

5th Edition

Elmasri / Navathe

Chapter 7

Relational Database Design by ER-
and EER-to-Relational Mapping



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Chapter Outline

- **ER-to-Relational Mapping Algorithm**
 - Step 1: Mapping of Regular Entity Types
 - Step 2: Mapping of Weak Entity Types
 - Step 3: Mapping of Binary 1:1 Relation Types
 - Step 4: Mapping of Binary 1:N Relationship Types.
 - Step 5: Mapping of Binary M:N Relationship Types.
 - Step 6: Mapping of Multivalued attributes.
 - Step 7: Mapping of N-ary Relationship Types.
- **Mapping EER Model Constructs to Relations**
 - Step 8: Options for Mapping Specialization or Generalization.
 - Step 9: Mapping of Union Types (Categories).

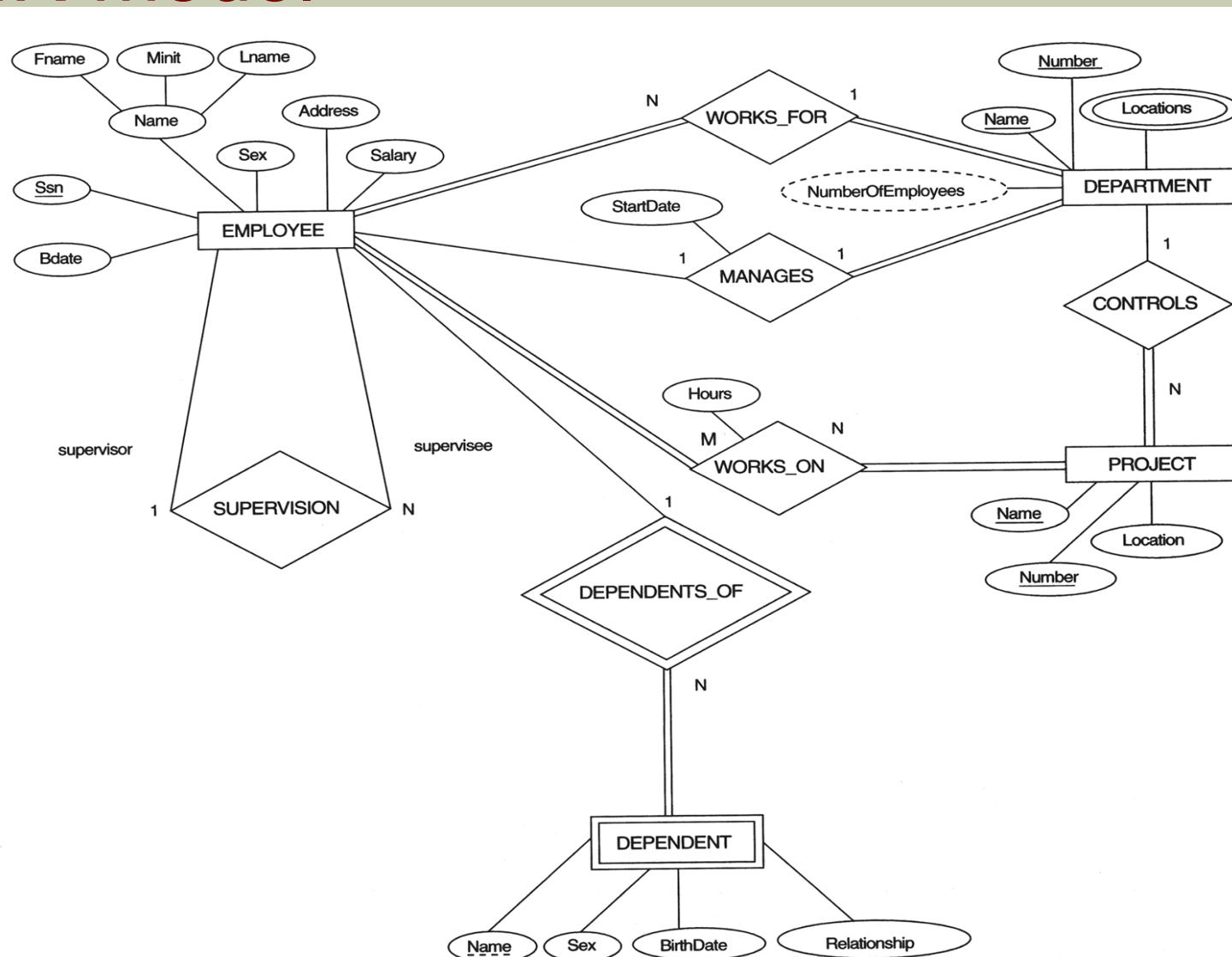
Why to map EER

EER is conceptual model

To implement database many models

- ❑ Relational model
- ❑ Network model
- ❑ Hierarchical model
- ❑ Object oriented model

EER model



Relational database schema

Entities and relationships mapped to relations and links in Relational database schema

ex:

EMPLOYEE

Fname	Minit	Lname	<u>Ssn</u>	Bdate	Address	Sex	Salary	Super_ssn	Dno
-------	-------	-------	------------	-------	---------	-----	--------	-----------	-----

DEPARTMENT

Dname	<u>Dnumber</u>	Mgr_ssn	Mgr_start_date
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DEPT_LOCATIONS

Dnumber	<u>Dlocation</u>
---------	------------------

PROJECT

Pname	<u>Pnumber</u>	<u>Plocation</u>	Dnum
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WORKS_ON

<u>Essn</u>	<u>Pno</u>	Hours
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DEPENDENT

<u>Essn</u>	Dependent_name	Sex	Bdate	Relationship
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Figure 7.2

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

EMPLOYEE

Fname	Minit	Lname	Ssn	Bdate	Address	Sex	Salary	Super_ssn	Dno
John	B	Smith	123456789	1965-01-09	731 Fondren, Houston, TX	M	30000	333445555	5
Franklin	T	Wong	333445555	1955-12-08	638 Voss, Houston, TX	M	40000	888665555	5
Alicia	J	Zelaya	999887777	1968-01-19	3321 Castle, Spring, TX	F	25000	987654321	4
Jennifer	S	Wallace	987654321	1941-06-20	291 Berry, Bellaire, TX	F	43000	888665555	4
Ramesh	K	Narayan	666884444	1962-09-15	975 Fire Oak, Humble, TX	M	38000	333445555	5
Joyce	A	English	453453453	1972-07-31	5631 Rice, Houston, TX	F	25000	333445555	5
Ahmad	V	Jabbar	987987987	1969-03-29	980 Dallas, Houston, TX	M	25000	987654321	4
James	E	Borg	888665555	1937-11-10	450 Stone, Houston, TX	M	55000	NULL	1

