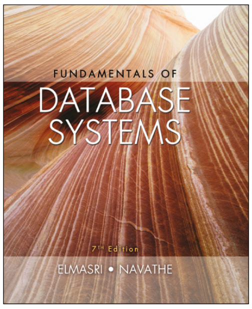
Fundamentals of Database Systems

Seventh Edition



Chapter 4

Enhanced Entity Relationship (EER) Modeling

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Enhanced/Extended ER (EER) model

- Created to design more accurate database schemas
  - Reflect the data properties and constraints more precisely
- Result of adding more semantic constructs to original entity relationship (ER) model
- Diagram using this model is called an EER diagram (EERD)

Advanced Data Modeling

- The Extended Entity Relationship (EER) model
- How to use flexible solutions for special data modeling cases

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Subclasses, Superclasses, and Inheritance

- EER model includes all modeling concepts of the ER model
- In addition, EER includes:
  - **Subclasses** and **superclasses**
  - **Specialization** and **generalization**
  - **Attribute** and **relationship inheritance**
- **Enhanced ER** or **EER diagrams**
  - Diagrammatic technique for displaying these concepts in an EER schema
  - Represented explicitly because of their significance to the database application

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Subclasses and Superclasses

- An entity type may have additional meaningful subgroupings of its entities
  - Example: EMPLOYEE may be further grouped into:
    - SECRETARY, ENGINEER, TECHNICIAN, …
      - Based on the EMPLOYEE's Job
    - MANAGER
      - EMPLOYEEs who are managers (the role they play)
    - SALARIED_EMPLOYEE, HOURLY_EMPLOYEE
      - Based on the EMPLOYEE's method of pay
- E E R diagrams extend E R diagrams to represent these additional subgroupings, called **subclasses** or **subtypes**

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Subclasses and Superclasses

- Terms for relationship between a superclass and any one of its subclasses
  - **Superclass/subclass**
  - **Supertype/subtype**
  - **Class/subclass** relationship
  - "**IS-A**" or **"IS-AN"** relationship
- **Type inheritance**
  - Subclass entity inherits all attributes and relationships of superclass
- **Entity superclass**
  - Generic entity type related to one or more entity subtypes
  - Contains common characteristics
- **Entity subclass**
  - Contains unique characteristics of each entity subtype

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FIGURE 6.1 Nulls created by unique attributes

EMP_ NUM	EMP_ LNAME	EMP_ FNAME	EMP_ INITIAL	EMP_ LICENCE	EMP_RATINGS	EMP_ MED_TYPE	EMP_HIRE_ DATE
100	Nkosi	Cela	T				15-Mar-98
101	Lewis	Marcos		ATP	SEL/MEL/Instr/CFII	1	25-Apr-99
102	Vandam	Jean					20-Dec-03
103	Jones	Victoria	R				28-Aug-13
104	Lange	Edith		ATP	SEL/MEL/Instr	1	20-Oct-07
105	Williams	Gabriel	U	COM	SEL/MEL/Instr/CFI	2	08-Nov-07
106	Naidu	Theeban		COM	SEL/MEL/Instr	2	05-Jan-14
107	Diante	Venite	L				02-Jul-07
108	Shenge	Mhambi					18-Nov-05
109	Travis	Brett	T	COM	SEL/MEL/SES/Instr/CFII	1	14-Apr-11
110	Genkazi	Stan					01-Dec-13

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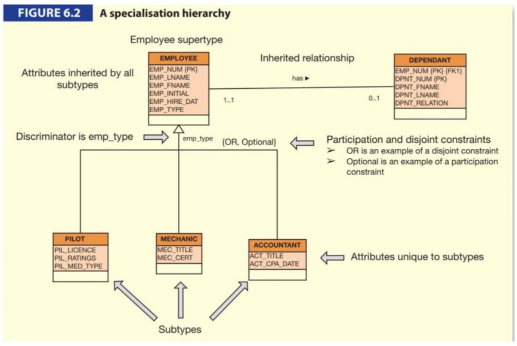
Subclasses and Superclasses

Figure 4.1 EER diagram notation to represent subclasses and specialization.

