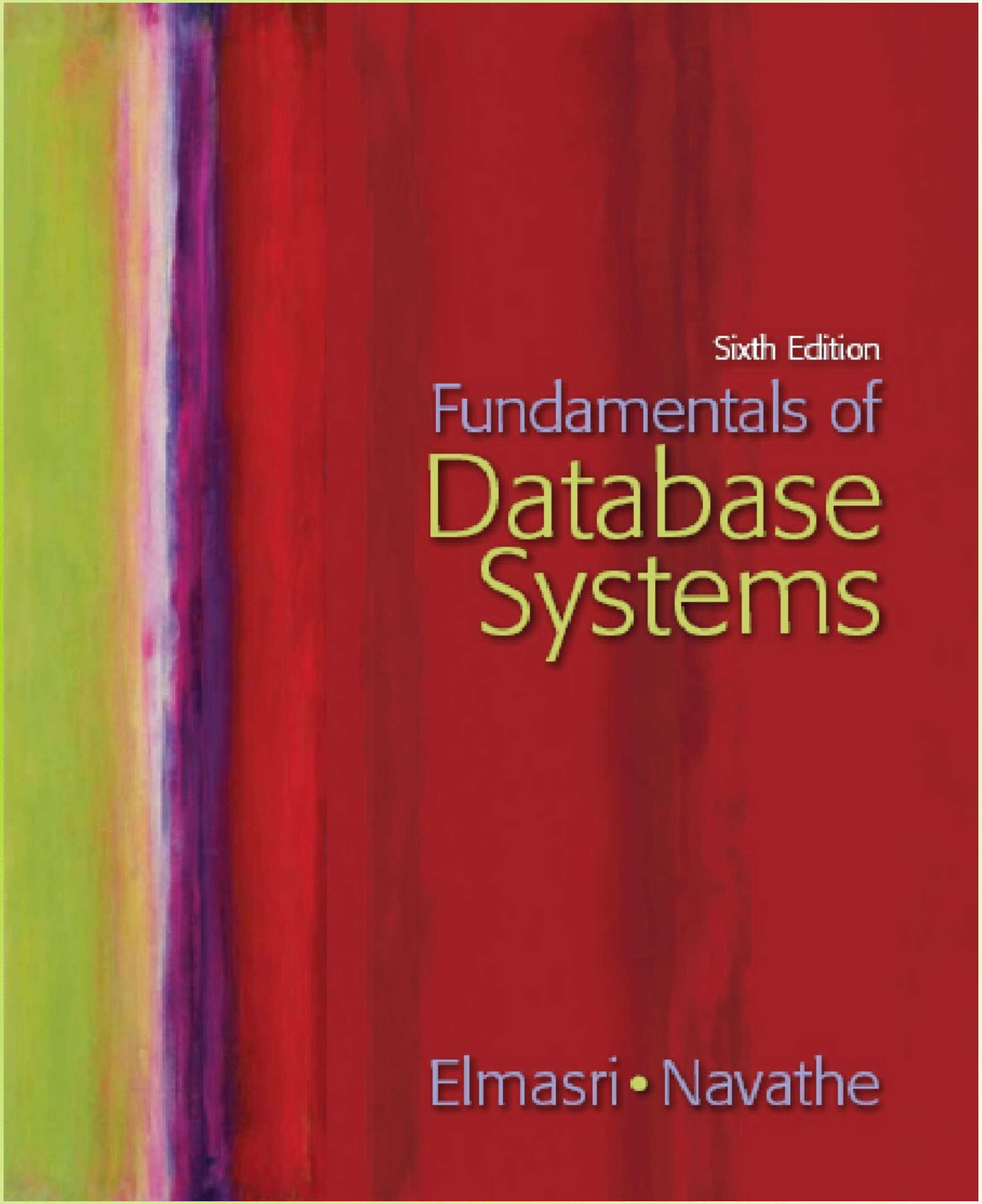
Chapter 7

Data Modeling Using the Entity-Relationship (ER) Model



Sixth Edition

Fundamentals of Database Systems

Elmasri • Navathe

Addison-Wesley
is an imprint of
PEARSON

Chapter 7 Outline

Using High-Level Conceptual Data Models for Database Design

A Sample Database Application

Entity Types, Entity Sets, Attributes, and Keys

Relationship Types, Relationship Sets, Roles, and Structural Constraints

Weak Entity Types

Addison-Wesley
is an imprint of
PEARSON

Chapter 7 Outline (cont’d.)

- Refining the ER Design for the COMPANY Database
- ER Diagrams, Naming Conventions, and Design Issues
- Example of Other Notation: UML Class Diagrams
- Relationship Types of Degree Higher than Two

Addison-Wesley
is an imprint of
PEARSON

Data Modeling Using the Entity-Relationship (ER) Model

Entity-Relationship (ER) model

Popular high-level conceptual data model

ER diagrams

Diagrammatic notation associated with the ER model

Unified Modeling Language (UML)

