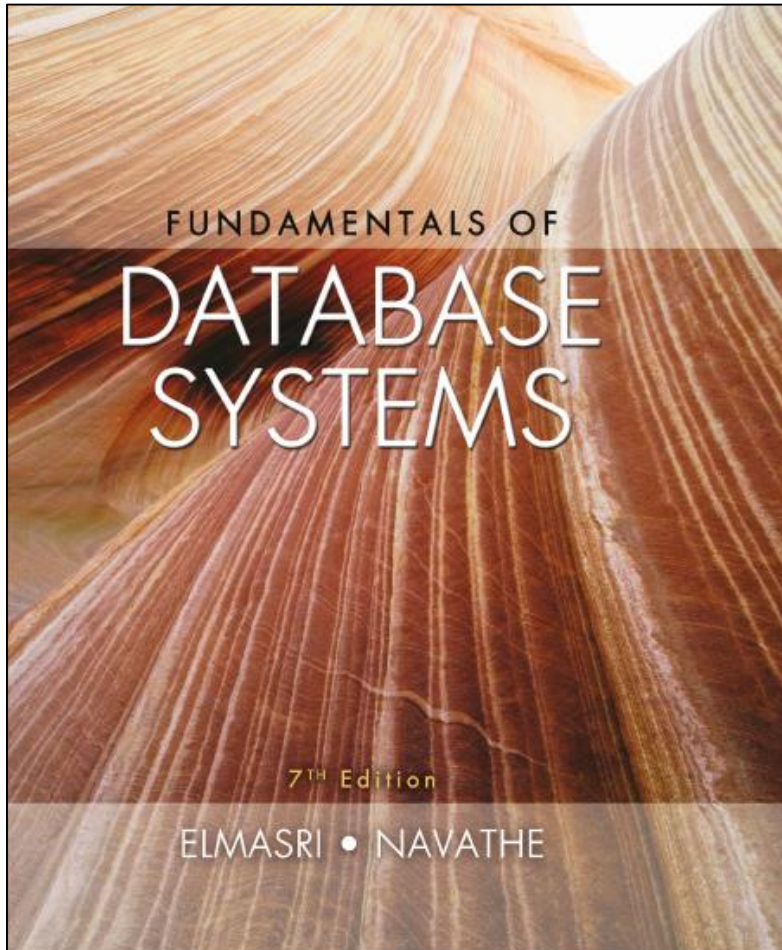


# Fundamentals of Database Systems

Seventh Edition



## Chapter 9

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

# Learning Objectives

## 9.1 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.

## 9.2 Mapping EER Model Constructs to Relations

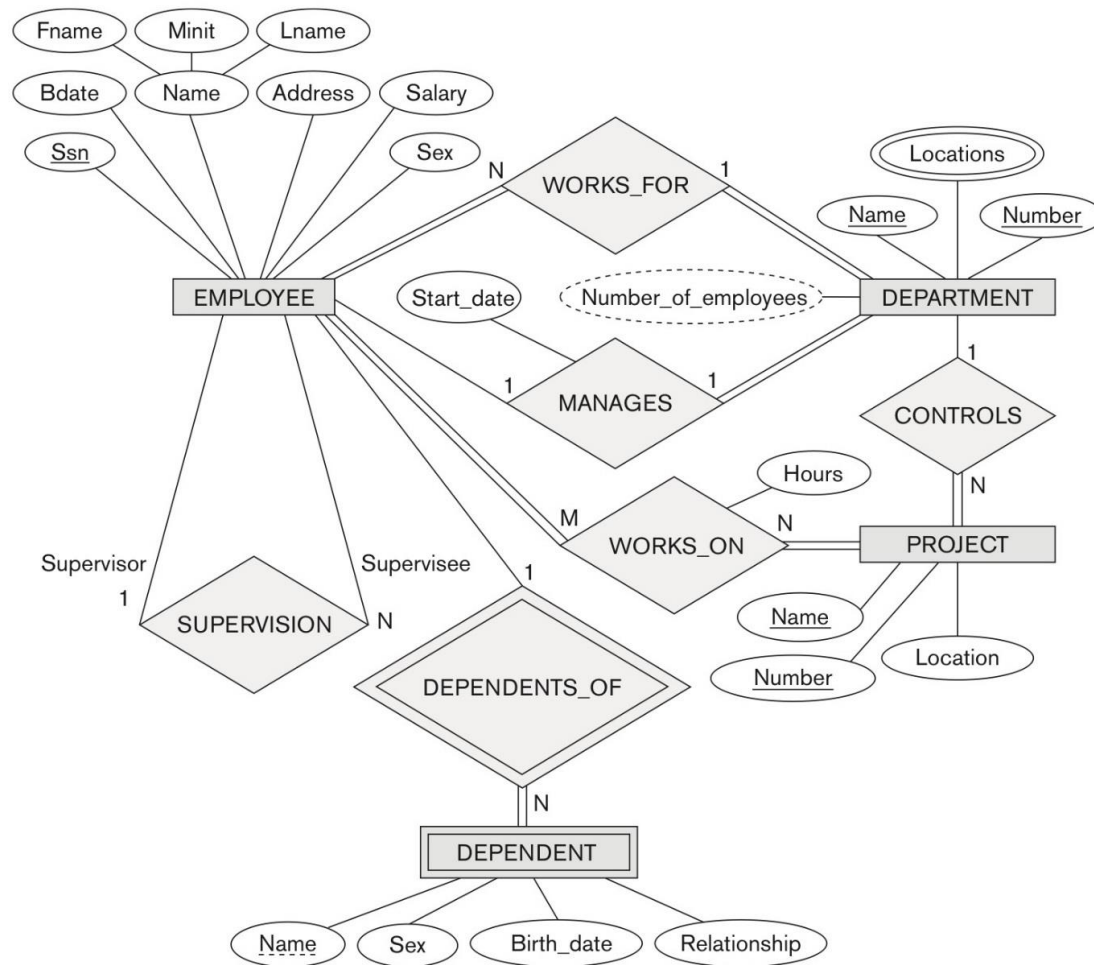
- Step 8: Options for Mapping Specialization or Generalization.
- Step 9: Mapping of Union Types (Categories).

# Goals during Mapping

- Preserve all information (that includes all attributes)
- Minimize null values
- Maintain the constraints to the extent possible  
(Relational Model cannot preserve all constraints- e.g.,  
max cardinality ratio such as 1:10 in E R;  
exhaustive classification into subtypes, e.g., STUDENTS are specialized  
into Domestic and Foreign)

**The mapping procedure described has been implemented in many commercial tools.**

# Figure 9.1 The ER Conceptual Schema Diagram for the COMPANY Database



# ER-to-Relational Mapping Algorithm (1 of 14)

- 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  $R$ .

## ER-to-Relational Mapping Algorithm (2 of 14)

- 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 (3 of 14)

- **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.

## ER-to-Relational Mapping Algorithm (4 of 14)

- **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 (5 of 14)

- **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 ( 2 relations) 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.