FIGURE 6.2 A specialisation hierarchy



- A member entity of the subclass represents the *same real-world entity* as some member of the superclass; MECHANIC entity is also an EMPLOYEE.

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Subclasses and Superclasses

FIGURE 6.3 The EMPLOYEE – PILOT supertype – subtype relationship

Table name: EMPLOYEE

EMP_NUM	EMP_LNAME	EMP_FNAME	EMP_INITIAL	EMP_HIRE_DATE	EMP_TYPE
100	Nkosi	Cela	T	15-Mar-98	
101	Lewis	Marcos		25-Apr-99	P
102	Vandam	Jean		20-Dec-03	A
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107	Diante	Venite	L	02-Jul-07	M
108	Shengi	Mhambi		18-Nov-05	M
109	Travis	Brett	T	14-Apr-11	P
110	Genkazi	Stan		01-Dec-13	A

Table name: PILOT

EMP_NUM	PIL_LICENCE	PIL_RATINGS	PIL_MED_TYPE
101	ATP	SEL/MEL/Instr/CFII	1
104	ATP	SEL/MEL/Instr	1
105	COM	SEL/MEL/Instr/CFI	2
106	COM	SEL/MEL/Instr	2
109	COM	SEL/MEL/SES/Instr/CFII	1

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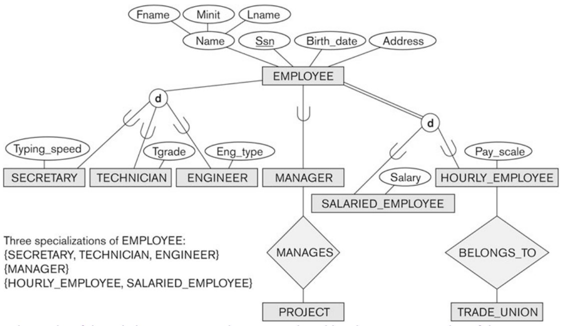
Subclasses and Superclasses

Figure 4.1 EER diagram notation to represent subclasses and specialization.



- A member entity of the subclass represents the *same real-world entity* as some member of the superclass; SECRETARY entity is also an EMPLOYEE.
- A salaried employee who is also an engineer belongs to the two subclasses ENGINEER and SALARIED employee. A member of the superclass can be optionally included as a member of any number of its subclasses

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Subclasses and Superclasses

- Each of these subgroupings is a subset of EMPLOYEE entities
- Each is called a subclass of EMPLOYEE
- EMPLOYEE is the superclass for each of these subclasses
- These are called superclass/subclass relationships:
  - EMPLOYEE/SECRETARY
  - EMPLOYEE/TECHNICIAN
  - EMPLOYEE/MANAGER
  - …

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Subclasses and Superclasses

- These are also called IS-A relationships
  - SECRETARY IS-AN EMPLOYEE, TECHNICIAN IS-AN EMPLOYEE, ….
- Note: An entity that is member of a subclass represents the same real-world entity as some member of the superclass:
  - The subclass member is the same entity in a **distinct specific role**
  - An entity cannot exist in the database merely by being a member of a subclass; it must also be a member of the superclass
  - A member of the superclass can be optionally included as a member of any number of its subclasses

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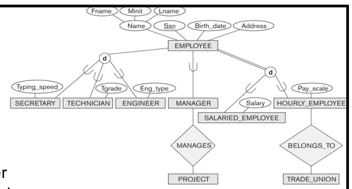
Subclasses and Superclasses



- Examples:
  - A salaried employee who is also an engineer belongs to the two subclasses:
    - ENGINEER, and
    - SALARIED_EMPLOYEE
  - A salaried employee who is also an engineering manager belongs to the three subclasses:
    - MANAGER,
    - ENGINEER, and
    - SALARIED_EMPLOYEE
- It is not necessary that every entity in a superclass be a member of some subclass

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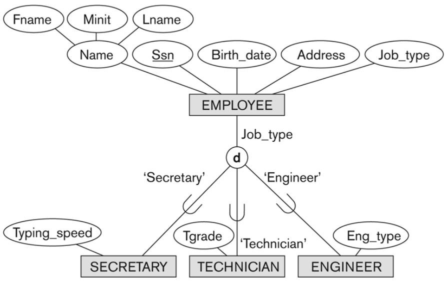
Representing Specialization in EER Diagrams

Figure 4.4 EER diagram notation for an attribute-defined specialization on Job_type.



