

3.7 ER Diagrams, Naming Conventions, and Design Issues

3.7.1 Summary of Notation for ER Diagrams

Figures 3.9 through 3.13 illustrate examples of the participation of entity types in relationship types by displaying their entity sets and relationship sets (or extensions)—the individual entity instances in an entity set and the individual relationship instances in a relationship set. In ER diagrams the emphasis is on representing the schemas rather than the instances. This is more useful in database design because a database schema changes rarely, whereas the contents of the entity sets may change frequently. In addition, the schema is obviously easier to display, because it is much smaller.

Figure 3.2 displays the COMPANY ER database schema as an ER diagram. We now review the full ER diagram notation. Regular (strong) entity types such as EMPLOYEE, DEPARTMENT, and PROJECT are shown in rectangular boxes. Relationship types such as WORKS_FOR, MANAGES, CONTROLS, and WORKS_ON are shown in diamond-shaped boxes attached to the participating entity types with straight lines. Attributes are shown in ovals, and each attribute is attached by a straight line to its entity type or relationship type. Component attributes of a composite attribute are attached to the oval representing the composite attribute, as illustrated by the Name attribute of EMPLOYEE. Multivalued attributes are shown in double ovals, as illustrated by the Locations attribute of DEPARTMENT. Key attributes have their names underlined. Derived attributes are shown in dotted ovals, as illustrated by the Number_of_employees attribute of DEPARTMENT.

Weak entity types are distinguished by being placed in double rectangles and by having their identifying relationship placed in double diamonds, as illustrated by the DEPENDENT entity type and the DEPENDENTS_OF identifying relationship type. The partial key of the weak entity type is underlined with a dotted line.

In Figure 3.2 the cardinality ratio of each *binary* relationship type is specified by attaching a 1, M, or N on each participating edge. The cardinality ratio of DEPARTMENT:EMPLOYEE in MANAGES is 1:1, whereas it is 1:N for DEPARTMENT:EMPLOYEE in WORKS_FOR, and M:N for WORKS_ON. The participation constraint is specified by a single line for partial participation and by double lines for total participation (existence dependency).

In Figure 3.2 we show the role names for the SUPERVISION relationship type because the same EMPLOYEE entity type plays two distinct roles in that relationship. Notice that the cardinality ratio is 1:N from supervisor to supervisee because each employee in the role of supervisee has at most one direct supervisor, whereas an employee in the role of supervisor can supervise zero or more employees.

Figure 3.14 summarizes the conventions for ER diagrams. It is important to note that there are many other alternative diagrammatic notations (see Section 3.7.4 and Appendix A).

3.7.2 Proper Naming of Schema Constructs

When designing a database schema, the choice of names for entity types, attributes, relationship types, and (particularly) roles is not always straightforward. One should choose names that convey, as much as possible, the meanings attached to the different constructs in the schema. We choose to use *singular names* for entity types, rather than plural ones, because the entity type name applies to each individual entity belonging to that entity type. In our ER diagrams, we will use the convention that entity type and relationship type names are in uppercase letters, attribute names have their initial letter capitalized, and role names are in lowercase letters. We have used this convention in Figure 3.2.

As a general practice, given a narrative description of the database requirements, the *nouns* appearing in the narrative tend to give rise to entity type names, and the *verbs* tend to indicate names of relationship types. Attribute names generally arise from additional nouns that describe the nouns corresponding to entity types.







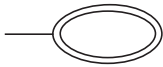
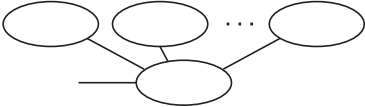

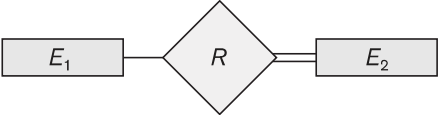

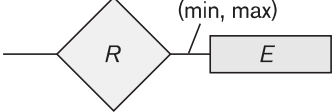
Another naming consideration involves choosing binary relationship names to make the ER diagram of the schema readable from left to right and from top to bottom. We have generally followed this guideline in Figure 3.2. To explain this naming convention further, we have one exception to the convention in Figure 3.2—the `DEPENDENTS_OF` relationship type, which reads from bottom to top. When we describe this relationship, we can say that the `DEPENDENT` entities (bottom entity type) are `DEPENDENTS_OF` (relationship name) an `EMPLOYEE` (top entity type). To change this to read from top to bottom, we could rename the relationship type to `HAS_DEPENDENTS`, which would then read as follows: An `EMPLOYEE` entity (top entity type) `HAS_DEPENDENTS` (relationship name) of type `DEPENDENT` (bottom entity type). Notice that this issue arises because each binary relationship can be described starting from either of the two participating entity types, as discussed in the beginning of Section 3.4.

3.7.3 Design Choices for ER Conceptual Design

It is occasionally difficult to decide whether a particular concept in the miniworld should be modeled as an entity type, an attribute, or a relationship type. In this section, we give some brief guidelines as to which construct should be chosen in particular situations.

