ER Model to Relational Model

ER Model, when conceptualized into diagrams, gives a good overview of entity relationship, which is easier to understand. ER diagrams can be mapped to relational schema, that is, it is possible to create relational schema using ER diagram. We cannot import all the ER constraints into relational model, but an approximate schema can be generated.

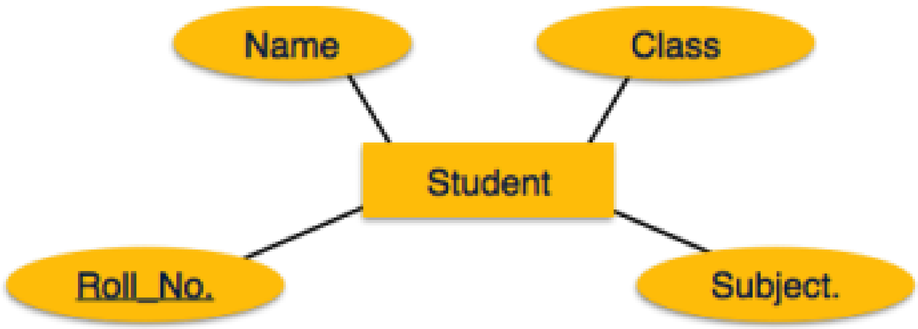
There are several processes and algorithms available to convert ER Diagrams into Relational Schema. Some of them are automated and some of them are manual. We may focus here on the mapping diagram contents to relational basics.

ER diagrams mainly comprise of −

- Entity and its attributes
- Relationship, which is association among entities.

Mapping Entity

An entity is a real-world object with some attributes.

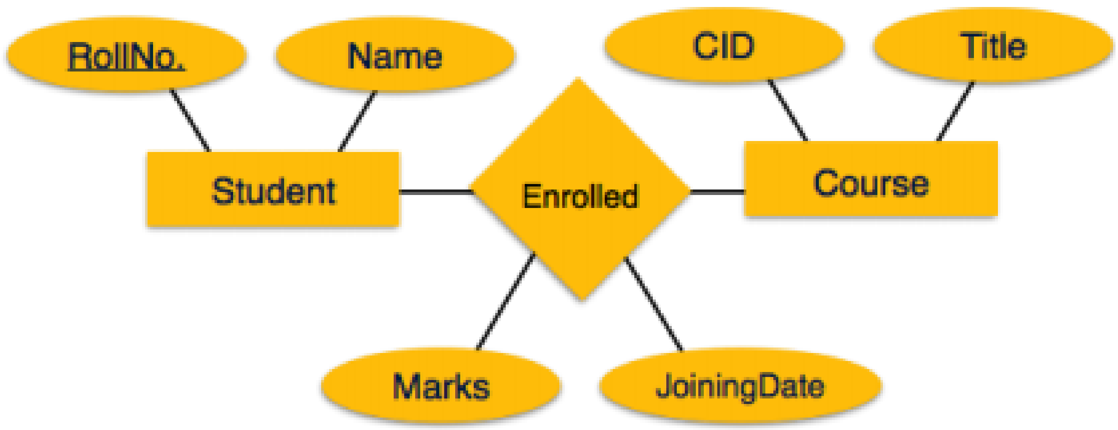


Mapping Process (Algorithm)

- Create table for each entity.
- Entity's attributes should become fields of tables with their respective data types.
- Declare primary key.

Mapping Relationship

A relationship is an association among entities.

