King Saud University

College of Engineering

IE – 462: “Industrial Information Systems”

Fall – 2020 (2^{nd} Sem. 1440-41H)

Chapter 3

Data Modeling and Design – p2 – E-R Diagram - ii

Prepared by: Ahmed M. El-Sherbeeny, PhD

Lesson Overview

Lesson Overview

- **E-R Diagram** – (part-i)
  - o **Introduction to E-R Modeling**
    - Introduction
    - Entities
    - Attributes
    - Candidate Keys and Identifiers
    - Other Attribute Types
    - Relationships

Lesson Overview

- **E-R Diagram** – (part-ii)
  - **Conceptual Data Modeling and the E-R Model**
    - Degree of a Relationship
      - Unary Relationships
      - Binary Relationships
      - Ternary Relationships
    - Cardinalities in Relationships
      - Minimum and Maximum Cardinalities
      - Alternative Cardinality System
      - Semantic Net Diagram

Lesson Overview

- **E-R Diagram** – (part-ii)
  - o **Conceptual Data Modeling and the E-R Model**
    - Naming Relationships
    - Associative Entities

CONCEPTUAL DATA MODELING AND THE E-R MODEL

Degree of a Relationship

Degree of a Relationship

- Degree of a relationship is a measure of the number of entities sharing the same association
- There are four cases:
  - **unary** relationships
  - **binary** relationships
  - **ternary** relationships
  - **n-ary** relationships

Degree of a Relationship

Unary Relationships

- A unary relationship is a relationship between the instances of one entity type (i.e. *within a single entity*)
  - o i.e. the entity has a relationship with itself
  - o aka ***recursive relationship***
- Examples:
  - o Is_married_to: *one-to-one* relationship between instances of PERSON entity
  - o Manages: *one-to-many* relationship between instances of EMPLOYEE entity (used to identify employees who report to a particular manager and vice versa)

(a)

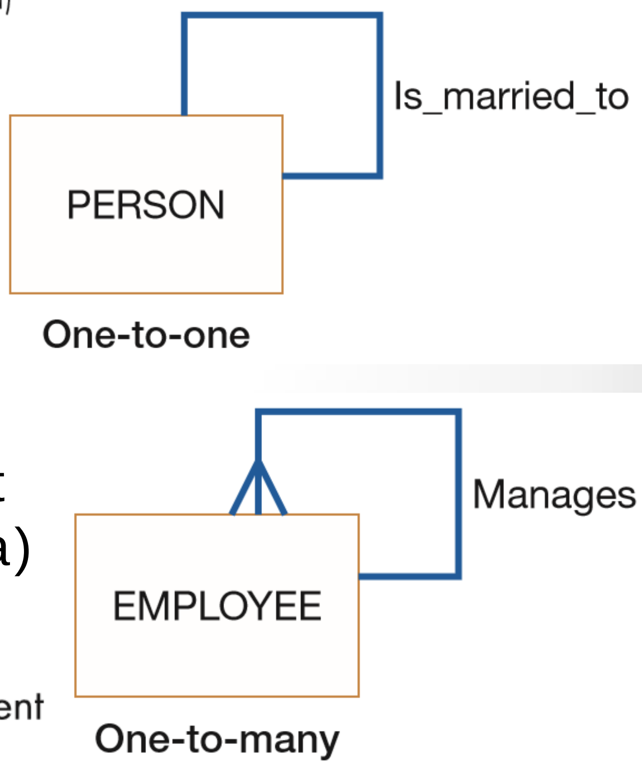


FIGURE 8-11
Examples of relationships of different degrees
(a) Unary relationships

Degree of a Relationship

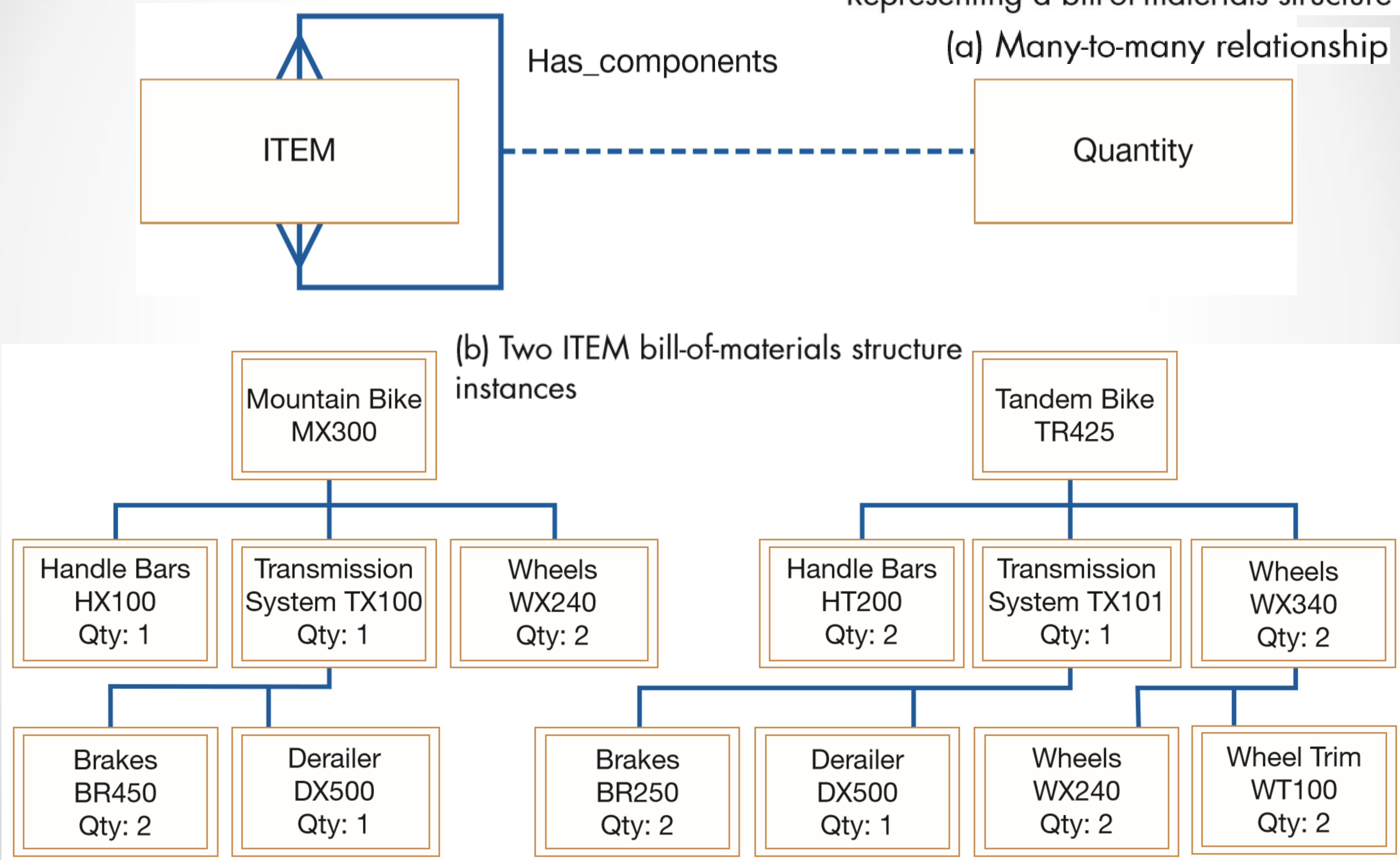
Unary Relationships (cont.)

- Next slide: example of another common unary relationship: ***bill-of-materials structure***
  - o Many manufactured products are made of subassemblies
  - o Subassemblies in turn are composed of other subassemblies and parts, and so on
  - o Figure 8-12a: shows this as *many-to-many unary* relationship
    - relationship name: Has_components
    - attribute Quantity: property of the relationship; indicates # of each component that is contained in a given assembly
  - o Figure 8-12b: 2 occurrences of this structure
    - easy to see associations are in fact many-to-many
    - e.g. TX100 consists of items BR450 (Qty 2) & DX500 (Qty 1)
    - also, some components are used in several higher-level assemblies (e.g. WX240 used in item MX300 & WX340)

Degree of a Relationship

Unary Relationships (cont.)

FIGURE 8-12
Representing a bill-of-materials structure



Degree of a Relationship

Binary Relationships

- Binary relationship:
  - Exists when two entities have an *associated relationship* (i.e. relationship between instances of two entities)
  - It is the most common relationship used in data modeling
- Three example are shown on the next slide

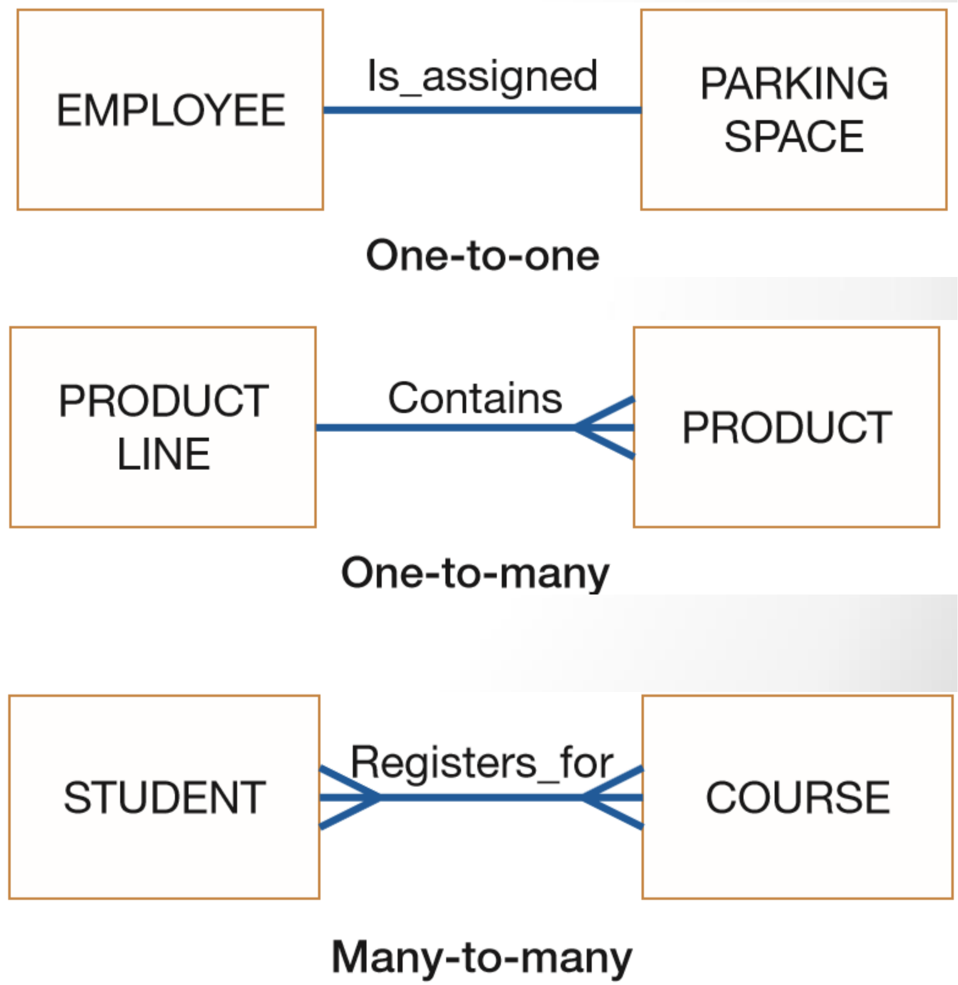
Degree of a Relationship

Binary Relationships (cont.)