## ER-to-Relational Mapping Algorithm (6 of 14)

2. **Merged relation (1 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 ( 3 relations) 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 (7 of 14)

- 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  $S$ .

## ER-to-Relational Mapping Algorithm (8 of 14)

- 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.
- An alternative approach is to use a Relationship relation (cross referencing relation) – this is rarely done.

# ER-to-Relational Mapping Algorithm (9 of 14)

- **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  $R$ . This is a **relationship relation**.
  - 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  $S$ .

## ER-to-Relational Mapping Algorithm (10 of 14)

- **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,  $\bar{PNO}$ }.

# ER-to-Relational Mapping Algorithm (11 of 14)

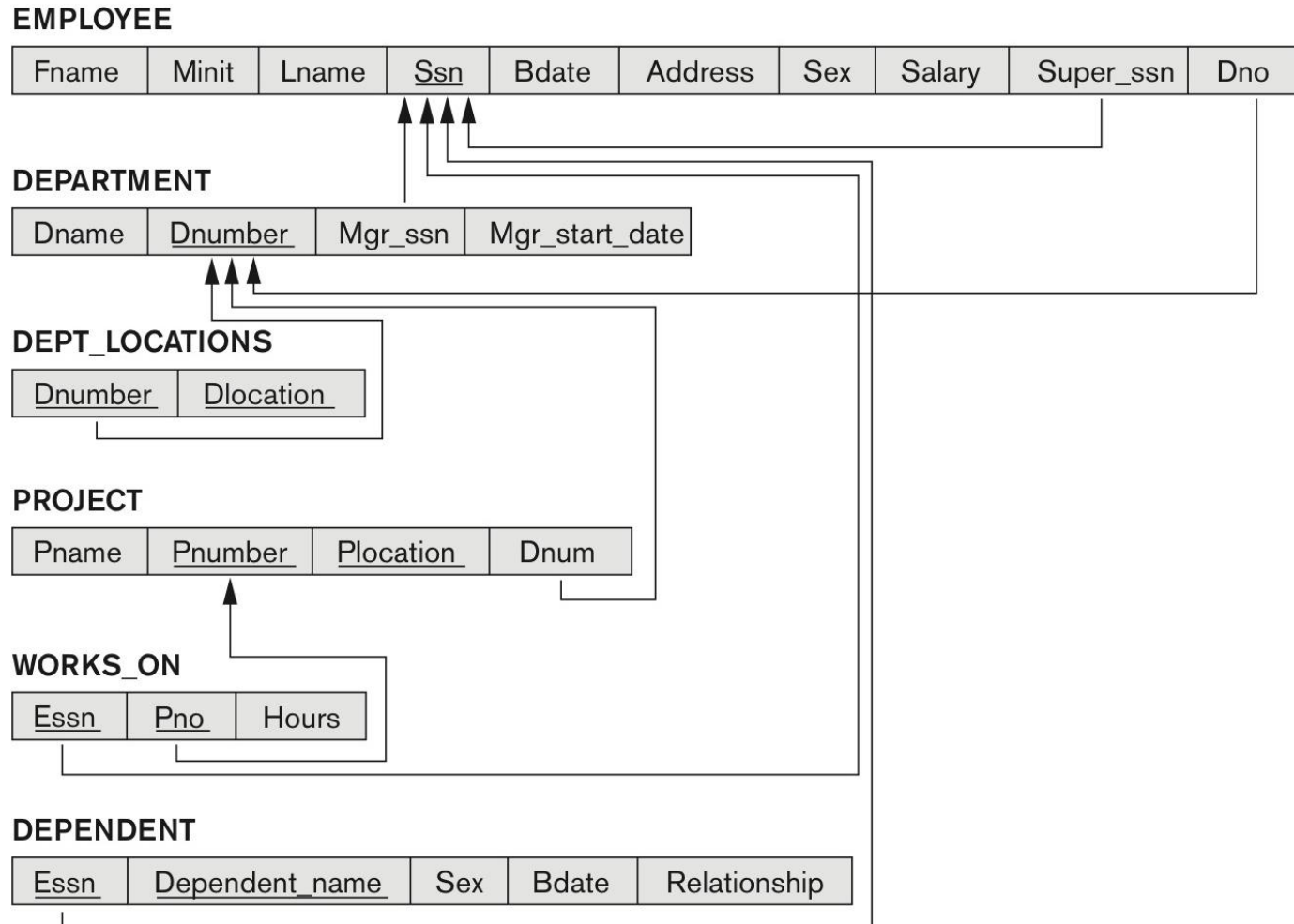
- **Step 6: Mapping of Multivalued attributes.**
  - For each multivalued attribute  $A$ , create a new relation  $R$ .
  - This relation  $R$  will include an attribute corresponding to  $A$ , plus the primary key attribute  $K$ -as a foreign key in  $R$ -of the relation that represents the entity type of 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.

## ER-to-Relational Mapping Algorithm (12 of 14)

- **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}.



## Figure 9.2 Result of Mapping the COMPANY ER Schema into a Relational Database Schema



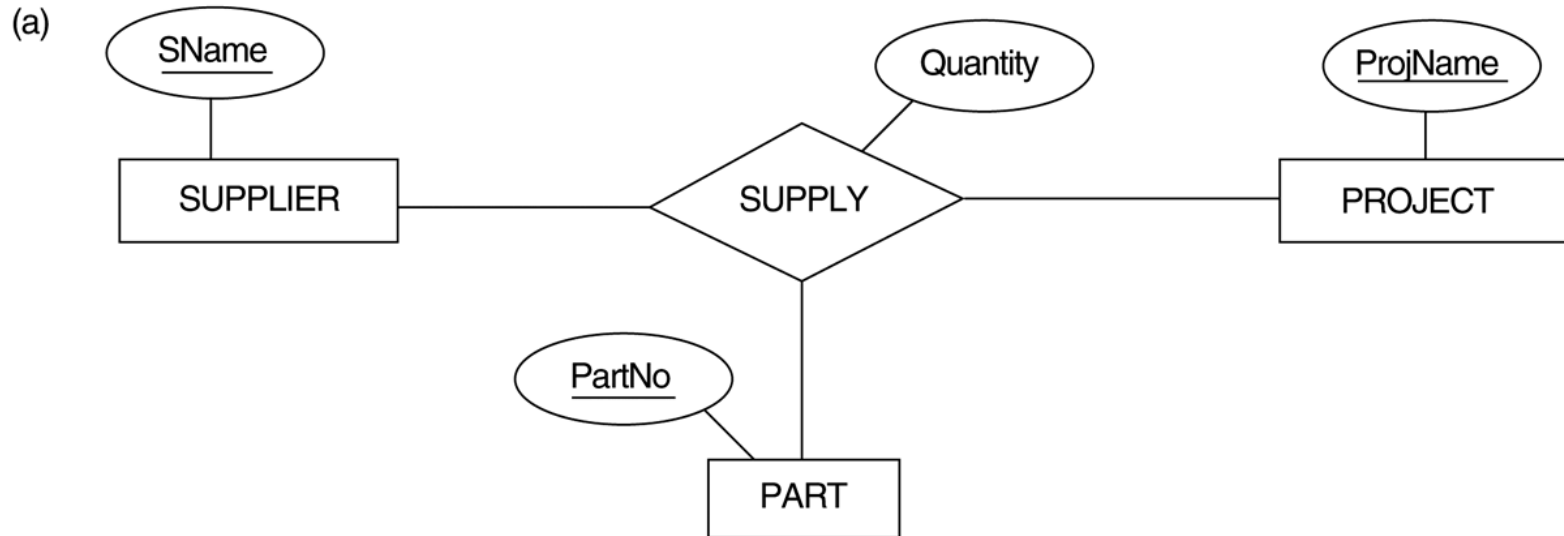
# ER-to-Relational Mapping Algorithm (13 of 14)

- **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  $S$ .