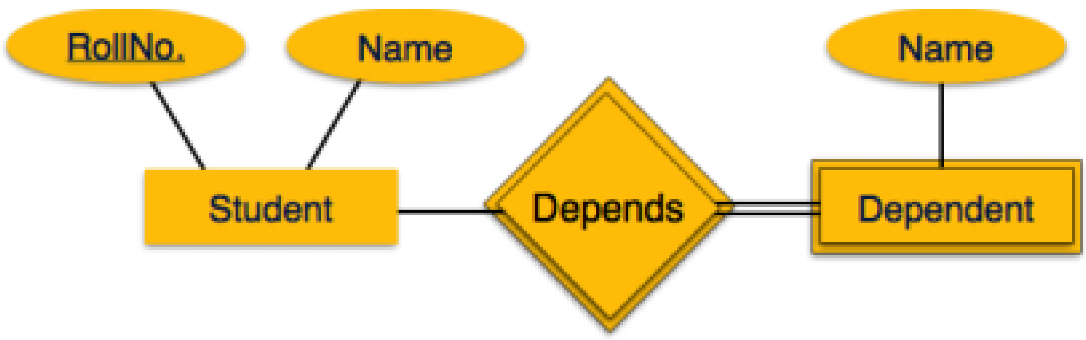


Mapping Process

- Create table for a relationship.
- Add the primary keys of all participating Entities as fields of table with their respective data types.
- If relationship has any attribute, add each attribute as field of table. · Declare a primary key composing all the primary keys of participating entities.
- Declare all foreign key constraints.

Mapping Weak Entity Sets

A weak entity set is one which does not have any primary key associated with it.

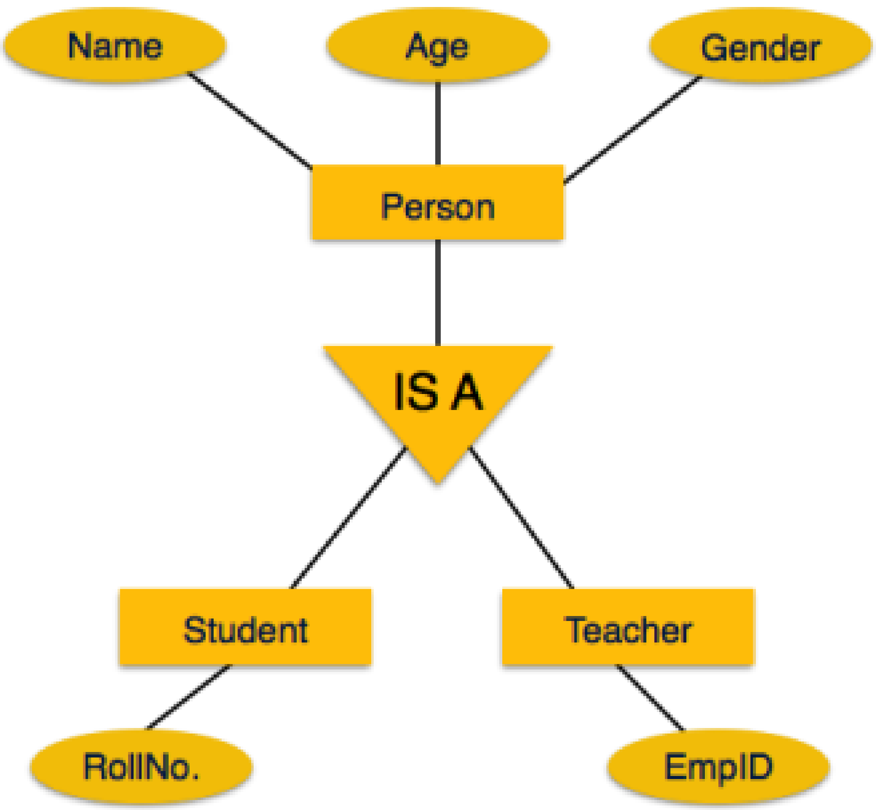


Mapping Process

- Create table for weak entity set.
- Add all its attributes to table as field.
- Add the primary key of identifying entity set.
- Declare all foreign key constraints.

Mapping Hierarchical Entities

ER specialization or generalization comes in the form of hierarchical entity



sets.

Mapping Process

- Create tables for all higher-level entities.
- Create tables for lower-level entities.
- Add primary keys of higher-level entities in the table of lower-level entities.
- In lower-level tables, add all other attributes of lower-level entities.
- Declare primary key of higher-level table and the primary key for lower level table.
- Declare foreign key constraints.