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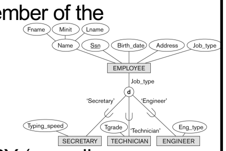
Attribute Inheritance in Superclass / Subclass Relationships



- An entity that is member of a subclass **inherits**
  - All attributes of the entity as a member of the superclass
  - All relationships of the entity as a member of the superclass
- Example:
  - In the previous slide, SECRETARY (as well as TECHNICIAN and ENGINEER) inherit the attributes Name, SSN, …, from EMPLOYEE
  - Every SECRETARY entity will have values for the inherited attributes

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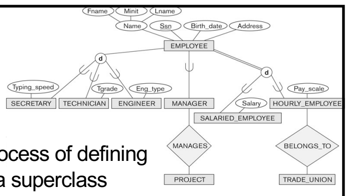
Specialization



- Specialization is the process of defining a set of subclasses of a superclass
- The set of subclasses is based upon some distinguishing characteristics of the entities in the superclass
  - Example: {SECRETARY, ENGINEER, TECHNICIAN} is a specialization of EMPLOYEE based upon **job type**.
  - Example: MANAGER **is a specialization of EMPLOYEE** based on **the role the employee plays**
    - May have several specializations of the same superclass

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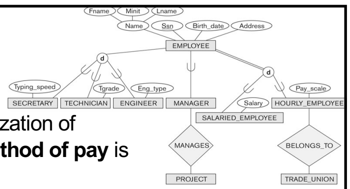
Specialization



- Example: Another specialization of EMPLOYEE based on **method of pay** is {SALARIED_EMPLOYEE, HOURLY_EMPLOYEE}.
  - Superclass/subclass relationships and specialization can be diagrammatically represented in EER diagrams
  - Attributes of a subclass are called **specific** or **local** attributes.
    - For example, the attribute TypingSpeed of SECRETARY
  - The subclass can also participate in specific relationship types.
    - For example, a relationship BELONGS_TO of HOURLY_EMPLOYEE

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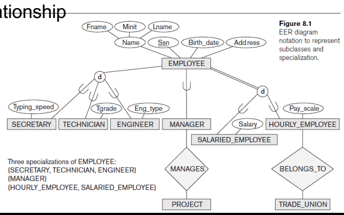
Specialization and Generalization

- Subclass can define:
  - **Specific attributes**
    - i.e. TypingSpeed of SECRETARY
  - **Specific relationship types**
    - i.e. HOURLY EMPLOYEE subclass participating in the BELONGS_TO relationship



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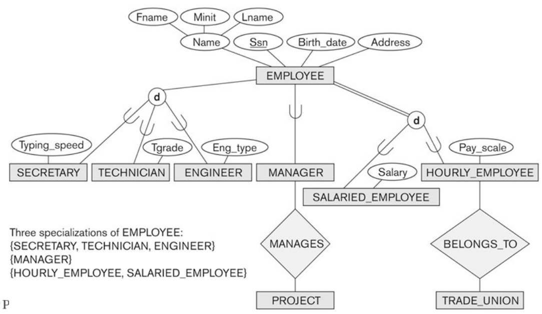
Specialization

Figure 4.1 EER diagram notation to represent subclasses and specialization.



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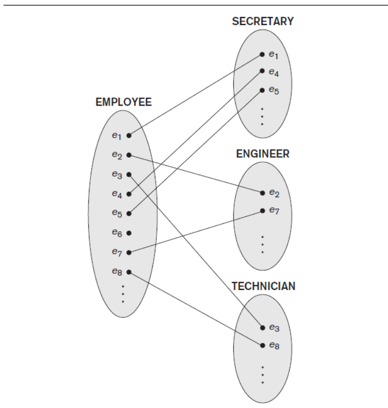

Figure 8.2
Instances of a specialization.

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Specialization and Generalization (cont'd.)