- Examples (cont.)
  - *one-to-one*: employee is assigned 1 parking place, each parking place is assigned to 1 employee
  - *one-to-many*: product line may contain several products, and each product belongs to only 1 product line
  - *many-to-many*: student may register for > 1 course, each course may have many student registrants

FIGURE 8-11
Examples of relationships of different degrees

(b) Binary relationships



Degree of a Relationship

Ternary Relationships

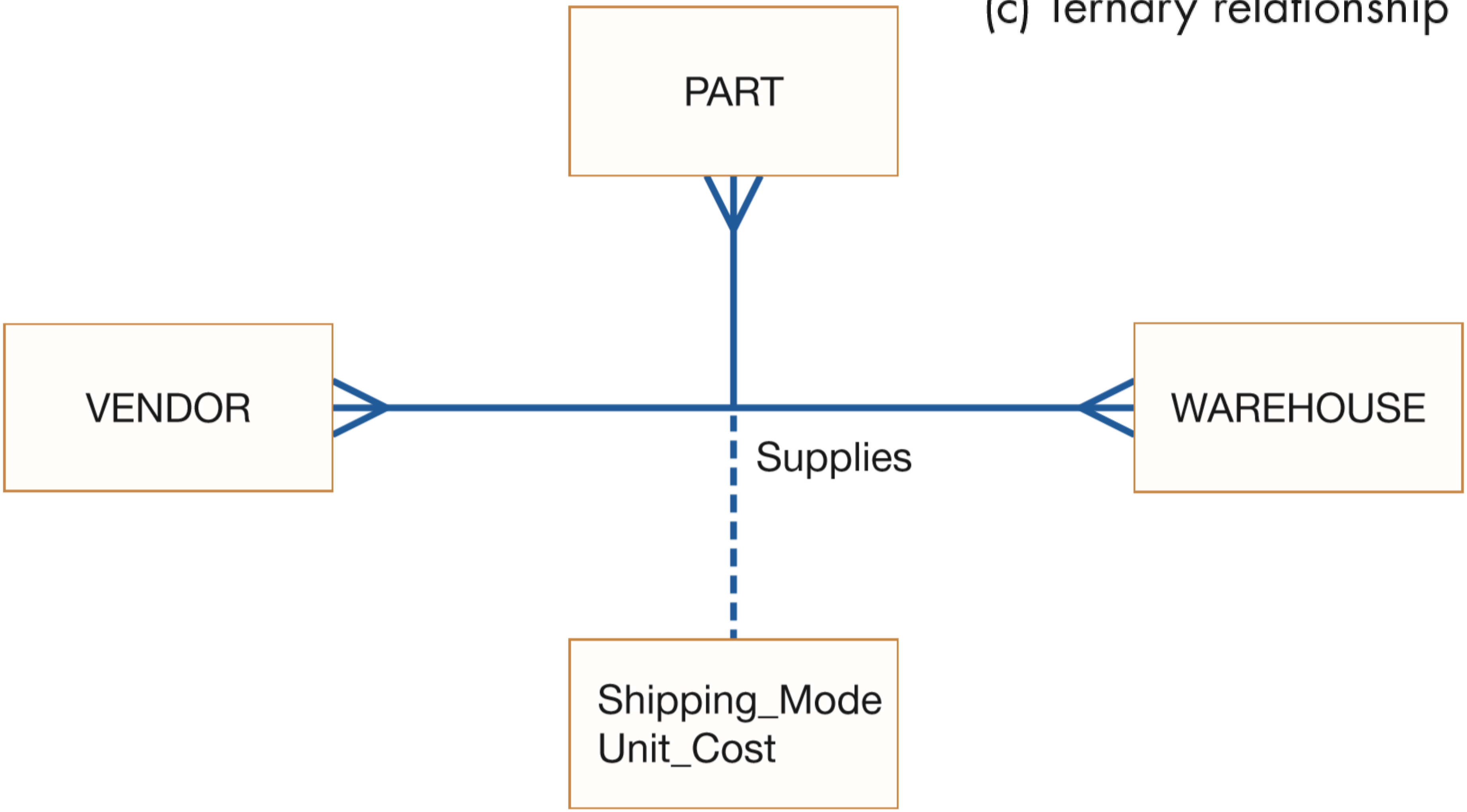
- Ternary relationship:
  - It is *simultaneous* relationship among instances of 3 entities
  - i.e. it occurs when 3 entities share a *common relationship*
- Examine example shown on the next slide:
  - Relationship: Supplies tracks the
    - quantity of a given part,
    - that is shipped by a particular vendor,
    - to a selected warehouse
  - All three entities are *many* participants (in this example)
  - Shipping_Mode
    - attribute of Supplies relationship
    - it's type of shipping carrier used for a particular PART, shipped from particular VENDOR to particular WAREHOUSE

Degree of a Relationship

Ternary Relationships (cont.)

FIGURE 8-11
Examples of relationships of different degrees

(c) Ternary relationship



Degree of a Relationship

N-ary Relationships

- Occurs when > 3 entities share a relationship
- This situation rarely occurs and can be ignored for the purposes of this course

Cardinalities in Relationships

Cardinalities in Relationships

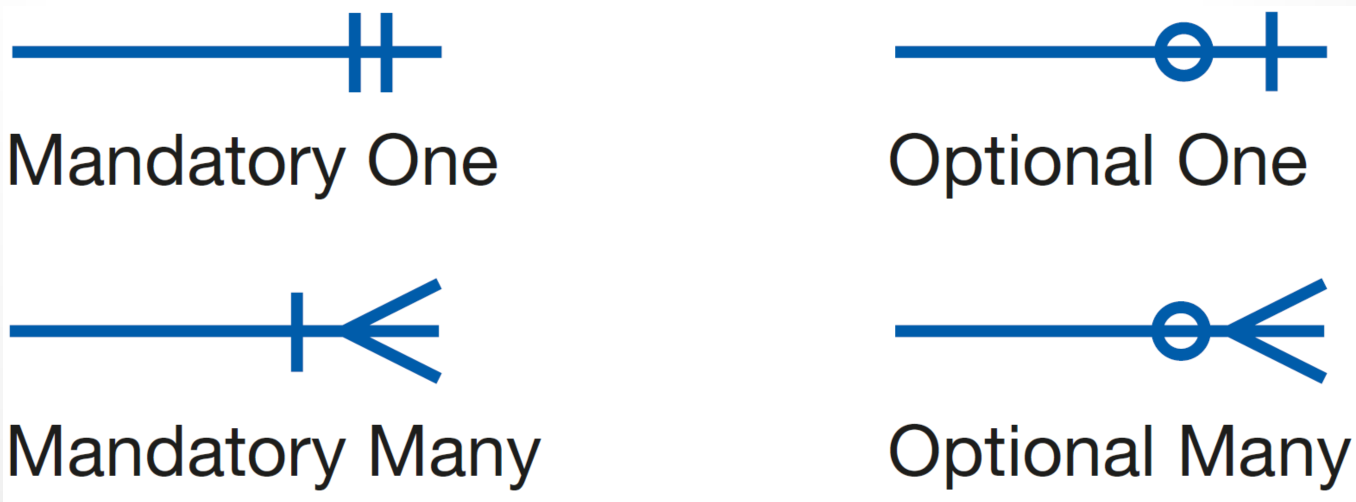
Cardinality

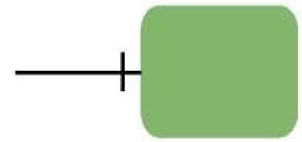
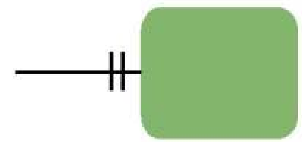
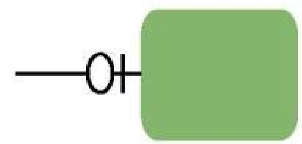
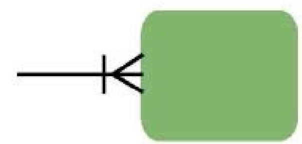
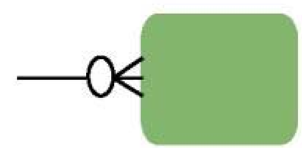
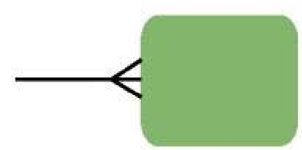
- This is the number of entity occurrences associated with 1 occurrence of the related entity
- Represented by Questions 5, 7, and 8 in Table 8-1
- Cardinality is indicated at the ends of the relationship arc by either
  - o Symbols (crow's foot notation), or
  - o Numbers (another system we will also discuss)
- Example:
  - o 2 entity types, A and B, are connected by a relationship
  - o ⇒ cardinality is number of instances of entity B that can (or must) be associated with each instance of entity A

Cardinalities in Relationships

Minimum and Maximum Cardinalities

- Consider relationship for DVDs at a video store:
  - Since video store may stock > 1 DVD of a given movie, it is clear that this is (basically) a "many" relationship (Fig. 8-13a)
- We use min. & max. cardinalities to more precisely indicate range of cardinalities for a relationship
  - This notation is shown below
  - A more detailed version is shown on the following slide



CARDINALITY INTERPRETATION	MINIMUM INSTANCES	MAXIMUM INSTANCES	GRAPHIC NOTATION
Exactly one (one and only one)	1	1	 – or – 
Zero or one	0	1	
One or more	1	many (>1)	
Zero, one, or more	0	many (>1)	
More than one	>1	>1	

Cardinalities in Relationships

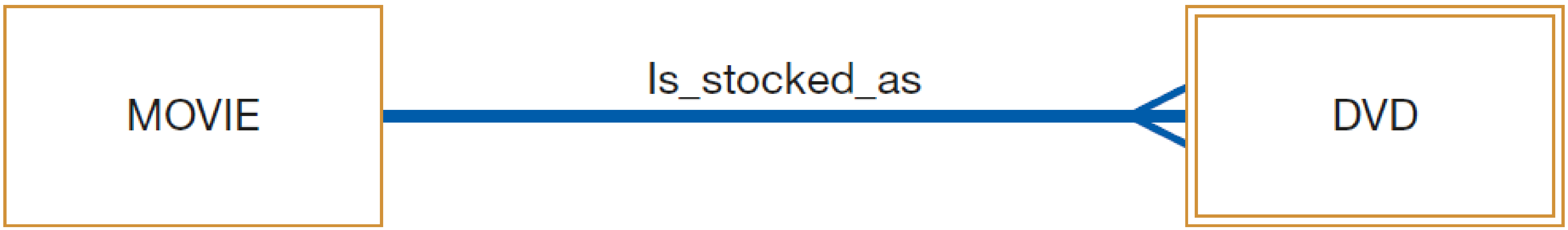
Minimum and Maximum Cardinalities (cont.)