Example with Explanation

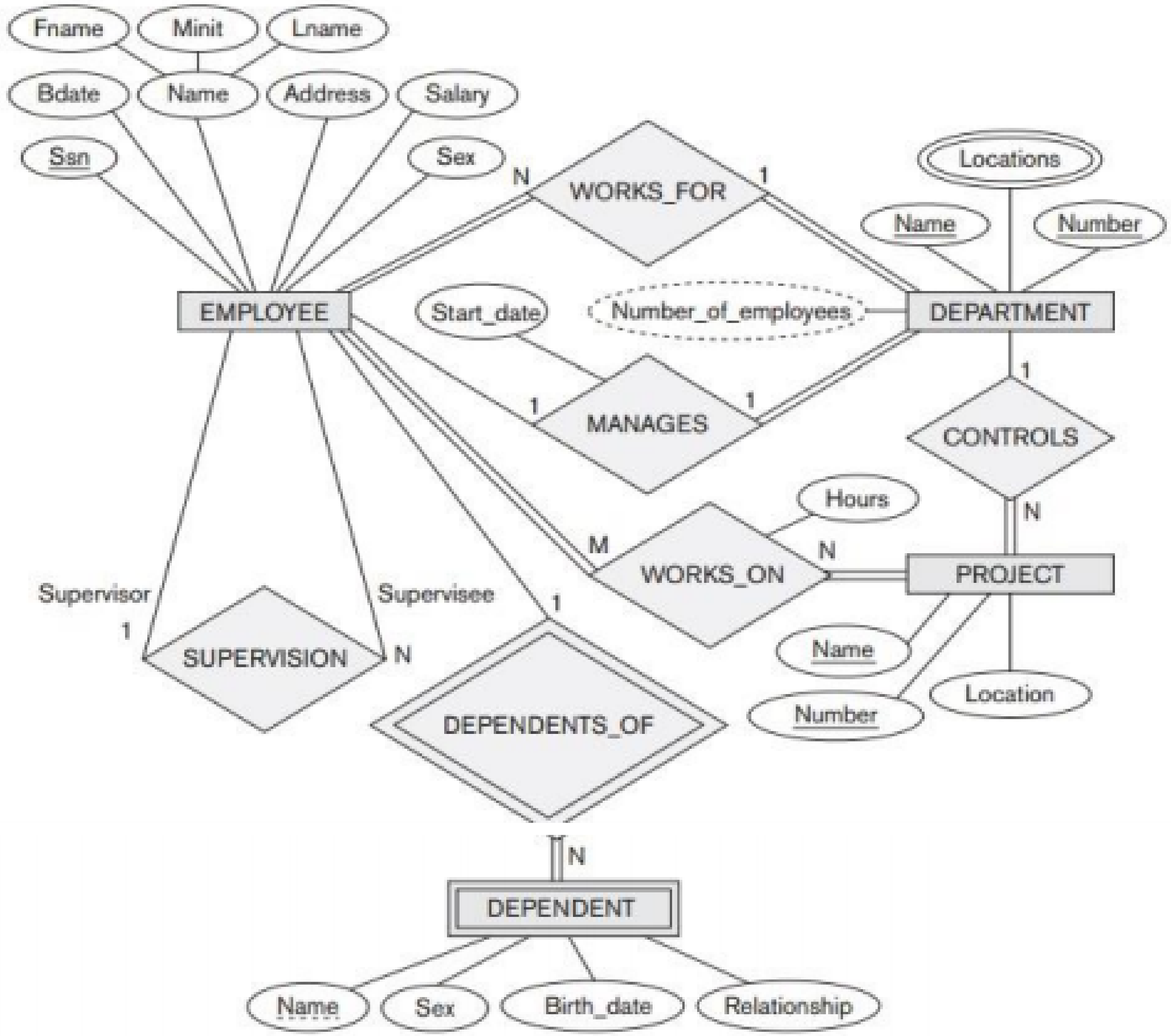
Relational Database Design Using ER-to-Relational

Mapping 1. ER-to-Relational Mapping Algorithm

In this section we describe the steps of an algorithm for ER-to-relational mapping. We use the COMPANY database example to illustrate the mapping procedure.