- Two main reasons for including class/subclass relationships and specialization in the data model;
  - Certain attributes may apply to some but not all entities of the superclass
  - Some relationship types may be participated in only by entities that are members of the subclass

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Specialization Hierarchy

- Depicts arrangement of higher-level entity supertypes and lower-level entity subtypes
- Relationships described in terms of "IS-A" relationships
- Subtype exists only within context of supertype
- Every subtype has only one supertype to which it is directly related
- Can have many levels of supertype/subtype relationships

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Specialization Hierarchy

FIGURE 6.4 Specialisation hierarchy

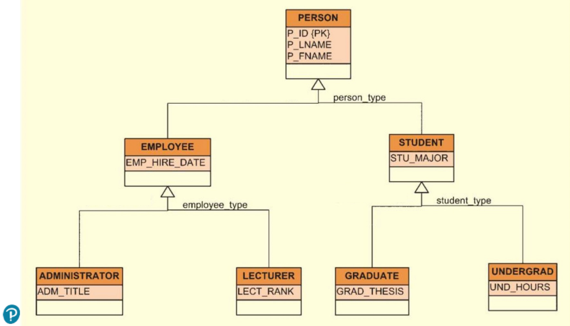

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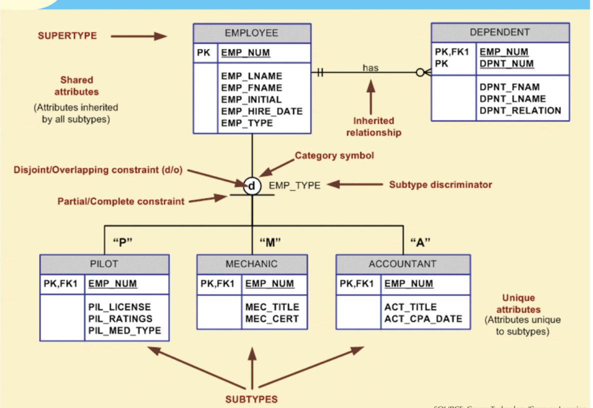
FIGURE 5.2 A specialization hierarchy 25



SOURCE: Course Technology/Cengage Learning

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Inheritance

- Enables entity subtype to inherit attributes and relationships of supertype
- All entity subtypes inherit their primary key attribute from their supertype
- At implementation level, supertype and its subtype(s) maintain a 1:1 relationship
- Entity subtypes inherit all relationships in which supertype entity participates
- Lower-level subtypes inherit all attributes and relationships from all upper-level supertypes

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FIGURE 6.3 **The EMPLOYEE – PILOT supertype – subtype relationship**

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Specialization and Generalization

- Specialization
  - Identifies more specific entity subtypes from higher-level entity supertype
  - Top-down process
  - Based on grouping unique characteristics and relationships of the subtypes
- Generalization
  - Identifies more generic entity supertype from lower-level entity subtypes
  - Bottom-up process
  - Based on grouping common characteristics and relationships of the subtypes
  - Process of defining a generalized entity type from the given entity types

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Generalization

- Generalization is the reverse of the specialization process
- Several classes with common features are generalized into a superclass;
  - original classes become its subclasses
- Example: CAR, TRUCK generalized into VEHICLE;
  - both CAR, TRUCK become subclasses of the superclass VEHICLE.
  - We can view {CAR, TRUCK} as a specialization of VEHICLE
  - Alternatively, we can view VEHICLE as a generalization of CAR and TRUCK
- **Generalize** into a single **superclass**
  - Original entity types are special subclasses

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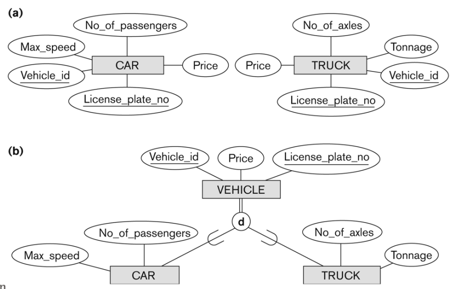
Generalization

Figure 4.3 Generalization. (a) Two entity types, CAR and TRUCK. (b) Generalizing CAR and TRUCK into the superclass VEHICLE.