DEPARTMENT

Dname	Dnumber	Mgr_ssn	Mgr_start_date
Research	5	333445555	1988-05-22
Administration	4	987654321	1995-01-01
Headquarters	1	888665555	1981-06-19

DEPT_LOCATIONS

Dnumber	Dlocation
1	Houston
4	Stafford
5	Bellaire
5	Sugarland
5	Houston

WORKS_ON

Essn	Pno	Hours
123456789	1	32.5
123456789	2	7.5
666884444	3	40.0
453453453	1	20.0
453453453	2	20.0
333445555	2	10.0
333445555	3	10.0
333445555	10	10.0
333445555	20	10.0
999887777	30	30.0
999887777	10	10.0
987987987	10	35.0
987987987	30	5.0
987654321	30	20.0
987654321	20	15.0
888665555	20	NULL

PROJECT

Pname	Pnumber	Plocation	Dnum
ProductX	1	Bellaire	5
ProductY	2	Sugarland	5
ProductZ	3	Houston	5
Computerization	10	Stafford	4
Reorganization	20	Houston	1
Newbenefits	30	Stafford	4

DEPENDENT

Essn	Dependent_name	Sex	Bdate	Relationship
333445555	Alice	F	1986-04-05	Daughter
333445555	Theodore	M	1983-10-25	Son
333445555	Joy	F	1958-05-03	Spouse
987654321	Abner	M	1942-02-28	Spouse
123456789	Michael	M	1988-01-04	Son
123456789	Alice	F	1988-12-30	Daughter
123456789	Elizabeth	F	1967-05-05	Spouse

ER-to-Relational Mapping Algorithm

- 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.
 - Choose one of the key attributes of E as the primary key for R.
 - If the chosen key of E is composite, the set of simple attributes that form it will together form the primary key of R.
- Example: We create the relations EMPLOYEE, DEPARTMENT, and PROJECT in the relational schema corresponding to the regular entities in the ER diagram.
 - SSN, DNUMBER, and PNUMBER are the primary keys for the relations EMPLOYEE, DEPARTMENT, and PROJECT as shown.

ER-to-Relational Mapping Algorithm (contd.)

- **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 & include all simple attributes (or simple components of composite attributes) of W as attributes of R.
 - Also, include as foreign key attributes of R the primary key attribute(s) of the relation(s) that correspond to the owner entity type(s).
 - 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.
- **Example:** Create the relation DEPENDENT in this step to correspond to the weak entity type DEPENDENT.
 - Include the primary key SSN of the EMPLOYEE relation as a foreign key attribute of DEPENDENT (renamed to ESSN).
 - The primary key of the DEPENDENT relation is the combination {ESSN, DEPENDENT_NAME} because DEPENDENT_NAME is the partial key of DEPENDENT.

ER-to-Relational Mapping Algorithm (contd.)

- **Step 3: Mapping of Binary 1:1 Relation 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. **Foreign Key approach:** Choose one of the relations-say S-and include 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.
 - Example: 1:1 relation MANAGES is mapped by choosing the participating entity type DEPARTMENT to serve in the role of S, because its participation in the MANAGES relationship type is total.
 2. **Merged relation option:** An alternate mapping of a 1:1 relationship type is possible by merging the two entity types and the relationship into a single relation. This may be appropriate when both participations are total.
 3. **Cross-reference or relationship relation option:** The third alternative 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.

ER-to-Relational Mapping Algorithm (contd.)

- Step 4: Mapping of Binary 1:N Relationship Types.
 - For each regular binary 1:N relationship type R, identify the relation S that represent 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.
 - Include any simple attributes of the 1:N relation type as attributes of S.
- Example: 1:N relationship types WORKS_FOR, CONTROLS, and SUPERVISION in the figure.
 - For WORKS_FOR we include the primary key DNUMBER of the DEPARTMENT relation as foreign key in the EMPLOYEE relation and call it DNO.

ER-to-Relational Mapping Algorithm (contd.)

- **Step 5: Mapping of Binary M:N Relationship Types.**
 - For each regular 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 simple attributes of the M:N relationship type (or simple components of composite attributes) as attributes of S.
- Example: The M:N relationship type WORKS_ON from the ER diagram is mapped by creating a relation WORKS_ON in the relational database schema.
 - The primary keys of the PROJECT and EMPLOYEE relations are included as foreign keys in WORKS_ON and renamed PNO and ESSN, respectively.
 - Attribute HOURS in WORKS_ON represents the HOURS attribute of the relation type. The primary key of the WORKS_ON relation is the combination of the foreign key attributes {ESSN, PNO}.

ER-to-Relational Mapping Algorithm (contd.)

- **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 an attribute.
 - The primary key of R is the combination of A and K. If the multivalued attribute is composite, we include its simple components.
- **Example:** The relation DEPT_LOCATIONS is created.
 - 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 R is the combination of {DNUMBER, DLOCATION}.

ER-to-Relational Mapping Algorithm (contd.)

- **Step 7: Mapping of N-ary Relationship Types.**
 - For each n-ary relationship type R, where $n > 2$, create a new relationship 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.
- **Example:** The relationship type SUPPY in the ER on the next slide.
 - This can be mapped to the relation SUPPLY shown in the relational schema, whose primary key is the combination of the three foreign keys {SNAME, PARTNO, PROJNAME}

FIGURE 4.11

Ternary relationship types. (a) The SUPPLY relationship.