The COMPANY ER schema is shown again in Figure 9.1, and the corresponding COMPANY relational database schema is shown in Figure 9.2 to illustrate the

Figure 9.1
The ER conceptual schema diagram for the COMPANY database.



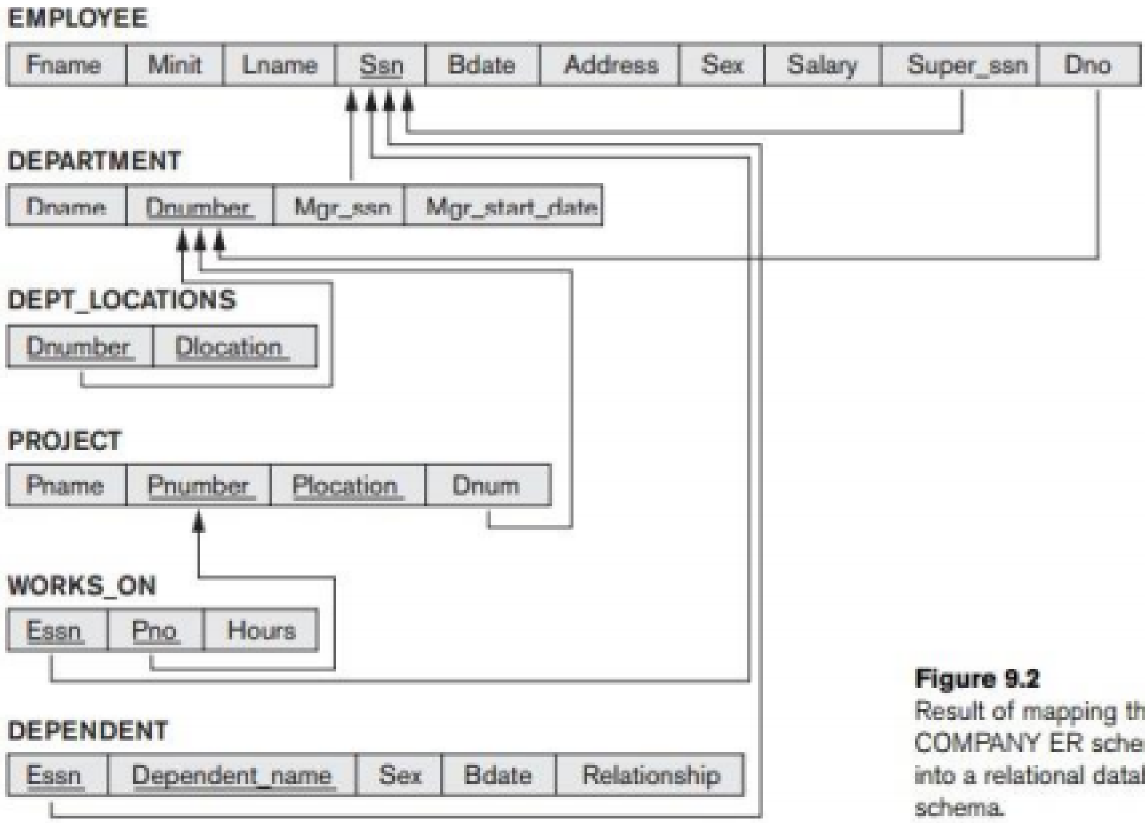


Figure 9.2
Result of mapping the COMPANY ER schema into a relational database schema.

mapping steps. We assume that the mapping will create tables with simple single valued attributes. The relational model constraints defined in Chapter 3, which include primary keys, unique keys (if any), and referential integrity constraints on the rela-tions, will also be specified in the mapping results.

Step 1: Mapping of Regular Entity Types. For each regular (strong) entity type

E in the ER schema, create a relation *R* that includes all the simple attributes of *E*. Include only the simple component attributes of a composite attribute. Choose one of the key attributes of *E* as the primary key for *R*. If the chosen key of *E* is a com-posite, then the set of simple attributes that form it will together form the primary key of *R*.

If multiple keys were identified for *E* during the conceptual design, the information describing the attributes that form each additional key is kept in order to specify secondary (unique) keys of relation *R*. Knowledge about keys is also kept for index-ing purposes and other types of analyses.

