# Database Systems: Design, Implementation, and Management

**Tenth Edition**

*Chapter 4*
*Entity Relationship (ER) Modeling*

## Objectives

- In this chapter, students will learn:
  - The main characteristics of entity relationship components
  - How relationships between entities are defined, refined, and incorporated into the database design process
  - How ERD components affect database design and implementation
  - That real-world database design often requires the reconciliation of conflicting goals



## The Entity Relationship Model (ERM)

- ER model forms the basis of an ER diagram
- ERD represents conceptual database as viewed by end user
- ERDs depict database's main components:
  - Entities
  - Attributes
  - Relationships

## Entities

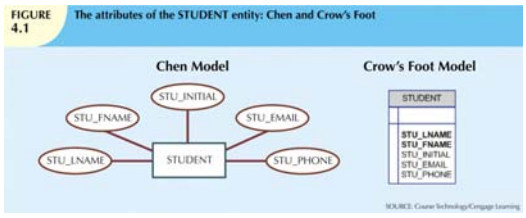
- Refers to entity set and not to single entity occurrence
- Corresponds to table and not to row in relational environment
- In Chen and Crow's Foot models, entity is represented by rectangle with entity's name
- The entity name, a noun, is written in capital letters



## Attributes

- Characteristics of entities
- Chen notation: attributes represented by ovals connected to entity rectangle with a line
  - Each oval contains the name of attribute it represents
- Crow's Foot notation: attributes written in attribute box below entity rectangle





## Attributes (cont'd.)

- Required attribute: must have a value
- Optional attribute: may be left empty
- Domain: set of possible values for an attribute
  - Attributes may share a domain
- Identifiers: one or more attributes that uniquely identify each entity instance
- Composite identifier: primary key composed of more than one attribute



FIGURE 4.2 The CLASS table (entity) components and contents

Database name: Ch04_TinyCollege

| CLASS_CODE | CRS_CODE | CLASS_SECTION | CLASS_TIME | ROOM_CODE | PROF_NUM |
|---|---|---|---|---|---|
| 10012 | ACCT-211 | 1 | MWF 8:00-8:50 a.m. | BUS311 | 105 |
| 10013 | ACCT-211 | 2 | MWF 9:00-9:50 a.m. | BUS260 | 105 |
| 10014 | ACCT-211 | 3 | TTh 2:30-3:45 p.m. | BUS252 | 342 |
| 10015 | ACCT-212 | 1 | MWF 10:00-10:50 a.m. | BUS311 | 301 |
| 10016 | ACCT-212 | 2 | Th 6:00-8:40 p.m. | BUS252 | 301 |
| 10017 | CIS-220 | 1 | MWF 9:00-9:50 a.m. | KLR209 | 229 |
| 10018 | CIS-220 | 2 | MWF 9:00-9:50 a.m. | KLR211 | 114 |
| 10019 | CIS-220 | 3 | MWF 10:00-10:50 a.m. | KLR209 | 228 |
| 10020 | CIS-420 | 1 | W 6:00-8:40 p.m. | KLR209 | 162 |
| 10021 | QM-261 | 1 | MWF 8:00-8:50 a.m. | KLR200 | 114 |
| 10022 | QM-261 | 2 | TTh 1:00-2:15 p.m. | KLR200 | 114 |
| 10023 | QM-362 | 1 | MWF 11:00-11:50 a.m. | KLR200 | 162 |
| 10024 | QM-362 | 2 | TTh 2:30-3:45 p.m. | KLR200 | 162 |
| 10025 | MATH-243 | 1 | Th 6:00-8:40 p.m. | DRE155 | 325 |

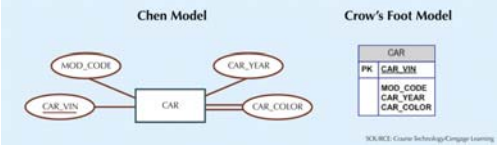
SOURCE: Course Technology/Cengage Learning



