Entity-Relationship Diagram

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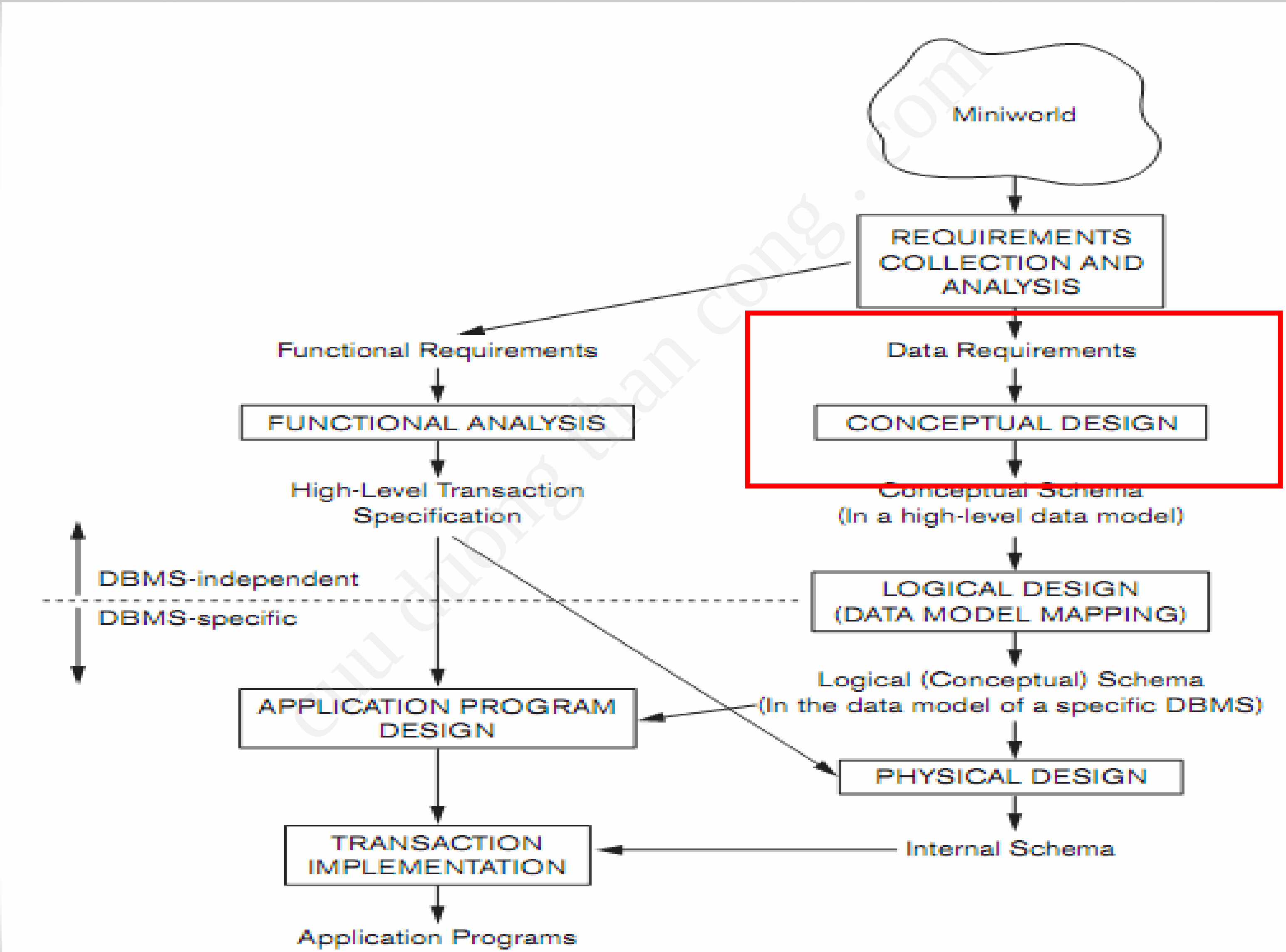
Contents

- Database design process
- ER Model

Database Design Process

- Two main activities:
  - Database design
  - Applications design
- Database design
  - To design the conceptual schema for a database application
- Applications design
  - Programs and interfaces that access the database
  - Generally considered part of software engineering

Database Design Process



Database Design Process

- Collect and Analyze requirements
  - Database designers interview prospective database users to understand and document data requirements
  - Outputs:
    - Data requirements
    - Functional requirements

Database Design Process

- Conceptual design
  - Create a conceptual schema for the database.
    - Description of data requirements
    - Uses the concepts provided by the high-level data model
    - Includes detailed descriptions of the entity types, relationships, and constraints
    - Independent of storage and implementation details.

Database Design Process

- Logical design or data model mapping
  - Output is a database schema in implementation data model of DBMS
- Physical design phase
  - Internal storage structures, file organizations, indexes, access paths, and physical design parameters for the database files specified

ER Model

What is ER Model?

- Entity-Relationship (ER) model
  - Popular high-level conceptual data model
  - A logical organisation of data within a database system
- ER diagrams:
  - Diagrammatic notation associated with the ER model

Why ER Model?

- User requirements can be specified formally & unambiguously
- The conceptual data model is independent of any particular DBMS
- It does not involve any physical or implemental details
- It can be easily understood by ordinary users.
- It provides an effective bridge between user requirements and logical database design and implementation