In our example, we create the relations EMPLOYEE, DEPARTMENT, and PROJECT in Figure 9.2 to correspond to the regular entity types EMPLOYEE, DEPARTMENT, and PROJECT in Figure 9.1. The foreign key and relationship attributes, if any, are not included yet; they will be added during subsequent steps. These include the attributes Super_ssn and Dno of EMPLOYEE, Mgr_ssn and Mgr_start_date of
DEPARTMENT, and Dnum of PROJECT. In our example, we choose Ssn, Dnumber, and Pnumber as primary keys for the relations EMPLOYEE, DEPARTMENT, and PROJECT, respectively. Knowledge that Dname of DEPARTMENT and Pname of PROJECT are secondary keys is kept for possible use later in the design.

The relations that are created from the mapping of entity types are sometimes called **entity relations** because each tuple represents an entity instance. The result after this mapping step is shown in Figure 9.3(a).

Step 2: Mapping of Weak Entity Types. For each weak entity type *W* in the ER schema with owner entity type *E*, create a relation *R* and include all simple attrib-utes (or simple components of composite attributes) of *W* as attributes of *R*. In addition, include as foreign key attributes of *R*, the primary key attribute(s) of the relation(s) that correspond to the owner entity type(s); this takes care of mapping the identifying relationship type of *W*. The primary key of *R* is the combination of the primary key(s) of the owner(s) and the partial key of the weak entity type *W*, if any.

If there is a weak entity type E_2 whose owner is also a weak entity type E_1, then E_1 should be mapped before E_2 to determine its primary key first.

In our example, we create the relation DEPENDENT in this step to correspond to the weak entity type DEPENDENT (see Figure 9.3(b)). We include the primary key Ssn of the EMPLOYEE relation—which corresponds to the owner entity type—as a for-eign key attribute of DEPENDENT; we rename it Essn, although this is not necessary.

Figure 9.3
Illustration of some mapping steps.
(a) *Entity* relations after step 1.
(b) Additional *weak entity* relation after step 2.
(c) *Relationship* relation after step 5.
(d) Relation representing multivalued attribute after step 6.

(a) **EMPLOYEE**

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary

DEPARTMENT

Dname	Dnumber

PROJECT

Pname	Pnumber	Plocation

(b) **DEPENDENT**

Essn	Dependent_name	Sex	Bdate	Relationship

(c) **WORKS_ON**

Essn	Pno	Hours

(d) **DEPT_LOCATIONS**

Dnumber	Dlocation

The primary key of the DEPENDENT relation is the combination {Essn, Dependent_name}, because Dependent_name (also renamed from Name in Figure 9.1) is the partial key of DEPENDENT.

It is common to choose the propagate (CASCADE) option for the referential triggered action (see Section 4.2) on the foreign key in the relation corresponding to the weak entity type, since a weak entity has an existence dependency on its owner entity. This can be used for both ON UPDATE and ON DELETE.

Step 3: Mapping of Binary 1:1 Relationship Types. For each binary 1:1 relationship type *R* in the ER schema, identify the relations *S* and *T* that correspond to the entity types participating in *R*. There are three possible approaches: (1) the foreign key approach, (2) the merged relationship approach, and (3) the cross-reference or relationship relation approach. The first approach is the most useful and should be followed unless special conditions exist, as we discuss below.

Foreign key approach: Choose one of the relations—*S*, say—and include as a foreign key in *S* the primary key of *T*. It is better to choose an entity type with *total participation* in *R* in the role of *S*. Include all the simple attributes (or simple components of composite attributes) of the 1:1 relationship type *R* as attributes of *S*.

In our example, we map the 1:1 relationship type MANAGES from Figure 9.1 by choosing the participating entity type DEPARTMENT to serve in the role of *S* because its participation in the MANAGES relationship type is total (every department has a manager). We include the primary key of the EMPLOYEE relation as foreign key in the DEPARTMENT relation and rename it Mgr_ssn. We also include the simple attribute Start_date of the MANAGES relationship type in the DEPARTMENT relation and rename it Mgr_start_date (see Figure 9.2).