(a)

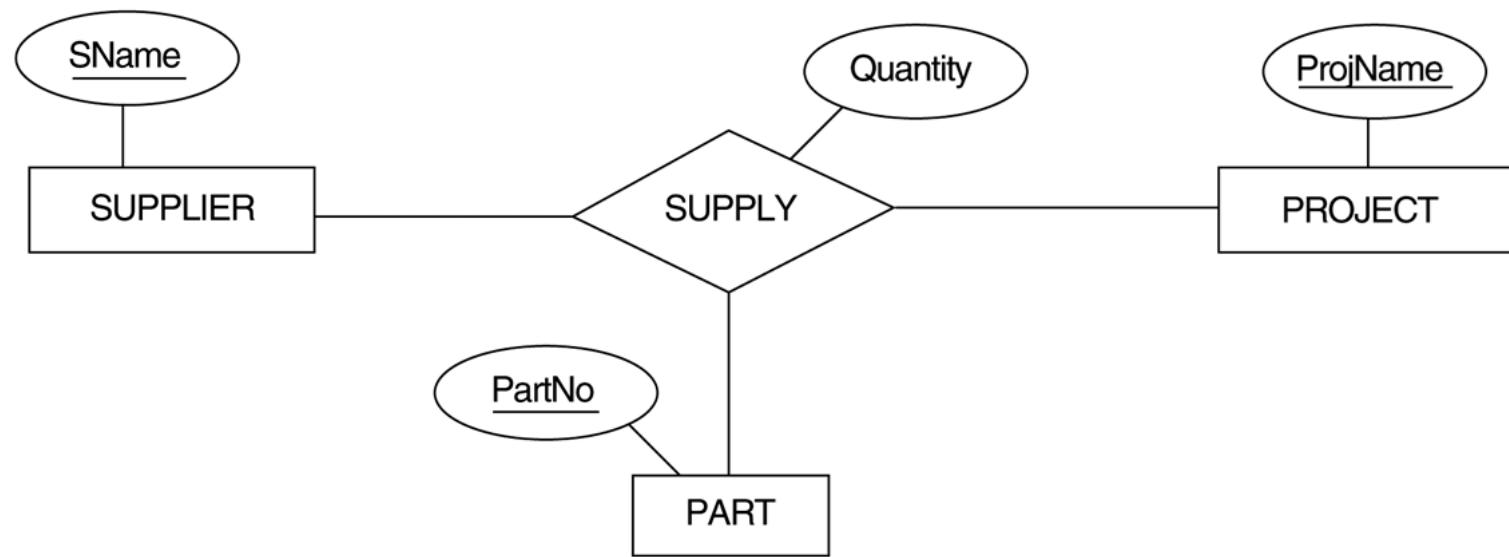


FIGURE 7.3

Mapping the *n*-ary relationship type SUPPLY from Figure 4.11a.

SUPPLIER

<u>SNAME</u>	• • •
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PROJECT

<u>PROJNAME</u>	• • •
-----------------	-------

PART

<u>PARTNO</u>	• • •
---------------	-------

SUPPLY

<u>SNAME</u>	<u>PROJNAME</u>	<u>PARTNO</u>	<u>QUANTITY</u>
--------------	-----------------	---------------	-----------------

students work
show the links in the ternary relationship of
previous slide

Summary of Mapping constructs and constraints

Table 7.1 Correspondence between ER and Relational Models

ER Model

Entity type

1:1 or 1:N relationship type

M:N relationship type

n-ary relationship type

Simple attribute

Composite attribute

Multivalued attribute

Value set

Key attribute

Relational Model

“Entity” relation

Foreign key (or “relationship” relation)

“Relationship” relation and two foreign keys

“Relationship” relation and *n* foreign keys

Attribute

Set of simple component attributes

Relation and foreign key

Domain

Primary (or secondary) key

Mapping EER Model Constructs to Relations

- **Step8: Options for Mapping Specialization or Generalization.**
 - Convert each specialization with m subclasses {S1, S2, ..., Sm} and generalized superclass C, where the attributes of C are {k, a1, ... an} and k is the (primary) key, into relational schemas using one of the four following options:
 - Option 8A: Multiple relations-Superclass and subclasses
 - Option 8B: Multiple relations-Subclass relations only
 - Option 8C: Single relation with one type attribute
 - Option 8D: Single relation with multiple type attributes

Mapping EER Model Constructs to Relations

- **Option 8A: Multiple relations-Superclass and subclasses**
 - Create a relation L for C with attributes $\text{Attrs}(L) = \{k, a_1, \dots, a_n\}$ and $\text{PK}(L) = k$. Create a relation L_i for each subclass S_i , $1 < i < m$, with the attributes $\text{Attrs}(L_i) = \{k\} \cup \{\text{attributes of } S_i\}$ and $\text{PK}(L_i)=k$.
 - This option works for any specialization (total or partial, disjoint or over-lapping).

FIGURE 4.4

EER diagram notation for an attribute-defined specialization on JobType.