- Minimum Cardinality:
  - This's the *minimum number* of instances of entity B that may be associated with each instance of entity A
  - In our e.g. min. # of DVDs available for a movie is 0
    ⇒ DVD is **optional participant** in the Is_stocked_as relationship
  - If minimum cardinality of a relationship = 1
    ⇒ entity B is a **mandatory participant** in the relationship

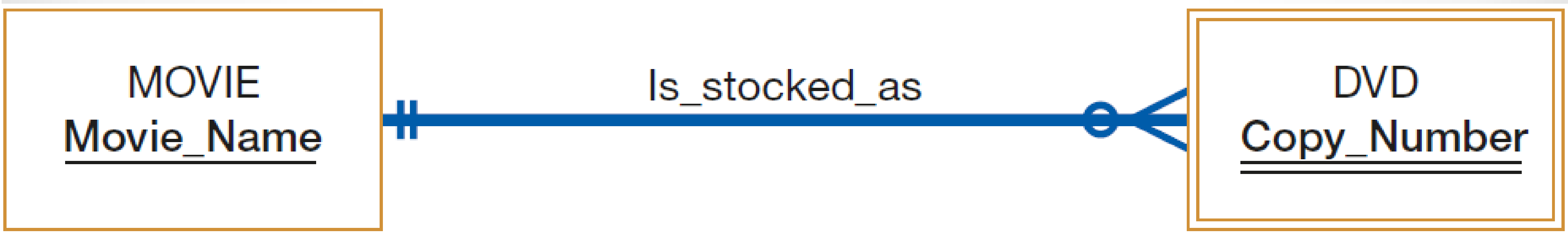
Cardinalities in Relationships

FIGURE 8-13
Introducing cardinality constraints

(a) Basic relationship



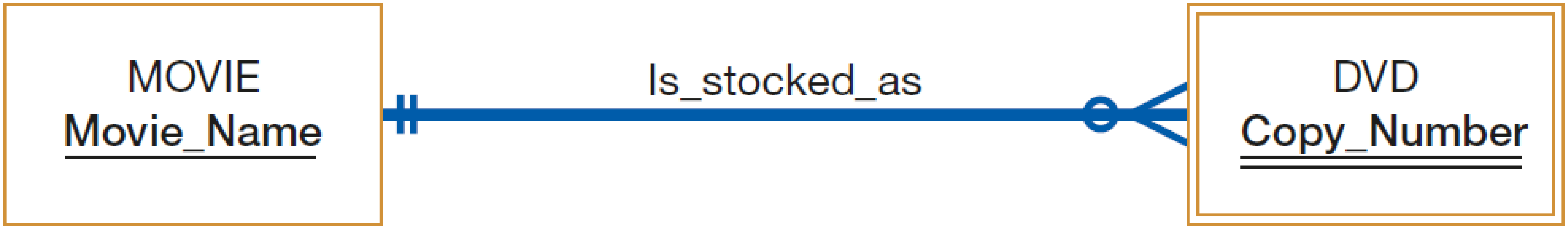
(b) Relationship with cardinality constraints



Cardinalities in Relationships

Minimum and Maximum Cardinalities (cont.)

- Maximum Cardinality:
  - o This's is the *maximum number* of instances of entity B that may be associated with each instance of entity A
  - o In our e.g. maximum is “many” (an unspecified number > 1)
  - o 0 thru line near DVD entity means min. cardinality of zero
  - o crow's foot notation means a “many” maximum cardinality
  - o double underline of Copy_Number:
    - indicates that this attribute is part of the identifier of DVD
    - note, full composite identifier must also include the identifier of MOVIE, Movie_Name



Cardinalities in Relationships

Minimum and Maximum Cardinalities (cont.)

- Following are 3 relationships that show *all possible combinations* of min. & max. cardinalities

1. PATIENT Has_recorded PATIENT_HISTORY
   - o Each patient has recorded *one or more patient* histories (note, 1st patient visit is recorded as PATIENT HISTORY instance)
   - o Each instance of PATIENT HISTORY is a record for *exactly one* PATIENT

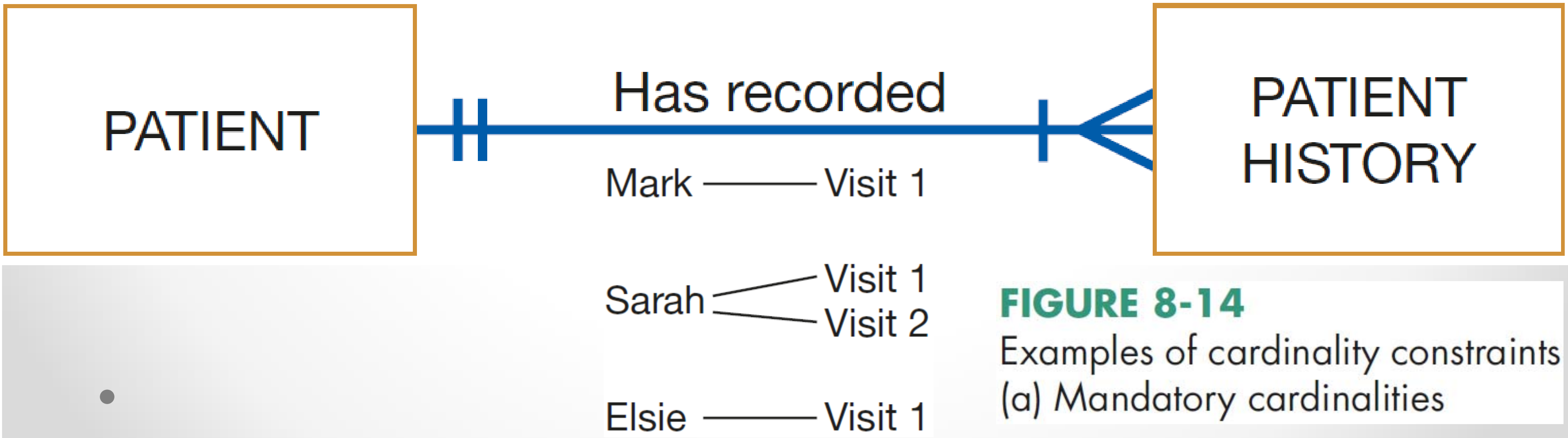


FIGURE 8-14
Examples of cardinality constraints
(a) Mandatory cardinalities

•

Cardinalities in Relationships

Minimum and Maximum Cardinalities (cont.)

2. EMPLOYEE Is_assigned_to PROJECT
   - Each PROJECT has *at least one* assigned EMPLOYEE
   - Each EMPLOYEE *may or may not* be assigned to any existing PROJECT, or may be assigned to several PROJECTs

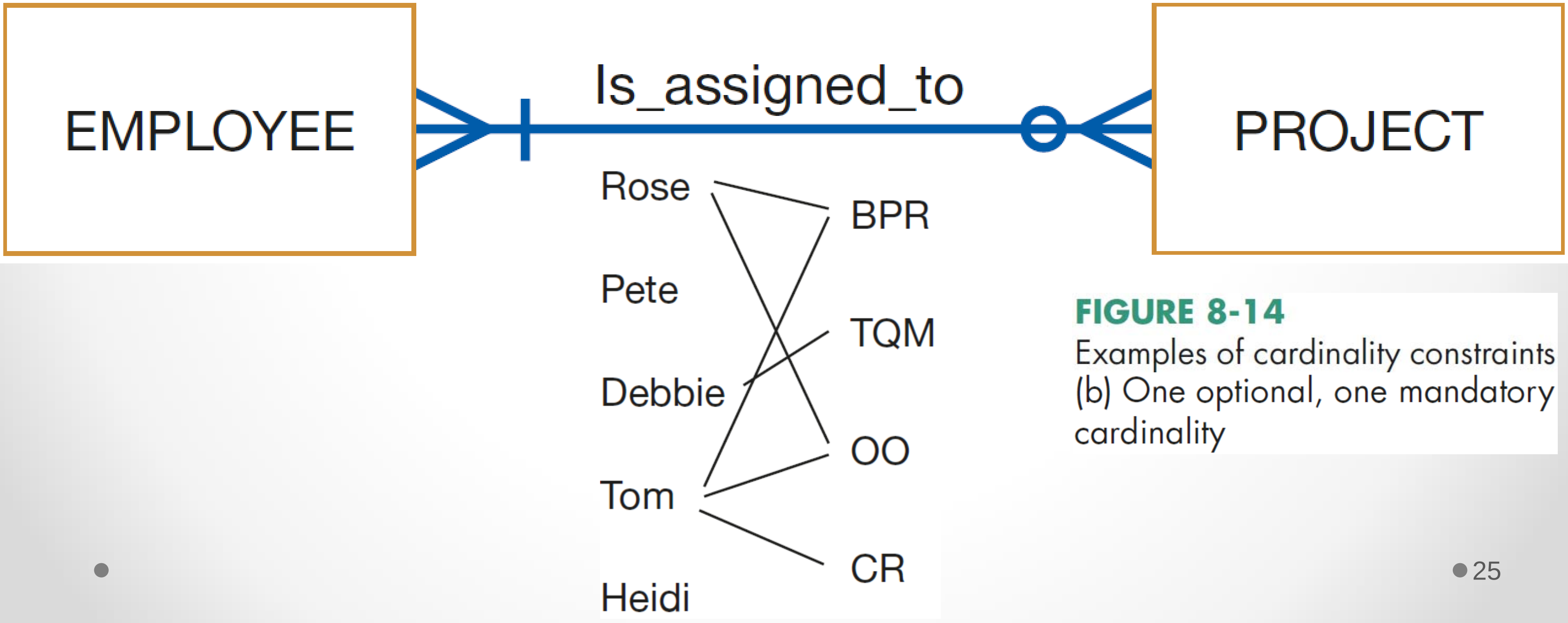


FIGURE 8-14
Examples of cardinality constraints
(b) One optional, one mandatory cardinality

Cardinalities in Relationships

Minimum and Maximum Cardinalities (cont.)