In general, the schema design process should be considered an iterative refinement process, where an initial design is created and then iteratively refined until the most suitable design is reached. Some of the refinements that are often used include the following:

- A concept may be first modeled as an attribute and then refined into a relationship because it is determined that the attribute is a reference to another entity type. It is often the case that a pair of such attributes that are inverses of one another are refined into a binary relationship. We discussed this type of refinement in detail in Section 3.6. It is important to note that in our notation,

Symbol	Meaning	Figure 3.14 Summary of the notation for ER diagrams.
	Entity	
	Weak Entity	
	Relationship	
	Identifying 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	

once an attribute is replaced by a relationship, the attribute itself should be removed from the entity type to avoid duplication and redundancy.

- Similarly, an attribute that exists in several entity types may be elevated or promoted to an independent entity type. For example, suppose that each of several entity types in a UNIVERSITY database, such as STUDENT, INSTRUCTOR, and COURSE, has an attribute Department in the initial design; the designer may then choose to create an entity type DEPARTMENT with a single attribute Dept_name and relate it to the three entity types (STUDENT, INSTRUCTOR, and COURSE) via appropriate relationships. Other attributes/relationships of DEPARTMENT may be discovered later.
- An inverse refinement to the previous case may be applied—for example, if an entity type DEPARTMENT exists in the initial design with a single attribute Dept_name and is related to only one other entity type, STUDENT. In this case, DEPARTMENT may be reduced or demoted to an attribute of STUDENT.
- Section 3.9 discusses choices concerning the degree of a relationship. In Chapter 4, we discuss other refinements concerning specialization/generalization.

3.7.4 Alternative Notations for ER Diagrams

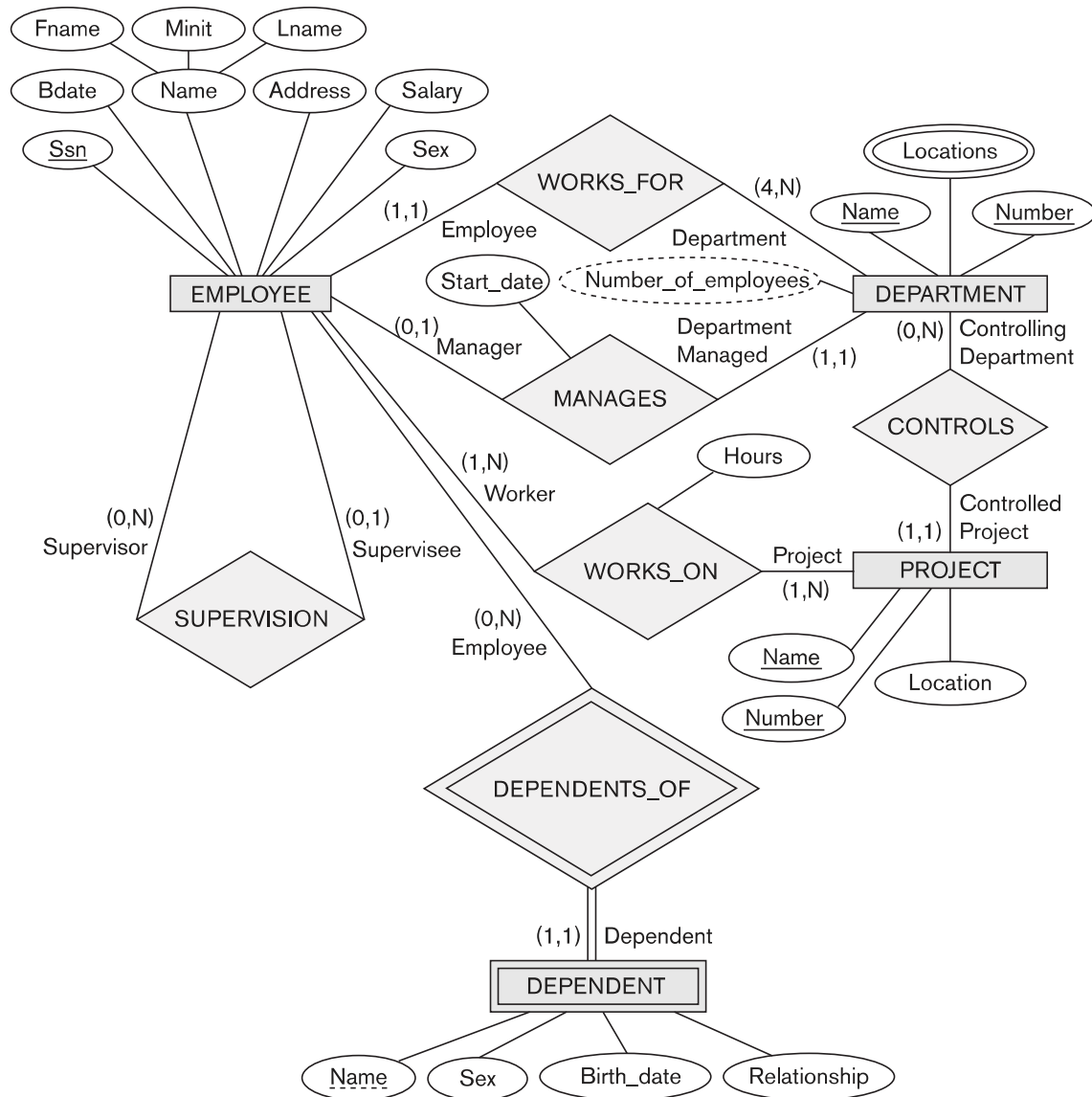
There are many alternative diagrammatic notations for displaying ER diagrams. Appendix A gives some of the more popular notations. In Section 3.8, we introduce the Unified Modeling Language (UML) notation for class diagrams, which has been proposed as a standard for conceptual object modeling.