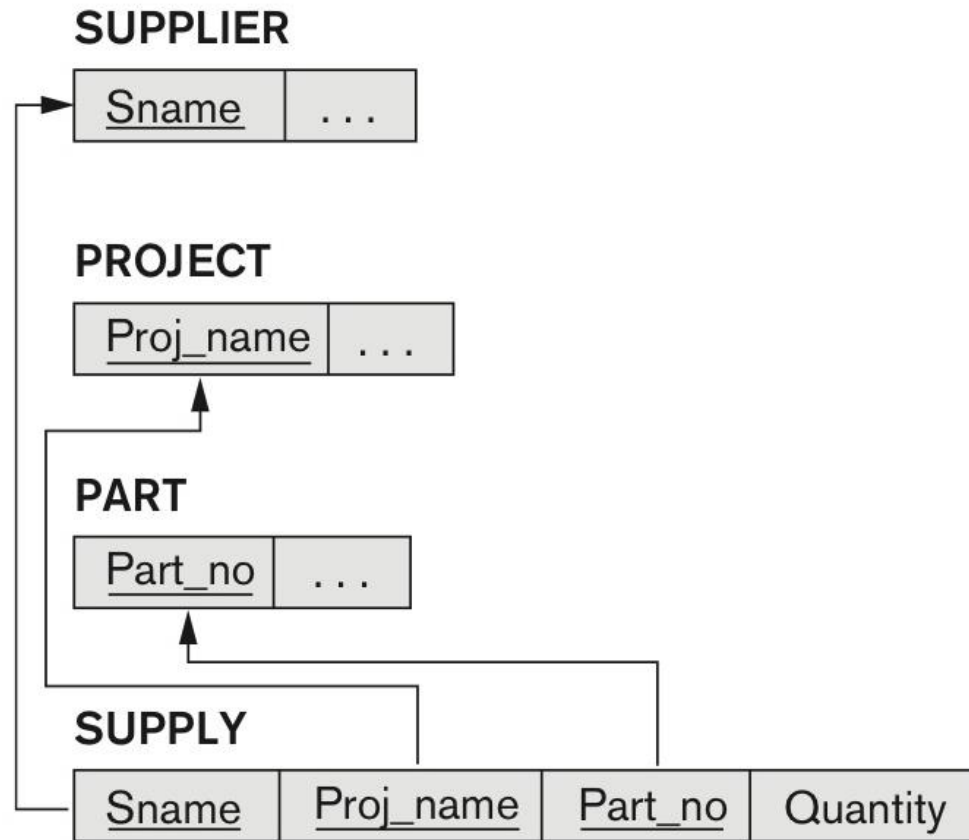
# ER-to-Relational Mapping Algorithm (14 of 14)

- **Example:** The relationship type SUPPLY 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, PART NO, PROJNAME}

## Figure 3.17 Ternary Relationship: Supply



# Mapping the $n$ -ary relationship type SUPPLY



# Summary of Mapping Constructs and Constraints

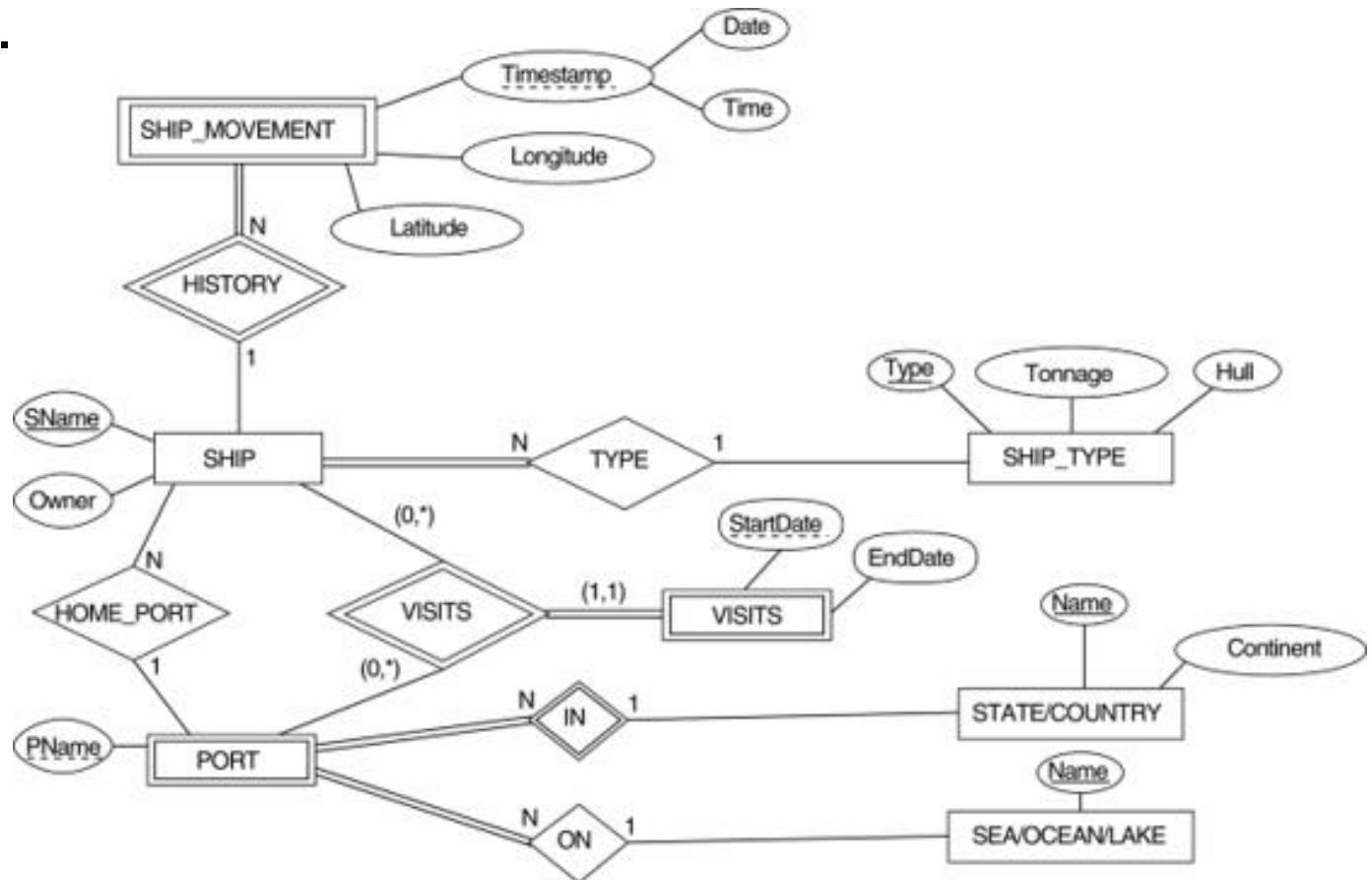
**Table 9.1** Correspondence between ER and Relational Models

ER Model	Relational Model
Entity type	<b>Entity</b> relation
1:1 or 1:N relationship type	Foreign key (or <b>relationship</b> relation)
M:N relationship type	<b>Relationship</b> relation and <b>two</b> foreign keys
<i>n</i> -ary relationship type	<b>Relationship</b> relation and <i>n</i> 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

# Mapping Exercise-1

Exercise 9.4 : Map this schema into a set of relations.