3. PERSON Is_married_to PERSON
   - This is an optional *zero or one cardinality* (in both directions)
   - i.e. person may or may not be married

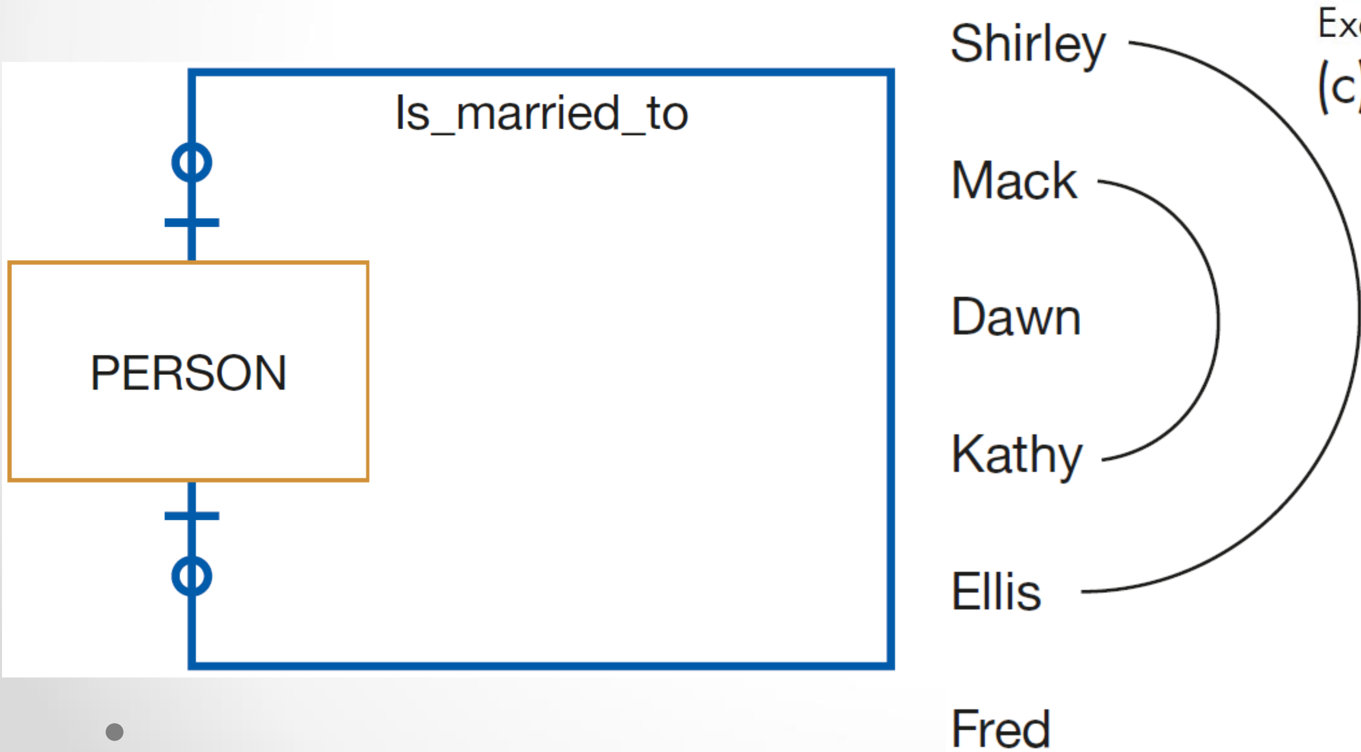
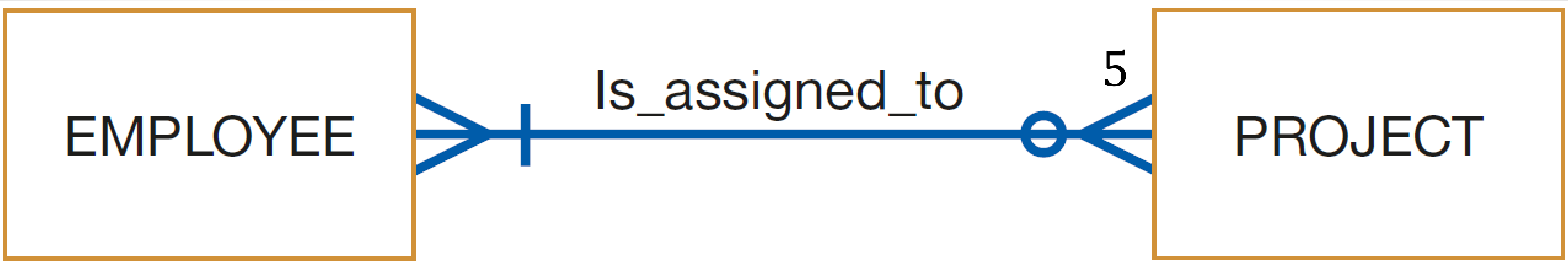


FIGURE 8-14
Examples of cardinality constraints
(c) Optional cardinalities

Cardinalities in Relationships

Alternative Cardinality System

- It is possible for the maximum cardinality to be a fixed number, not an arbitrary "many" value
  - Cardinality limits are determined according to the way in which the business is operated (**business rules** of enterprise)
- e.g. suppose corporate policy states that employee may work on *at most* 5 projects at the same time
  - We could show this business rule by placing a "5" above (or below) crow's foot next to PROJECT entity



Cardinalities in Relationships

Alternative Cardinality System (cont.)

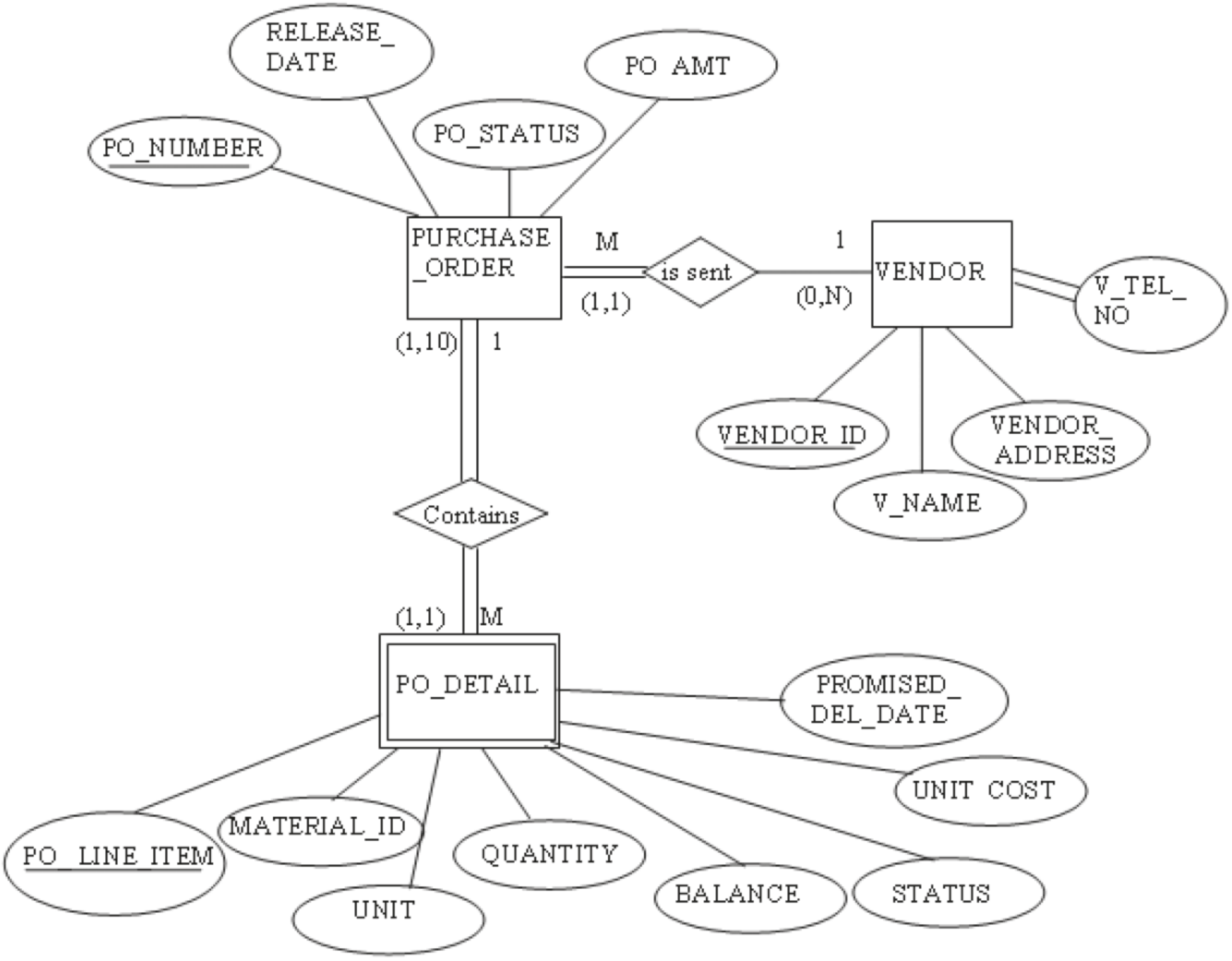
- Uses *letters* and *numbers* instead of *Crow's foot notation* (sometimes called *Chen's notation*)
- Type of relationship is expressed in the following way:
  - 1 : 1 (one-to-one)
  - 1 : M (one-to-many)
  - M : N (many-to-many)
- Cardinality limits are shown in parentheses (min. cardinality ,max cardinality); examples:
  - (1, 1)
  - (1, 7)
  - (0, N)

Cardinalities in Relationships

Alternative Cardinality System (cont.)

- Examine e.g. of this shown on the next slide
  - o Cardinality 1 : M means:
    - each instance of an entity is associated with 0, 1, or many instances of the entity on the M side of the relationship
  - o Relationship between PURCHASE_ORDER and PO_DETAIL:
    - cardinality limits for PO_DETAIL are (1,1)
    - ⇒ each PO_DETAIL is associated with one purchase order
  - o Similarly, the cardinality limits of PURCHASE_ORDER is (1,10):
    - ⇒ a minimum of 1 and a maximum of 10 line items are associated with one purchase order
  - o Also, relationship between PURCHASE_ORDER and VENDOR:
    - cardinality limits for VENDOR are (0,N)
    - ⇒ each vendor is sent 0, 1 or many purchase orders

Cardinalities in Relationships



Cardinalities in Relationships

Alternative Cardinality System (cont.)