Addison-Wesley
is an imprint of
PEARSON

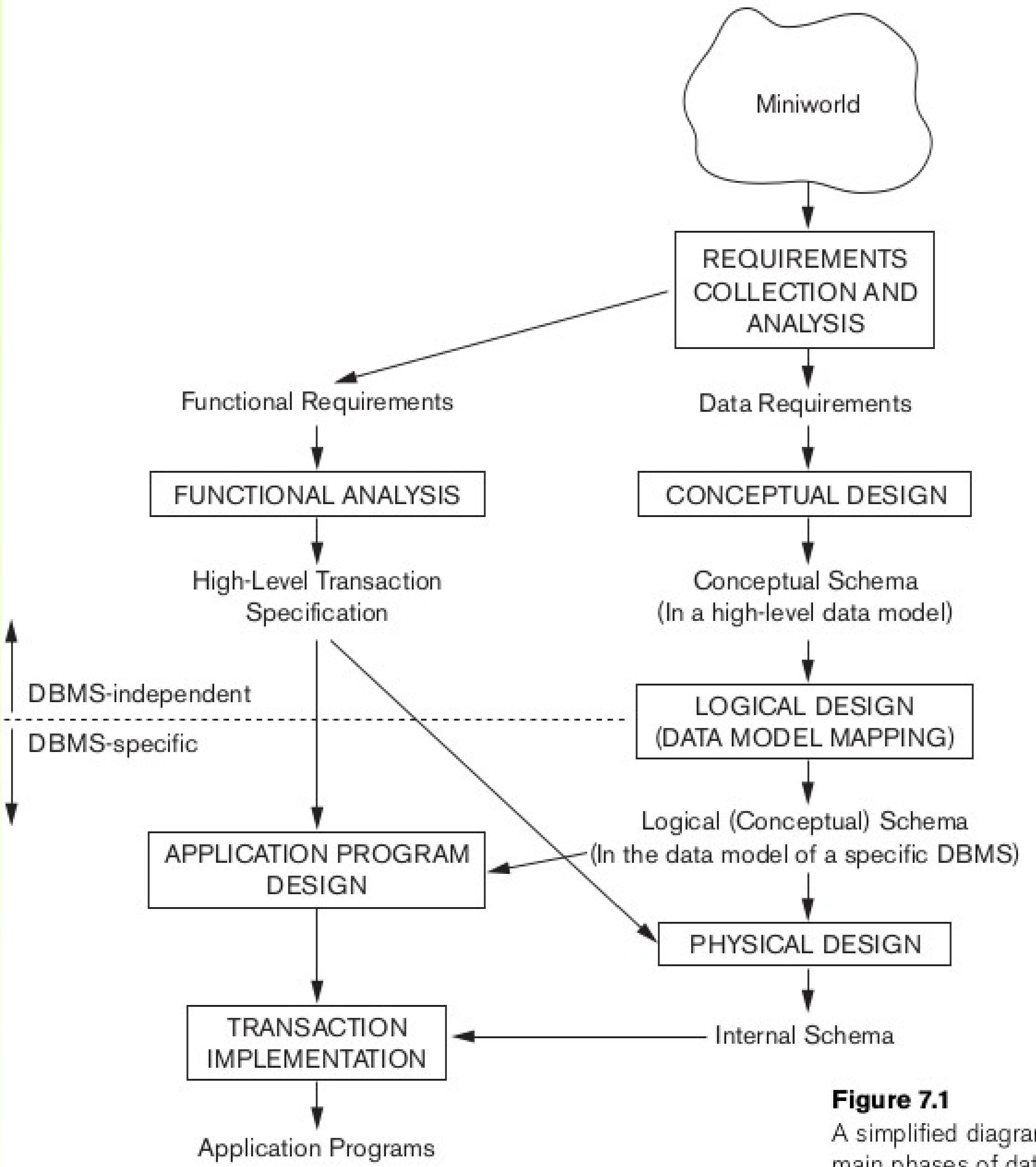

Miniworld
REQUIREMENTS COLLECTION AND ANALYSIS
Functional Requirements
Data Requirements
FUNCTIONAL ANALYSIS
CONCEPTUAL DESIGN
High-Level Transaction Specification
Conceptual Schema (In a high-level data model)
DBMS-independent
DBMS-specific
LOGICAL DESIGN (DATA MODEL MAPPING)
Logical (Conceptual) Schema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

Figure 7.1
A simplified diagram to illustrate the main phases of database design.

Using High-Level Conceptual Data Models for Database Design

Requirements collection and analysis

Database designers interview prospective database users to understand and document data requirements

Result: **data requirements**

Functional requirements of the application

Addison-Wesley is an imprint of PEARSON

Using High-Level Conceptual Data Models (cont'd.)

Conceptual schema

- Conceptual design
- Description of data requirements
- Includes detailed descriptions of the entity types, relationships, and constraints
- Transformed from high-level data model into implementation data model

Addison-Wesley
is an imprint of
PEARSON

Using High-Level Conceptual Data Models (cont'd.)

Logical design or **data model mapping**

Result is a database schema in implementation data model of DBMS

Physical design phase

Internal storage structures, file organizations, indexes, access paths, and physical design parameters for the database files specified

Addison-Wesley
is an imprint of
PEARSON

A Sample Database Application

COMPANY

Employees, departments, and projects

Company is organized into departments

Department:

- has a unique name, a unique number, and a particular employee who manages the department.
- may have several locations.
- controls a number of projects
- Keep track of the start date of the manager.

Project: has a unique name, a unique number, and a single location.

Addison-Wesley
is an imprint of
PEARSON

A Sample Database Application

COMPANY

Employee: store each employee’s name, Social Security number, address, salary, sex (gender), and birth date

- An employee is assigned to one department, but may work on several projects
- keep track of the current number of hours per week that an employee works on each project.
- keep track of the direct supervisor of each employee
- Keep track of the dependents of each employee (dependent’s first name, sex, birth date, and relationship to the employee)

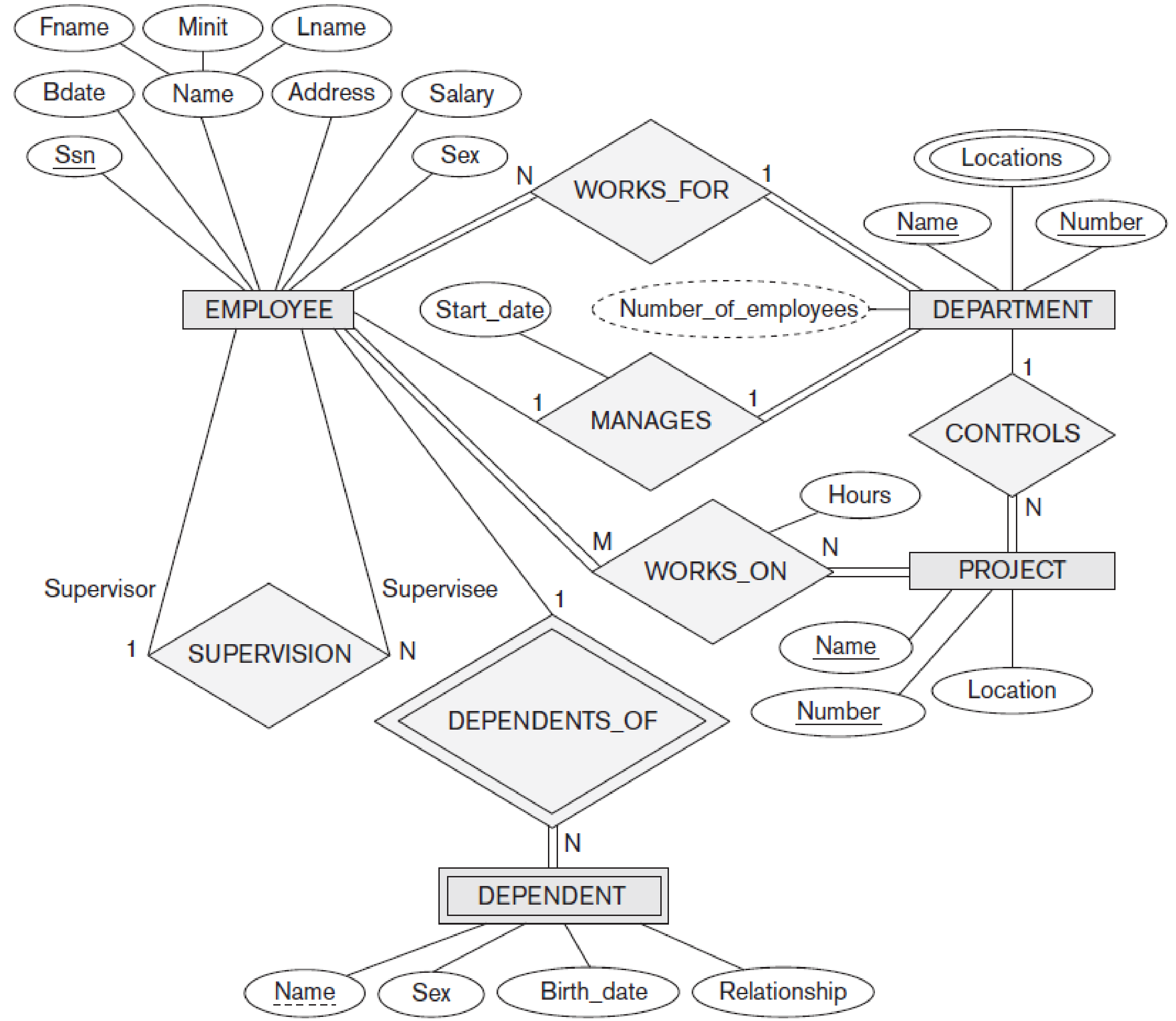


Figure 7.2
An ER schema diagram for the COMPANY database. The diagrammatic notation is introduced gradually throughout this chapter and is summarized in Figure 7.14.