In this section, we describe one alternative ER notation for specifying structural constraints on relationships, which replaces the cardinality ratio (1:1, 1:N, M:N) and single/double-line notation for participation constraints. This notation involves associating a pair of integer numbers (min, max) with each *participation* of an entity type E in a relationship type R , where $0 \leq \min \leq \max$ and $\max \geq 1$. The numbers mean that for each entity e in E , e must participate in at least *min* and at most *max* relationship instances in R at any point in time. In this method, $\min = 0$ implies partial participation, whereas $\min > 0$ implies total participation.

Figure 3.15 displays the COMPANY database schema using the (min, max) notation.¹⁴ Usually, one uses either the cardinality ratio/single-line/double-line notation or the (min, max) notation. The (min, max) notation is more precise, and we can use it to specify some structural constraints for relationship types of *higher degree*. However, it is not sufficient for specifying some key constraints on higher-degree relationships, as discussed in Section 3.9.

Figure 3.15 also displays all the role names for the COMPANY database schema.

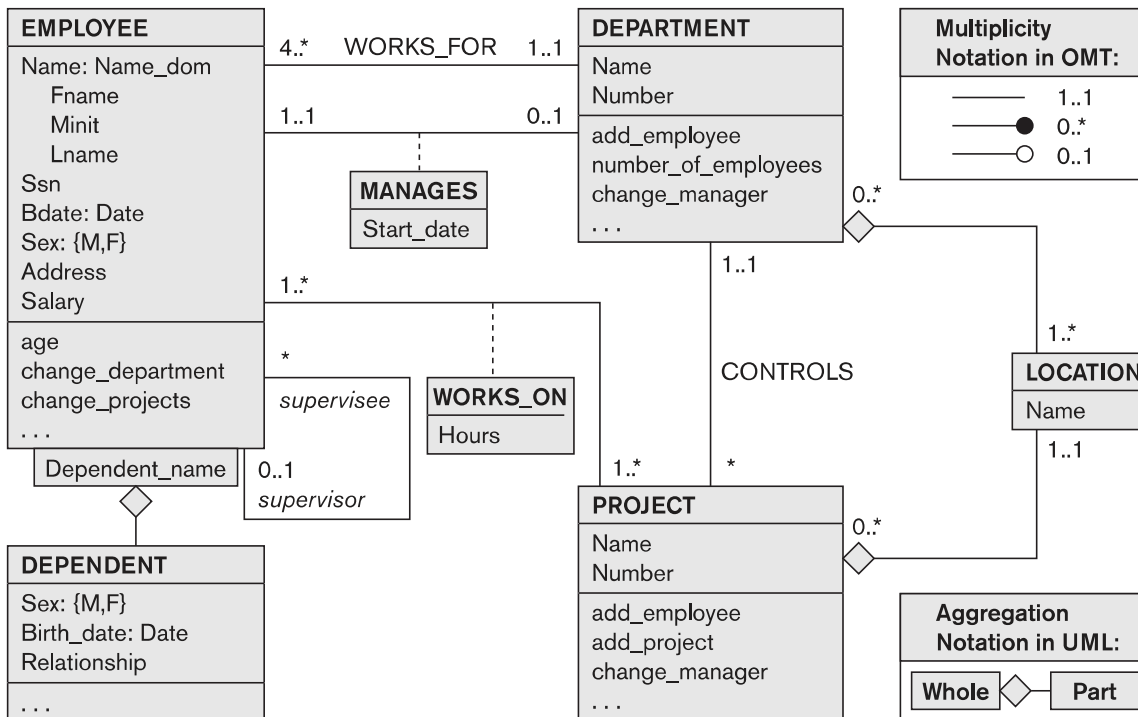
¹⁴In some notations, particularly those used in object modeling methodologies such as UML, the (min, max) is placed on the *opposite sides* to the ones we have shown. For example, for the WORKS_FOR relationship in Figure 3.15, the (1,1) would be on the DEPARTMENT side, and the (4,N) would be on the EMPLOYEE side. Here we used the original notation from Abrial (1974).

**Figure 3.15**

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

3.8 Example of Other Notation: UML Class Diagrams

The UML methodology is being used extensively in software design and has many types of diagrams for various software design purposes. We only briefly present the basics of **UML class diagrams** here and compare them with ER diagrams. In some

**Figure 3.16**

The COMPANY conceptual schema in UML class diagram notation.

ways, class diagrams can be considered as an alternative notation to ER diagrams. Additional UML notation and concepts are presented in Section 8.6. Figure 3.16 shows how the COMPANY ER database schema in Figure 3.15 can be displayed using UML class diagram notation. The *entity types* in Figure 3.15 are modeled as *classes* in Figure 3.16. An *entity* in ER corresponds to an *object* in UML.