- Let's see if you can determine for the e.g. below:
  - o Type and degree of relationship
  - o Cardinality limits for each entity

Cardinalities in Relationships

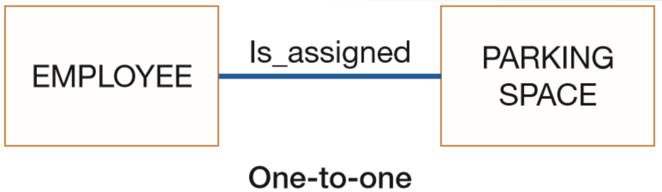
Semantic Net Diagram

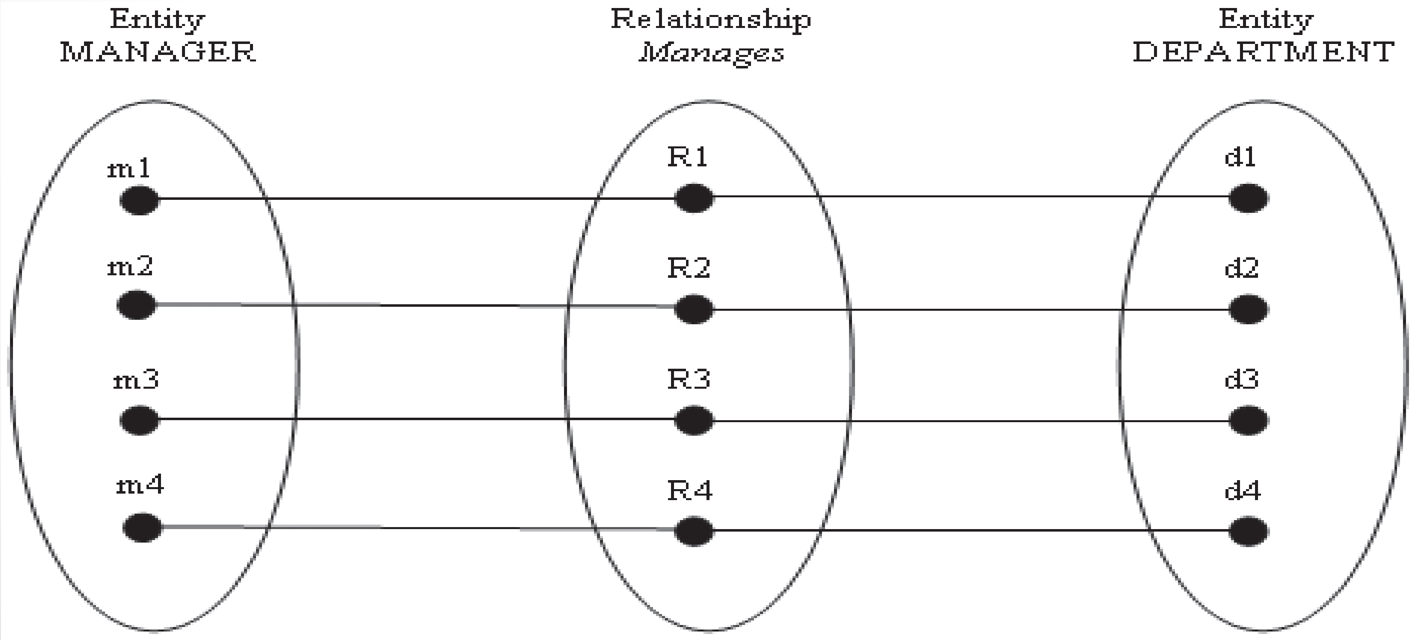
- M : N relationship is difficult to handle in a database query
  - o ⇒ it is usu. expanded into a series of 1: M relationships in the final database tables
- Semantic net diagram:
  - o Useful graphical tool that assists in visualizing the cardinality of a relationship
  - o Can be used to represent (see upcoming slides):
    1. 1 : 1 relationship
    2. 1 : M relationship
    3. M : N relationship
  - o Note how in M : N relationship, # of instances of relationship (6) is > # of related instances in an entity set (2, 4)

Cardinalities in Relationships

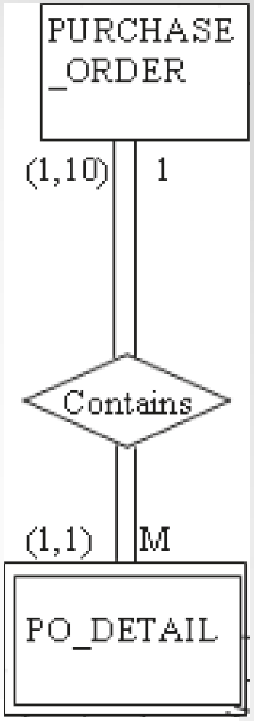
Semantic Net Diagram (cont.)

1. 1 : 1 semantic net diagram for relationship between MANAGER and DEPARTMENT



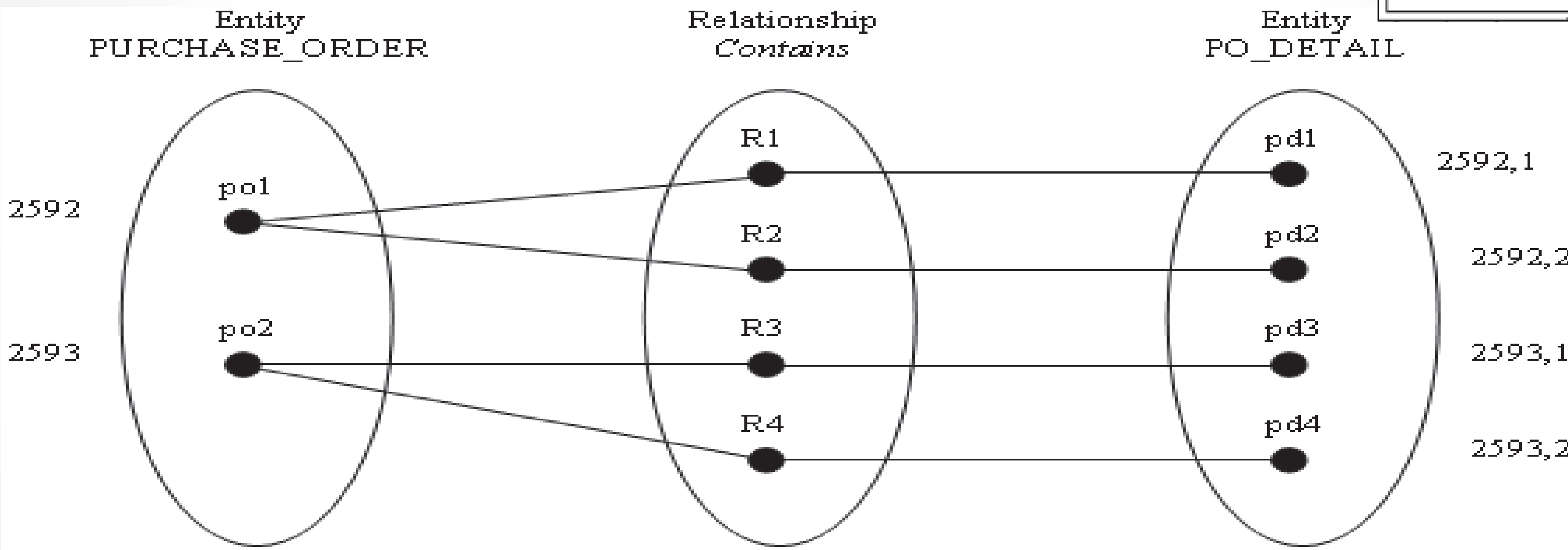


Cardinalities in Relationships



Semantic Net Diagram (cont.)

2. 1 : M semantic net diagram for relationship between PURCHASE_ORDER and PO_DETAIL

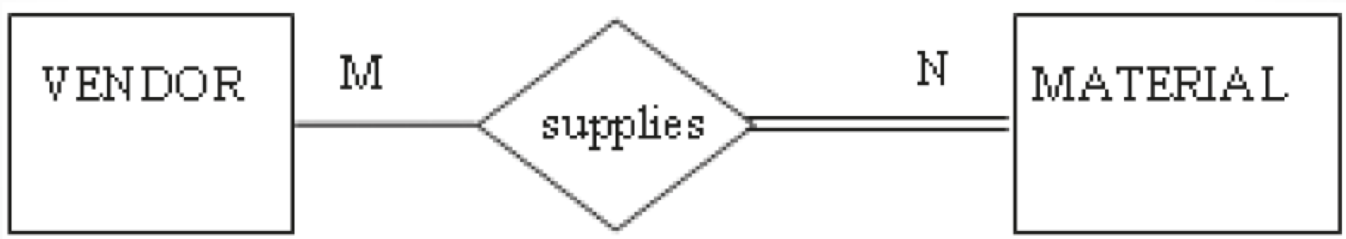


Cardinalities in Relationships

Semantic Net Diagram (cont.)

3. M : N semantic net diagram for relationship between VENDOR and MATERIAL

- Business rules:
  - o A vendor supplies material to a company
  - o 1 vendor may supply > 1 material
  - o Also, specific material may be supplied by > 1 vendor



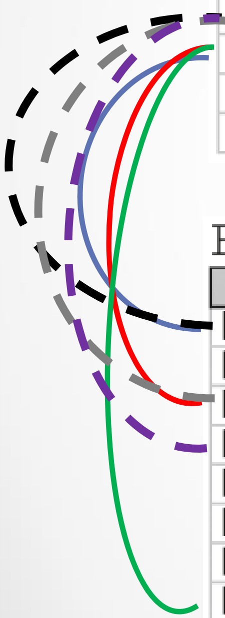
Cardinalities in Relationships

Semantic Net Diagram (cont.)

- M : N semantic net diagram for relationship between VENDOR and MATERIAL (cont.):

Entity Set: VENDOR

VENDOR ID	V NAME	V STREET	V CITY	V STATE	V ZIP
V110	Jersey	2 Main St.	Patterson	NJ	07055
V25	General	125 Common	Boise	ID	44830
V250	Spices	25 Salty Lane	East Hampton	NY	10027
V75	Pasta Supply,	34 Henry St.	Philadelphia	PA	09098