**Figure 9.8** An ER schema for a SHIP\_TRACKING database.



# Mapping EER Model Constructs to Relations

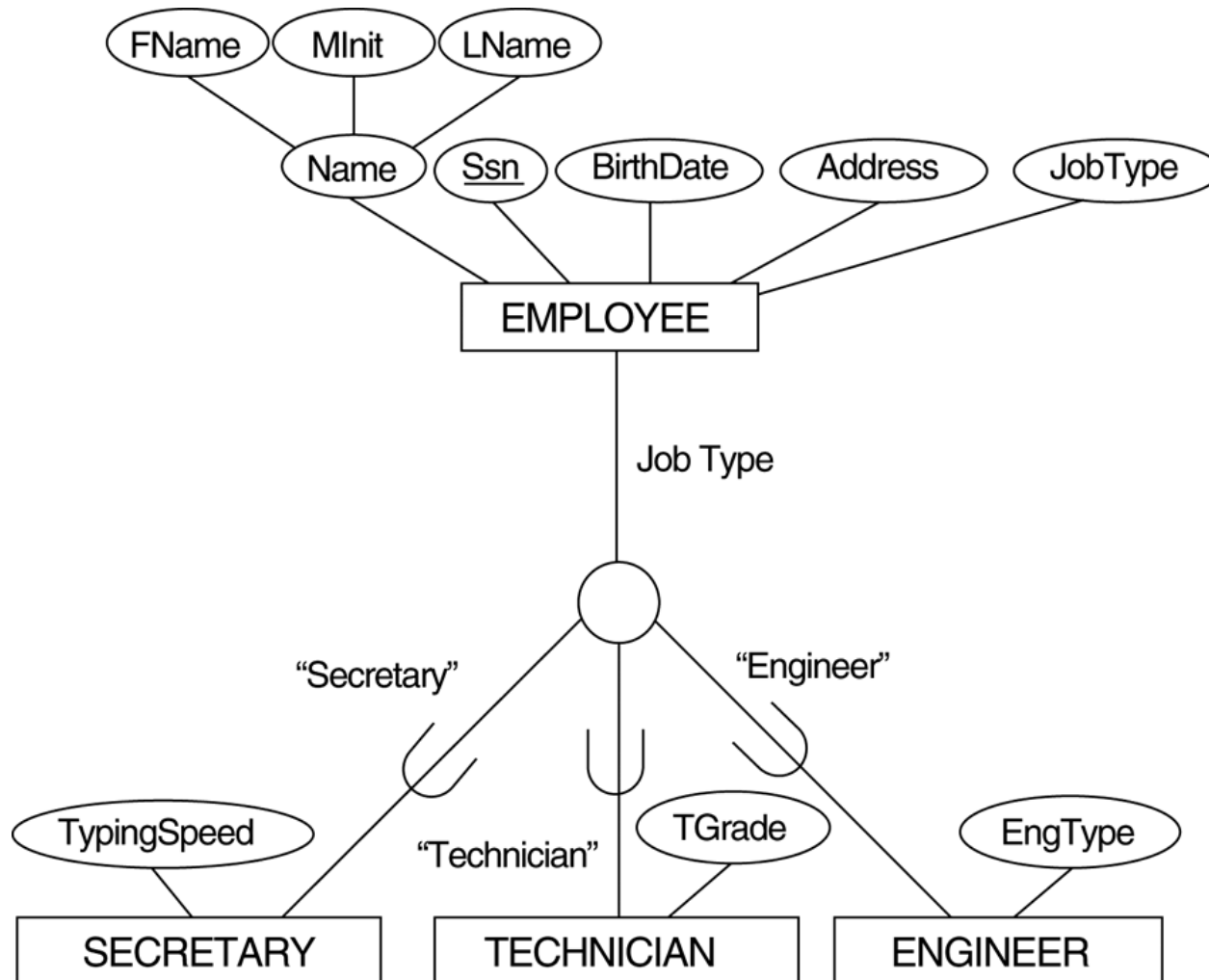
- **Step 8: Options for Mapping Specialization or Generalization.**
  - Convert each specialization with  $m$  subclasses  $\{S_1, S_2, \dots, S_m\}$  and generalized superclass  $C$ , where the attributes of  $C$  are  $\{k, a_1, \dots, a_n\}$  and  $k$  is the (primary) key, into relational schemas 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**