## Attributes (cont'd.)

- Composite attribute can be subdivided
- Simple attribute cannot be subdivided
- Single-value attribute can have only a single value
- Multivalued attributes can have many values

FIGURE 4.3 A multivalued attribute in an entity






## Attributes (cont'd.)

- M:N relationships and multivalued attributes should not be implemented
  - Create several new attributes for each of the original multivalued attributes' components
  - Create new entity composed of original multivalued attributes' components
- Derived attribute: value may be calculated from other attributes
  - Need not be physically stored within database



FIGURE 4.6 Depiction of a derived attribute

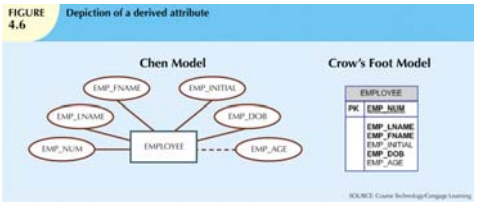



TABLE 4.2 Advantages and Disadvantages of Storing Derived Attributes

| | DERIVED ATTRIBUTE | |
|---|---|---|
| | STORED | NOT STORED |
| Advantage | Saves CPU processing cycles<br>Saves data access time<br>Data value is readily available<br>Can be used to keep track of historical data | Saves storage space<br>Computation always yields current value |
| Disadvantage | Requires constant maintenance to ensure derived value is current, especially if any values used in the calculation change | Uses CPU processing cycles<br>Increases data access time<br>Adds coding complexity to queries |

## Relationships

- Association between entities
- Participants are entities that participate in a relationship
- Relationships between entities always operate in both directions
- Relationship can be classified as 1:M
- Relationship classification is difficult to establish if only one side of the relationship is known

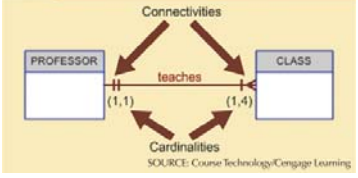


## Connectivity and Cardinality

- Connectivity
  - Describes the relationship classification
- Cardinality
  - Expresses minimum and maximum number of entity occurrences associated with one occurrence of related entity
- Established by very concise statements known as business rules



FIGURE 4.7 Connectivity and cardinality in an ERD




SOURCE: Course Technology/Cengage Learning

## Existence Dependence

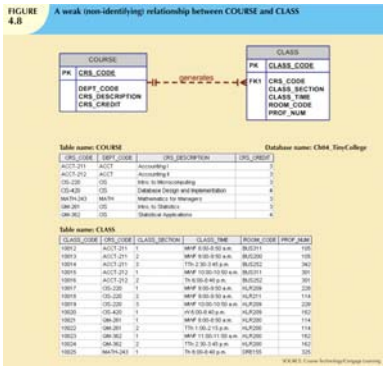
- Existence dependence
  - Entity exists in database only when it is associated with another related entity occurrence
- Existence independence
  - Entity can exist apart from one or more related entities
  - Sometimes such an entity is referred to as a strong or regular entity

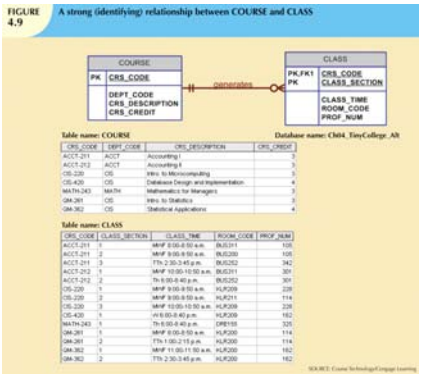


## Relationship Strength

- Weak (non-identifying) relationships
  - Exists if PK of related entity does not contain PK component of parent entity
- Strong (identifying) relationships
  - Exists when PK of related entity contains PK component of parent entity










## Weak Entities

- Weak entity meets two conditions
  - Existence-dependent
  - Primary key partially or totally derived from parent entity in relationship
- Database designer determines whether an entity is weak based on business rules