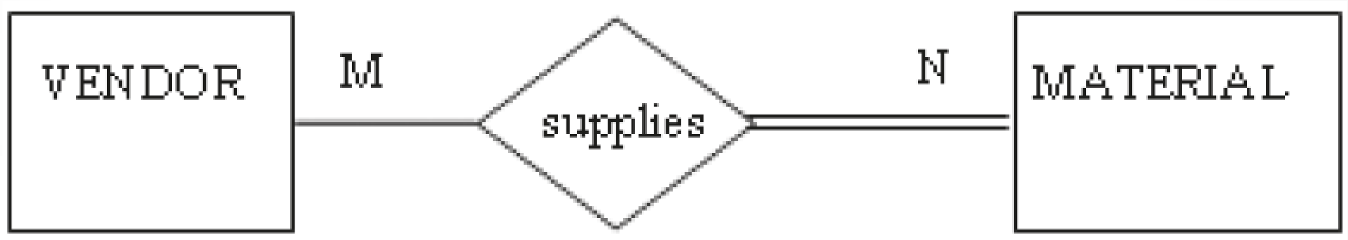
Entity Set: MATERIAL

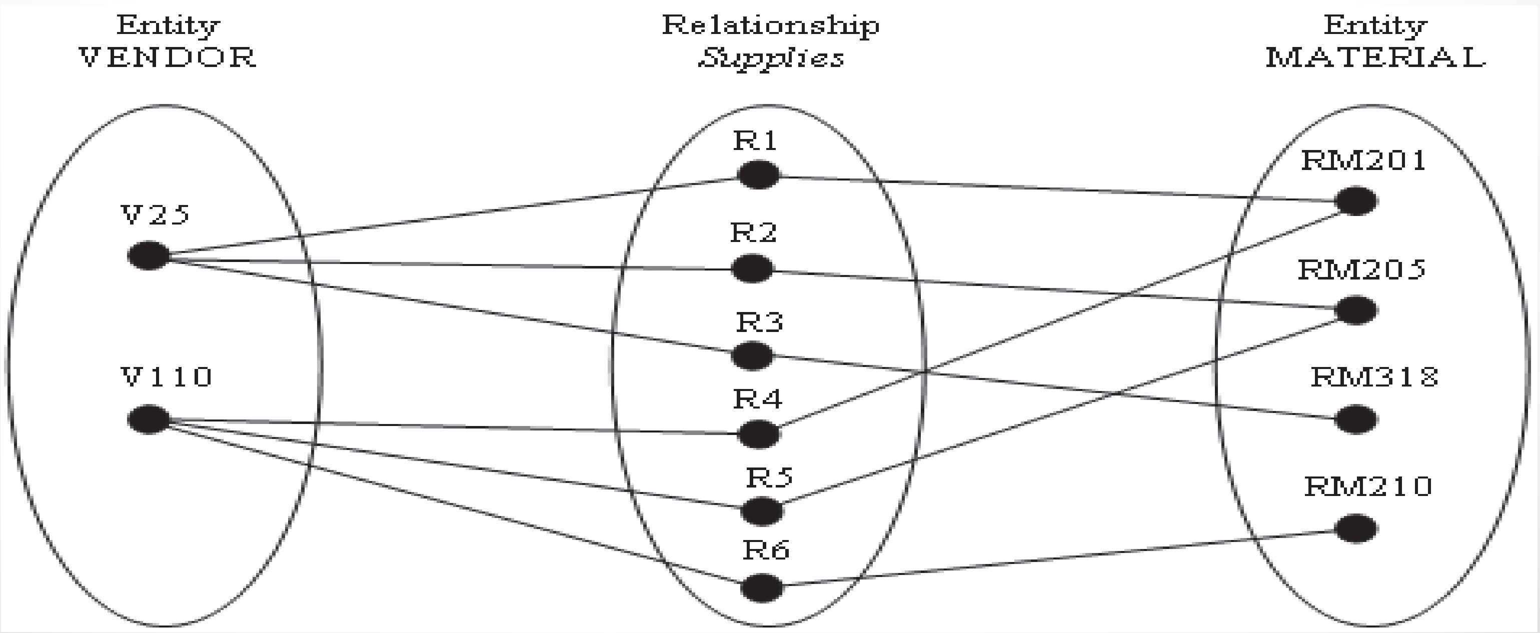
MATERIAL ID	MATL DESCRIPTION
RM201	Carrots, whole
RM202	Carrots, diced, 1/4 inch
RM205	Potatoes, Eastern,
RM210	Peas, shelled
RM211	Tomatoes, whole
RM310	Garlic, whole
RM311	Garlic powder
RM318	Salt, iodized
RM308	Onion salt
RM305	Paprika
RM340	Sugar, bulk
RM805	Olive oil
RM810	Vinegar, white

Cardinalities in Relationships

Semantic Net Diagram (cont.)

- M : N semantic net diagram for relationship between VENDOR and MATERIAL (cont.):





Naming Relationships

Naming Relationships

Few special guidelines for naming relationships:

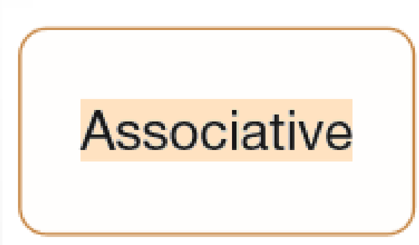
- Relationship name is a verb phrase
  - e.g. Assigned_to, Supplies, or Teaches
- Relationships represent actions, usually in the present tense
- Relationship name states the action taken, not the result of the action
  - e.g. use Assigned_to, not Assignment
- Avoid vague names
  - e.g. such as Has or Is_related_to
- Use descriptive verb phrases (action verbs)

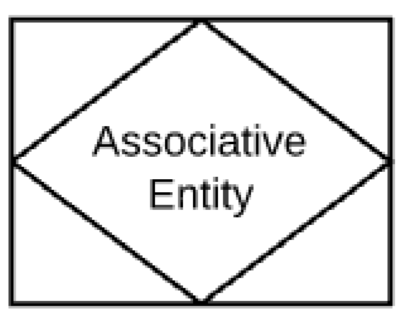
Associative Entities

Associative Entities

- Also called composite/bridge entity
- Entity type that relates/associates instances of 1 or more entity types (e.g. Has_components, Supplies)
- Transforms M : N relationship into 1 : M relationships
- Contains attributes specific to the relationship between those entity instances

- Two different notations below:





Associative Entities

- Example 1: organization wishes to record date (month/year) that employee completes each course

Employee_ID	Course_Name	Date_Completed
549-23-1948	Basic Algebra	March 2017
629-16-8407	Software Quality	June 2017
816-30-0458	Software Quality	February 2017
549-23-1948	C Programming	May 2017

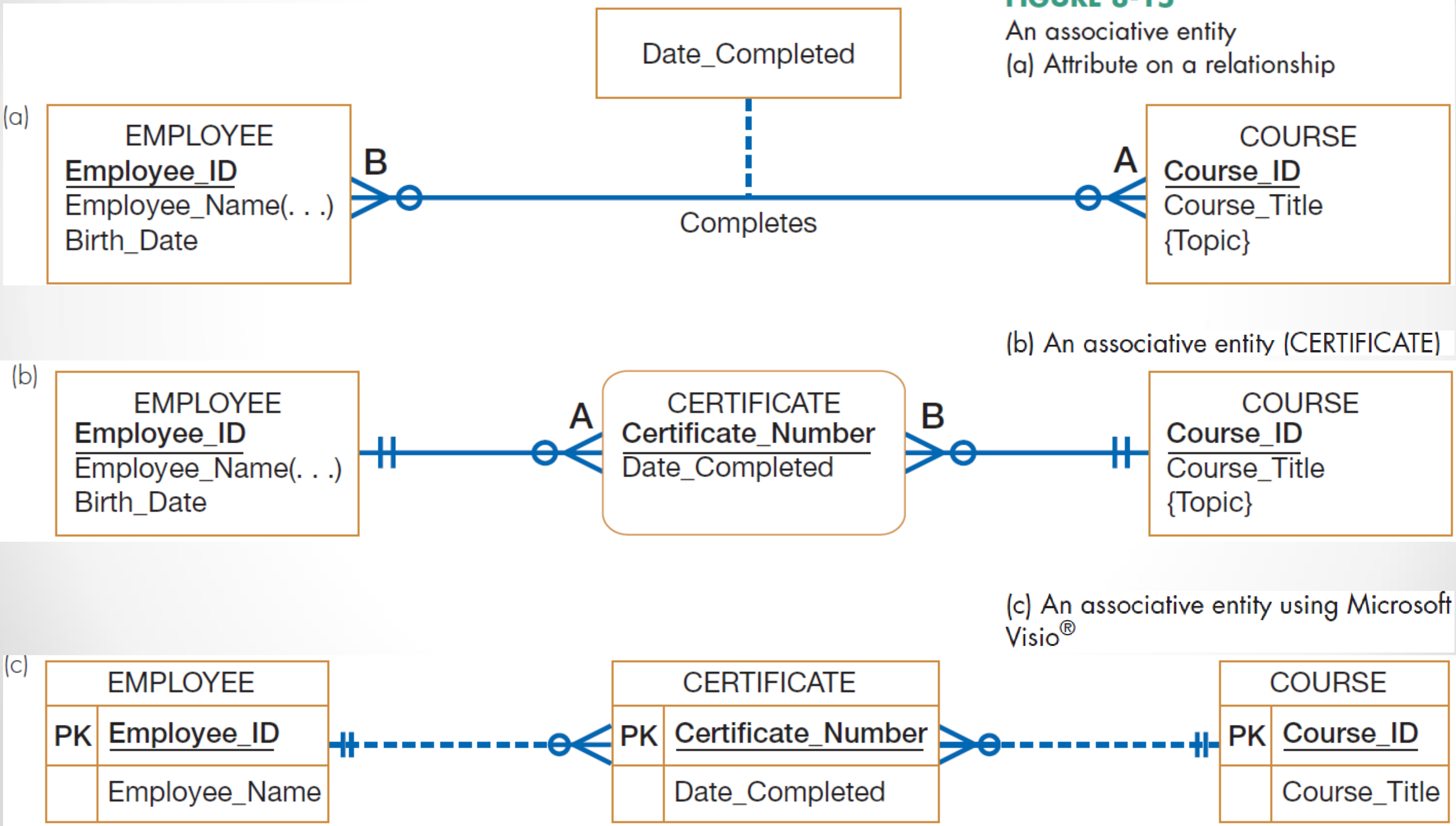
- Date_Completed is *not* a property of entity EMPLOYEE
  - e.g. 549-23-1948 completed courses on different dates
- Also, Date_Completed is *not* a property of COURSE
  - e.g. Software Quality was completed on different dates
- ⇒ Date_Completed is a property of the *relationship* between EMPLOYEE and COURSE (*next slide*)

Associative Entities

FIGURE 8-15
An associative entity
(a) Attribute on a relationship

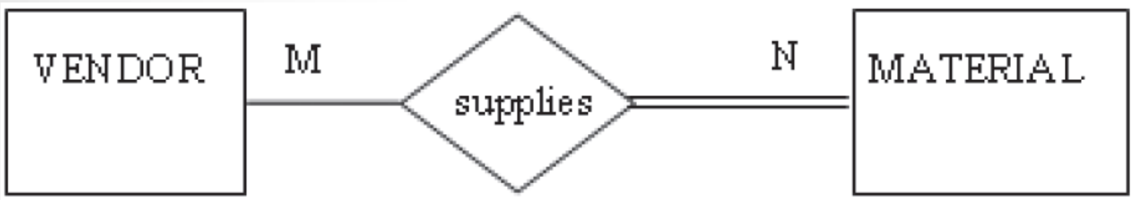
(b) An associative entity (CERTIFICATE)

(c) An associative entity using Microsoft Visio®



Associative Entities

- Example 2: Convert M : N relationship between VENDOR and MATERIAL into associative entity