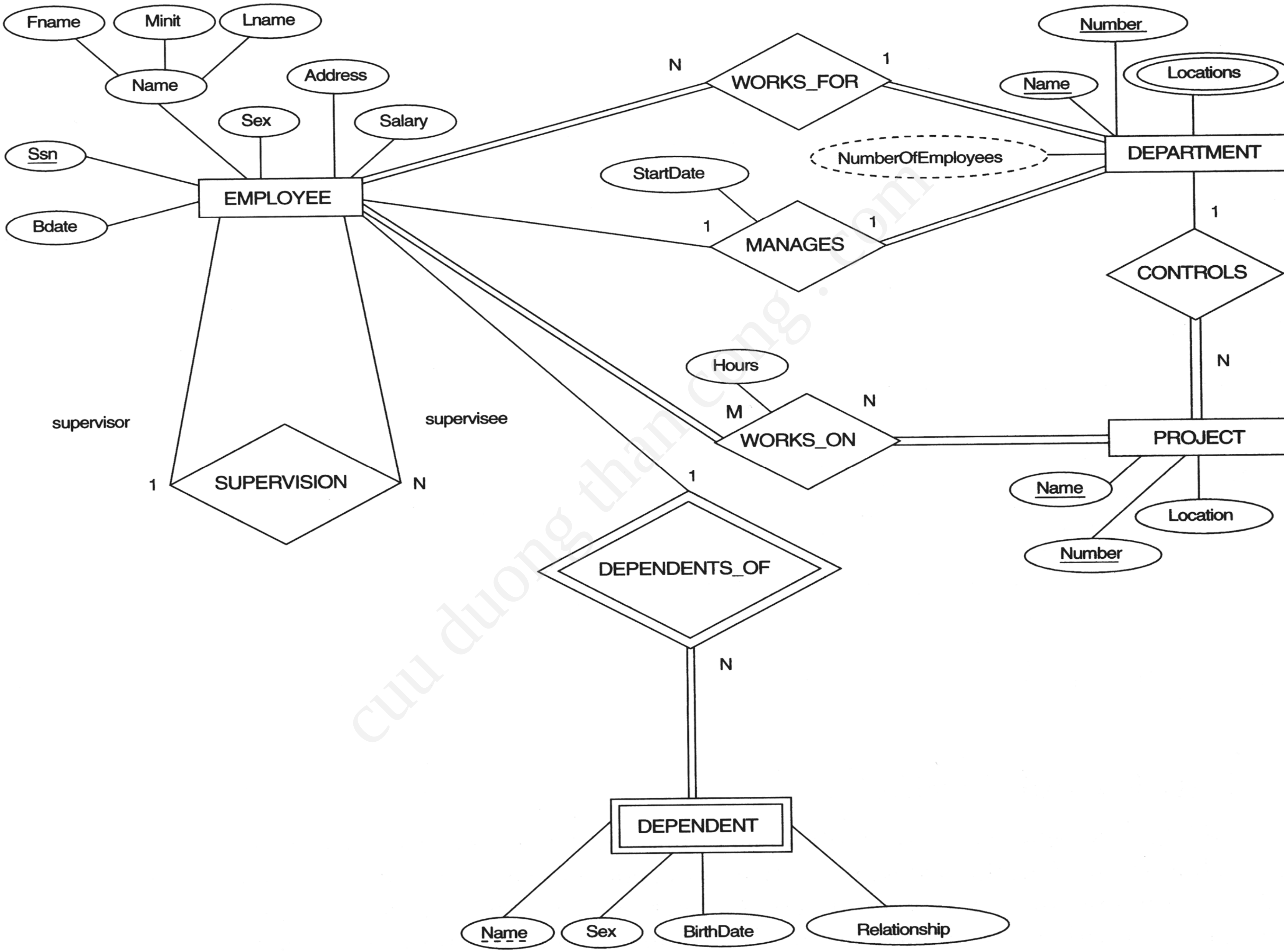
A Sample Database Application

- The **COMPANY** database: keeps track of **employees, departments, and projects.**

- The company is organized into DEPARTMENTs.
  - Each department has a unique name, a unique number, and a particular employee who *manages* the department.
  - We keep track of the start date when that employee began managing the department.
  - A department may have several locations.
- A department controls a number of PROJECTs
  - Each of which has a unique name, a unique number, and a single location.

A Sample Database Application

- We store EMPLOYEE's name, Social Security number, address, salary, sex, and birth date.
  - *An employee is assigned to one department, but may work on several projects*, which are not necessarily controlled by the same department. We keep track of the current number of hours per week that an employee works on each project.
  - We also keep track of the direct supervisor of each employee.
- We want to keep track of the DEPENDENTs of each employee, including first name, sex, birth date, and relationship to the employee.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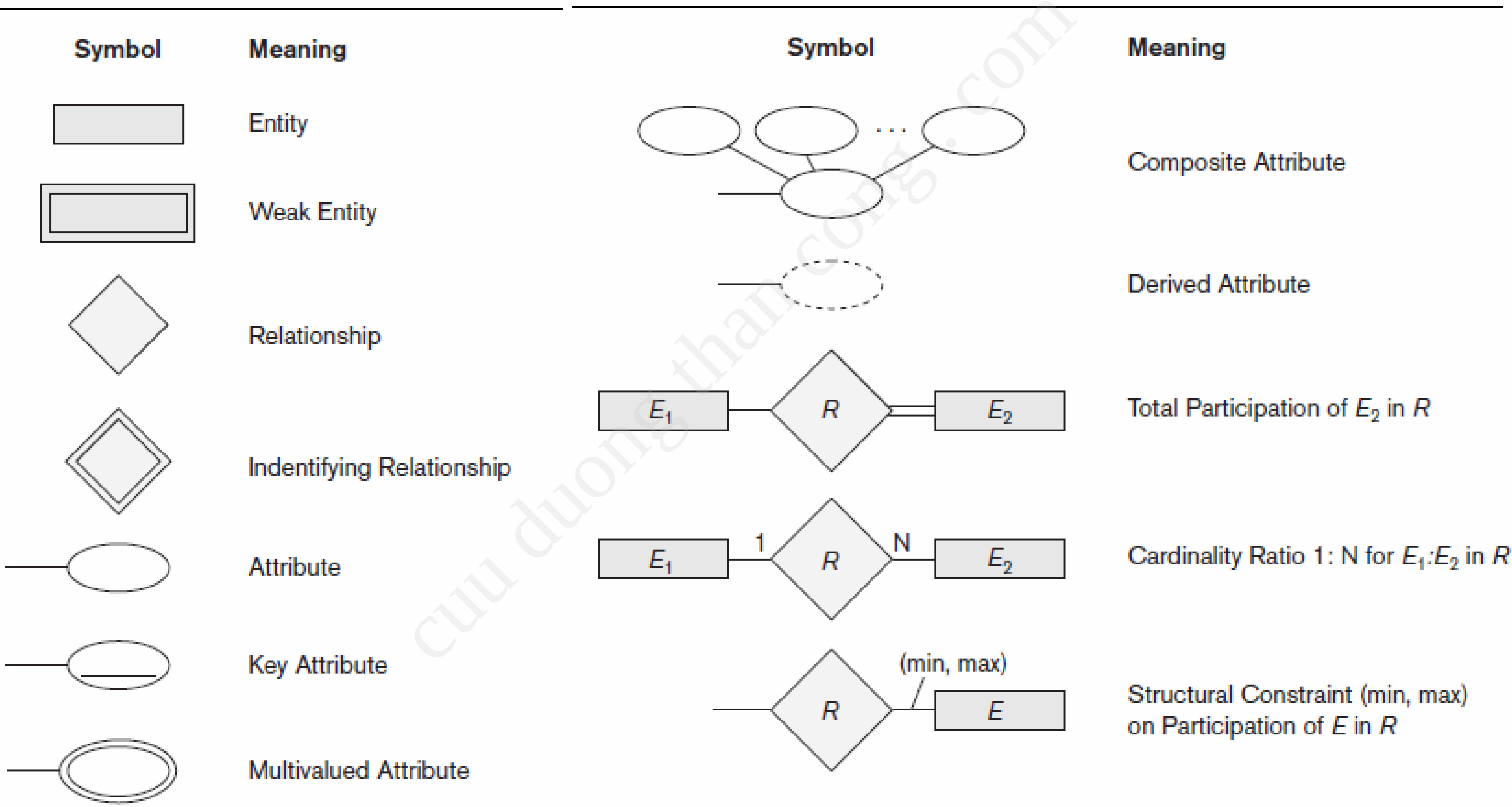
Relationship