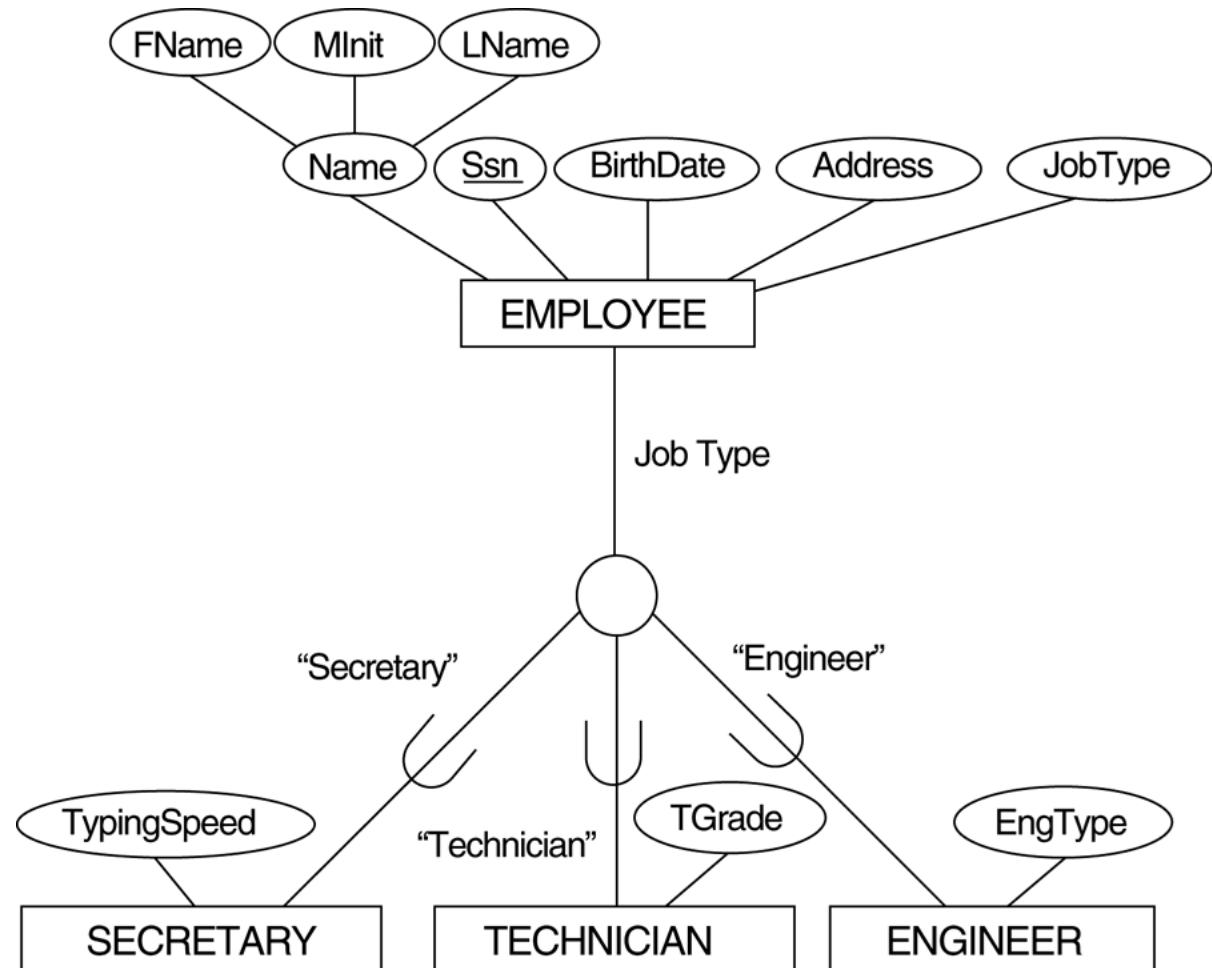


FIGURE 7.4

Options for mapping specialization or generalization.

(a) Mapping the EER schema in Figure 4.4 using option 8A.

(a) **EMPLOYEE**

<u>SSN</u>	FName	MInit	LName	BirthDate	Address	JobType
------------	-------	-------	-------	-----------	---------	---------

SECRETARY

<u>SSN</u>	TypingSpeed
------------	-------------

TECHNICIAN

<u>SSN</u>	TGrade
------------	--------

ENGINEER

<u>SSN</u>	EngType
------------	---------

FIGURE 4.3

Generalization. (b) Generalizing CAR and TRUCK into the superclass VEHICLE.

what is the disjoint constraint ?

(b)

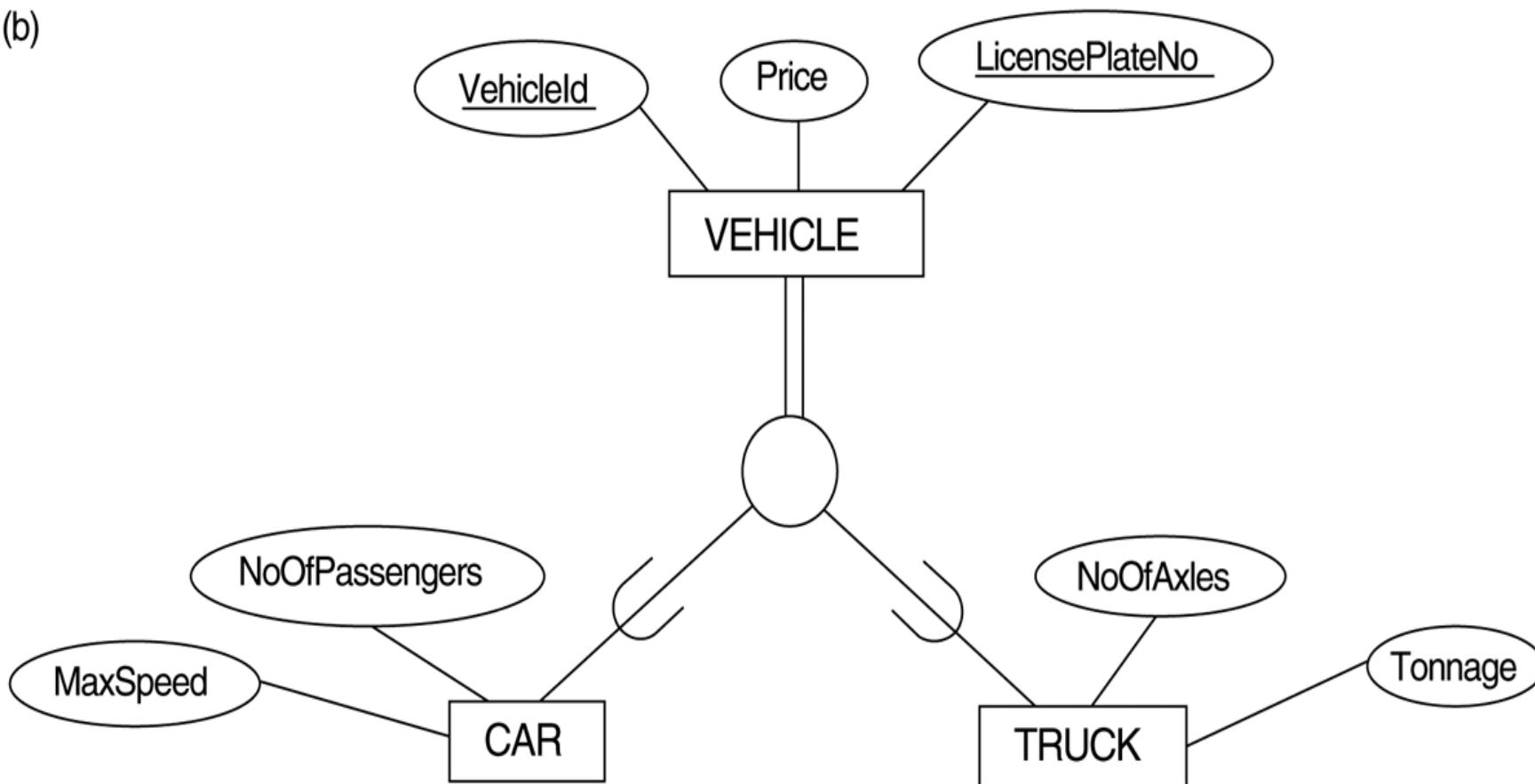


FIGURE 7.4

Options for mapping specialization or generalization.