Note that it is possible to include the primary key of *S* as a foreign key in *T* instead. In our example, this amounts to having a foreign key attribute, say Department_managed in the EMPLOYEE relation, but it will have a NULL value for employee tuples who do not manage a department. If only 2 percent of employees manage a department, then 98 percent of the foreign keys would be NULL in this case. Another possibility is to have foreign keys in both relations *S* and *T* redundantly, but this creates redundancy and incurs a penalty for consistency maintenance.

Merged relation approach: An alternative mapping of a 1:1 relationship type is to merge the two entity types and the relationship into a single rela-tion. This is possible when *both participations are total,* as this would indicate that the two tables will have the exact same number of tuples at all times.

Cross-reference or relationship relation approach: The third option is to set up a third relation *R* for the purpose of cross-referencing the primary keys of the two relations *S* and *T* representing the entity types. As we will see, this approach is required for binary M:N relationships. The relation *R* is called a **relationship relation** (or sometimes a **lookup table**), because each tuple in *R* represents a relationship instance that relates one tuple from *S* with one tuple from *T*. The relation *R* will include the primary key attributes of *S* and *T* as foreign keys to *S* and *T*. The primary key of *R* will be one of the two foreign keys, and the other foreign key will be a unique key of *R*. The drawback is having an extra relation, and requiring an extra join operation when combining related tuples from the tables.

Step 4: Mapping of Binary 1:N Relationship Types. For each regular binary 1:N relationship type *R*, identify the relation *S* that represents the participating entity type at the *N-side* of the relationship type. Include as foreign key in *S* the primary key of the relation *T* that represents the other entity type participating in *R*; we do this because each entity instance on the N-side is related to at most one entity instance on the 1-side of the relationship type. Include any simple attributes (or simple compo-nents of composite attributes) of the 1:N relationship type as attributes of *S*.

In our example, we now map the 1:N relationship types WORKS_FOR, CONTROLS, and SUPERVISION from Figure 9.1. For WORKS_FOR we include the primary key Dnumber of the DEPARTMENT relation as foreign key in the EMPLOYEE relation and call it Dno. For SUPERVISION we include the primary key of the EMPLOYEE relation as foreign key in the EMPLOYEE relation itself— because the relationship is recur-sive—and call it Super_ssn. The CONTROLS relationship is mapped to the foreign key attribute Dnum of PROJECT, which references the primary key Dnumber of the DEPARTMENT relation. These foreign keys are shown in Figure 9.2.

An alternative approach is to use the **relationship relation** (cross-reference) option as in the third option for binary 1:1 relationships. We create a separate relation *R* whose attributes are the primary keys of *S* and *T*, which will also be foreign keys to *S* and *T*. The primary key of *R* is the same as the primary key of *S*. This option can be used if few tuples in *S* participate in the relationship to avoid excessive NULL val-ues in the foreign key.

Step 5: Mapping of Binary M:N Relationship Types. For each binary M:N relationship type *R*, create a new relation *S* to represent *R*. Include as foreign key attributes in *S* the primary keys of the relations that represent the participating entity types; their *combination* will form the primary key of *S*. Also include any sim-ple attributes of the M:N relationship type (or simple components of composite attributes) as attributes of *S*. Notice that we cannot represent an M:N relationship type by a single foreign key attribute in one of the participating relations (as we did for 1:1 or 1:N relationship types) because of the M:N cardinality ratio; we must cre-ate a separate *relationship relation S*.

In our example, we map the M:N relationship type WORKS_ON from Figure 9.1 by creating the relation WORKS_ON in Figure 9.2. We include the primary keys of the PROJECT and EMPLOYEE relations as foreign keys in WORKS_ON and rename them Pno and Essn, respectively. We also include an attribute Hours in WORKS_ON to represent the Hours attribute of the relationship type. The primary key of the WORKS_ON relation is the combination of the foreign key attributes {Essn, Pno}. This **relationship relation** is shown in Figure 9.3(c).