ER Model Concepts

ER Model Concepts

- ER model describes data as:
  - Entities
  - Relationships
  - Attributes

ER Diagram: Summary

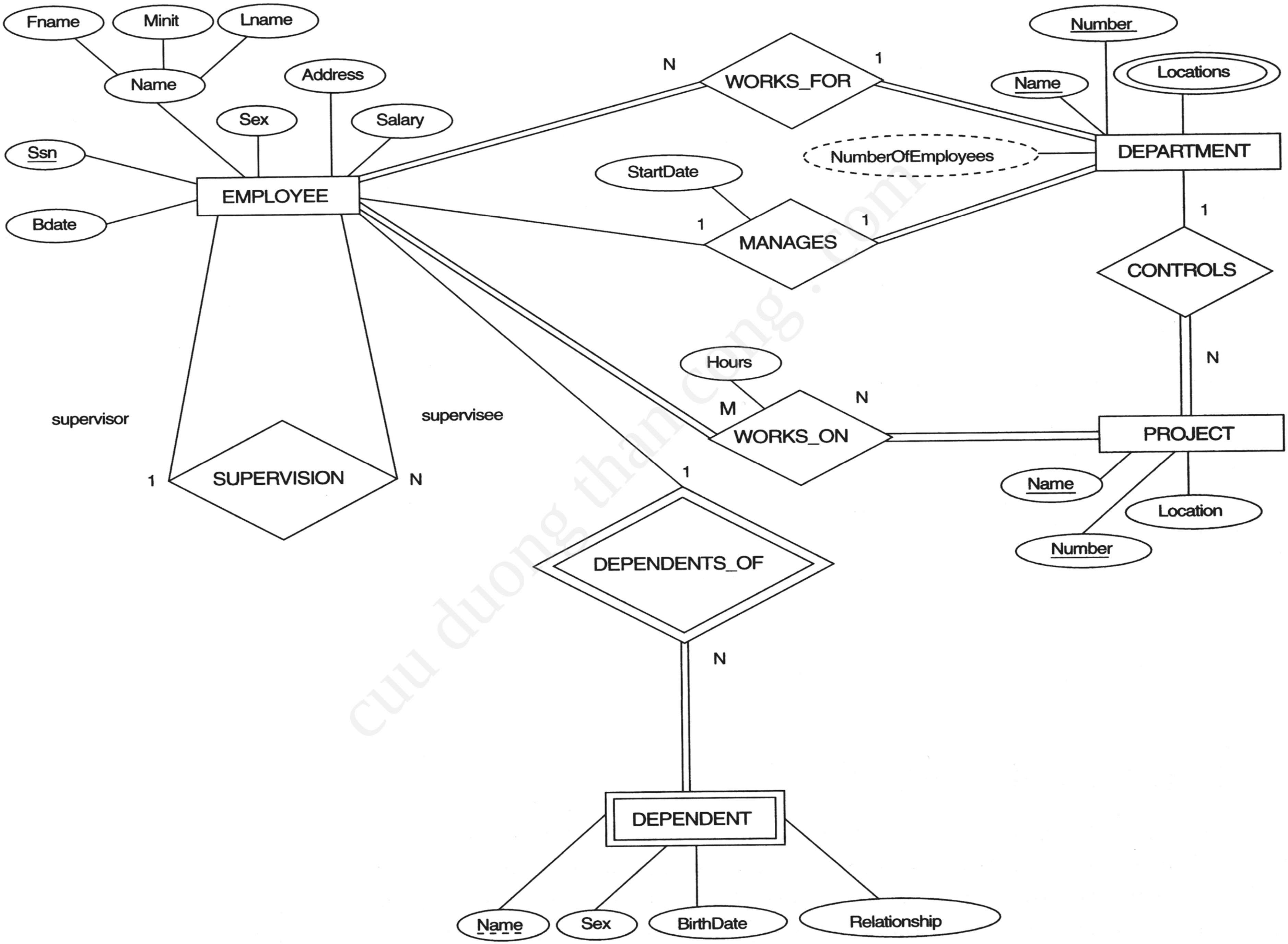


Entities and Attributes

- **Entity** is a thing in the real world with an independent existence.
  - Ex: the EMPLOYEE John Smith, the Research DEPARTMENT, the ProductX PROJECT
- **Attributes** are properties describing an entity.
  - Ex: an EMPLOYEE entity may have Name, SSN, Address, Sex, BirthDate
- A specific entity will have a value for each of its attributes
- Each attribute has a **value set** (or data type) associated with it.