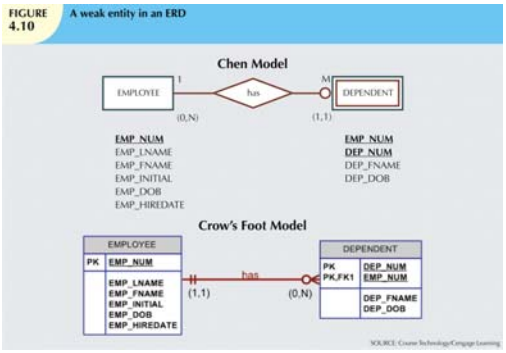


**FIGURE 4.11** A weak entity in a strong relationship

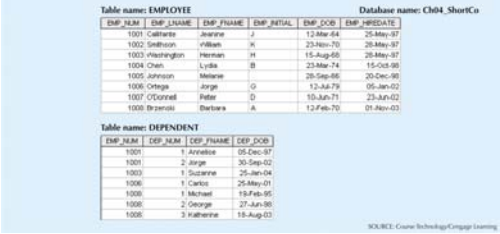


Table name: EMPLOYEE — Database name: Ch04_ShortCo

| EMP_NUM | EMP_LNAME | EMP_FNAME | EMP_INITIAL | EMP_DOB | EMP_HIREDATE |
|---|---|---|---|---|---|
| 1001 | Callifante | Jeanine | J | 12-Mar-64 | 25-May-97 |
| 1002 | Smithson | William | K | 23-Nov-70 | 28-May-97 |
| 1003 | Washington | Herman | H | 15-Aug-68 | 28-May-97 |
| 1004 | Chen | Lydia | B | 23-Mar-74 | 15-Oct-98 |
| 1005 | Johnson | Melanie | | 28-Sep-66 | 20-Dec-98 |
| 1006 | Ortega | Jorge | G | 12-Jul-79 | 05-Jan-02 |
| 1007 | O'Donnell | Peter | D | 10-Jun-71 | 23-Jun-02 |
| 1008 | Brzenski | Barbara | A | 12-Feb-70 | 01-Nov-03 |

Table name: DEPENDENT

| EMP_NUM | DEP_NUM | DEP_FNAME | DEP_DOB |
|---|---|---|---|
| 1001 | 1 | Annelise | 05-Dec-97 |
| 1001 | 2 | Jorge | 30-Sep-02 |
| 1003 | 1 | Suzanne | 25-Jan-04 |
| 1006 | 1 | Carlos | 25-May-01 |
| 1008 | 1 | Michael | 19-Feb-95 |
| 1008 | 2 | George | 27-Jun-98 |
| 1008 | 3 | Katherine | 18-Aug-03 |

SOURCE: Course Technology/Cengage Learning



## Relationship Participation

- Optional participation
  - One entity occurrence does not require corresponding entity occurrence in particular relationship
- Mandatory participation
  - One entity occurrence requires corresponding entity occurrence in particular relationship



**TABLE 4.3** Crow's Foot Symbols

| CROW'S FOOT SYMBOLS | CARDINALITY | COMMENT |
|---|---|---|
| O< | (0,N) | Zero or many; the "many" side is optional. |
| I< | (1,N) | One or many; the "many" side is mandatory. |
| II | (1,1) | One and only one; the "1" side is mandatory. |
| OI | (0,1) | Zero or one; the "1" side is optional. |

FIGURE 4.13 CLASS is optional to COURSE

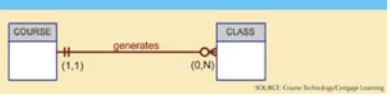
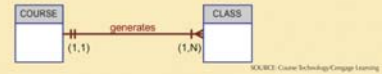



FIGURE 4.14 COURSE and CLASS in a mandatory relationship






## Relationship Degree

- Indicates number of entities or participants associated with a relationship
- Unary relationship
  - Association is maintained within single entity
- Binary relationship
  - Two entities are associated
- Ternary relationship
  - Three entities are associated