Addison-Wesley
is an imprint of
PEARSON

Entity Types, Entity Sets, Attributes, and Keys

ER model describes data as:

- Entities
- Relationships
- Attributes

Entities and Attributes

Entity

Thing in real world with independent existence

Attributes

Particular properties that describe entity

Types of attributes:

- *Composite* versus *simple* (atomic) *attributes*
- **Single-valued** versus **multivalued** attributes
- **Stored** versus **derived** attributes
- **NULL** values
- **Complex** attributes

Entities and Attributes (cont'd.)

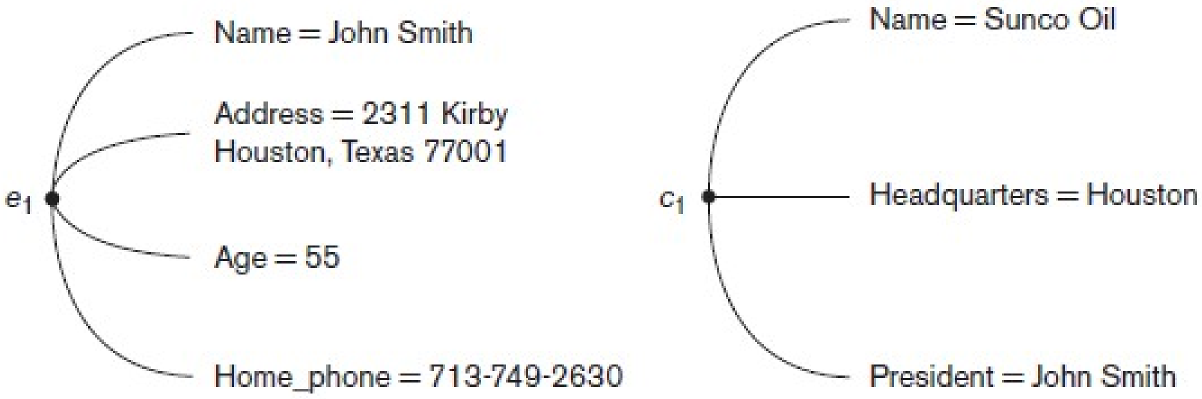


Figure 7.3
Two entities, EMPLOYEE e_1, and COMPANY c_1, and their attributes.

Addison-Wesley
is an imprint of
PEARSON

Entity Types, Entity Sets, Keys, and Value Sets

Entity type

Collection (or set) of entities that have the same attributes

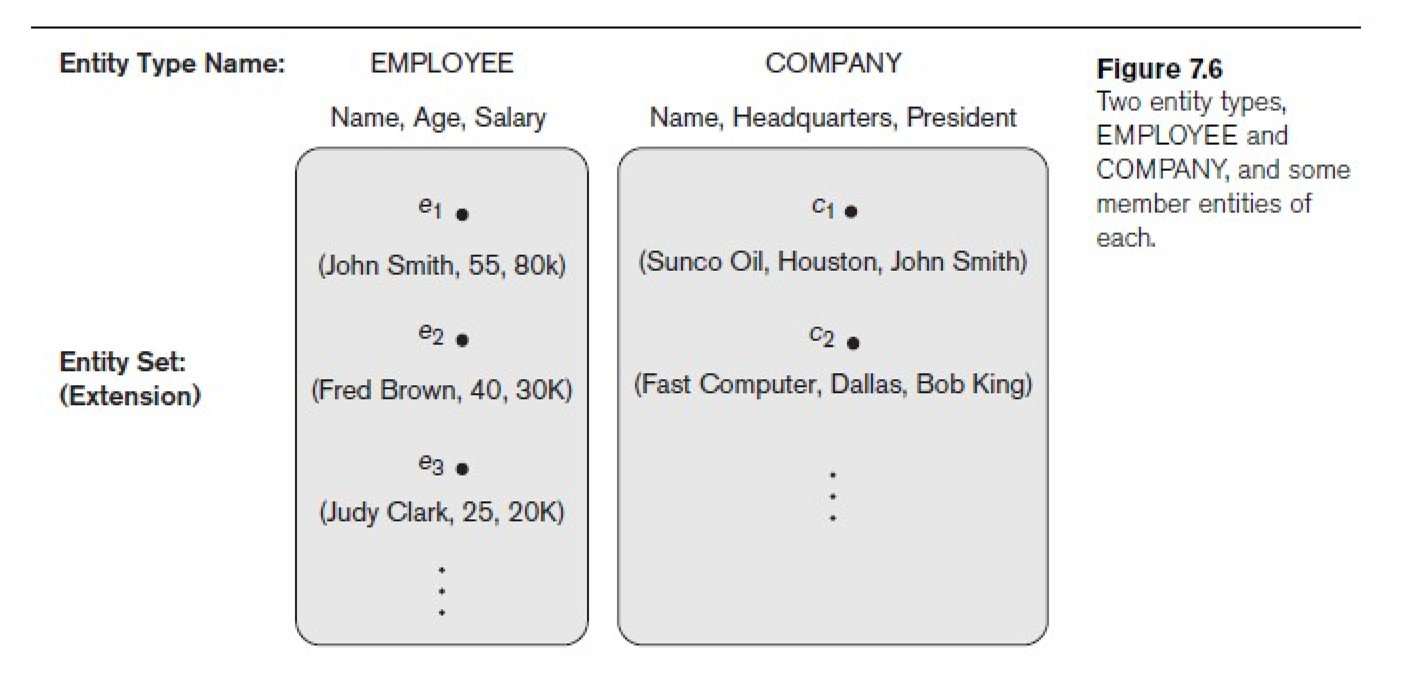


Figure 7.6
Two entity types, EMPLOYEE and COMPANY, and some member entities of each.

Entity Types, Entity Sets, Keys, and Value Sets (cont'd.)

Key or **uniqueness constraint**

Attributes whose values are distinct for each individual entity in entity set

Key attribute

- Uniqueness property must hold for every entity set of the entity type

Value sets (or **domain of values**)

Specifies set of values that may be assigned to that attribute for each individual entity