Entities and Attributes

- **Types of Attributes**
  - **Simple attributes:** each entity has a single atomic value for the attribute.
  - **Composite attributes:** attribute may be composed of several components.
  - **Multi-valued attributes:** an entity may have multiple values for that attribute.
  - **Derived:** attribute represents a value that is derivable from value of a related attribute, set of attributes, or relationships.
  - **Complex attributes:** composite and multivalued attributes can be nested arbitrarily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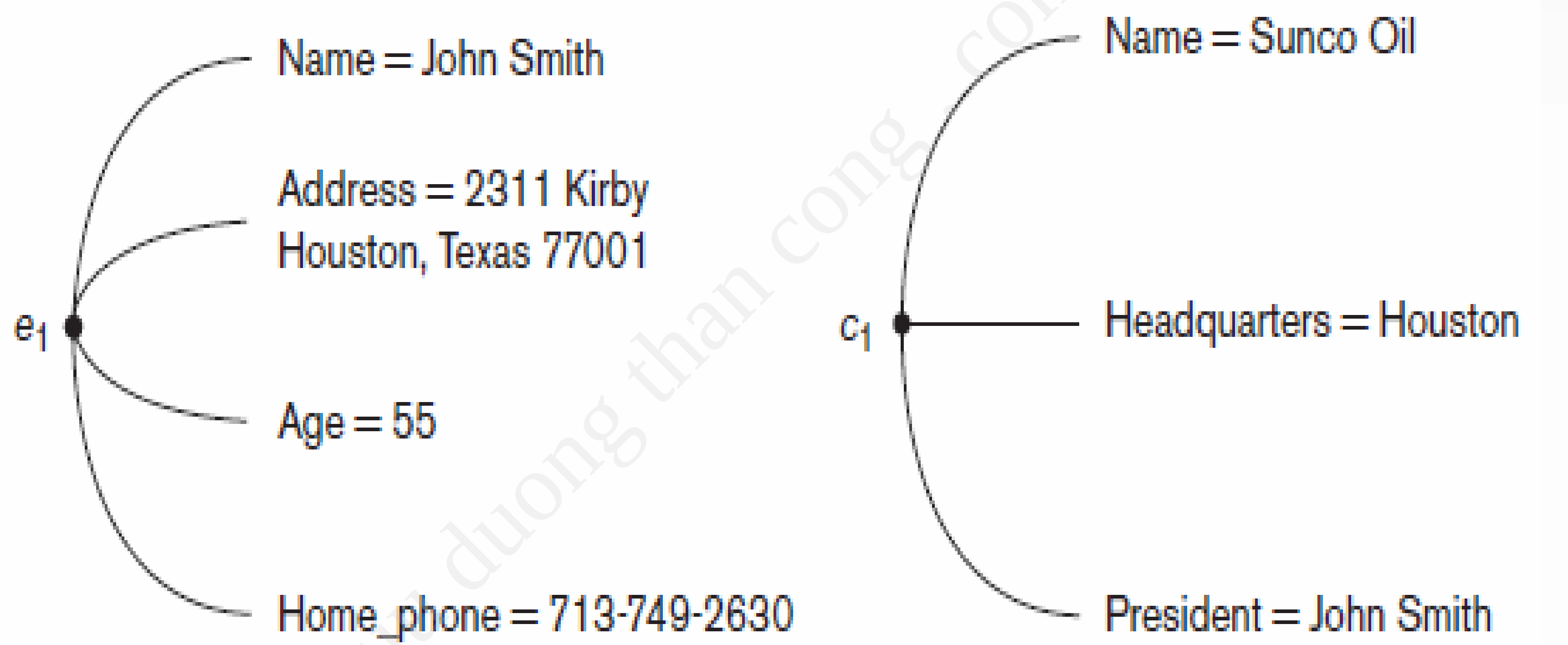
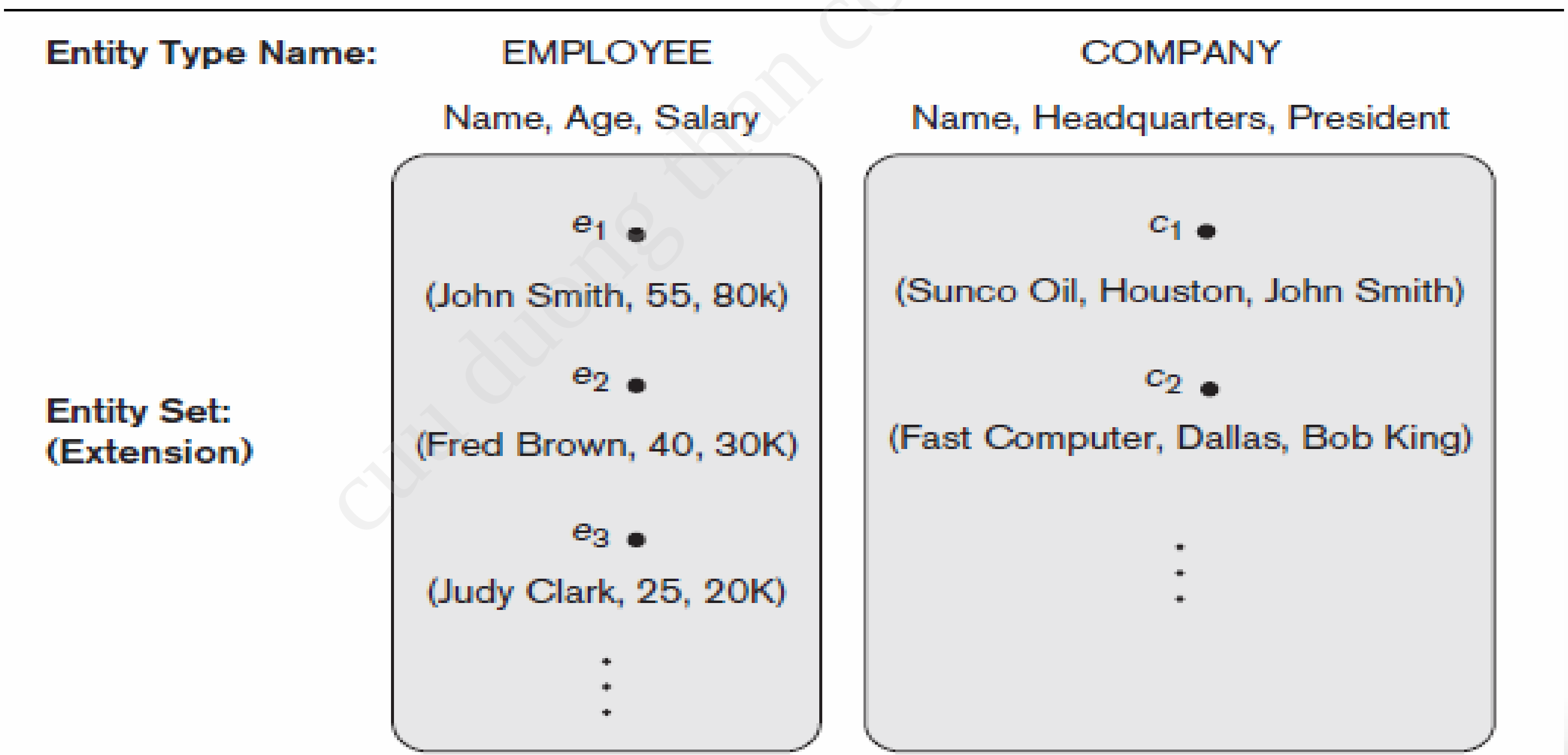
Entities and Attributes



