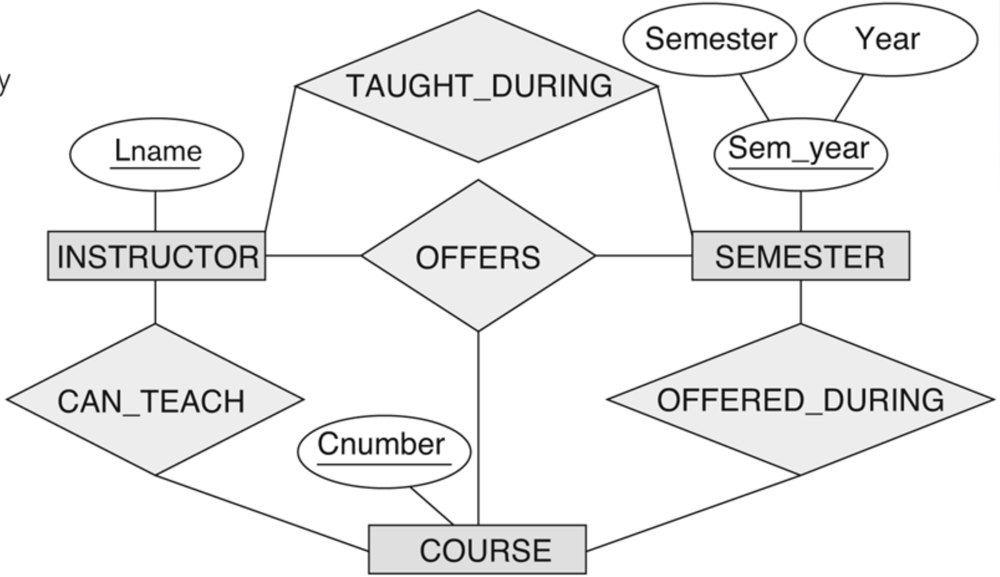
Figure 3.17
Ternary relationship types. (a) The SUPPLY relationship. (b) Three binary relationships not equivalent to SUPPLY. (c) SUPPLY represented as a weak entity type.

Discussion of n-ary relationships (n > 2)

- If a particular binary relationship can be derived from a higher-degree relationship at all times, then it is redundant
- For example, the TAUGHT_DURING binary relationship in Figure 3.18 (see next slide) can be derived from the ternary relationship OFFERS (based on the meaning of the relationships)

Another example of a ternary relationship

Figure 3.18
Another example of ternary versus binary relationship types.



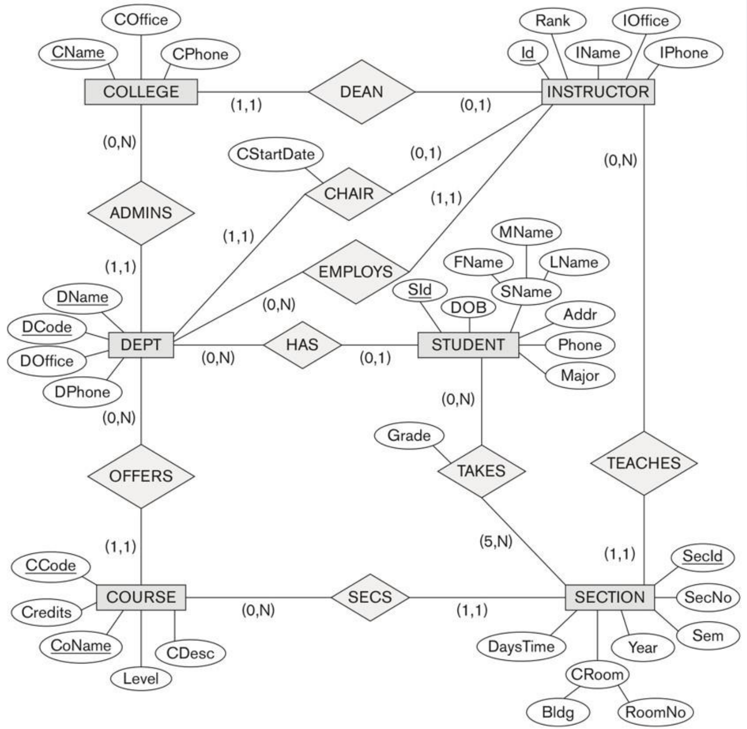
Displaying constraints on higher-degree relationships

- The (min, max) constraints can be displayed on the edges – however, they do not fully describe the constraints
- Displaying a 1, M, or N indicates additional constraints
  - An M or N indicates no constraint
  - A 1 indicates that an entity can participate in at most one relationship instance *that has a particular combination of the other participating entities*
- In general, both (min, max) and 1, M, or N are needed to describe fully the constraints
- Overall, the constraint specification is difficult and possibly ambiguous when we consider relationships of a degree higher than two.

Another Example: A UNIVERSITY Database

- To keep track of the enrollments in classes and student grades, another database is to be designed.
- It keeps track of the COLLEGEs, DEPARTMENTs within each college, the COURSEs offered by departments, and SECTIONs of courses, INSTRUCTORs who teach the sections etc.
- These entity types and the relationships among these entity types are shown on the next slide in Figure 3.20.

UNIVERSITY database conceptual schema



Summary

- In this chapter we presented the modeling concepts of a high-level conceptual data model, the entity–relationship (ER) model.
- We started by discussing the role that a high-level data model plays in the database design process, and then we presented a sample set of database requirements for the COMPANY database, which is one of the examples that is used throughout this text.
- We defined the basic ER model concepts of entities and their attributes. Then we discussed NULL values and presented the various types of attributes, which can be nested arbitrarily to produce complex attributes:
  - Simple or atomic
  - Composite
  - Multivalued

Summary

- We also briefly discussed stored versus derived attributes. Then we discussed the ER model concepts at the schema or “intension” level:
  - Entity types and their corresponding entity sets
  - Key attributes of entity types
  - Value sets (domains) of attributes
  - Relationship types and their corresponding relationship sets
  - Participation roles of entity types in relationship types