The propagate (CASCADE) option for the referential triggered action (see Section 4.2) should be specified on the foreign keys in the relation corresponding to the relationship *R*, since each relationship instance has an existence dependency on each of the entities it relates. This can be used for both ON UPDATE and ON DELETE.

Notice that we can always map 1:1 or 1:N relationships in a manner similar to M:N relationships by using the cross-reference (relationship relation) approach, as we discussed earlier. This alternative is particularly useful when few relationship instances exist, in order to avoid NULL values in foreign keys. In this case, the primary key of the relationship relation will be *only one* of the foreign keys that refer-ence the participating entity relations. For a 1:N relationship, the primary key of the relationship relation will be the foreign key that references the entity relation on the N-side. For a 1:1 relationship, either foreign key can be used as the primary key of the relationship relation.

Step 6: Mapping of Multivalued Attributes. For each multivalued attribute *A*, create a new relation *R*. This relation *R* will include an attribute corresponding to *A*, plus the primary key attribute *K*—as a foreign key in *R*—of the relation that represents the entity type or relationship type that has *A* as a multivalued attribute. The primary key of *R* is the combination of *A* and *K*. If the multivalued attribute is composite, we include its simple components.
In our example, we create a relation DEPT_LOCATIONS (see Figure 9.3(d)).

The attribute Dlocation represents the multivalued attribute LOCATIONS of DEPARTMENT, while Dnumber—as foreign key— represents the primary key of the DEPARTMENT relation. The primary key of DEPT_LOCATIONS is the combination of {Dnumber, Dlocation}. A separate tuple will exist in DEPT_LOCATIONS for each loca-tion that a department has.

The propagate (CASCADE) option for the referential triggered action (see Section 4.2) should be specified on the foreign key in the relation *R* corresponding to the multivalued attribute for both ON UPDATE and ON DELETE. We should also note that the key of *R* when mapping a composite, multivalued attribute requires some analysis of the meaning of the component attributes. In some cases, when a multi-valued attribute is composite, only some of the component attributes are required to be part of the key of *R*; these attributes are similar to a partial key of a weak entity type that corresponds to the multivalued attribute (see Section 7.5).

Figure 9.2 shows the COMPANY relational database schema obtained with steps 1 through 6, and Figure 3.6 shows a sample database state. Notice that we did not yet discuss the mapping of *n*-ary relationship types ($n > 2$) because none exist in Figure 9.1; these are mapped in a similar way to M:N relationship types by including the following additional step in the mapping algorithm.

Step 7: Mapping of *N*-ary Relationship Types. For each *n*-ary relationship type *R*, where $n > 2$, create a new relation *S* to represent *R*. Include as foreign key attributes in *S* the primary keys of the relations that represent the participating entity types. Also include any simple attributes of the *n*-ary relationship type (or simple components of composite attributes) as attributes of *S*. The primary key of *S* is usually a combination of all the foreign keys that reference the relations representing the participating entity types. However, if the cardinality constraints on any of the entity types *E* participating in *R* is 1, then the primary key of *S* should not include the foreign key attribute that references the relation *E* corresponding to *E* (see the discussion in Section 7.9.2 concerning constraints on *n*-ary relationships).
For example, consider the relationship type SUPPLY in Figure 7.17. This can be mapped to the relation SUPPLY shown in Figure 9.4, whose primary key is the com-bination of the three foreign keys {Sname, Part_no, Proj_name}.

2. Discussion and Summary of Mapping for ER Model Constructs

Table 9.1 summarizes the correspondences between ER and relational model con structs and constraints.

One of the main points to note in a relational schema, in contrast to an ER schema, is that relationship types are not represented explicitly; instead, they are represented by having two attributes *A* and *B*, one a primary key and the other a foreign key (over the same domain) included in two relations *S* and *T*. Two tuples in *S* and *T* are related when they have the same value for *A* and *B*. By using the EQUIJOIN operation (or NATURAL JOIN if the two join attributes have the same name) over *S.A* and *T.B*, we can combine all pairs of related tuples from *S* and *T* and materialize the relationship. When a binary 1:1 or 1:N relationship type is involved, a single join operation is usually needed. For a binary M:N relationship type, two join operations are needed, whereas for *n*-ary relationship types, *n* joins are needed to fully materialize the relationship instances.