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Generalization and Specialization

- Data Modeling with Specialization and Generalization
  - A superclass or subclass represents a collection (or set or grouping) of entities
  - It also represents a particular **type of entity**
  - Shown in rectangles in EER diagrams (as are entity types)
  - We can call all entity types (and their corresponding collections) **classes**, whether they are entity types, superclasses, or subclasses

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Specialization/Generalization Hierarchies,

- In **specialization**, start with an entity type and then define subclasses of the entity type by successive specialization
  - called a **top down** conceptual refinement process
- In **generalization**, start with many entity types and generalize those that have common properties
  - Called a **bottom up** conceptual synthesis process
- In practice, a **combination of both processes** is usually employed

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Design Cases: Learning Flexible Database Design

- Data modeling and design requires skills acquired through experience
- Experience acquired through practice
- Four special design cases that highlight:
  - Importance of flexible design
  - Proper identification of primary keys
  - Placement of foreign keys

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Design Case 1: Implementing 1:1 Relationships

- Foreign keys work with primary keys to properly implement relationships in relational model
- Put primary key of the "one" side on the "many" side as foreign key
  - Primary key: parent entity
  - Foreign key: dependent entity
- In 1:1 relationship, there are two options:
  - Place a foreign key in both entities (not recommended)
  - Place a foreign key in one of the entities
    - Primary key of one of the two entities appears as foreign key of other
    - As FK in entity that causes least number of nulls

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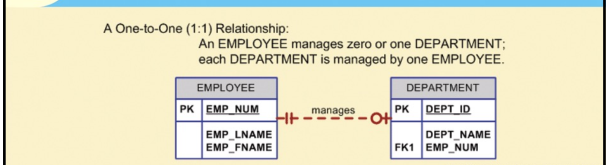
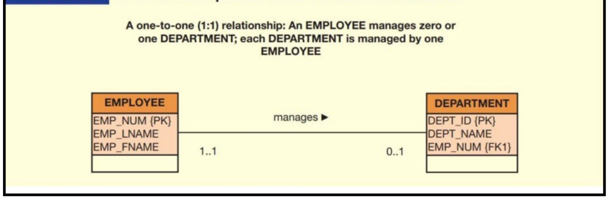
FIGURE 5.7 The 1:1 relationship between DEPARTMENT and EMPLOYEE



SOURCE: Course Technology/Cengage Learning

FIGURE 6.9 A 1:1 relationship between DEPARTMENT and EMPLOYEE



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Design Case 2: Maintaining History of Time-Variant Data

- Normally, existing attribute values are replaced with new value without regard to previous value
- Time-variant data:
  - Values change over time
  - Must keep a history of data changes
- Keeping history of time-variant data equivalent to having a multivalued attribute in your entity
- Must create new entity in 1:M relationships with original entity
- New entity contains new value, date of change

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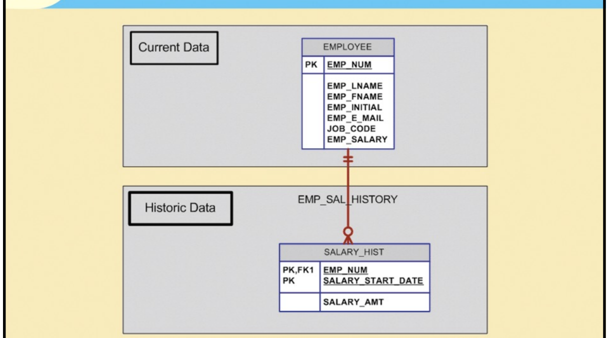
FIGURE 5.8 Maintaining salary history



SOURCE: Course Technology/Cengage Learning

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FIGURE 6.10 Maintaining manager history

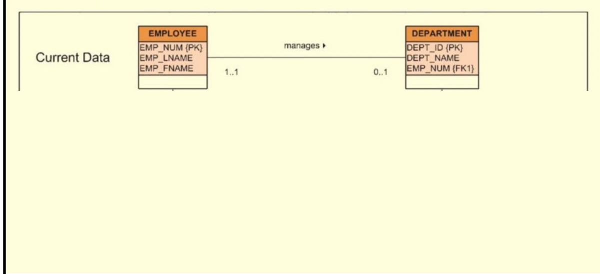

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FIGURE 6.10 Maintaining manager history