In UML class diagrams, a **class** (similar to an entity type in ER) is displayed as a box (see Figure 3.16) that includes three sections: The top section gives the **class name** (similar to entity type name); the middle section includes the **attributes**; and the last section includes **operations** that can be applied to individual objects (similar to individual entities in an entity set) of the class. Operations are *not* specified in ER diagrams. Consider the EMPLOYEE class in Figure 3.16. Its attributes are Name, Ssn, Bdate, Sex, Address, and Salary. The designer can optionally specify the **domain** (or data type) of an attribute if desired, by placing a colon (:) followed by the domain name or description, as illustrated by the Name, Sex, and Bdate attributes of EMPLOYEE in Figure 3.16. A composite attribute is modeled as a **structured domain**, as illustrated by the Name attribute of EMPLOYEE. A multivalued attribute will generally be modeled as a separate class, as illustrated by the LOCATION class in Figure 3.16.

Relationship types are called **associations** in UML terminology, and relationship instances are called **links**. A **binary association** (binary relationship type) is represented as a line connecting the participating classes (entity types), and may optionally have a name. A relationship attribute, called a **link attribute**, is placed in a box that is connected to the association's line by a dashed line. The (min, max) notation described in Section 3.7.4 is used to specify relationship constraints, which are called **multiplicities** in UML terminology. Multiplicities are specified in the form *min..max*, and an asterisk (*) indicates no maximum limit on participation. However, the multiplicities are placed *on the opposite ends of the relationship* when compared with the (min, max) notation discussed in Section 3.7.4 (compare Figures 3.15 and 3.16). In UML, a single asterisk indicates a multiplicity of 0..*, and a single 1 indicates a multiplicity of 1..1. A recursive relationship type (see Section 3.4.2) is called a **reflexive association** in UML, and the role names—like the multiplicities—are placed at the opposite ends of an association when compared with the placing of role names in Figure 3.15.

In UML, there are two types of relationships: association and aggregation. **Aggregation** is meant to represent a relationship between a whole object and its component parts, and it has a distinct diagrammatic notation. In Figure 3.16, we modeled the locations of a department and the single location of a project as aggregations. However, aggregation and association do not have different structural properties, and the choice as to which type of relationship to use—aggregation or association—is somewhat subjective. In the ER model, both are represented as relationships.

UML also distinguishes between **unidirectional** and **bidirectional** associations (or aggregations). In the unidirectional case, the line connecting the classes is displayed with an arrow to indicate that only one direction for accessing related objects is needed. If no arrow is displayed, the bidirectional case is assumed, which is the default. For example, if we always expect to access the manager of a department starting from a DEPARTMENT object, we would draw the association line representing the MANAGES association with an arrow from DEPARTMENT to EMPLOYEE. In addition, relationship instances may be specified to be **ordered**. For example, we could specify that the employee objects related to each department through the WORKS_FOR association (relationship) should be ordered by their Start_date attribute value. Association (relationship) names are *optional* in UML, and relationship attributes are displayed in a box attached with a dashed line to the line representing the association/aggregation (see Start_date and Hours in Figure 3.16).

The operations given in each class are derived from the functional requirements of the application, as we discussed in Section 3.1. It is generally sufficient to specify the operation names initially for the logical operations that are expected to be applied to individual objects of a class, as shown in Figure 3.16. As the design is refined, more details are added, such as the exact argument types (parameters) for each operation, plus a functional description of each operation. UML has *function descriptions* and *sequence diagrams* to specify some of the operation details, but these are beyond the scope of our discussion.

Weak entities can be modeled using the UML construct called **qualified association** (or **qualified aggregation**); this can represent both the identifying relationship and the partial key, which is placed in a box attached to the owner class. This is illustrated by the `DEPENDENT` class and its qualified aggregation to `EMPLOYEE` in Figure 3.16. In UML terminology, the partial key attribute `Dependent_name` is called the **discriminator**, because its value distinguishes the objects associated with (related to) the same `EMPLOYEE` entity. Qualified associations are not restricted to modeling weak entities, and they can be used to model other situations in UML.

This section is not meant to be a complete description of UML class diagrams, but rather to illustrate one popular type of alternative diagrammatic notation that can be used for representing ER modeling concepts.