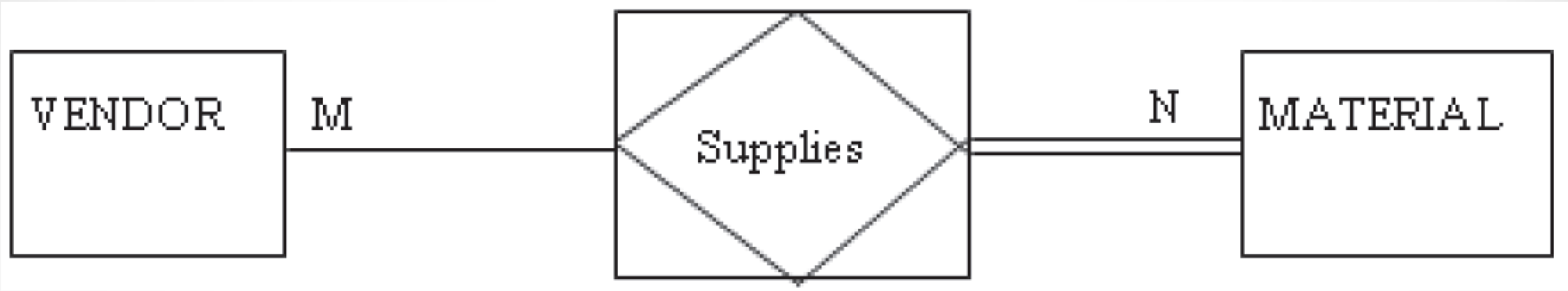
Entity Set: MATERIAL

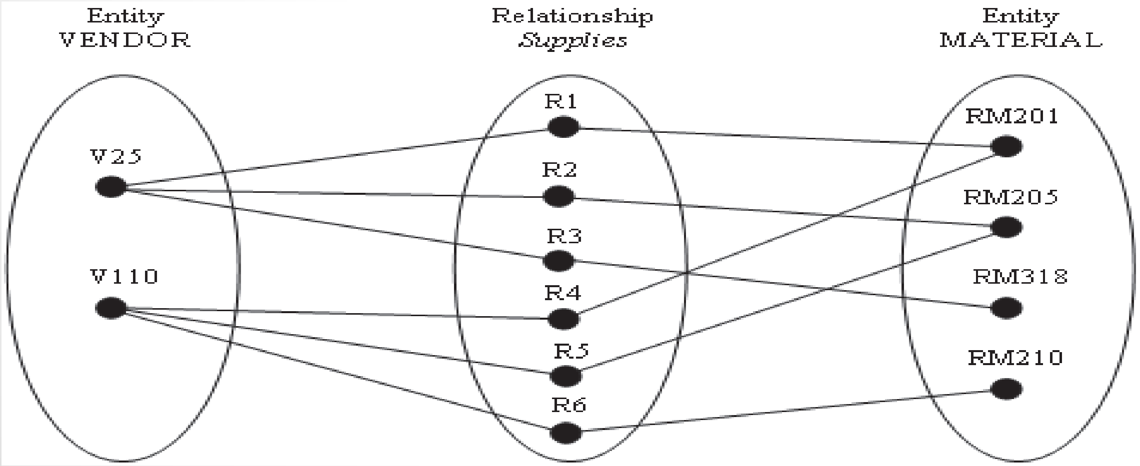
MATERIAL ID	MATL DESCRIPTION
RM201	Carrots, whole
RM202	Carrots, diced, 1/4 inch
RM205	Potatoes, Eastern,
RM210	Peas, shelled
RM211	Tomatoes, whole
RM310	Garlic, whole
RM311	Garlic powder
RM318	Salt, iodized
RM308	Onion salt
RM305	Paprika
RM340	Sugar, bulk
RM805	Olive oil
RM810	Vinegar, white

Entity Set: VENDOR

VENDOR ID	V NAME	V STREET	V CITY	V STATE	V ZIP
V110	Jersey	2 Main St.	Patterson	NJ	07055
V25	General	125 Common	Boise	ID	44830
V250	Spices	25 Salty Lane	East Hampton	NY	10027
V75	Pasta Supply,	34 Henry St.	Philadelphia	PA	09098

Associative Entities





Entity Set: VENDOR_MATL_XREF

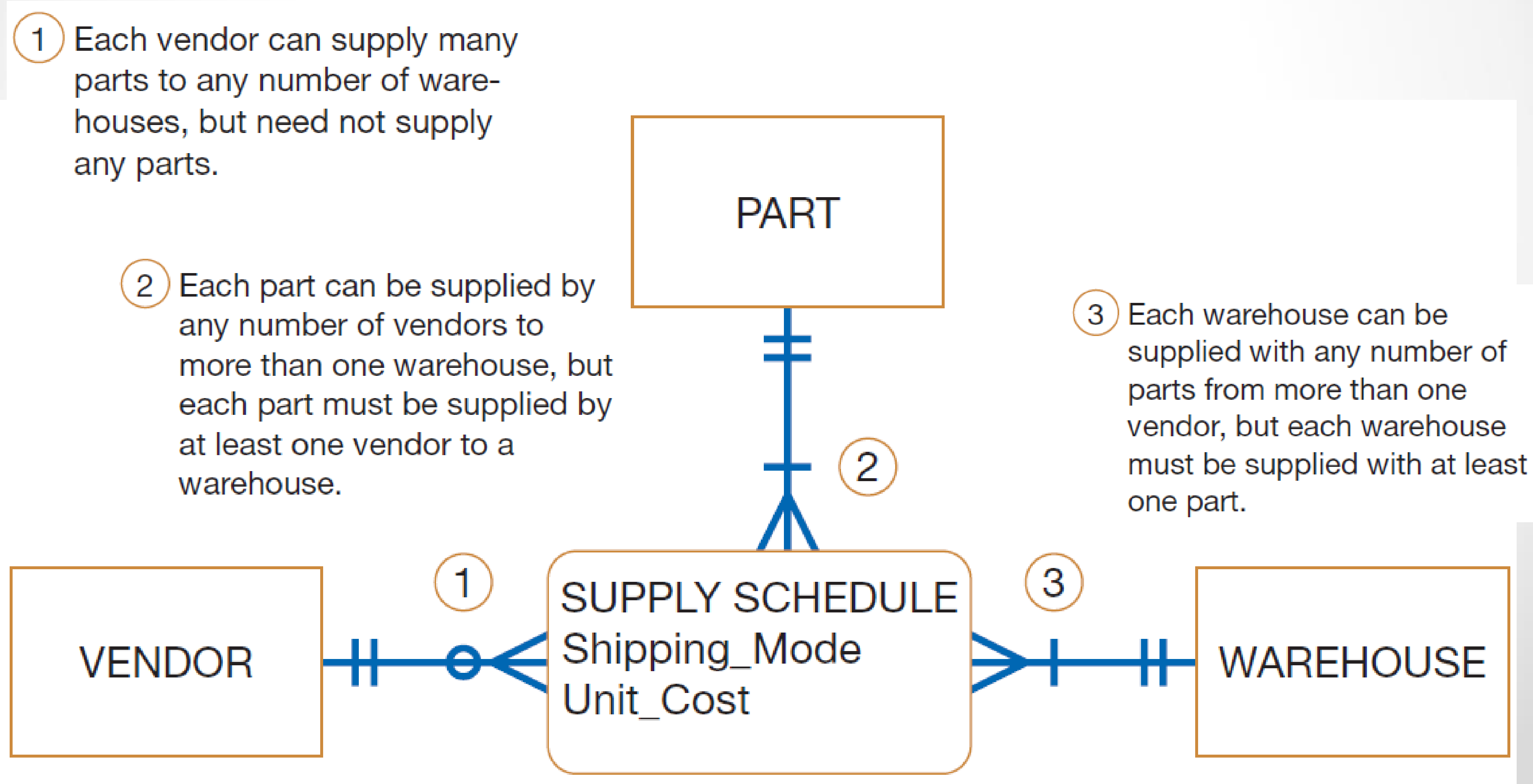
VENDOR_ID	MATERIAL_ID
V25	RM201
V25	RM205
V25	RM318
V25	RM340
V110	RM201
V110	RM202
V110	RM205
V110	RM210
V110	RM211
V250	RM310
V250	RM311
V250	RM318
V250	RM340
V250	RM308
V250	RM305
V25	RM805
V25	RM810

Associative Entities

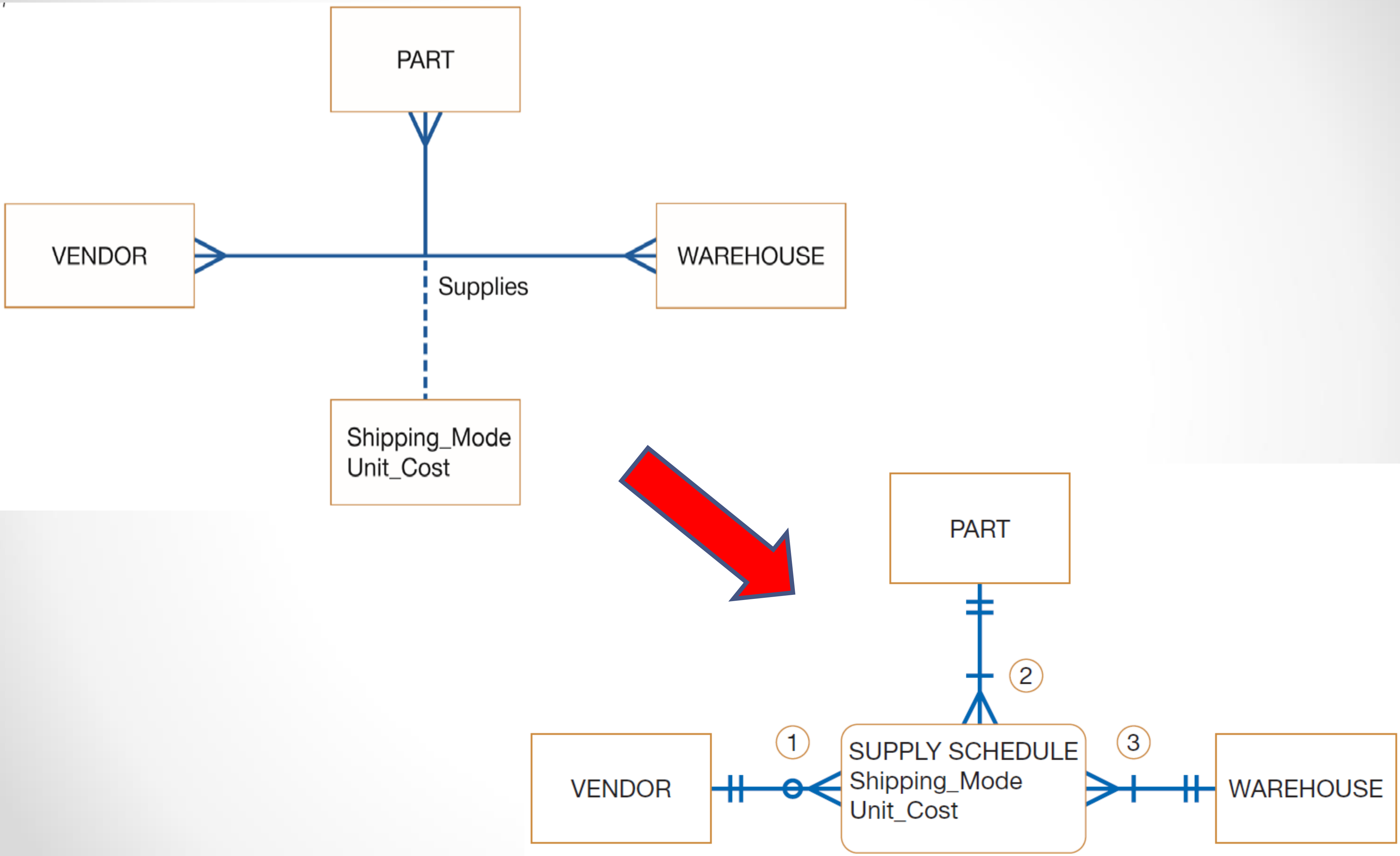
- Entity VENDOR_MATL_XREF is a bridge between the entities VENDOR and MATERIAL
  - i.e. associate/composite entity is used here to convert semantic net diagram for this M:N relationship into an entity
- Note the following:
  - each instance in VENDOR is associated with M instances of VENDOR_MATL_XREF, and
  - each instance of MATERIAL is associated with M instances of VENDOR_MATL_XREF
  - ⇒ M : N relationship is converted to two 1 : M relationships
  - VENDOR_ID/MATERIAL_ID serves as the (composite) primary key of VENDOR_MATL_XREF