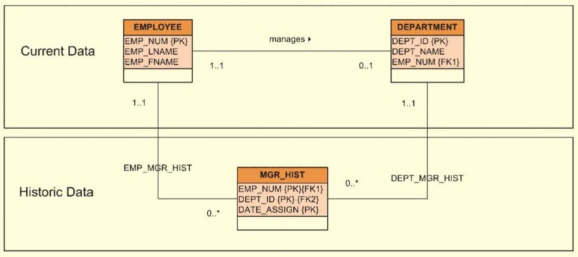

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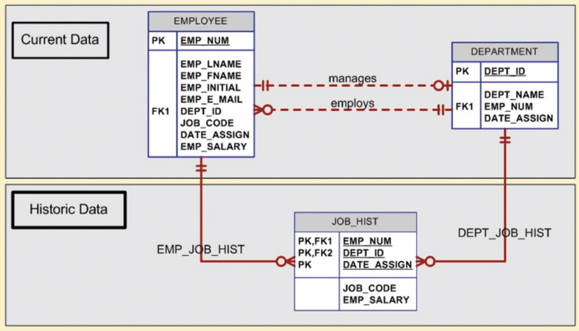
FIGURE 5.10 Maintaining job history



SOURCE: Course Technology/Cengage Learning

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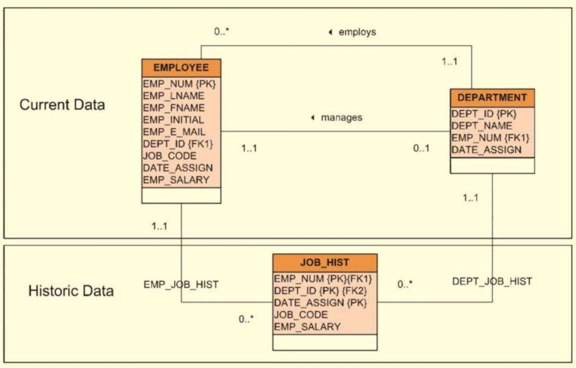
FIGURE 6.11 Maintaining job history



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Design Case 3: Fan Traps

- Design trap occurs when relationship is improperly or incompletely identified
  - Represented in a way not consistent with the real world
- Most common design trap is known as fan trap
- Fan trap occurs when one entity is in two 1:M relationships to other entities
  - Produces an association among other entities not expressed in the model

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FIGURE 5.11 Incorrect ERD with fan trap problem

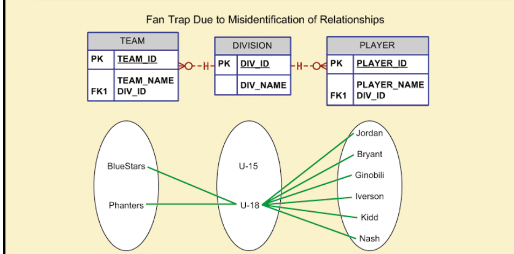

FIGURE 6.12 Incorrect ERD with fan trap problem

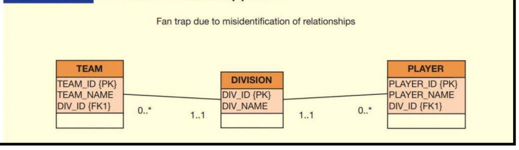

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FIGURE 5.12 Corrected ERD after removal of the fan trap

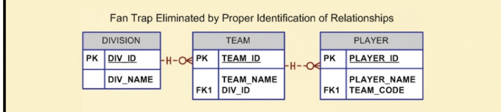
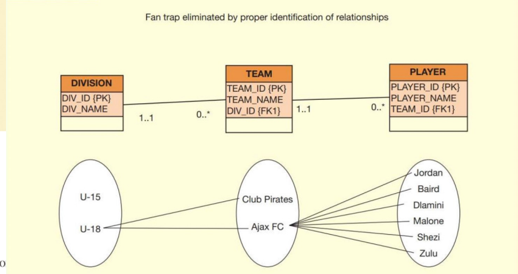