Addison-Wesley
is an imprint of
PEARSON

Initial Conceptual Design of the COMPANY Database

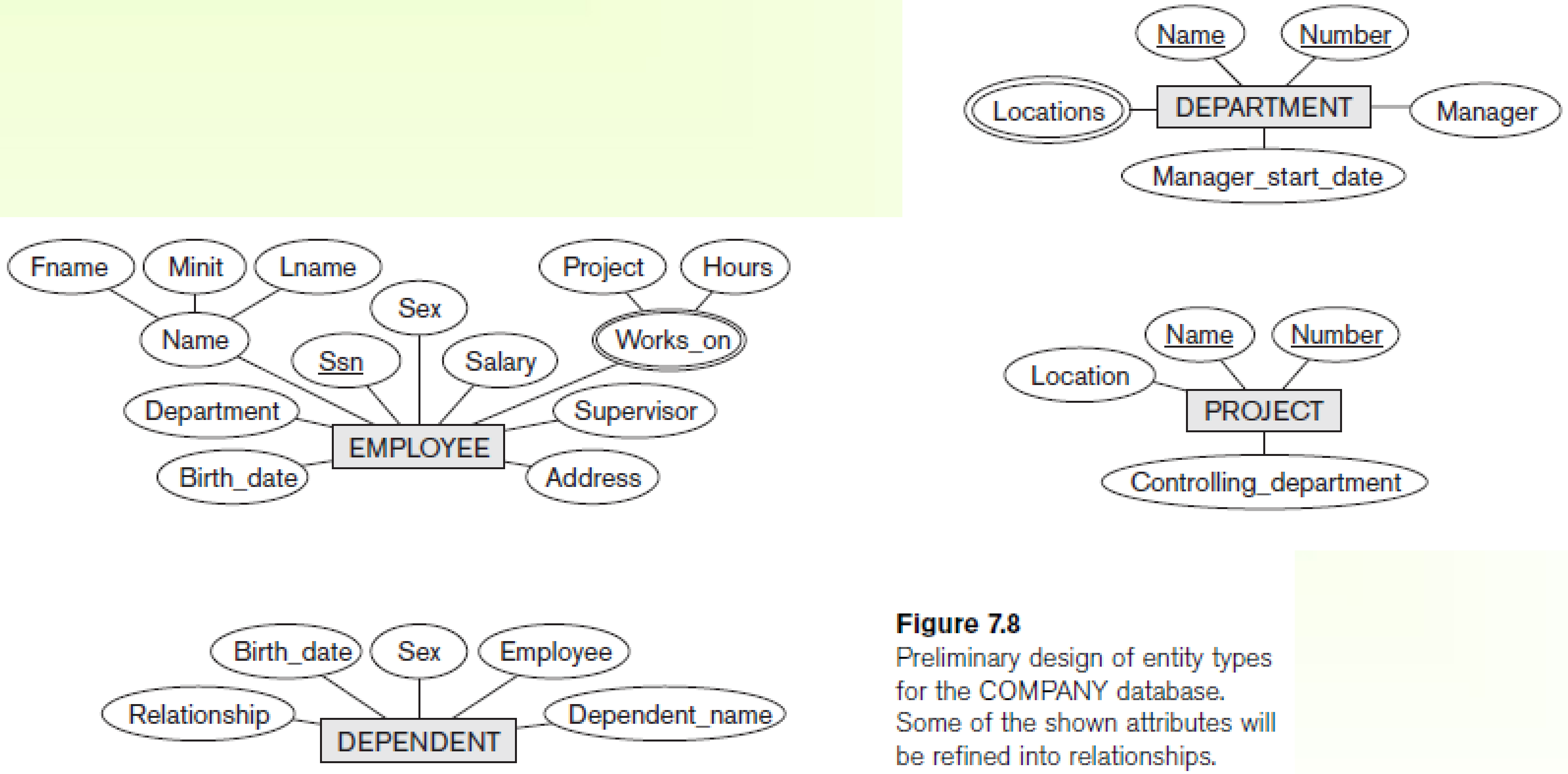


Figure 7.8
Preliminary design of entity types for the COMPANY database. Some of the shown attributes will be refined into relationships.

Relationship Types, Relationship Sets, Roles, and Structural Constraints

Relationship

When an attribute of one entity type refers to another entity type

Represent references as relationships not attributes

Relationship Types, Sets, and Instances

- **Relationship type** R among n entity types $E_1, E_2, \ldots, E_n$
  - Defines a set of associations among entities from these entity types
- **Relationship instances** r_i
  - Each r_i associates n individual entities ($e_1, e_2, \ldots, e_n$)
  - Each entity e_j in r_i is a member of entity set E_j

Addison-Wesley
is an imprint of
PEARSON

Relationship Types, Sets, and Instances

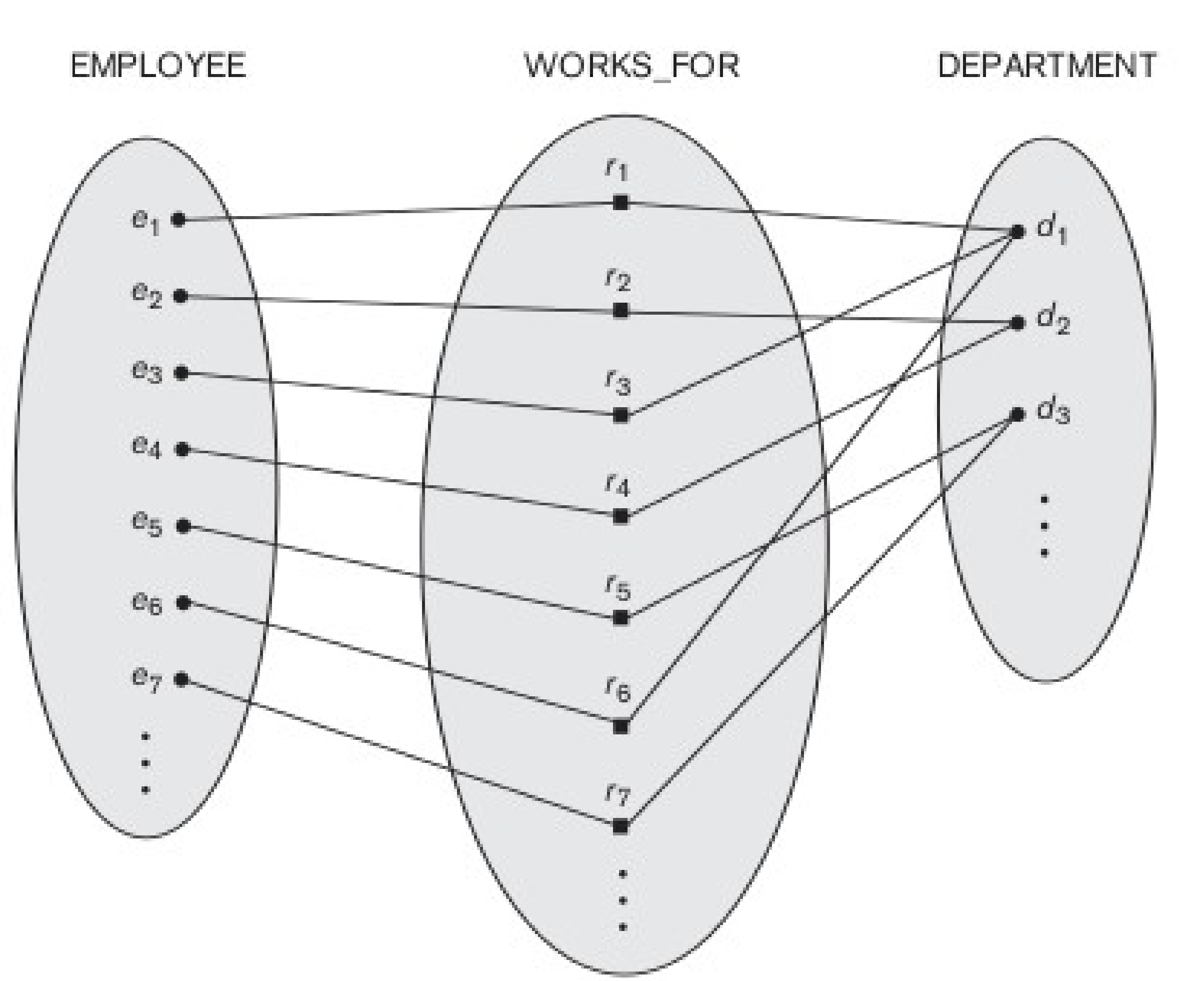


Figure 7.9
Some instances in the WORKS_FOR relationship set, which represents a relationship type WORKS_FOR between EMPLOYEE and DEPARTMENT.