# 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
------------	--------

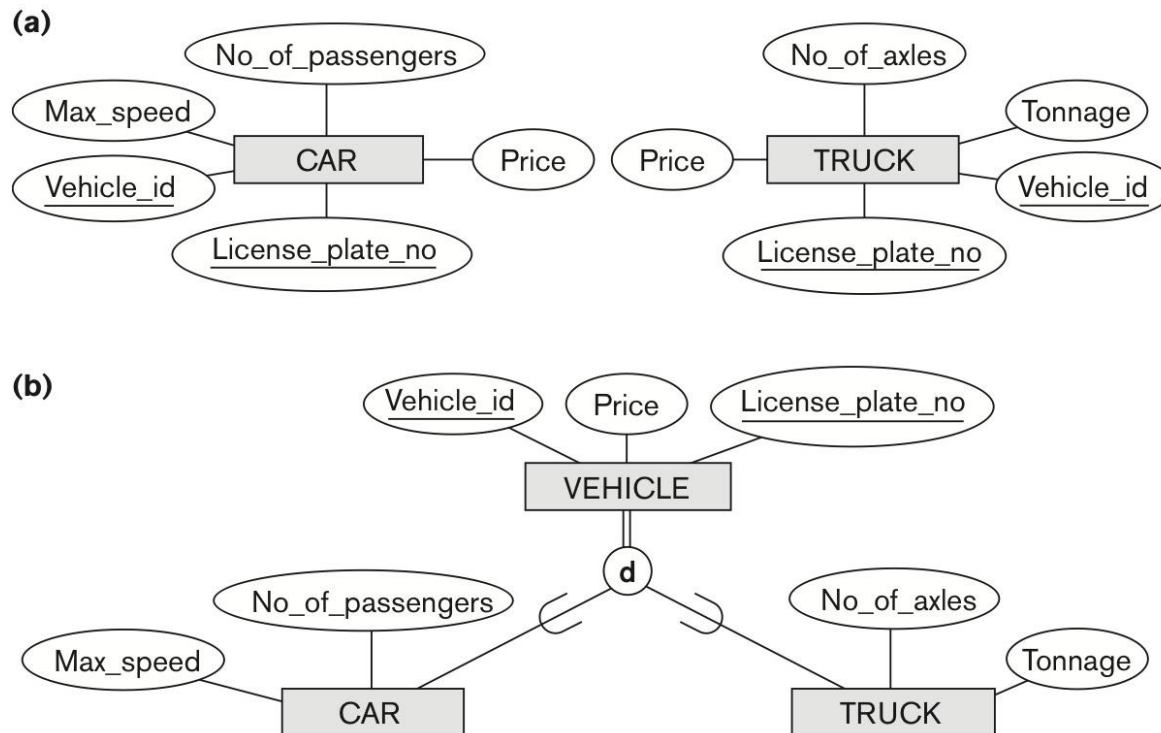
ENGINEER

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

# Mapping EER Model Constructs to Relations

- **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).

## Figure 4.3 (b) Generalizing CAR and TRUCK into the Superclass VEHICLE



# Mapping the EER Schema in Figure 4.3b Using Option 8B

(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

- **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

# Mapping the EER Schema in Figure 4.4 Using Option 8C

(c) EMPLOYEE

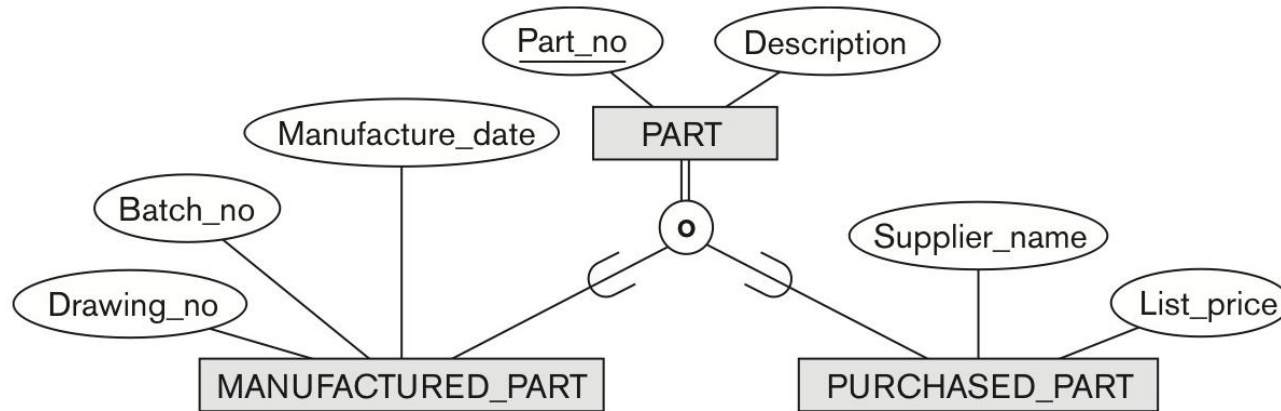
<u>SSN</u>	FName	MInit	LName	BirthDate	Address	JobType	TypingSpeed	TGrade	
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# Mapping EER Model Constructs to Relations

- **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  $S_i$ .

# Figure 4.5 An Overlapping (Non-Disjoint) Specialization



# Mapping Figure 4.5 Using Option 8D with Boolean Type Fields Mflag and Pflag

(d) PART

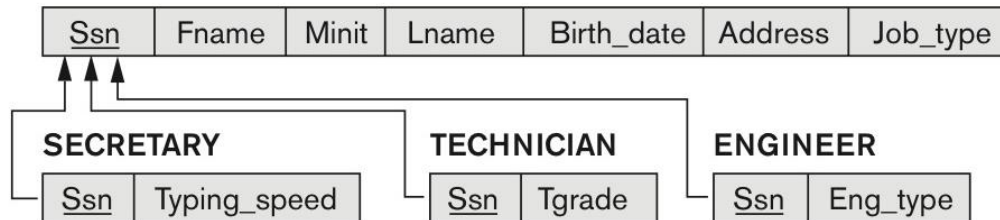
<u>PartNo</u>	Description	MFlag	DrawingNo	ManufactureDate	BatchNo	PFlag	SupplierName	ListPrice
---------------	-------------	-------	-----------	-----------------	---------	-------	--------------	-----------

# Different Options for Mapping Generalization Hierarchies

- **Next Slide :Figure 9.5** (see slide 35) Options for mapping specialization or generalization. (a) Mapping the EER schema in Figure 4.4 using option 8A.
- (b) Mapping the EER schema in Figure 4.3(b) using option 8B.
- (c) Mapping the EER schema in Figure 4.4 using option 8C.
- (d) Mapping Figure 4.5 using option 8D with Boolean type fields Mflag and Pflag.

# Figure 9.5: Different Options for Mapping Generalization Hierarchies - Summary

## (a) EMPLOYEE



## (b) CAR

<u>Vehicle_id</u>	License_plate_no	Price	Max_speed	No_of_passengers
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## TRUCK

<u>Vehicle_id</u>	License_plate_no	Price	No_of_axles	Tonnage
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## (c) EMPLOYEE

<u>Ssn</u>	Fname	Minit	Lname	Birth_date	Address	Job_type	Typing_speed	Tgrade	Eng_type
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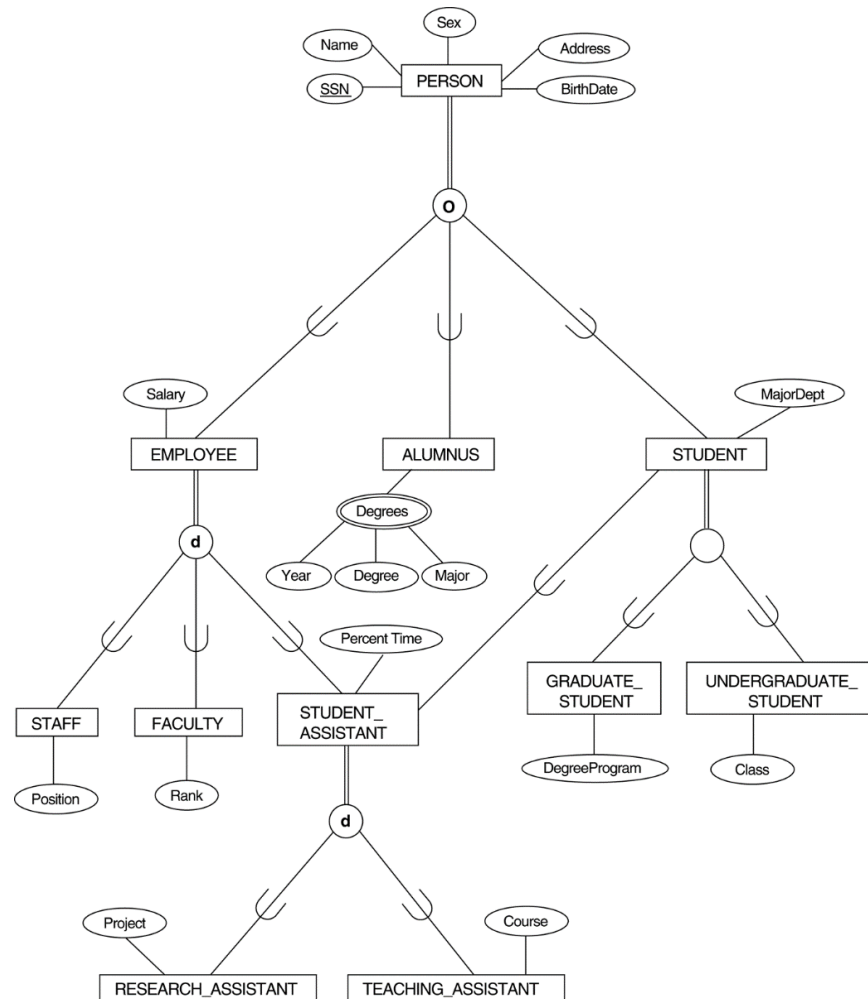
## (d) PART