Two entities, EMPLOYEE e1, and COMPANY c1, and their attributes.

Entity Types and Keys

- Entity type
  - Collection (or set) of entities that have the same attributes



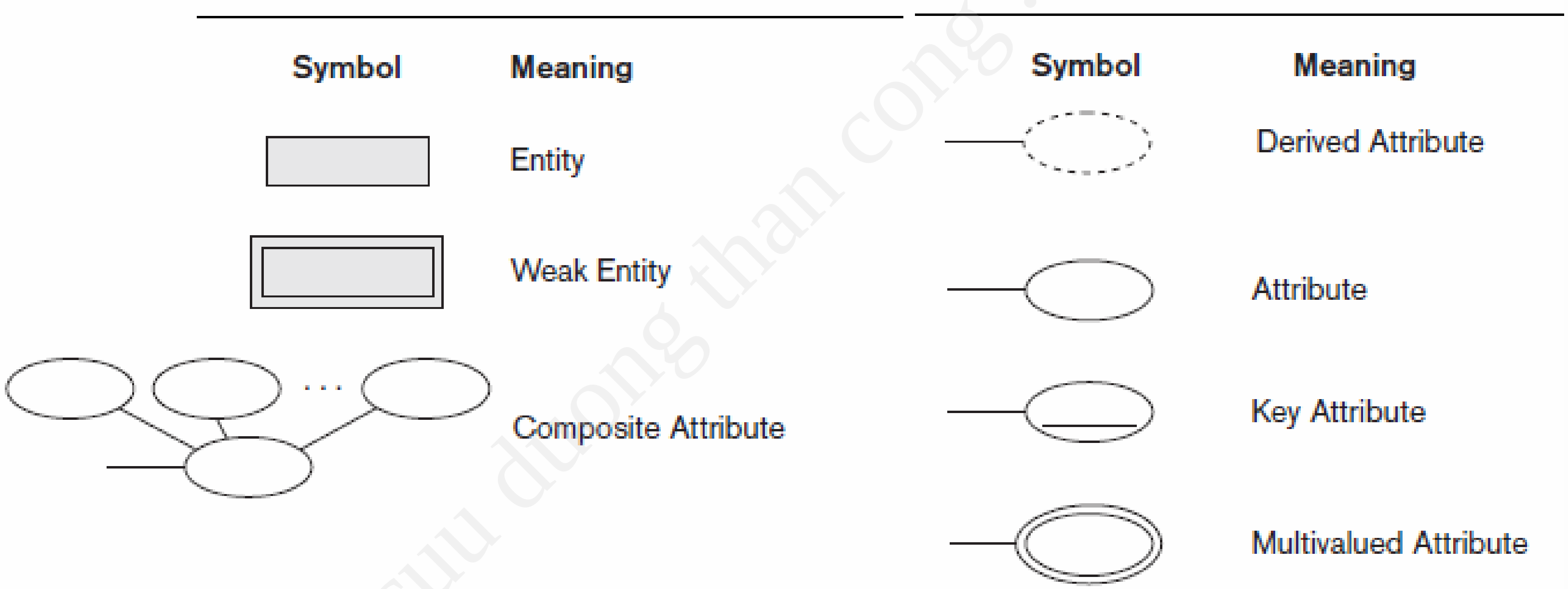
Entity Types and Keys

- **Key** or **uniqueness constraint**
  - Attributes whose values are distinct for each individual entity in entity set
  - Uniqueness property must hold for *every entity set* of the entity type
  - Ex: SSN of EMPLOYEE
- An entity type may have more than one key
  - Ex: the STUDENT entity type may have two keys (in university context):
    - Citizen ID and
    - Student ID