Relationship Degree

Degree of a relationship type

- Number of participating entity types
- **Binary**, **ternary**

Relationships as attributes

- Think of a binary relationship type in terms of attributes

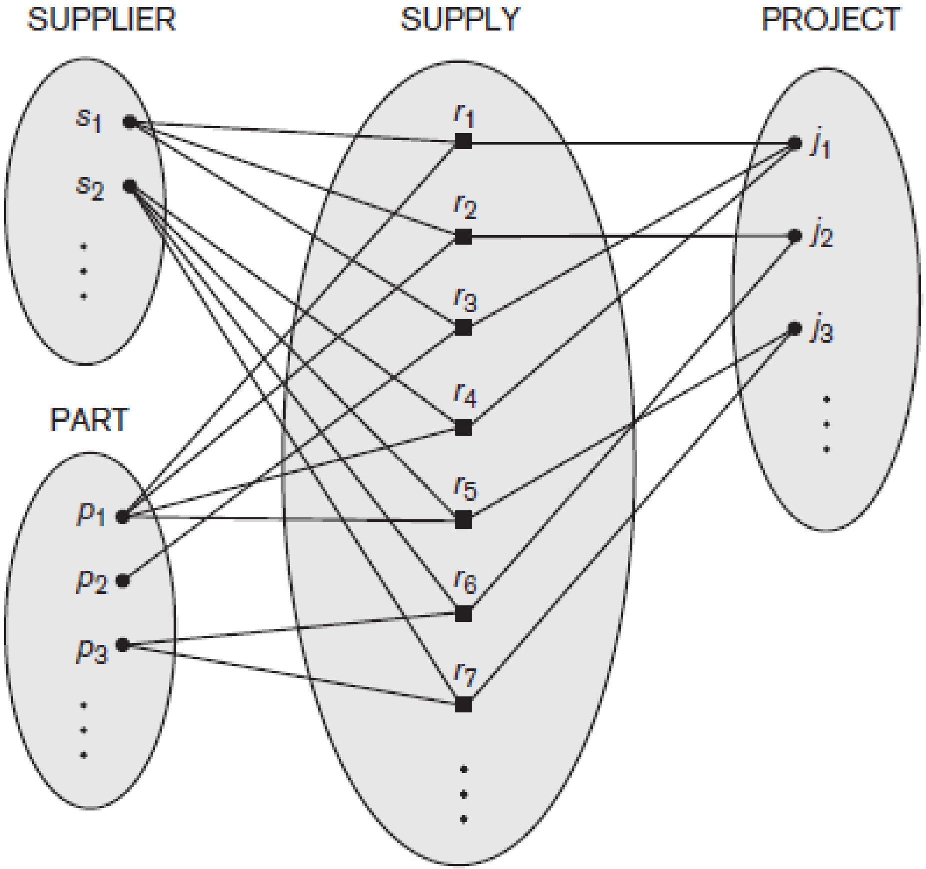


Figure 7.10
Some relationship instances in the SUPPLY ternary relationship set.

Role Names and Recursive Relationships

- **Role names** and recursive relationships
  - Role name signifies role that a participating entity plays in each relationship instance
- **Recursive** relationships
  - Same entity type participates more than once in a relationship type in different roles
  - Must specify role name

Addison-Wesley
is an imprint of
PEARSON

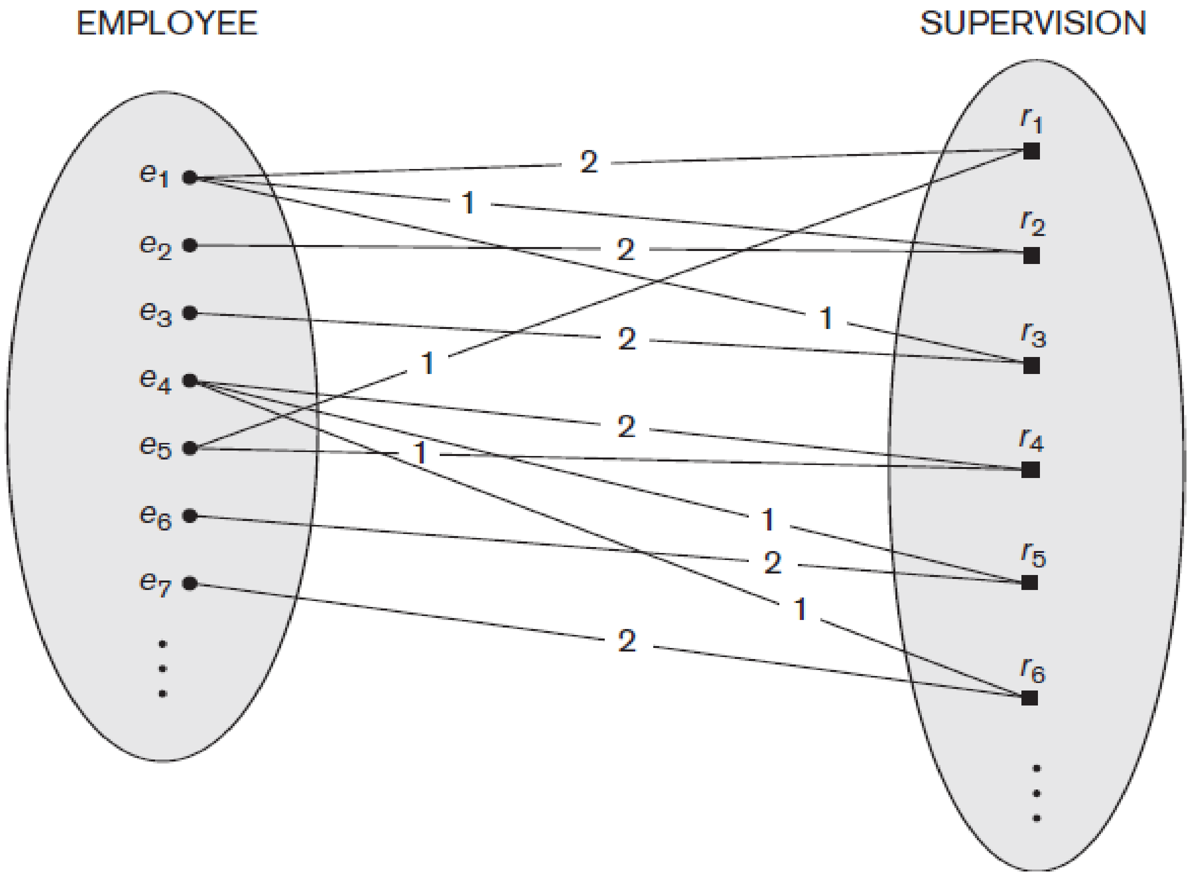


Figure 7.11
A recursive relationship SUPERVISION between EMPLOYEE in the *supervisor* role (1) and EMPLOYEE in the *subordinate* role (2).