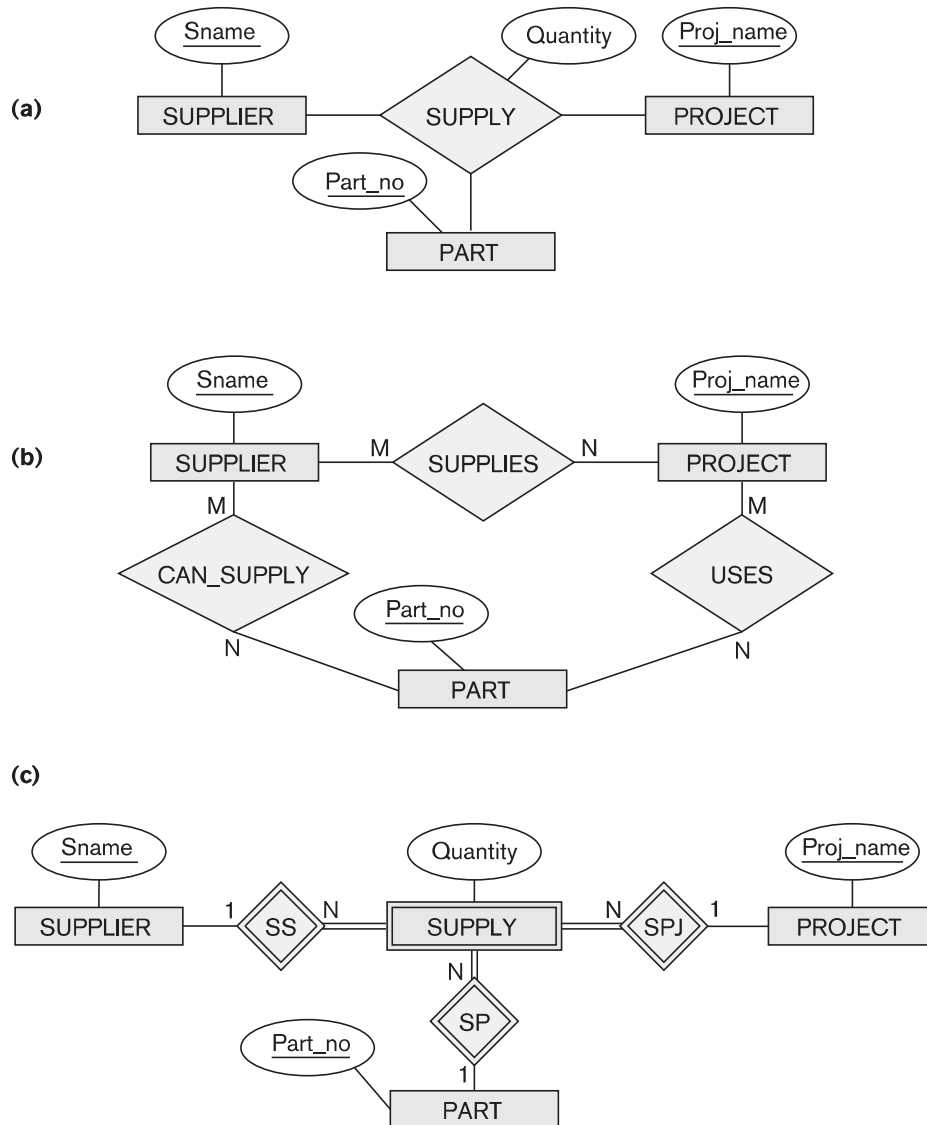
3.9 Relationship Types of Degree Higher than Two

In Section 3.4.2 we defined the **degree** of a relationship type as the number of participating entity types and called a relationship type of degree two *binary* and a relationship type of degree three *ternary*. In this section, we elaborate on the differences between binary and higher-degree relationships, when to choose higher-degree versus binary relationships, and how to specify constraints on higher-degree relationships.

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

The ER diagram notation for a ternary relationship type is shown in Figure 3.17(a), which displays the schema for the `SUPPLY` relationship type that was displayed at the instance level in Figure 3.10. Recall that the relationship set of `SUPPLY` is a set of relationship instances (s, j, p) , where the meaning is that s is a `SUPPLIER` who is currently supplying a `PART` p to a `PROJECT` j . In general, a relationship type R of degree n will have n edges in an ER diagram, one connecting R to each participating entity type.

Figure 3.17(b) shows an ER diagram for three binary relationship types `CAN_SUPPLY`, `USES`, and `SUPPLIES`. In general, a ternary relationship type represents different information than do three binary relationship types. Consider the three binary relationship types `CAN_SUPPLY`, `USES`, and `SUPPLIES`. Suppose that `CAN_SUPPLY`, between `SUPPLIER` and `PART`, includes an instance (s, p) whenever supplier s *can supply* part p (to any project); `USES`, between `PROJECT` and `PART`, includes an instance (j, p) whenever project j uses part p ; and `SUPPLIES`, between `SUPPLIER` and `PROJECT`, includes an instance (s, j) whenever supplier s supplies *some part* to project j . The existence of three relationship instances (s, p) , (j, p) , and (s, j) in `CAN_SUPPLY`, `USES`, and `SUPPLIES`, respectively, does not necessarily imply that an instance (s, j, p) exists in the ternary relationship `SUPPLY`, because the *meaning is different*. It is often tricky to decide whether a particular relationship should be represented as a relationship type of degree n or should be

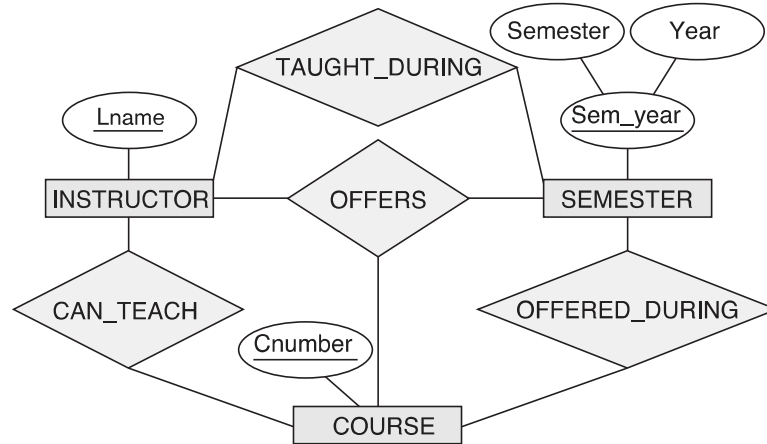
**Figure 3.17**

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

broken down into several relationship types of smaller degrees. The designer must base this decision on the semantics or meaning of the particular situation being represented. The typical solution is to include the ternary relationship *plus* one or more of the binary relationships, if they represent different meanings and if all are needed by the application.