(b) Mapping the EER schema in Figure 4.3b using option 8B.

Option 8B: Multiple relations-Subclass relations only

Create a relation L_i for each subclass S_i , $1 < i < m$, with the attributes $\text{Attr}(L_i) = \{\text{attributes of } S_i\} \cup \{k, a_1, \dots, a_n\}$ and $\text{PK}(L_i) = k$.

This option only works for a specialization **whose subclasses are total** (every entity in the superclass must belong to (at least) one of the subclasses).

(b) CAR

<u>VehicleId</u>	LicensePlateNo	Price	MaxSpeed	NoOfPassengers
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TRUCK

<u>VehicleId</u>	LicensePlateNo	Price	NoOfAxles	
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Mapping EER Model Constructs to Relations (contd.)

- **Option 8C: Single relation with one type attribute**
 - Create a single relation L with attributes $\text{Attrs}(L) = \{k, a_1, \dots, a_n\} \cup \{\text{attributes of } S_1\} \cup \dots \cup \{\text{attributes of } S_m\} \cup \{t\}$ and $\text{PK}(L) = k$.
The attribute t is called a type (or **discriminating**) attribute that indicates the subclass to which each tuple belongs

FIGURE 4.4

EER diagram notation for an attribute-defined specialization on JobType.

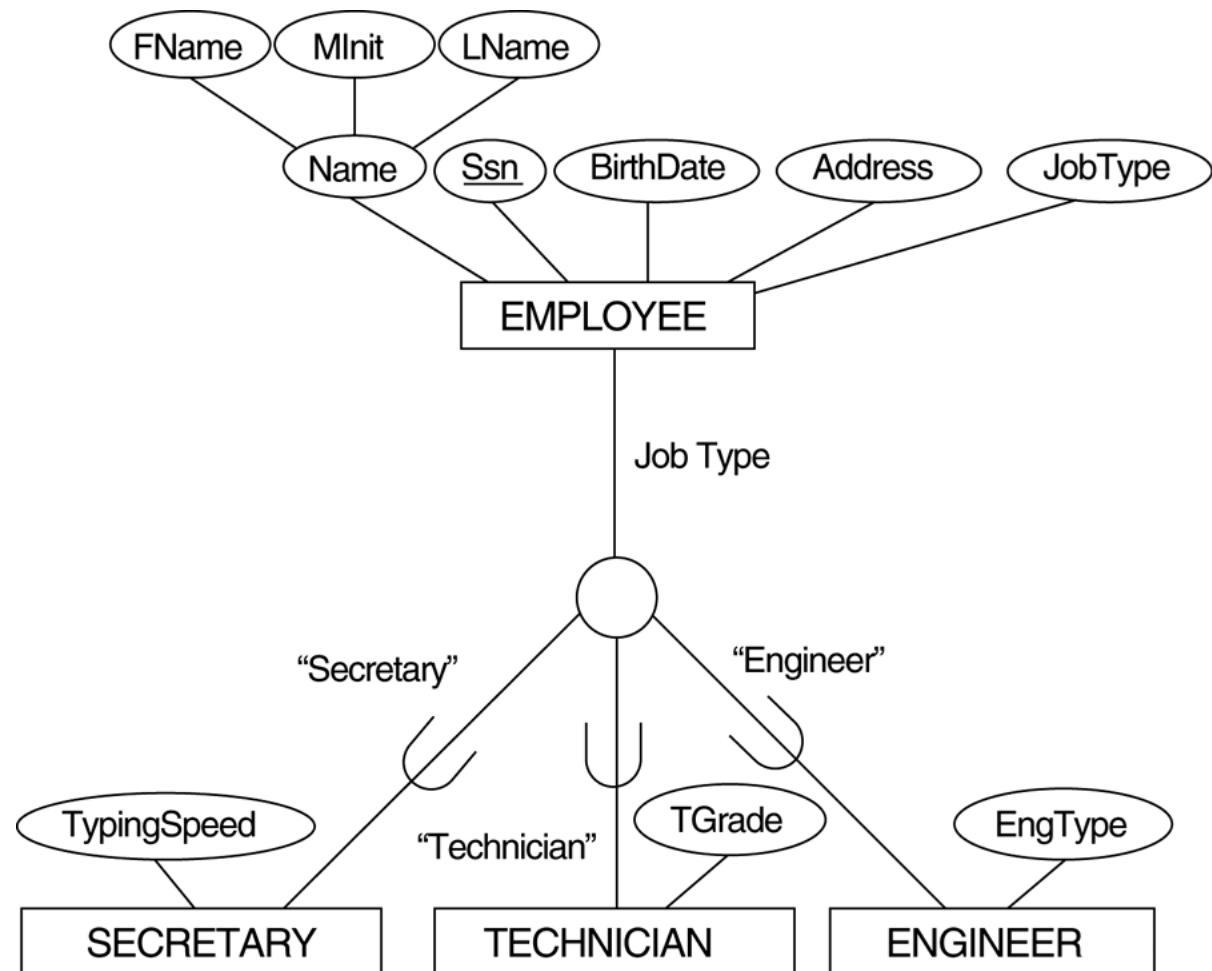


FIGURE 7.4

Options for mapping specialization or generalization.

(c) Mapping the EER schema in Figure 4.4 using option 8C.

(c) EMPLOYEE

SSN	FName	MInit	LName	BirthDate	Address	JobType	TypingSpeed	TGrade	
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FIGURE 4.5

EER diagram notation for an overlapping (non-disjoint) specialization.