Addison-Wesley
is an imprint of
PEARSON

Constraints on Binary Relationship Types

- **Cardinality ratio** for a binary relationship
  - Specifies maximum number of relationship instances that entity can participate in.
  - The possible cardinality ratios for binary relationship types: 1:1, 1:N, N:1, and M:N.
- **Participation constraint**
  - Specifies whether existence of entity depends on its being related to another entity
  - Types: **total** and **partial**

Addison-Wesley
is an imprint of
PEARSON

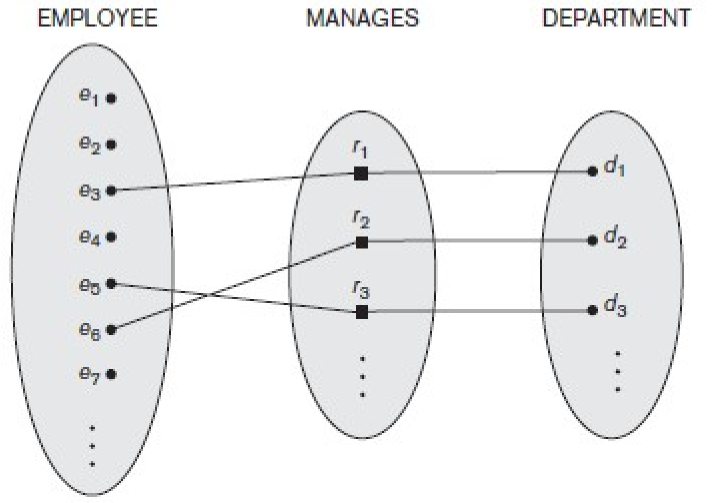


Figure 7.12
A 1:1 relationship,
MANAGES.

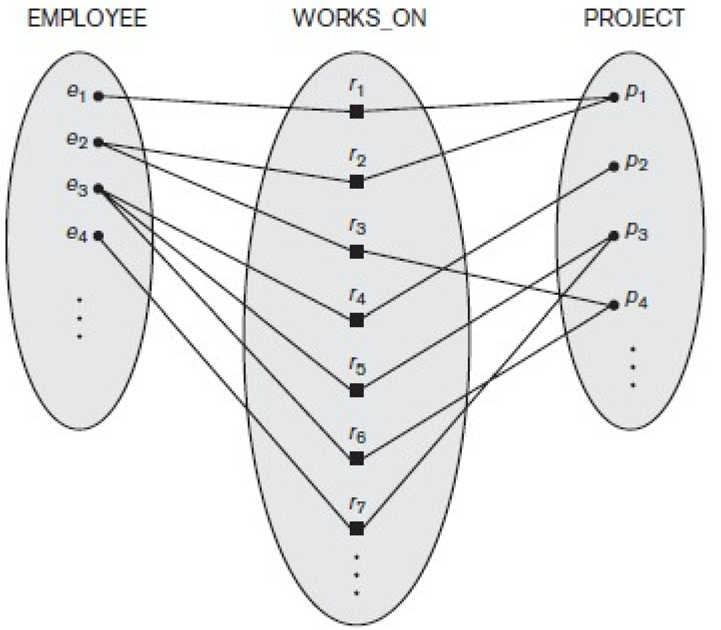


Figure 7.13
An M:N relationship,
WORKS_ON.

Attributes of Relationship Types

- Attributes of 1:1 or 1:N relationship types can be migrated to one entity type
- For a 1:N relationship type
  - Relationship attribute can be migrated only to entity type on N-side of relationship
- For M:N relationship types
  - Some attributes may be determined by combination of participating entities
  - Must be specified as relationship attributes

Addison-Wesley is an imprint of PEARSON

Weak Entity Types

- Do not have key attributes of their own
  - Identified by being related to specific entities from another entity type
- **Identifying relationship**
  - Relates a weak entity type to its owner
- Always has a total participation constraint

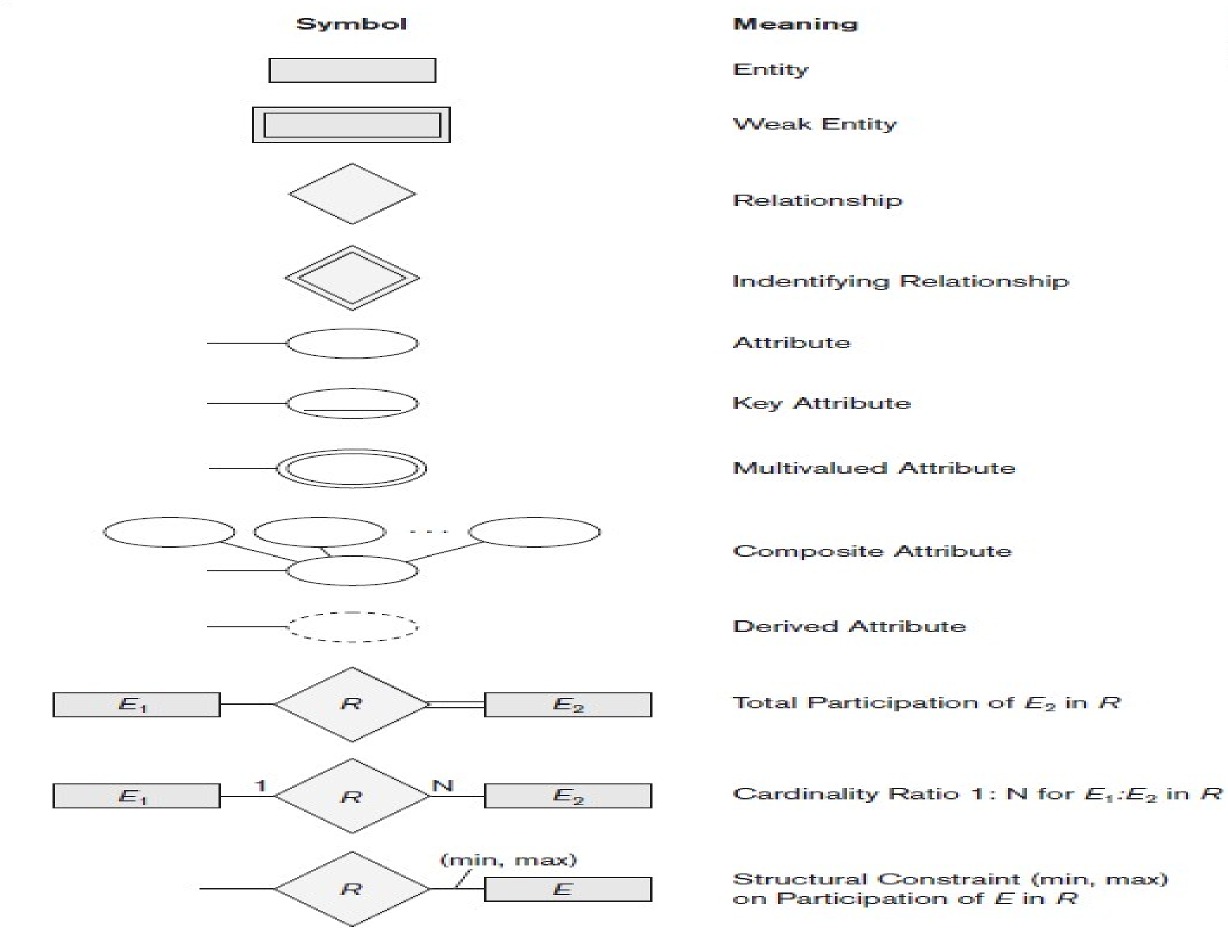
Addison-Wesley
is an imprint of
PEARSON

Refining the ER Design for the COMPANY Database

- Change attributes that represent relationships into relationship types
- Determine cardinality ratio and participation constraint of each relationship type

Addison-Wesley
is an imprint of
PEARSON

ER Diagrams, Naming Conventions, and Design Issues



Symbol

Meaning

Entity

Weak Entity

Relationship

Indentifying Relationship

Attribute

Key Attribute

Multivalued Attribute

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

Figure 7.14
Summary of the notation for ER diagrams.