Figure 3.18

Another example of ternary versus binary relationship types.



Some database design tools are based on variations of the ER model that permit only binary relationships. In this case, a ternary relationship such as SUPPLY must be represented as a weak entity type, with no partial key and with three identifying relationships. The three participating entity types SUPPLIER, PART, and PROJECT are together the owner entity types (see Figure 3.17(c)). Hence, an entity in the weak entity type SUPPLY in Figure 3.17(c) is identified by the combination of its three owner entities from SUPPLIER, PART, and PROJECT.

It is also possible to represent the ternary relationship as a regular entity type by introducing an artificial or surrogate key. In this example, a key attribute Supply_id could be used for the supply entity type, converting it into a regular entity type. Three binary N:1 relationships relate SUPPLY to each of the three participating entity types.

Another example is shown in Figure 3.18. The ternary relationship type OFFERS represents information on instructors offering courses during particular semesters; hence it includes a relationship instance (i, s, c) whenever INSTRUCTOR i offers COURSE c during SEMESTER s . The three binary relationship types shown in Figure 3.18 have the following meanings: CAN_TEACH relates a course to the instructors who *can teach* that course, TAUGHT_DURING relates a semester to the instructors who *taught some course* during that semester, and OFFERED_DURING relates a semester to the courses offered during that semester *by any instructor*. These ternary and binary relationships represent different information, but certain constraints should hold among the relationships. For example, a relationship instance (i, s, c) should not exist in OFFERS *unless* an instance (i, s) exists in TAUGHT_DURING, an instance (s, c) exists in OFFERED_DURING, and an instance (i, c) exists in CAN_TEACH. However, the reverse is not always true; we may have instances (i, s) , (s, c) , and (i, c) in the three binary relationship types with no corresponding instance (i, s, c) in OFFERS. Note that in this example, based on the meanings of the relationships, we can infer the instances of TAUGHT_DURING and OFFERED_DURING from the instances in OFFERS, but

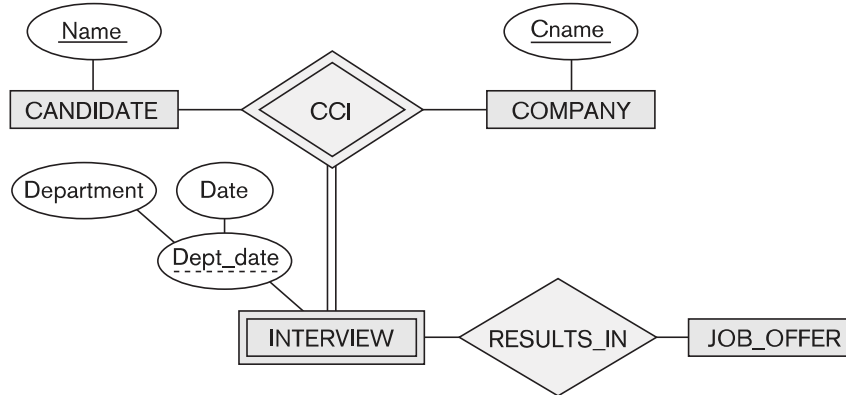


Figure 3.19
A weak entity type
INTERVIEW with a
ternary identifying
relationship type.

we cannot infer the instances of CAN_TEACH; therefore, TAUGHT_DURING and OFFERED_DURING are redundant and can be left out.

Although in general three binary relationships *cannot* replace a ternary relationship, they may do so under certain *additional constraints*. In our example, if the CAN_TEACH relationship is 1:1 (an instructor can teach only one course, and a course can be taught by only one instructor), then the ternary relationship OFFERS can be left out because it can be inferred from the three binary relationships CAN_TEACH, TAUGHT_DURING, and OFFERED_DURING. The schema designer must analyze the meaning of each specific situation to decide which of the binary and ternary relationship types are needed.

Notice that it is possible to have a weak entity type with a ternary (or n -ary) identifying relationship type. In this case, the weak entity type can have *several* owner entity types. An example is shown in Figure 3.19. This example shows part of a database that keeps track of candidates interviewing for jobs at various companies, which may be part of an employment agency database. In the requirements, a candidate can have multiple interviews with the same company (for example, with different company departments or on separate dates), but a job offer is made based on one of the interviews. Here, INTERVIEW is represented as a weak entity with two owners CANDIDATE and COMPANY, and with the partial key Dept_date. An INTERVIEW entity is uniquely identified by a candidate, a company, and the combination of the date and department of the interview.

3.9.2 Constraints on Ternary (or Higher-Degree) Relationships

There are two notations for specifying structural constraints on n -ary relationships, and they specify different constraints. They should thus *both be used* if it is important to fully specify the structural constraints on a ternary or higher-degree relationship. The first notation is based on the cardinality ratio notation of binary relationships displayed in Figure 3.2. Here, a 1, M, or N is specified on each

participation arc (both M and N symbols stand for *many* or *any number*).¹⁵ Let us illustrate this constraint using the SUPPLY relationship in Figure 3.17.