<u>Part_no</u>	Description	Mflag	Drawing_no	Manufacture_date	Batch_no	Pflag	Supplier_name	List_price
----------------	-------------	-------	------------	------------------	----------	-------	---------------	------------

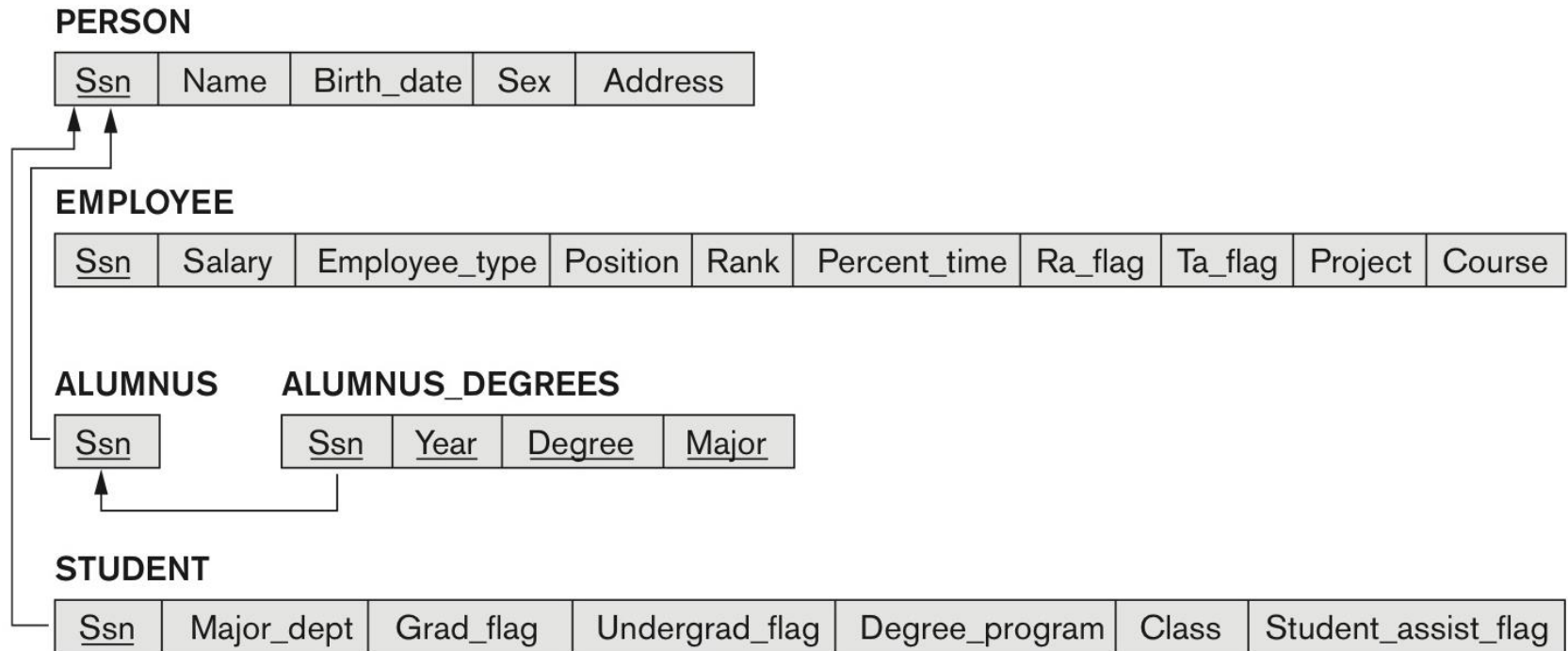
# Mapping EER Model Constructs to Relations (4 of 5)

- 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 9.6 Mapping the EER Specialization Lattice in Figure 4.7 (see slide 37) Using Multiple Options