Proper Naming of Schema Constructs

- Choose names that convey meanings attached to different constructs in schema
- Nouns give rise to entity type names
- Verbs indicate names of relationship types
- Choose binary relationship names to make ER diagram readable from left to right and from top to bottom

Design Choices for ER Conceptual Design

- Model concept first as an attribute
  - Refined into a relationship if attribute is a reference to another entity type
- Attribute that exists in several entity types may be elevated to an independent entity type
  - Can also be applied in the inverse

Addison-Wesley
is an imprint of
PEARSON

Alternative Notations for ER Diagrams

Specify structural constraints on relationships

- Replaces cardinality ratio (1:1, 1:N, M:N) and single/double line notation for participation constraints
- Associate a pair of integer numbers (min, max) with each participation of an entity type *E* in a relationship type *R*, where 0 ≤ min ≤ max and max ≥ 1

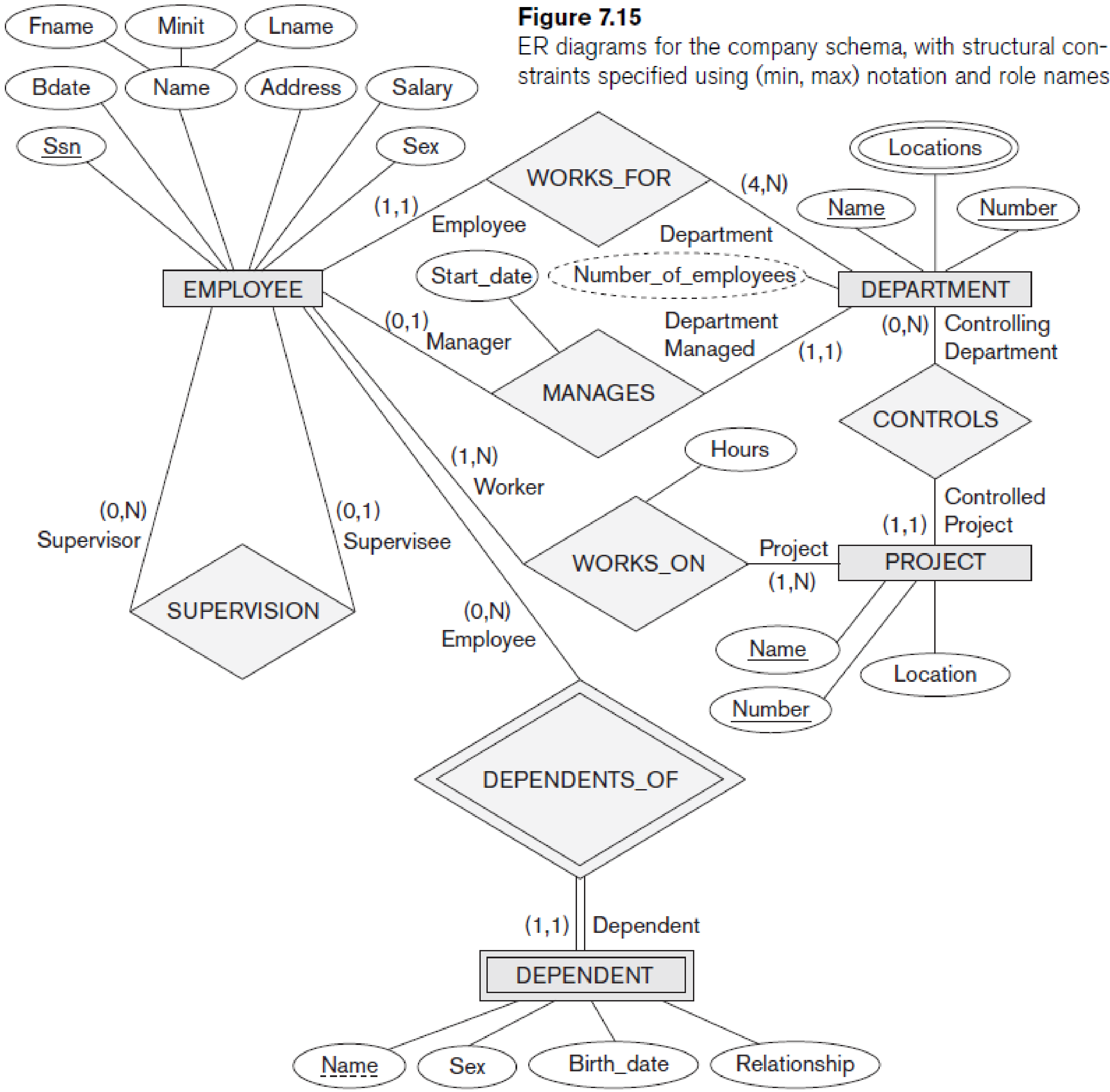


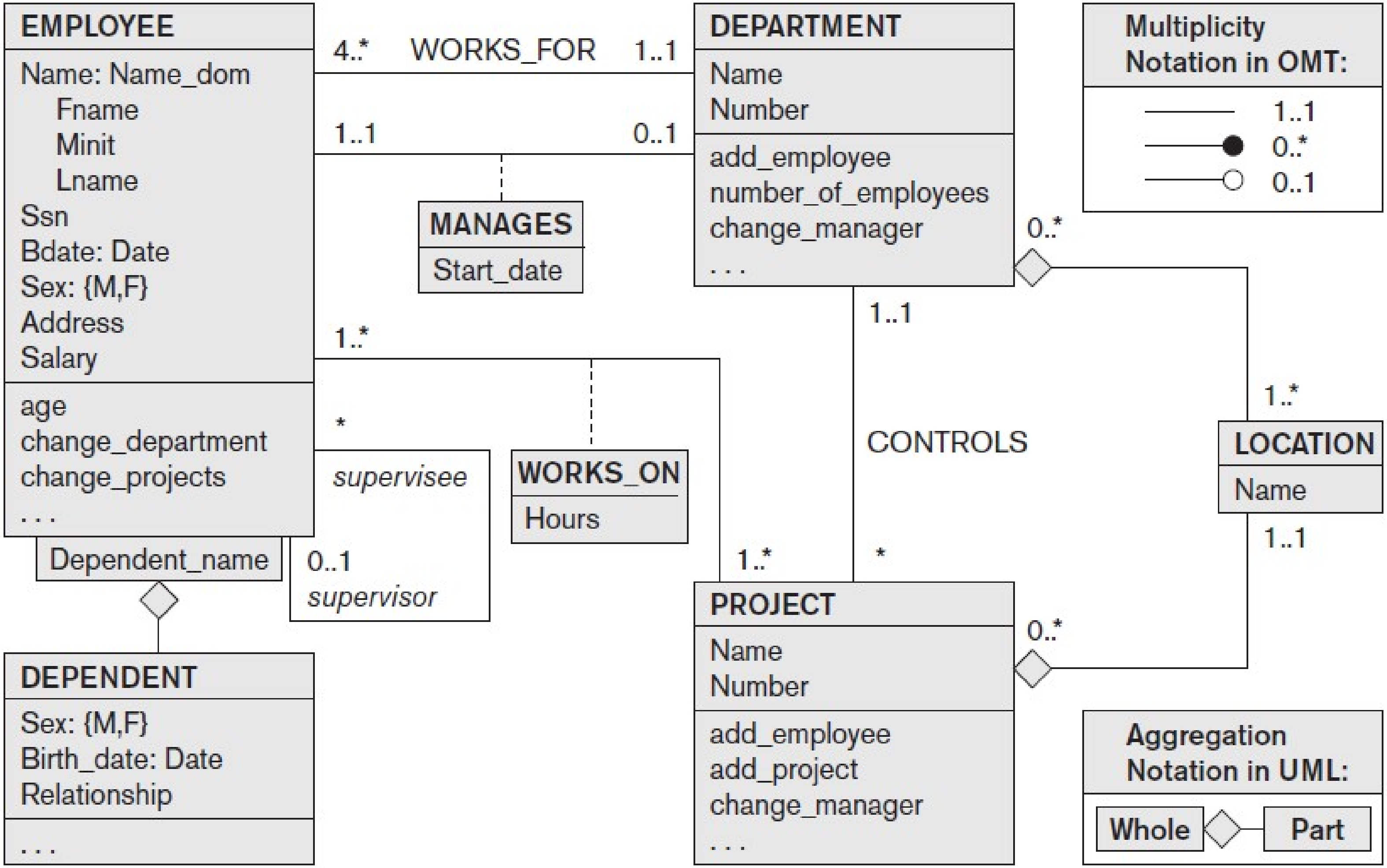
Figure 7.15
ER diagrams for the company schema, with structural constraints specified using (min, max) notation and role names.