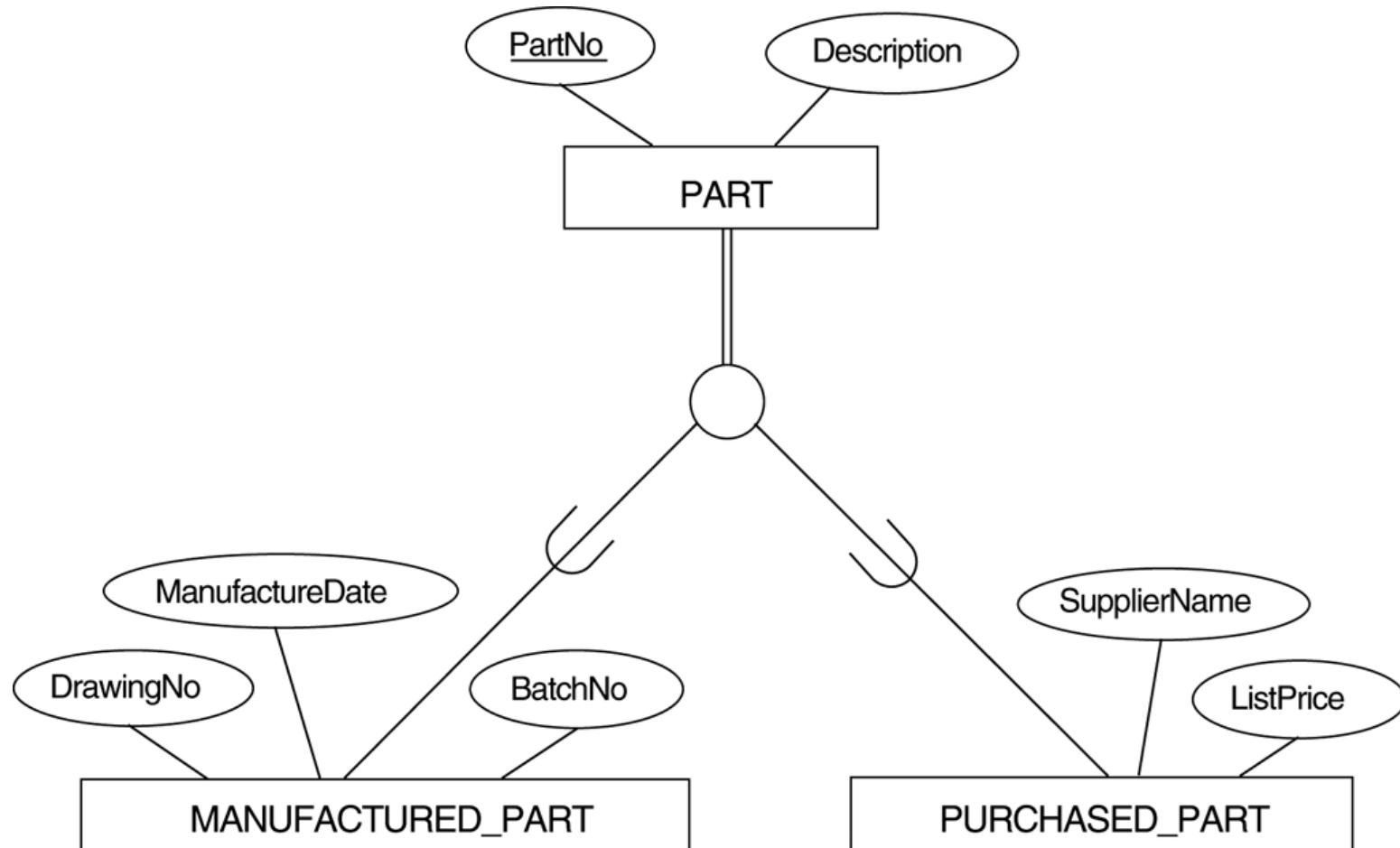


FIGURE 7.4

Options for mapping specialization or generalization. (d) Mapping Figure 4.5 using option 8D with Boolean type fields Mflag and Pflag.

Option 8D: Single relation with multiple type attributes

Create a single relation schema L with attributes $\text{Attrs}(L) = \{k, a_1, \dots, a_n\} \cup \{\text{attributes of } S_1\} \cup \dots \cup \{\text{attributes of } S_m\} \cup \{t_1, t_2, \dots, t_m\}$ and $\text{PK}(L) = k$. Each t_i , $1 < i < m$, is a Boolean type attribute indicating whether a tuple belongs to the subclass S_i .

(d)

PART

PartNo	Description	MFlag	DrawingNo	ManufactureDate	BatchNo	PFlag	SupplierName	ListPrice

Mapping EER Model Constructs to Relations (contd.)

- Mapping of Shared Subclasses (Multiple Inheritance)
 - A shared subclass, such as STUDENT_ASSISTANT, is a subclass of several classes, indicating multiple inheritance. These classes must all have the same key attribute; otherwise, the shared subclass would be modeled as a category.
 - We can apply any of the options discussed in Step 8 to a shared subclass, subject to the restriction discussed in Step 8 of the mapping algorithm. Below both 8C and 8D are used for the shared class STUDENT_ASSISTANT.

FIGURE 4.7

A specialization lattice with multiple inheritance for a UNIVERSITY database.