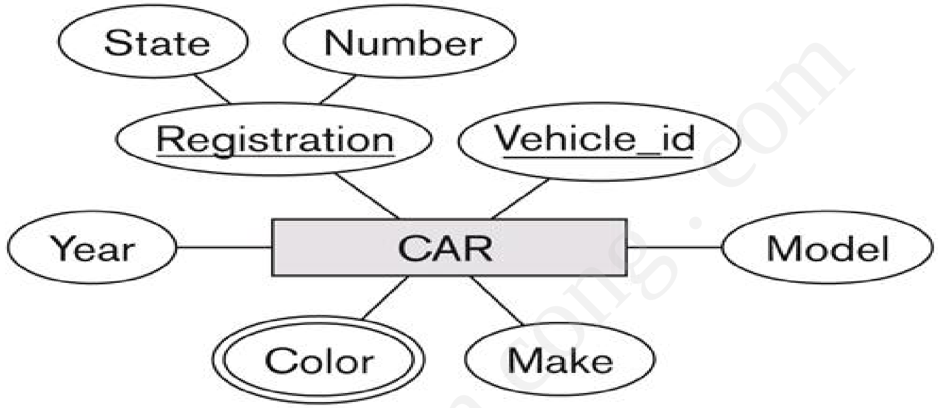
Entity Types and Keys

- **Super key:** A set of attributes (one or more) that together define an entity in an entity set
- **Candidate key:** A minimal super key, meaning it has the least possible number of attributes to still be a super key. An entity set may have more than one candidate key
- **Primary key:** A candidate key chosen by the database designer to uniquely identify the entity set

ERD: Entity


Symbol
Meaning
Entity
Weak Entity
Composite Attribute
Symbol
Meaning
Derived Attribute
Attribute
Key Attribute
Multivalued Attribute

Entity Type: Example



CAR
Registration (Number, State), Vehicle_id, Make, Model, Year, {Color}

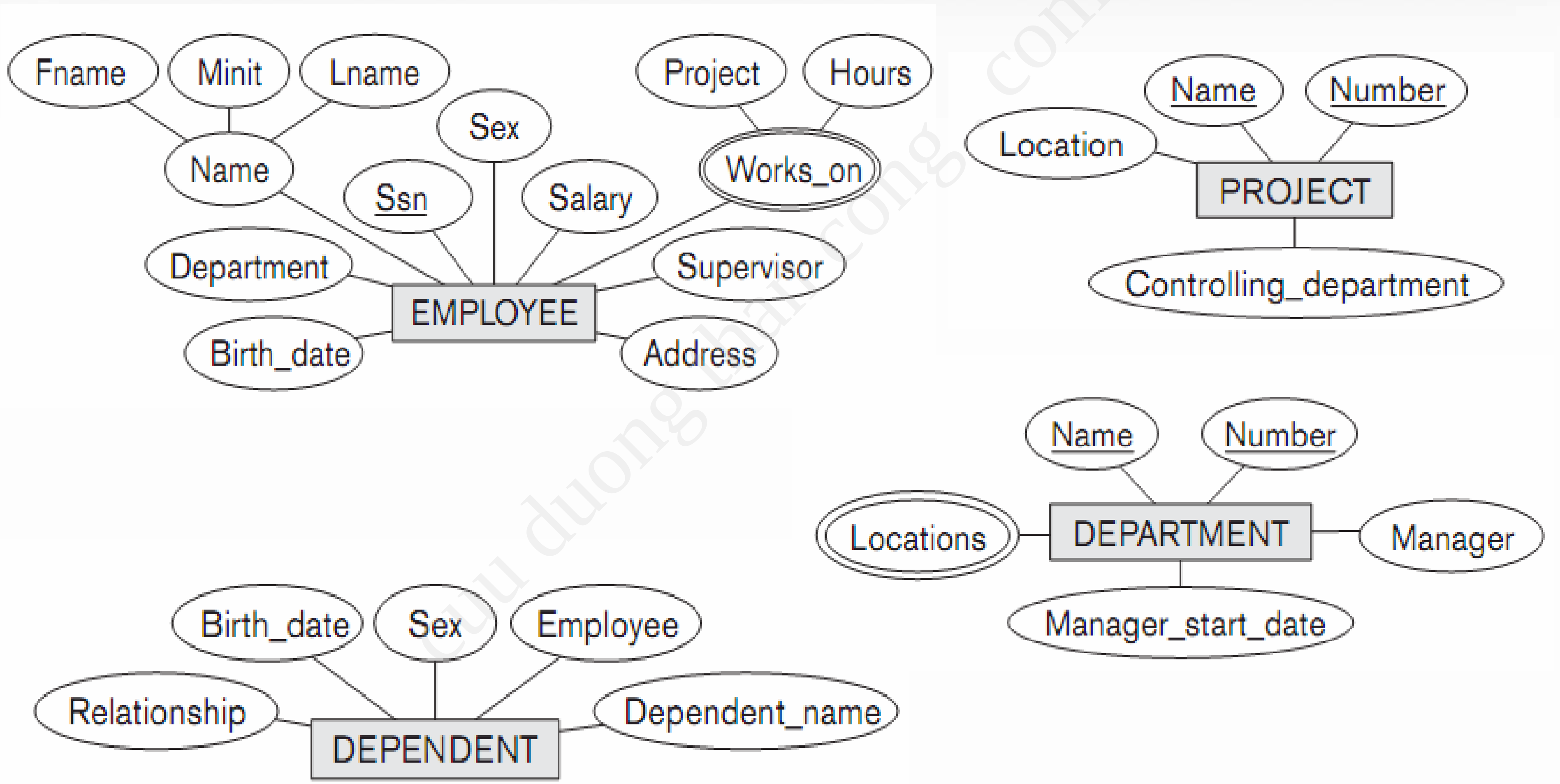
CAR_1
((ABC 123, TEXAS), TK629, Ford Mustang, convertible, 2004 {red, black})

CAR_2
((ABC 123, NEW YORK), WP9872, Nissan Maxima, 4-door, 2005, {blue})

CAR_3
((VSY 720, TEXAS), TD729, Chrysler LeBaron, 4-door, 2002, {white, blue})