Figure 9.4
Mapping the *n*-ary relationship type SUPPLY from Figure 7.17(a).

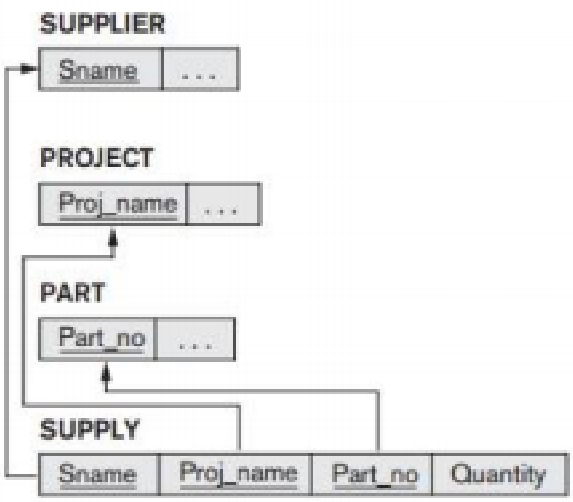


Table 9.1 Correspondence between ER and Relational Models

ER MODEL	RELATIONAL MODEL
Entity type	*Entity* relation
1:1 or 1:N relationship type	Foreign key (or *relationship* relation)
M:N relationship type	*Relationship* relation and *two* foreign keys
n-ary relationship type	*Relationship* relation and *n* foreign keys
Simple attribute	Attribute
Composite attribute	Set of simple component attributes
Multivalued attribute	Relation and foreign key
Value set	Domain
Key attribute	Primary (or secondary) key

For example, to form a relation that includes the employee name, project name, and hours that the employee works on each project, we need to connect each EMPLOYEE tuple to the related PROJECT tuples via the WORKS_ON relation in Figure 9.2. Hence, we must apply the EQUIJOIN operation to the EMPLOYEE and WORKS_ON relations with the join condition Ssn = Essn, and then apply another EQUIJOIN operation to the resulting relation and the PROJECT relation with join condition Pno = Pnumber. In general, when multiple relationships need to be traversed, numerous join operations must be specified. A relational database user must always be aware of the foreign key attributes in order to use them correctly in combining related tuples from two or more relations. This is sometimes considered to be a drawback of the relational data model, because the foreign key/primary key correspondences are not always obvious upon inspection of relational schemas. If an EQUIJOIN is performed among attributes of two relations that do not represent a foreign key/primary key relationship, the result can often be meaningless and may lead to spurious data. For example, the reader can try joining the PROJECT and DEPT_LOCATIONS relations on the condition Dlocation = Plocation and examine the result (see the discussion of spurious tuples in Section 15.1.4).

In the relational schema we create a separate relation for *each* multivalued attribute. For a particular entity with a set of values for the multivalued attribute, the key attribute value of the entity is repeated once for each value of the multivalued attribute in a separate tuple because the basic relational model does *not* allow multiple values (a list, or a set of values) for an attribute in a single tuple. For example, because department 5 has three locations, three tuples exist in the DEPT_LOCATIONS relation in Figure 3.6; each tuple specifies one of the locations. In our example, we apply EQUIJOIN to DEPT_LOCATIONS and DEPARTMENT on the Dnumber attribute to get the values of all locations along with other DEPARTMENT attributes. In the resulting relation, the values of the other DEPARTMENT attributes are repeated in separate tuples for every location that a department has.

The basic relational algebra does not have a NEST or COMPRESS operation that would produce a set of tuples of the form {<‘1’, ‘Houston’>, <‘4’, ‘Stafford’>, <‘5’, {‘Bellaire’, ‘Sugarland’, ‘Houston’}>} from the DEPT_LOCATIONS relation in Figure 3.6. This is a serious drawback of the basic normalized or *flat* version of the relational model. The object data model and object-relational systems (see Chapter 11) do allow multivalued attributes.