FIGURE 4.15 Three types of relationship degree

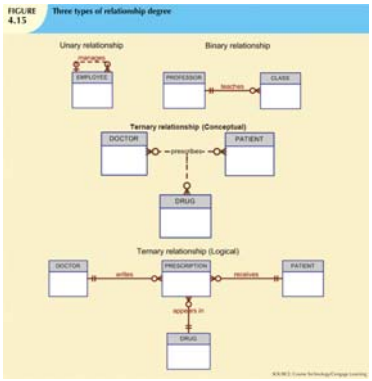


**FIGURE 4.16** The implementation of a ternary relationship




## Recursive Relationships

- Relationship can exist between occurrences of the same entity set
  - Naturally found within unary relationship

**FIGURE 4.19** Another unary relationship: "PART contains PART"

Table name: PART_V1 Database name: Ch04_PartCo

| PART_CODE | PART_DESCRIPTION | PART_IN_STOCK | PART_UNITS_NEEDED | PART_OF_PART |
|---|---|---|---|---|
| AA21-6 | 2.5 cm. washer, 1.0 mm. rim | 432 | 4 | C-130 |
| AB-121 | Cotter pin, copper | 1034 | 2 | C-130 |
| C-130 | Rotor assembly | 36 | | |
| E129 | 2.5 cm. steel shank | 128 | 1 | C-130 |
| X10 | 10.25 cm. rotor blade | 345 | 4 | C-130 |
| X34AVV | 2.5 cm. hex nut | 879 | 2 | C-130 |

SOURCE: Course Technology/Cengage Learning



**FIGURE 4.20** Implementation of the M:N recursive relationship "PART contains PART"

Table name: COMPONENT Database name: Ch04_PartCo

| COMP_CODE | PART_CODE | COMP_PARTS_NEEDED |
|---|---|---|
| C-130 | AA21-6 | 4 |
| C-130 | AB-121 | 2 |
| C-130 | E129 | 1 |
| C-131A2 | E129 | 1 |
| C-130 | X10 | 4 |
| C-131A2 | X10 | 1 |
| C-130 | X34AVV | 2 |
| C-131A2 | X34AVV | 2 |

Table name: PART

| PART_CODE | PART_DESCRIPTION | PART_IN_STOCK |
|---|---|---|
| AA21-6 | 2.5 cm. washer, 1.0 mm. rim | 432 |
| AB-121 | Cotter pin, copper | 1034 |
| C-130 | Rotor assembly | 36 |
| E129 | 2.5 cm. steel shank | 128 |
| X10 | 10.25 cm. rotor blade | 345 |
| X34AVV | 2.5 cm. hex nut | 879 |

SOURCE: Course Technology/Cengage Learning

FIGURE 4.22 Implementation of the 1:M recursive relationship "EMPLOYEE manages EMPLOYEE"

Database name: Ch04_PartCo

Table name: EMPLOYEE_V2

| EMP_CODE | EMP_LNAME | EMP_MANAGER |
|---|---|---|
| 101 | Waddell | 102 |
| 102 | Orincone | |
| 103 | Jones | 102 |
| 104 | Rebaldo | 102 |
| 105 | Robertson | 102 |
| 106 | Deltona | 102 |

SOURCE: Course Technology/Cengage Learning



## Associative (Composite) Entities

- Also known as bridge entities
- Used to implement M:N relationships
- Composed of primary keys of each of the entities to be connected
- May also contain additional attributes that play no role in connective process



FIGURE 4.23 Converting the M:N relationship into two 1:M relationships

Database name: Ch04_CollegeTry

Table name: STUDENT

| STU_NUM | STU_LNAME |
|---|---|
| 321452 | Bowser |
| 324257 | Smithson |

Table name: ENROLL

| CLASS_CODE | STU_NUM | ENROLL_GRADE |
|---|---|---|
| 10014 | 321452 | C |
| 10014 | 324257 | B |
| 10018 | 321452 | A |
| 10018 | 324257 | B |
| 10021 | 321452 | C |
| 10021 | 324257 | C |