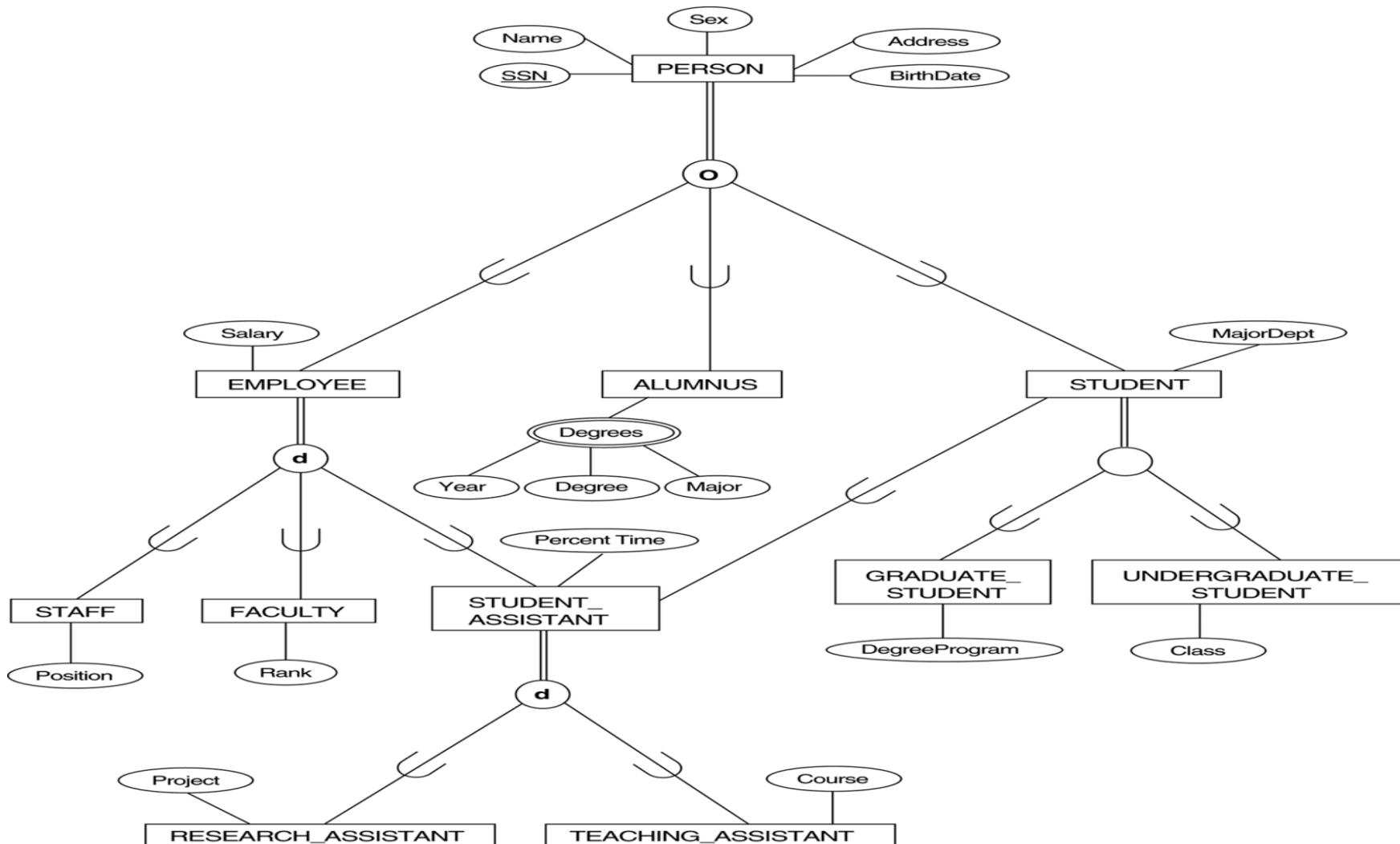


FIGURE 7.5

Mapping the EER specialization lattice in Figure 4.6 using multiple options.

PERSON

<u>SSN</u>	Name	BirthDate	Sex	Address
------------	------	-----------	-----	---------

EMPLOYEE

<u>SSN</u>	Salary	EmployeeType	Position	Rank	PercentTime	RAFlag	TAFlag	Project
------------	--------	--------------	----------	------	-------------	--------	--------	---------

ALUMNUS

<u>SSN</u>

ALUMNUS_DEGREES

<u>SSN</u>	Year	Degree	
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STUDENT

<u>SSN</u>	MajorDept	GradFlag	UndergradFlag	DegreeProgram	Class	StudAssistFlag
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Mapping EER Model Constructs to Relations (contd.)

- **Step 9: Mapping of Union Types (Categories).**
 - For mapping a category whose defining superclass have different keys, it is customary to specify a new key attribute, called a surrogate key, when creating a relation to correspond to the category.
 - In the example below we can create a relation OWNER to correspond to the OWNER category and include any attributes of the category in this relation. The primary key of the OWNER relation is the surrogate key, which we called OwnerId.

FIGURE 4.8

Two categories (union types): OWNER and REGISTERED_VEHICLE.