Associative Entities

- Example 3: associative entity for a ternary relationship (alternative and more explicit representation of the ternary Supplies relationship shown in Figure 8-11)



Associative Entities



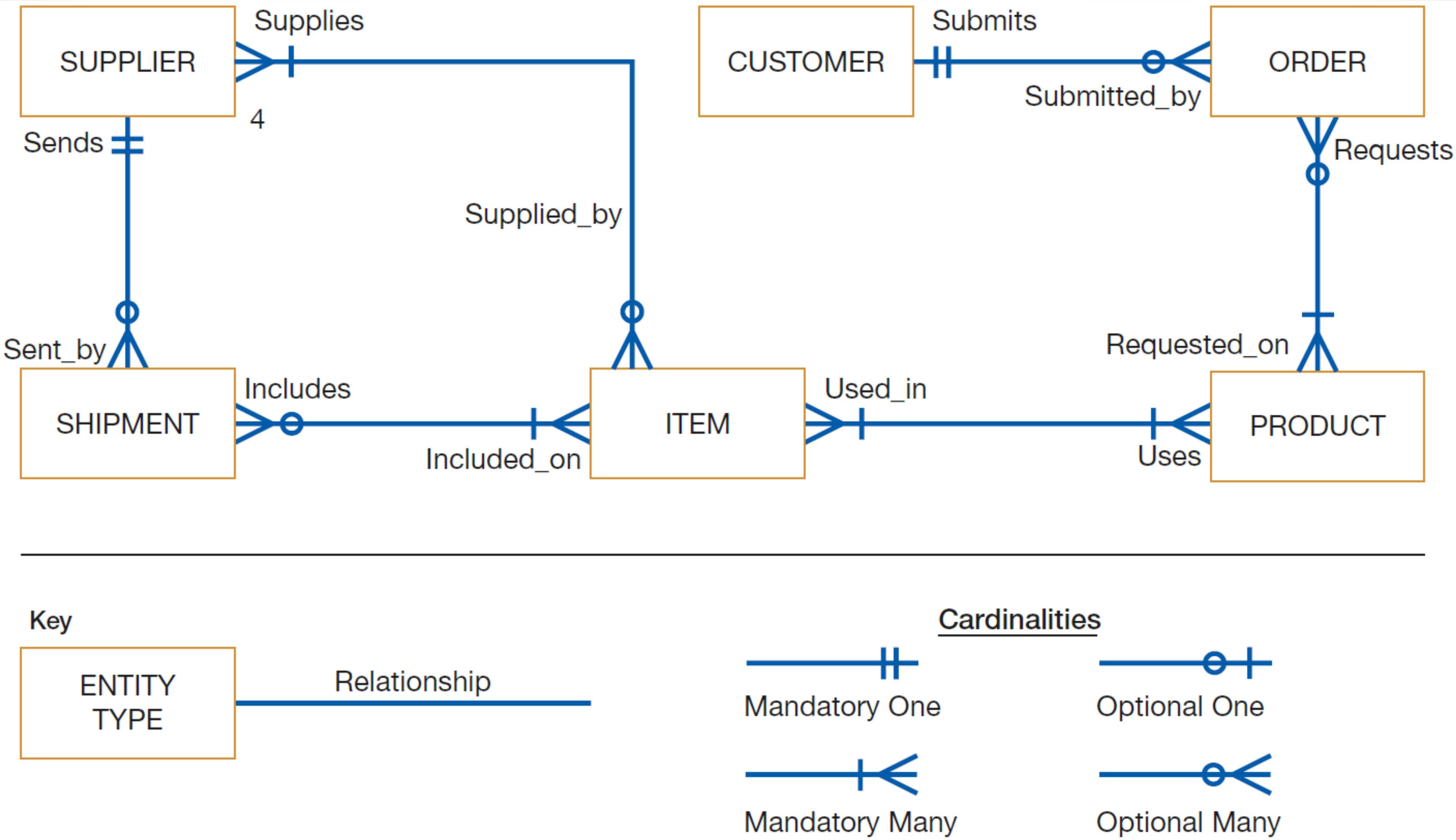
Videos to Watch

- **Entity Relationship Diagram (ERD) Tutorial - Part 1**
  https://youtu.be/QpdhBUYk7Kk
- **Entity Relationship Diagram (ERD) Tutorial - Part 2**
  https://youtu.be/-CuY5ADwn24
- **Entity-Relationship Diagrams** (another system)
  https://youtu.be/c0_9Y8QAstg
- **Entity Relationship Diagram (ERD) Training Video**
  https://youtu.be/-fQ-bRllhXc
- **Associative Entities**
  https://youtu.be/BWJeR44KNJU

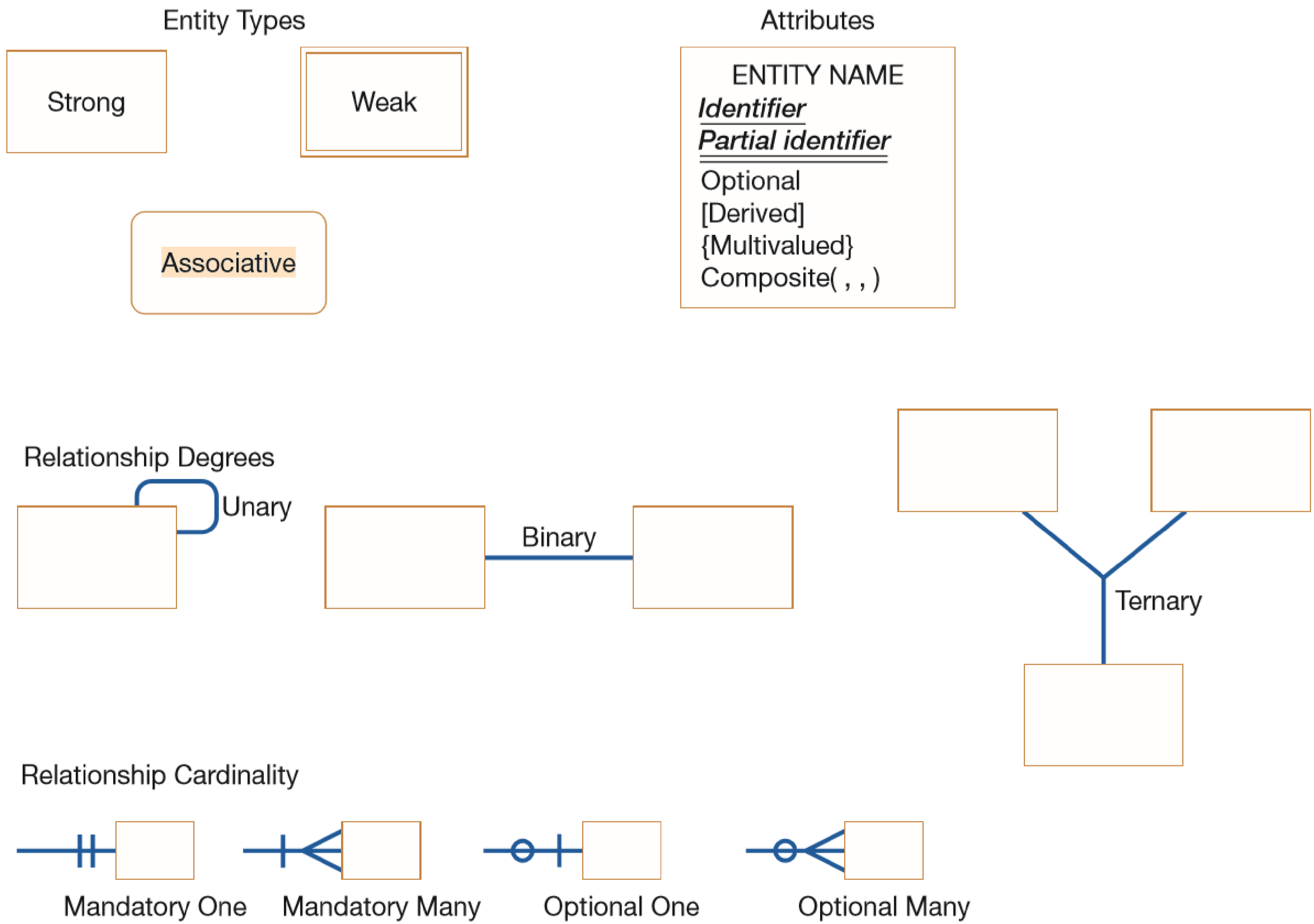
Sources

- "**Chapter 3: Database Modeling and Design**"; Slides by Dr. Sabeur Kosantini (2017)
- "**Types of Database Management Systems**" (2017) by Arjun Panwar, c-sharpcorner.com; Available at: https://www.c/sharpcorner.com/UploadFile/65fc13/types-of-database-management-systems/
- **Modern Systems Analysis and Design**. Joseph S. Valacich and Joey F. George. Pearson. Eighth Ed. 2017. Chapter 8.
- **Design of Industrial Information Systems**. Thomas Boucher, and Ali Yalcin. Academic Press. First Ed. 2006. Chapter 3.

Sample E-R Diagram



Basic E-R Notation



Gathering Info. for Conceptual Data Modeling

TABLE 8-1 Requirements Determination Questions for Data Modeling

1. *What are the subjects/objects of the business?* What types of people, places, things, materials, events, etc. are used or interact in this business, about which data must be maintained? How many instances of each object might exist?—**data entities and their descriptions**
2. *What unique characteristic (or characteristics) distinguishes each object from other objects of the same type?* Might this distinguishing feature change over time or is it permanent? Might this characteristic of an object be missing even though we know the object exists?—**primary key**
3. *What characteristics describe each object?* On what basis are objects referenced, selected, qualified, sorted, and categorized? What must we know about each object in order to run the business?—**attributes and secondary keys**
4. *How do you use these data?* That is, are you the source of the data for the organization, do you refer to the data, do you modify it, and do you destroy it? Who is not permitted to use these data? Who is responsible for establishing legitimate values for these data?—**security controls and understanding who really knows the meaning of data**

Gathering Info. for Conceptual Data Modeling

TABLE 8-1 Requirements Determination Questions for Data Modeling

5. *Over what period of time are you interested in these data?* Do you need historical trends, current "snapshot" values, and/or estimates or projections? If a characteristic of an object changes over time, must you know the obsolete values?—**cardinality and time dimensions of data**
6. *Are all instances of each object the same?* That is, are there special kinds of each object that are described or handled differently by the organization? Are some objects summaries or combinations of more detailed objects?—**supertypes, subtypes, and aggregations**
7. *What events occur that imply associations among various objects?* What natural activities or transactions of the business involve handling data about several objects of the same or a different type?—**relationships and their cardinality and degree**
8. *Is each activity or event always handled the same way or are there special circumstances?* Can an event occur with only some of the associated objects, or must all objects be involved? Can the associations between objects change over time (for example, employees change departments)? Are values for data characteristics limited in any way?—**integrity rules, minimum and maximum cardinality, time dimensions of data**