Table name: CLASS

| CLASS_CODE | CRS_CODE | CLASS_SECTION | CLASS_TIME | ROOM_CODE | PROF_NUM |
|---|---|---|---|---|---|
| 10014 | ACCT-211 | 3 | TTh 2:30-3:45 p.m. | BUS252 | 342 |
| 10018 | CIS-220 | 2 | MWF 9:00-9:50 a.m. | KLR211 | 114 |
| 10021 | QM-261 | 1 | MWF 8:00-8:50 a.m. | KLR200 | 114 |

SOURCE: Course Technology/Cengage Learning

FIGURE 4.24 The M:N relationship between STUDENT and CLASS

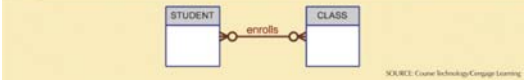
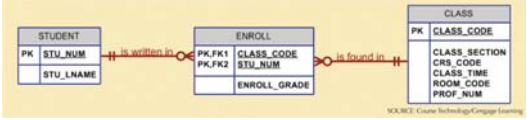



FIGURE 4.25 A composite entity in an ERD






## Developing an ER Diagram

- Database design is an iterative process
  - Create detailed narrative of organization's description of operations
  - Identify business rules based on description of operations
  - Identify main entities and relationships from business rules
  - Develop initial ERD
  - Identify attributes and primary keys that adequately describe entities
  - Revise and review ERD



FIGURE 4.26 The first Tiny College ERD segment

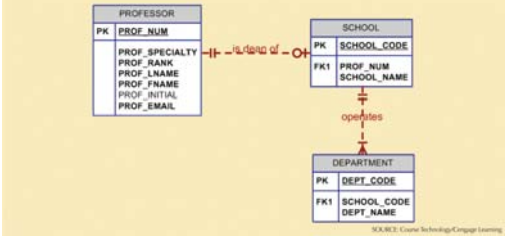


FIGURE 4.27 The second Tiny College ERD segment

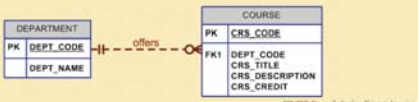



FIGURE 4.28 The third Tiny College ERD segment

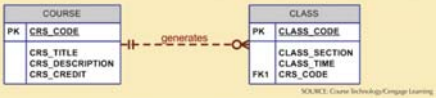





FIGURE 4.29 The fourth Tiny College ERD segment

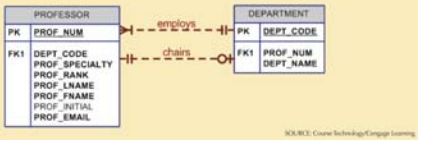





FIGURE 4.30 The fifth Tiny College ERD segment

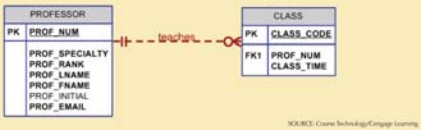


FIGURE 4.31 The sixth Tiny College ERD segment

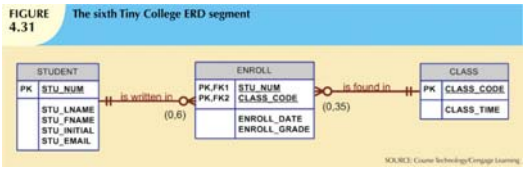





FIGURE 4.32 The seventh Tiny College ERD segment

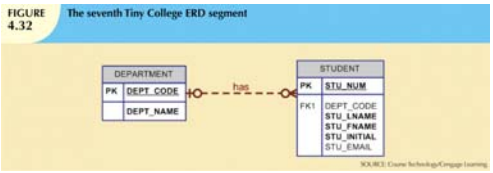
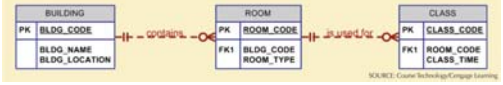