Recall that the relationship set of SUPPLY is a set of relationship instances (s, j, p) , where s is a SUPPLIER, j is a PROJECT, and p is a PART. Suppose that the constraint exists that for a particular project-part combination, only one supplier will be used (only one supplier supplies a particular part to a particular project). In this case, we place 1 on the SUPPLIER participation, and M, N on the PROJECT, PART participations in Figure 3.17. This specifies the constraint that a particular (j, p) combination can appear at most once in the relationship set because each such (PROJECT, PART) combination uniquely determines a single supplier. Hence, any relationship instance (s, j, p) is uniquely identified in the relationship set by its (j, p) combination, which makes (j, p) a key for the relationship set. In this notation, the participations that have a 1 specified on them are not required to be part of the identifying key for the relationship set.¹⁶ If all three cardinalities are M or N, then the key will be the combination of all three participants.

The second notation is based on the (min, max) notation displayed in Figure 3.15 for binary relationships. A (min, max) on a participation here specifies that each entity is related to at least *min* and at most *max relationship instances* in the relationship set. These constraints have no bearing on determining the key of an n -ary relationship, where $n > 2$,¹⁷ but specify a different type of constraint that places restrictions on how many relationship instances each entity can participate in.

3.10 Another Example: A UNIVERSITY Database

We now present another example, a UNIVERSITY database, to illustrate the ER modeling concepts. Suppose that a database is needed to keep track of student enrollments in classes and students' final grades. After analyzing the miniworld rules and the users' needs, the requirements for this database were determined to be as follows (for brevity, we show the chosen entity type names and attribute names for the conceptual schema in parentheses as we describe the requirements; relationship type names are only shown in the ER schema diagram):

- The university is organized into colleges (COLLEGE), and each college has a unique name (CName), a main office (COffice) and phone (CPhone), and a particular faculty member who is dean of the college. Each college administers a number of academic departments (DEPT). Each department has a unique name (DName), a unique code number (DCode), a main office (DOOffice) and phone (DPhone), and a particular faculty member who chairs the department. We keep track of the start date (CStartDate) when that faculty member began chairing the department.

¹⁵This notation allows us to determine the key of the *relationship relation*, as we discuss in Chapter 9.

¹⁶This is also true for cardinality ratios of binary relationships.

¹⁷The (min, max) constraints can determine the keys for binary relationships.

- A department offers a number of courses (COURSE), each of which has a unique course name (CoName), a unique code number (CCode), a course level (Level: this can be coded as 1 for freshman level, 2 for sophomore, 3 for junior, 4 for senior, 5 for MS level, and 6 for PhD level), a course credit hours (Credits), and a course description (CDesc). The database also keeps track of instructors (INSTRUCTOR); and each instructor has a unique identifier (Id), name (IName), office (IOffice), phone (IPhone), and rank (Rank); in addition, each instructor works for one primary academic department.
- The database will keep student data (STUDENT) and stores each student's name (SName, composed of first name (FName), middle name (MName), last name (LName)), student id (Sid, unique for every student), address (Addr), phone (Phone), major code (Major), and date of birth (DoB). A student is assigned to one primary academic department. It is required to keep track of the student's grades in each section the student has completed.
- Courses are offered as sections (SECTION). Each section is related to a single course and a single instructor and has a unique section identifier (SecId). A section also has a section number (SecNo: this is coded as 1, 2, 3, . . . for multiple sections offered during the same semester/year), semester (Sem), year (Year), classroom (CRoom: this is coded as a combination of building code (Bldg) and room number (RoomNo) within the building), and days/times (DaysTime: for example, 'MWF 9am-9.50am' or 'TR 3.30pm-5.20pm'—restricted to only allowed days/time values). (*Note:* The database will keep track of all the sections offered for the past several years, in addition to the current offerings. The SecId is unique for all sections, not just the sections for a particular semester.) The database keeps track of the students in each section, and the grade is recorded when available (this is a many-to-many relationship between students and sections). A section must have at least five students.

The ER diagram for these requirements is shown in Figure 3.20 using the min-max ER diagrammatic notation. Notice that for the SECTION entity type, we only showed SecID as an underlined key, but because of the miniworld constraints, several other combinations of values have to be unique for each section entity. For example, each of the following combinations must be unique based on the typical miniworld constraints:

1. (SecNo, Sem, Year, CCode (of the COURSE related to the SECTION)): This specifies that the section numbers of a particular course must be different during each particular semester and year.
2. (Sem, Year, CRoom, DaysTime): This specifies that in a particular semester and year, a classroom cannot be used by two different sections at the same days/time.
3. (Sem, Year, DaysTime, Id (of the INSTRUCTOR teaching the SECTION)): This specifies that in a particular semester and year, an instructor cannot teach two sections at the same days/time. Note that this rule will not apply if an instructor is allowed to teach two combined sections together in the particular university.

Can you think of any other attribute combinations that have to be unique?