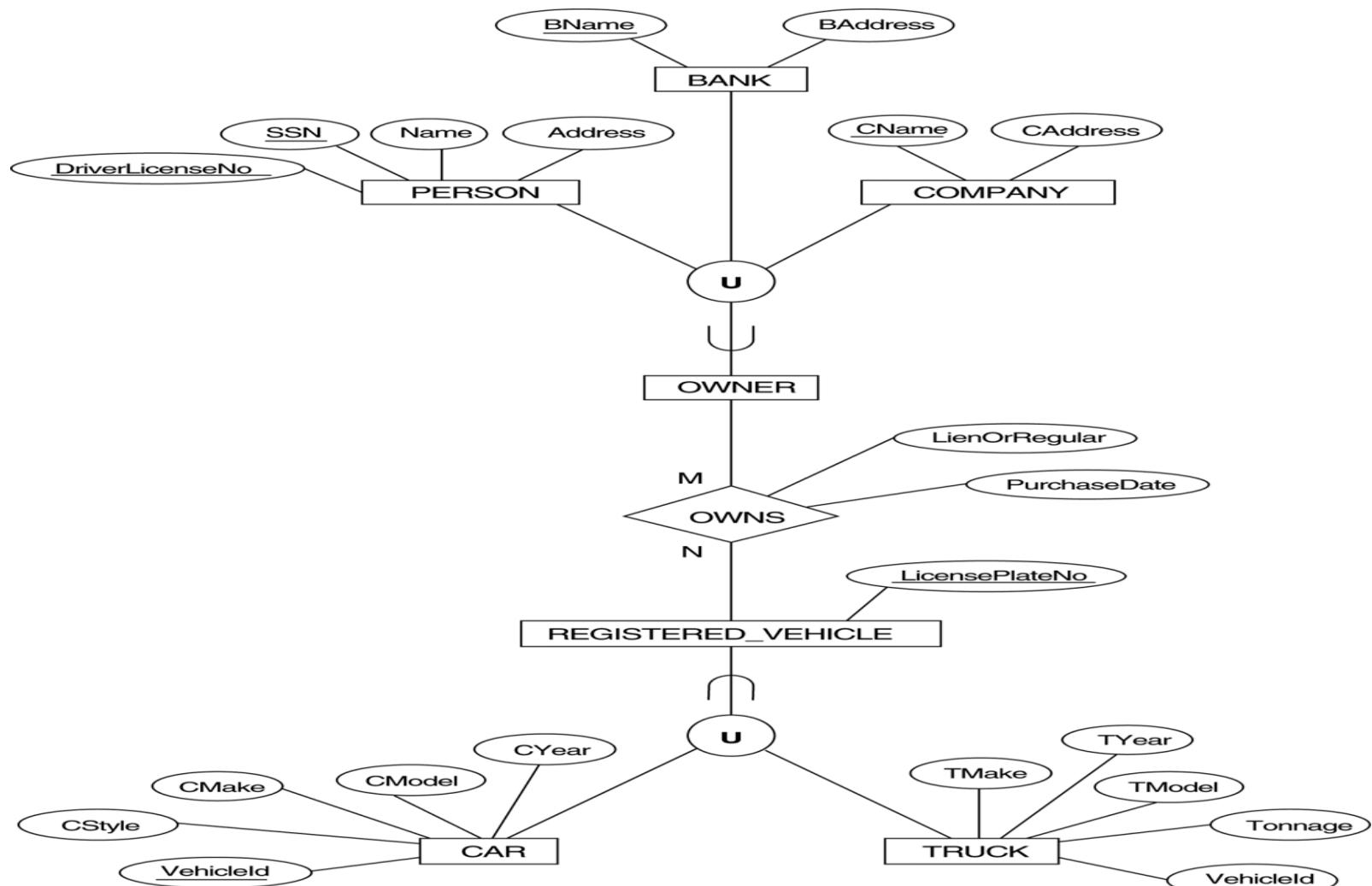


FIGURE 7.6

Mapping the EER categories (union types) in Figure 4.7 to relations.

PERSON

<u>SSN</u>	DriverLicenseNo	Name	Address	
------------	-----------------	------	---------	--

BANK

<u>BName</u>	BAddress	OwnerId
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COMPANY

<u>CName</u>	CAddress	OwnerId
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OWNER

<u>OwnerId</u>

students :
draw the
reference
links

REGISTERED_VEHICLE

<u>VehicleId</u>	LicensePlateNumber
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CAR

<u>VehicleId</u>	CStyle	CMake	CModel	
------------------	--------	-------	--------	--

TRUCK

<u>VehicleId</u>	TMake	TModel	Tonnage	TYear
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OWNS

<u>OwnerId</u>	<u>VehicleId</u>	PurchaseDate	LienOrRegular
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Mapping Exercise

Exercise 7.4.

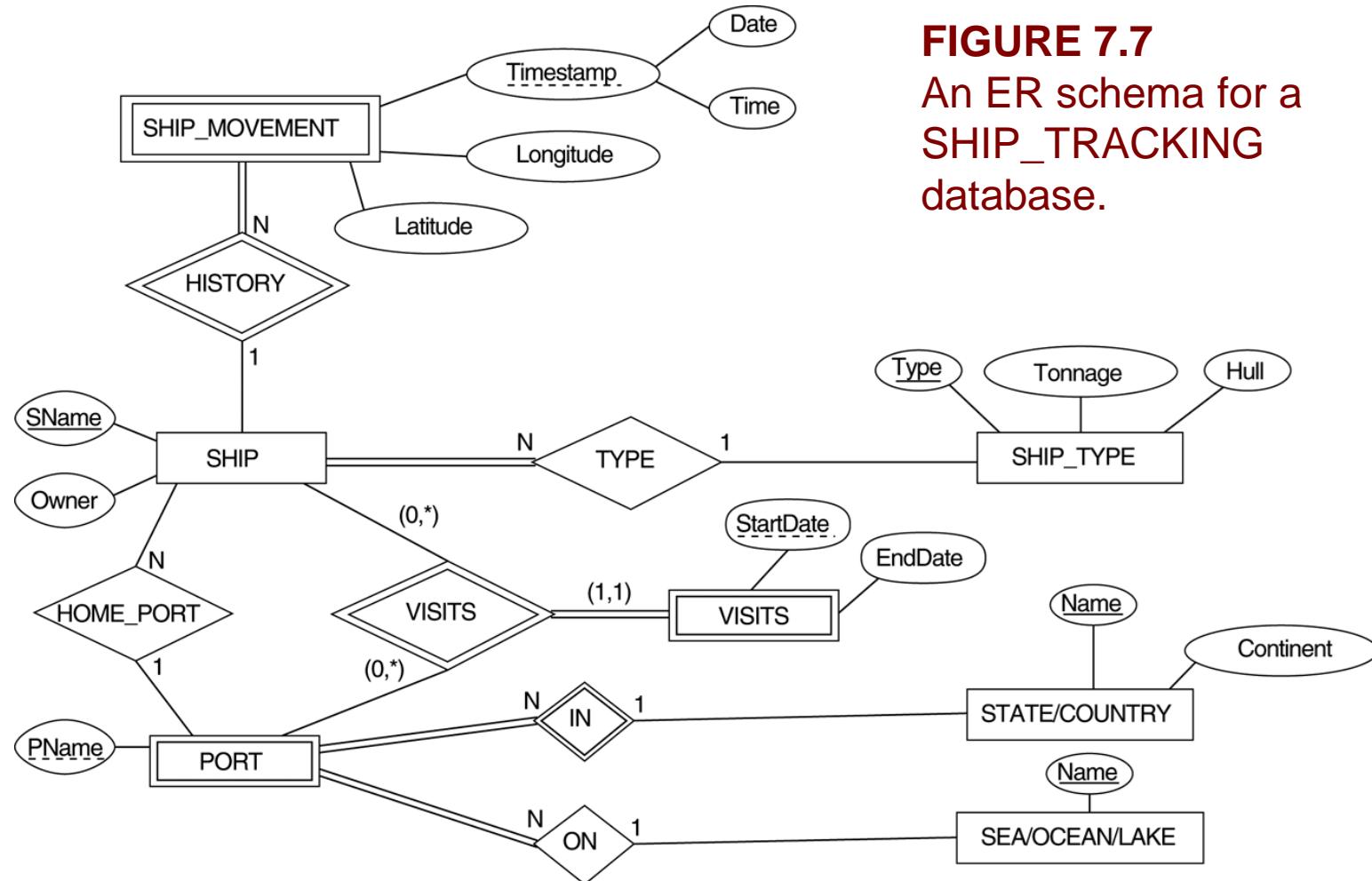


FIGURE 7.7
An ER schema for a
SHIP_TRACKING
database.

Chapter Summary

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 - Step 1: Mapping of Regular Entity Types
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 - Step 8: Options for Mapping Specialization or Generalization.
 - Step 9: Mapping of Union Types (Categories).