FIGURE 6.13 Corrected ERD after removal of the fan trap



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Design Case 4: Redundant Relationships

- Redundancy is seldom a good thing in database environment
- Occurs when there are multiple relationship paths between related entities
- Main concern is that redundant relationships remain consistent across model
- Some designs use redundant relationships to simplify the design

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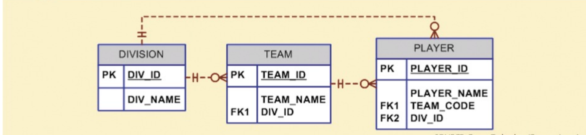
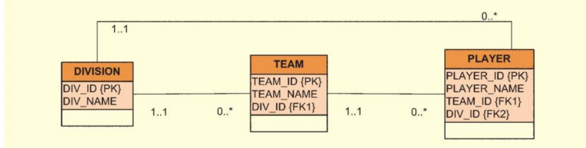
FIGURE 5.13 A redundant relationship



SOURCE: Course Technology/Cengage Learning

FIGURE 6.14 A redundant relationship



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Summary

- Extended entity relationship (EER) model adds semantics to ER model
  - Adds semantics via entity supertypes and subtypes
  - Entity supertype is a generic entity type related to one or more entity subtypes
- Specialization hierarchy
  - Depicts arrangement and relationships between entity supertypes and entity subtypes
- Inheritance means an entity subtype inherits attributes and relationships of supertype

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Summary (cont'd.)

- Composite keys are useful to represent
  - M:N relationships
- In a 1:1 relationship, place the PK of mandatory entity:
  - As FK in optional entity
  - As FK in entity that causes least number of nulls
  - As FK where the role is played

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Summary (cont'd.)

- Time-variant data
  - Data whose values change over time
  - Requires keeping a history of changes
- To maintain history of time-variant data:
  - Create entity containing the new value, date of change, other time-relevant data
  - Entity maintains 1:M relationship with entity for which history maintained

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Summary (cont'd.)

- Fan trap:
  - One entity in two 1:M relationships to other entities
  - Association among the other entities not expressed in model
- Redundant relationships occur when multiple relationship paths between related entities
  - Main concern is that they remain consistent across the model

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Logical Design

- When the conceptual design is completed, the ERD reflects the business rules that define the entities, relationships, optionalities, connectivities, cardinalities and constraints.
- Conceptual model's entities must be normalized before they are implemented.
- Logical design translates conceptual model to format for selected DBMS
- Table structures are created, relationships are established

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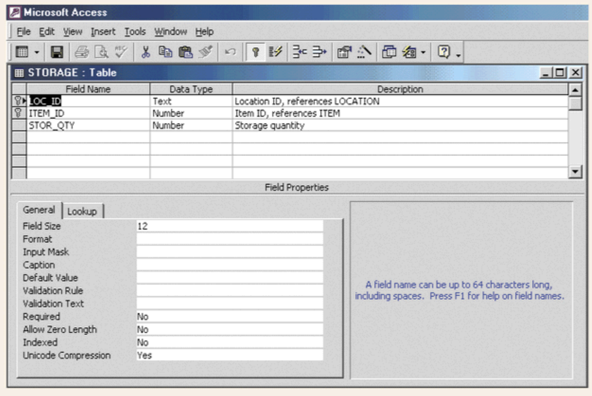

The STORAGE Table Structure Defined in Microsoft Access

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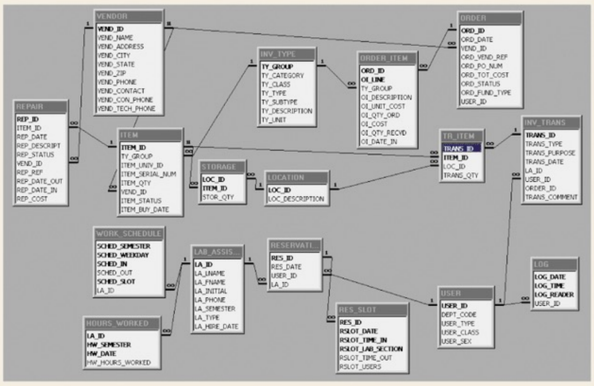

The COMPUTER LAB Database

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