FIGURE 4.33 The eighth Tiny College ERD segment

FIGURE 4.34 The ninth Tiny College ERD segment




SOURCE: Course Technology/Cengage Learning



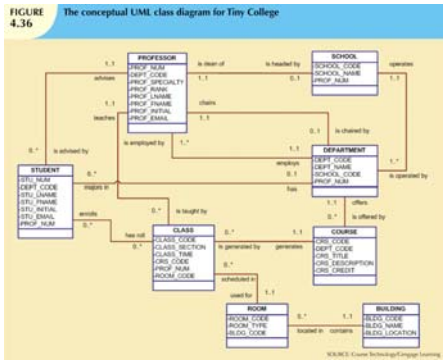
TABLE 4.4 Components of the ERM

| ENTITY | RELATIONSHIP | CONNECTIVITY | ENTITY |
|---|---|---|---|
| SCHOOL | operates | 1:M | DEPARTMENT |
| DEPARTMENT | has | 1:M | STUDENT |
| DEPARTMENT | employs | 1:M | PROFESSOR |
| DEPARTMENT | offers | 1:M | COURSE |
| COURSE | generates | 1:M | CLASS |
| PROFESSOR | is dean of | 1:1 | SCHOOL |
| PROFESSOR | chairs | 1:1 | DEPARTMENT |
| PROFESSOR | teaches | 1:M | CLASS |
| PROFESSOR | advises | 1:M | STUDENT |
| STUDENT | enrolls in | M:N | CLASS |
| BUILDING | contains | 1:M | ROOM |
| ROOM | is used for | 1:M | CLASS |

Note: ENROLL is the composite entity that implements the M:N relationship "STUDENT enrolls in CLASS."

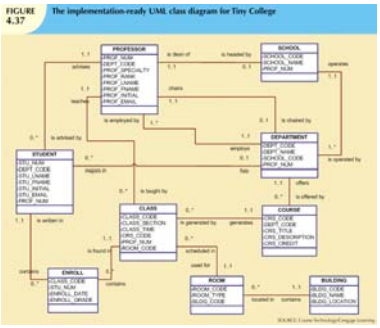


FIGURE 4.36 The conceptual UML class diagram for Tiny College




SOURCE: Course Technology/Cengage Learning

FIGURE 4.37 The implementation-ready UML class diagram for Tiny College



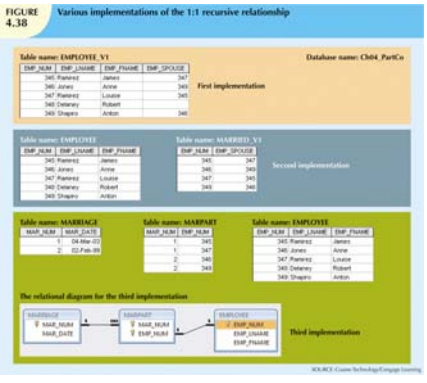


## Database Design Challenges: Conflicting Goals

- Database designers must make design compromises
  - Conflicting goals: design standards, processing speed, information requirements
- Important to meet logical requirements and design conventions
- Design is of little value unless it delivers all specified query and reporting requirements
- Some design and implementation problems do not yield “clean” solutions



FIGURE 4.38 Various implementations of the 1:1 recursive relationship



## Summary

- Entity relationship (ER) model
  - Uses ERD to represent conceptual database as viewed by end user
  - ERM's main components:
    - Entities
    - Relationships
    - Attributes
  - Includes connectivity and cardinality notations



## Summary (cont'd.)

- Connectivities and cardinalities are based on business rules
- M:N relationship is valid at conceptual level
  - Must be mapped to a set of 1:M relationships
- ERDs may be based on many different ERMs
- UML class diagrams are used to represent the static data structures in a data model
- Database designers are often forced to make design compromises