Addison-Wesley
is an imprint of
PEARSON

Example of Other Notation: UML Class Diagrams

- UML methodology
  - Used extensively in software design
  - Many types of diagrams for various software design purposes
- UML class diagrams
  - Entity in ER corresponds to an object in UML

Figure 7.16
The COMPANY conceptual schema
in UML class diagram notation.



Addison-Wesley
is an imprint of
PEARSON

Example of Other Notation: UML Class Diagrams (cont'd.)

Class includes three sections:

- Top section gives the class name
- Middle section includes the attributes;
- Last section includes operations that can be applied to individual objects

Example of Other Notation: UML Class Diagrams (cont’d.)

Associations: relationship types

Relationship instances: links

Binary association

- Represented as a line connecting participating classes
- May optionally have a name

Link attribute

- Placed in a box connected to the association’s line by a dashed line

Example of Other Notation: UML Class Diagrams (cont'd.)

Multiplicities: min..max, asterisk (*) indicates no maximum limit on participation

Types of relationships: **association** and **aggregation**

Model weak entities using **qualified association**

Addison-Wesley
is an imprint of
PEARSON

Relationship Types of Degree Higher than Two

- **Degree** of a relationship type
  - Number of participating entity types
- *Binary*
  - Relationship type of degree two
- *Ternary*
  - Relationship type of degree three

Addison-Wesley
is an imprint of
PEARSON

Choosing between Binary and Ternary (or Higher-Degree) Relationships

- Some database design tools permit only binary relationships
  - Ternary relationship must be represented as a weak entity type
  - No partial key and three identifying relationships
- Represent ternary relationship as a regular entity type

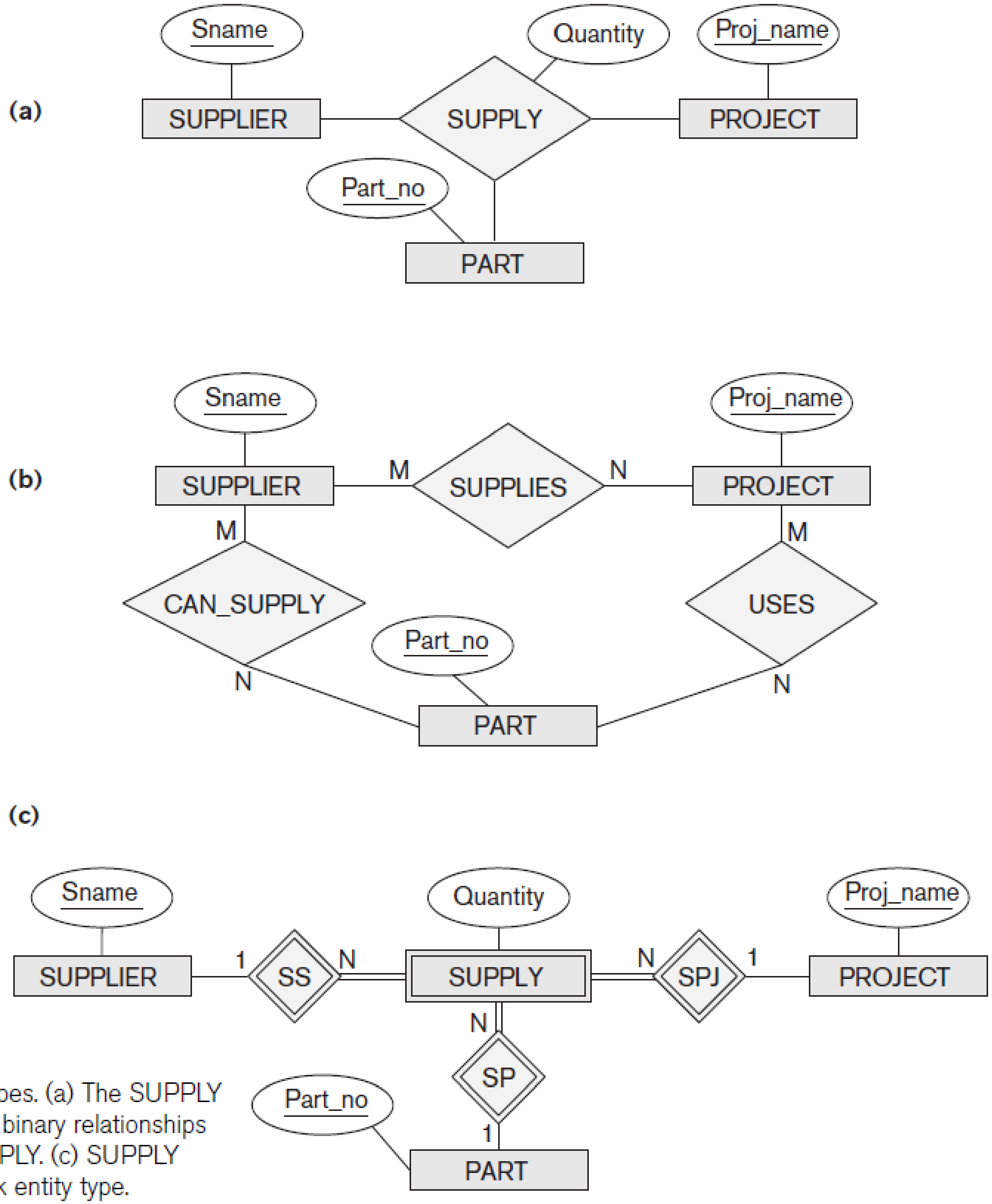


Figure 7.17
Ternary relationship types. (a) The SUPPLY relationship. (b) Three binary relationships not equivalent to SUPPLY. (c) SUPPLY represented as a weak entity type.

Addison-Wesley
is an imprint of
PEARSON

Constraints on Ternary (or Higher-Degree) Relationships

- Notations for specifying structural constraints on *n*-ary relationships
  - Should both be used if it is important to fully specify structural constraints

Summary

- Basic ER model concepts of entities and their attributes
  - Different types of attributes
  - Structural constraints on relationships
- ER diagrams represent E-R schemas
- UML class diagrams relate to ER modeling concepts

Addison-Wesley
is an imprint of
PEARSON