⋮

Example: COMPANY Database



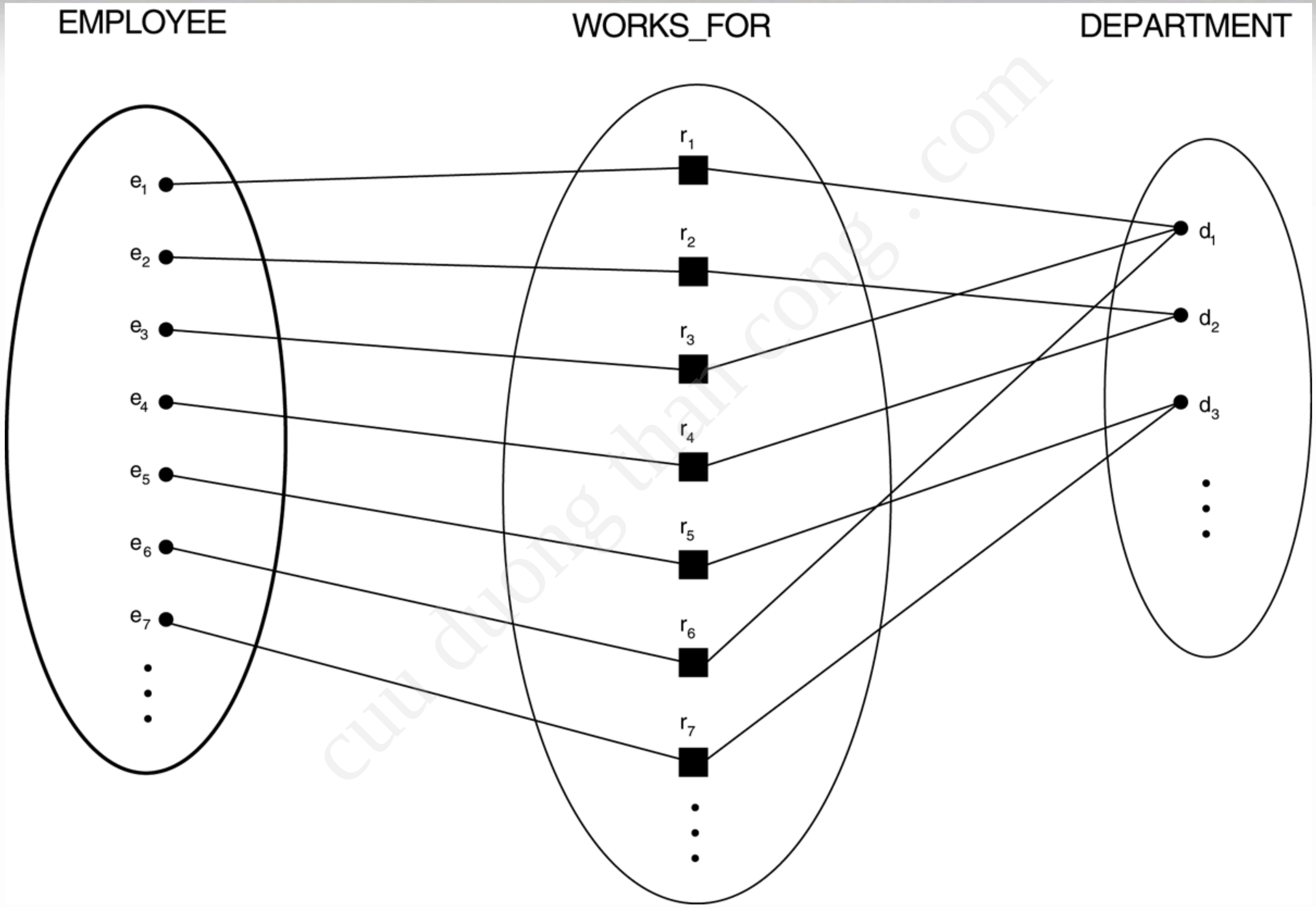
Relationships

- **Relationship type** R among n entity types E_1, E_2, ..., E_n
  - Defines a set of associations among entities from these entity types
  - Ex: the WORKS_FOR relationship type between EMPLOYEEs and DEPARTMENTs
- **Relationship instances** r_i
  - Each r_i associates n individual entities (e_1, e_2, ..., e_n). Each entity e_j in r_i is a member of entity set E_j
  - Ex: EMPLOYEE John Smith works on the ProductX PROJECT

Relationships

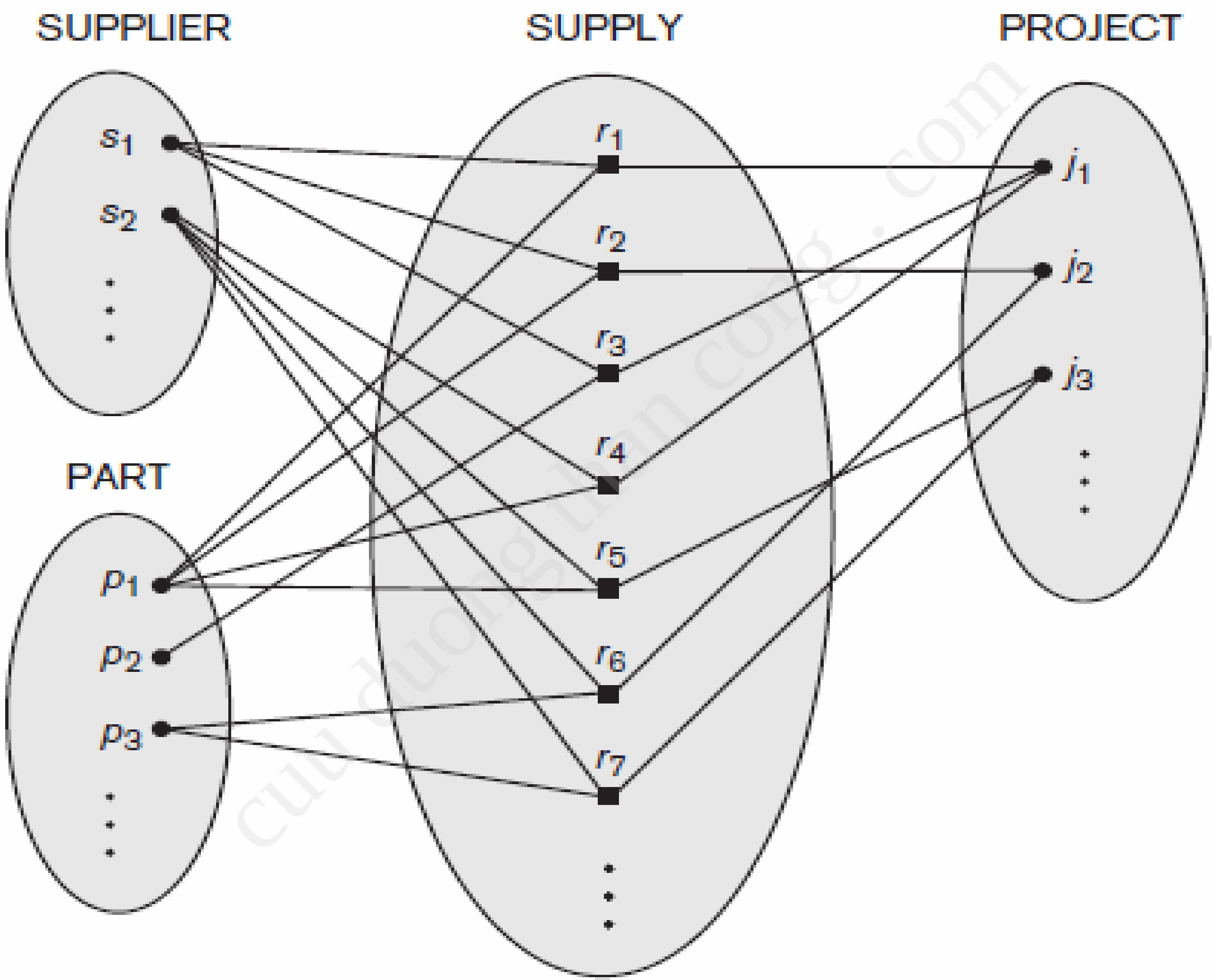
- **Degree** of a relationship type
  - Number of participating entity types
  - Binary (degree 2), ternary (degree 3), and n-ary (degree n)
- More than one relationship type can exist with the same participating entity types
  - Ex: MANAGES and WORKS_FOR are distinct relationships between EMPLOYEE and DEPARTMENT, but with different meanings and different relationship instances