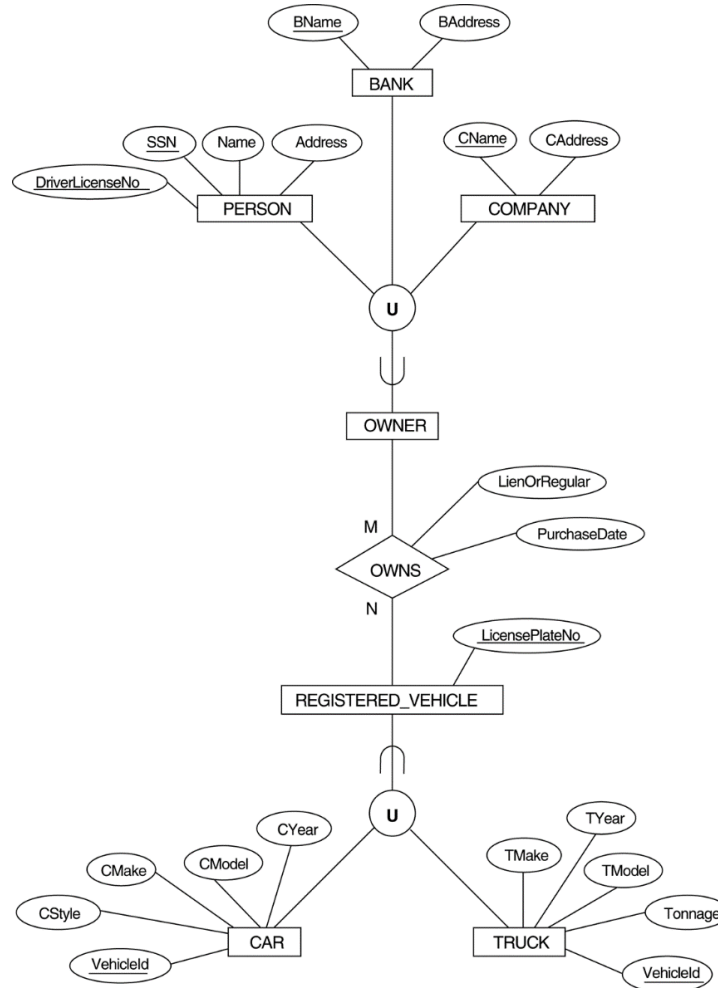




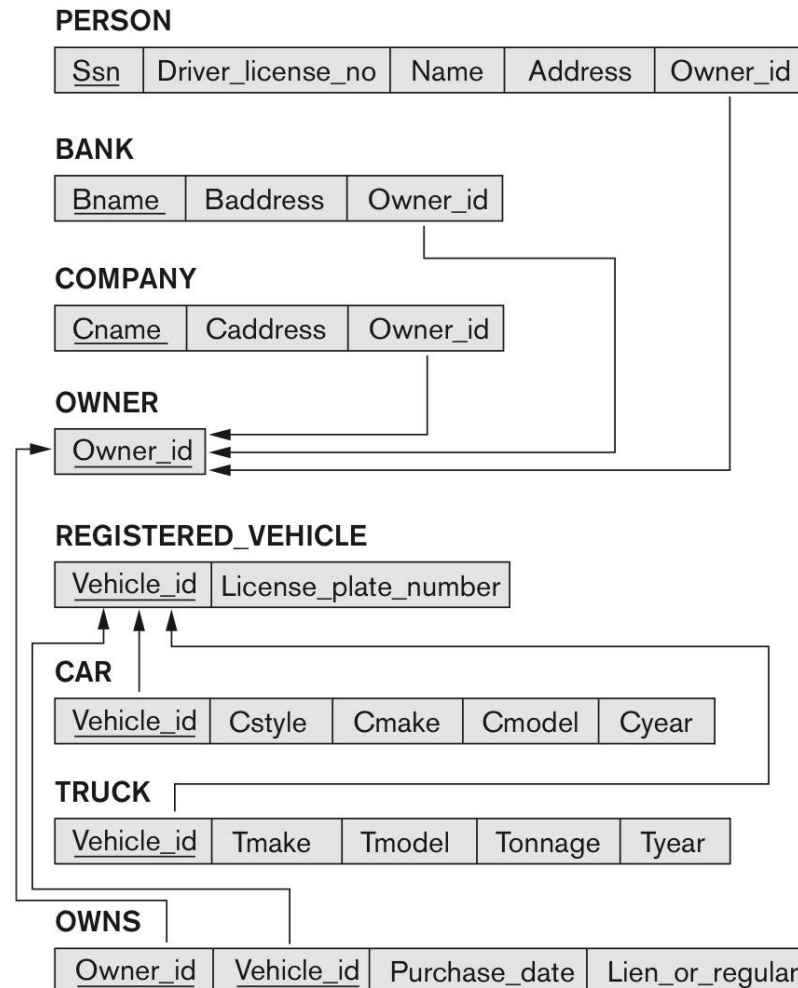
# Mapping EER Model Constructs to Relations (5 of 5)

- **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.

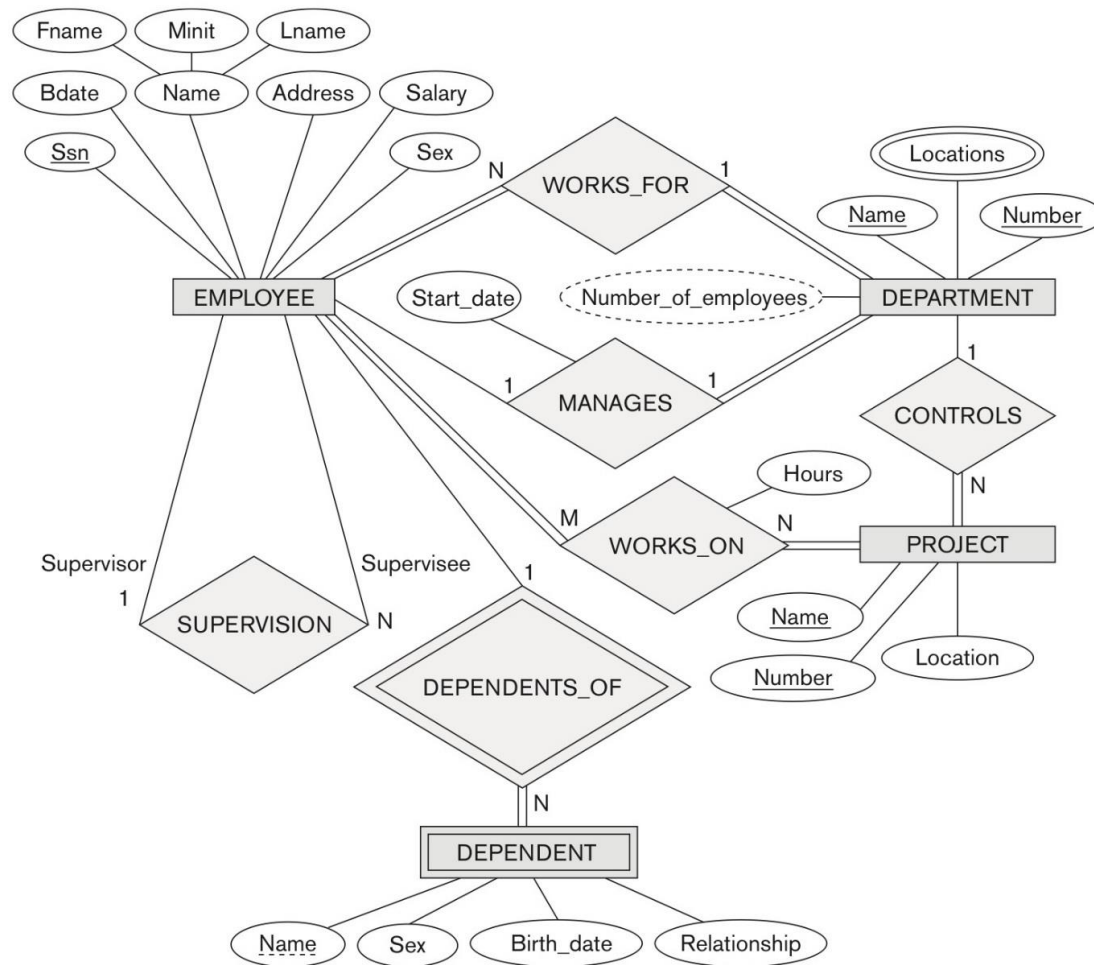
# Figure 4.8 Two Categories (Union Types): OWNER and REGISTERED\_VEHICLE