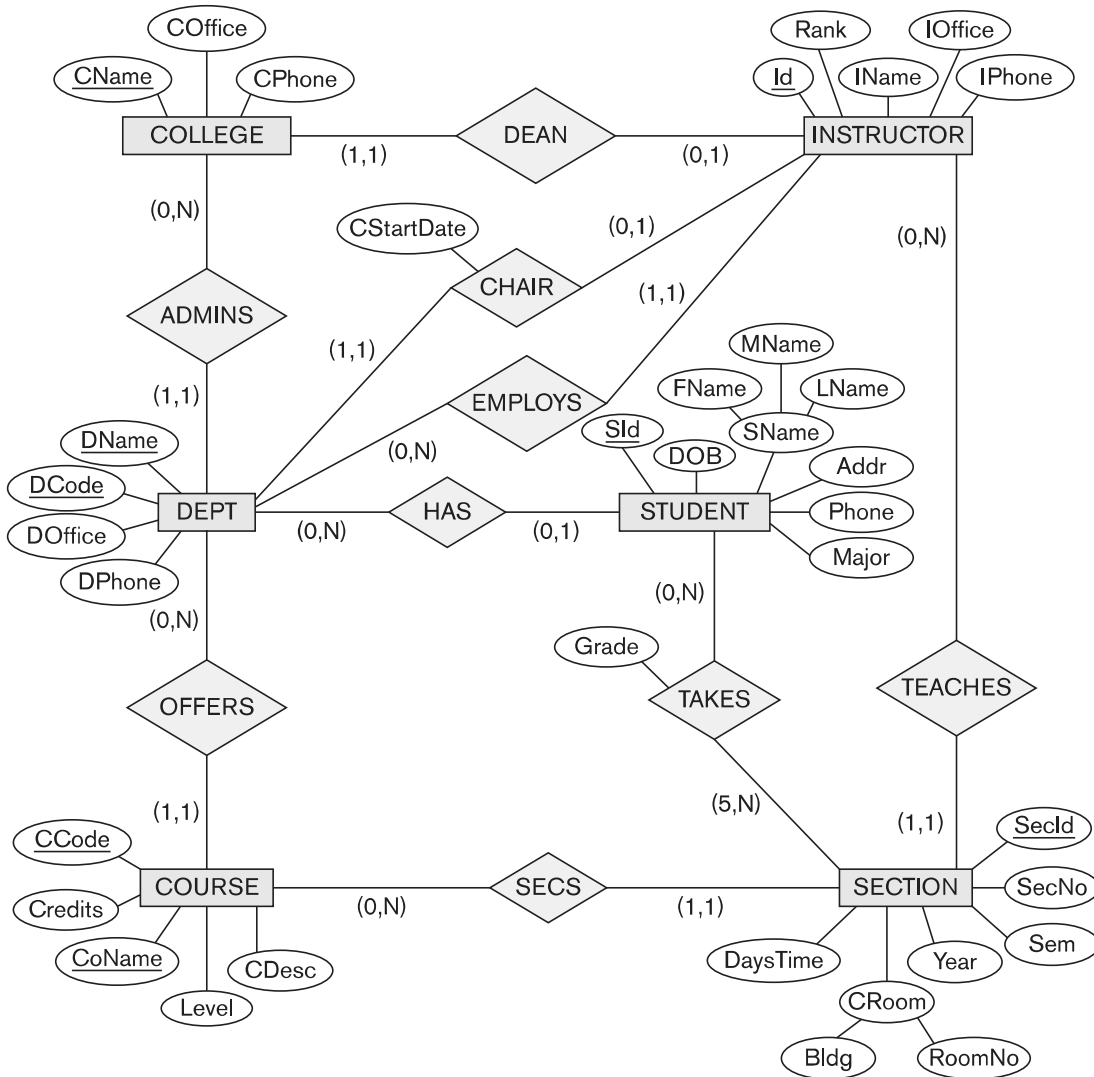


Figure 3.20
An ER diagram for a UNIVERSITY database schema.

3.11 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

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

We presented two methods for specifying the structural constraints on relationship types. The first method distinguished two types of structural constraints:

- Cardinality ratios (1:1, 1:N, M:N for binary relationships)
- Participation constraints (total, partial)

We noted that, alternatively, another method of specifying structural constraints is to specify minimum and maximum numbers (min, max) on the participation of each entity type in a relationship type. We discussed weak entity types and the related concepts of owner entity types, identifying relationship types and partial key attributes.

Entity–relationship schemas can be represented diagrammatically as ER diagrams. We showed how to design an ER schema for the COMPANY database by first defining the entity types and their attributes and then refining the design to include relationship types. We displayed the ER diagram for the COMPANY database schema. We discussed some of the basic concepts of UML class diagrams and how they relate to ER modeling concepts. We also described ternary and higher-degree relationship types in more detail, and we discussed the circumstances under which they are distinguished from binary relationships. Finally, we presented requirements for a UNIVERSITY database schema as another example, and we showed the ER schema design.

The ER modeling concepts we have presented thus far—entity types, relationship types, attributes, keys, and structural constraints—can model many database applications. However, more complex applications—such as engineering design, medical information systems, and telecommunications—require additional concepts if we want to model them with greater accuracy. We discuss some advanced modeling concepts in Chapter 8 and revisit further advanced data modeling techniques in Chapter 26.