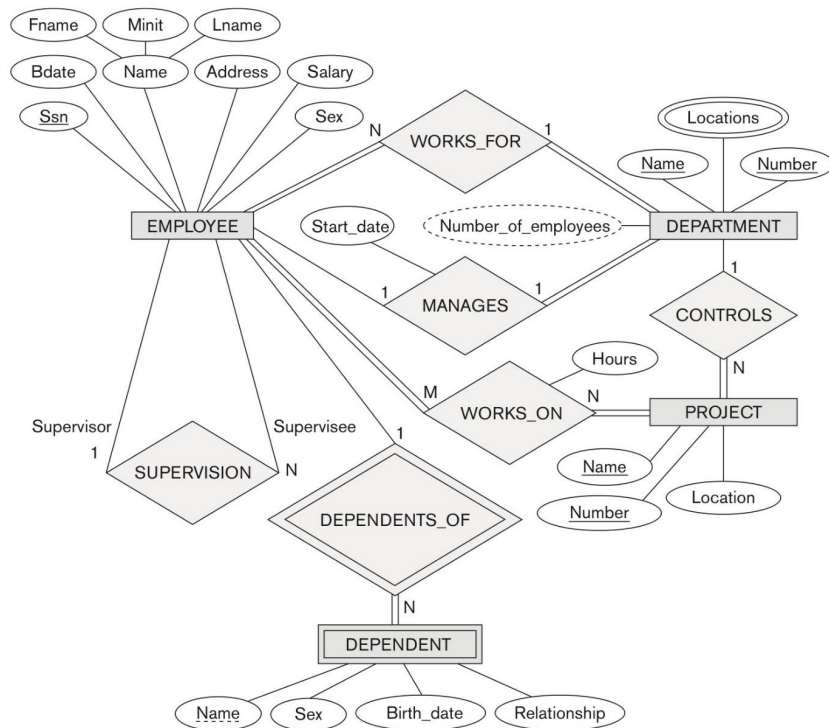
# Figure 9.7 Mapping the EER Categories (Union Types) in Figure 4.8 to Relations



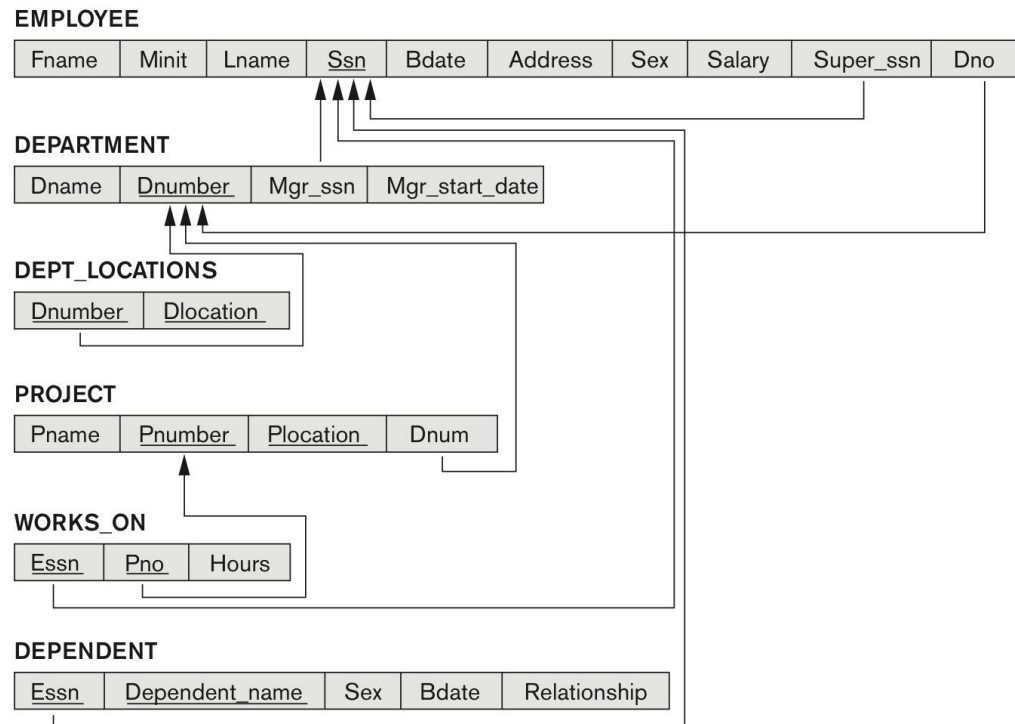
# Figure 9.1 The E R Conceptual Schema Diagram for the COMPANY Database



**Figure 9.1 The E R Conceptual Schema Diagram for the COMPANY Database**



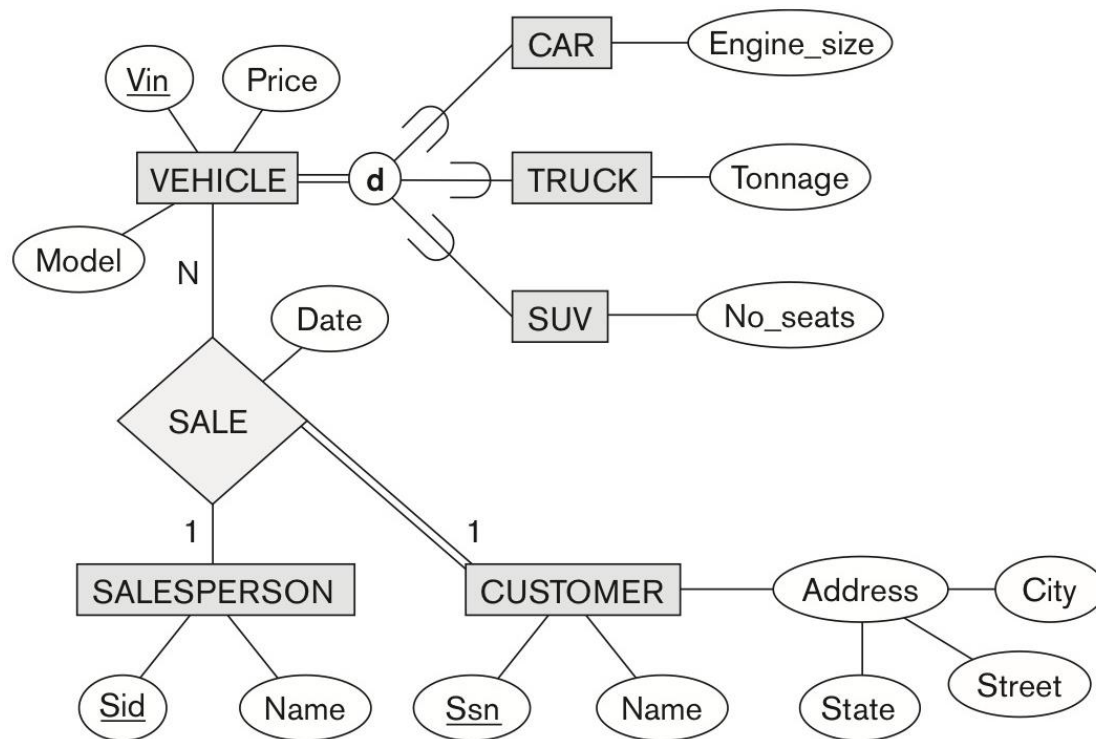
**Figure 9.2 Result of Mapping the COMPANY E R Schema into a Relational Database Schema**



# Mapping Exercise-2

Exercise 9.9 : Map this schema into a set of relations

**Figure 9.9** EER Diagram for a Car Dealer



# Chapter Summary

- **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).