Relationship Instances: Example

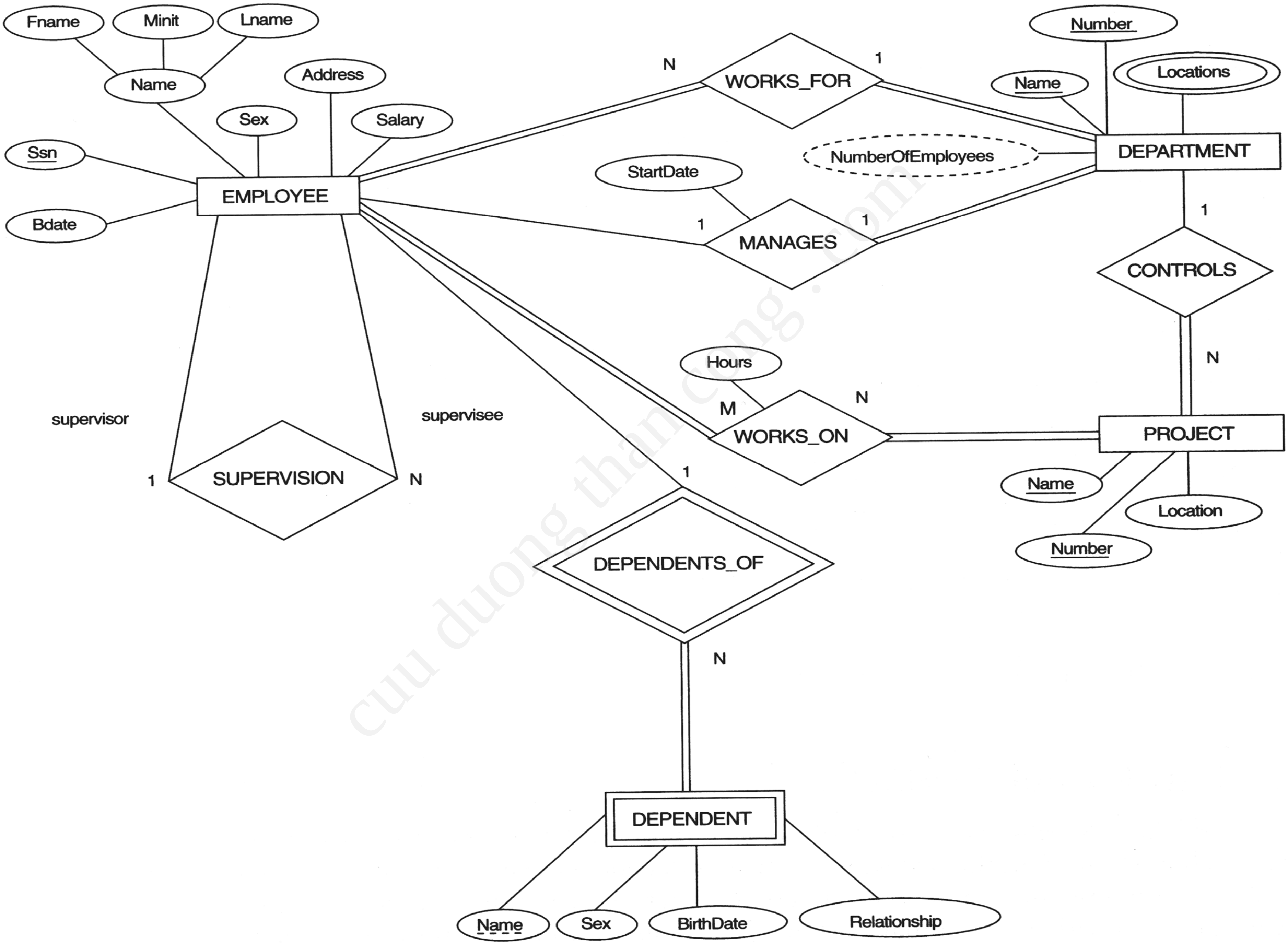


A binary relationship

Relationship Instances: Example



A ternary relationship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Sex
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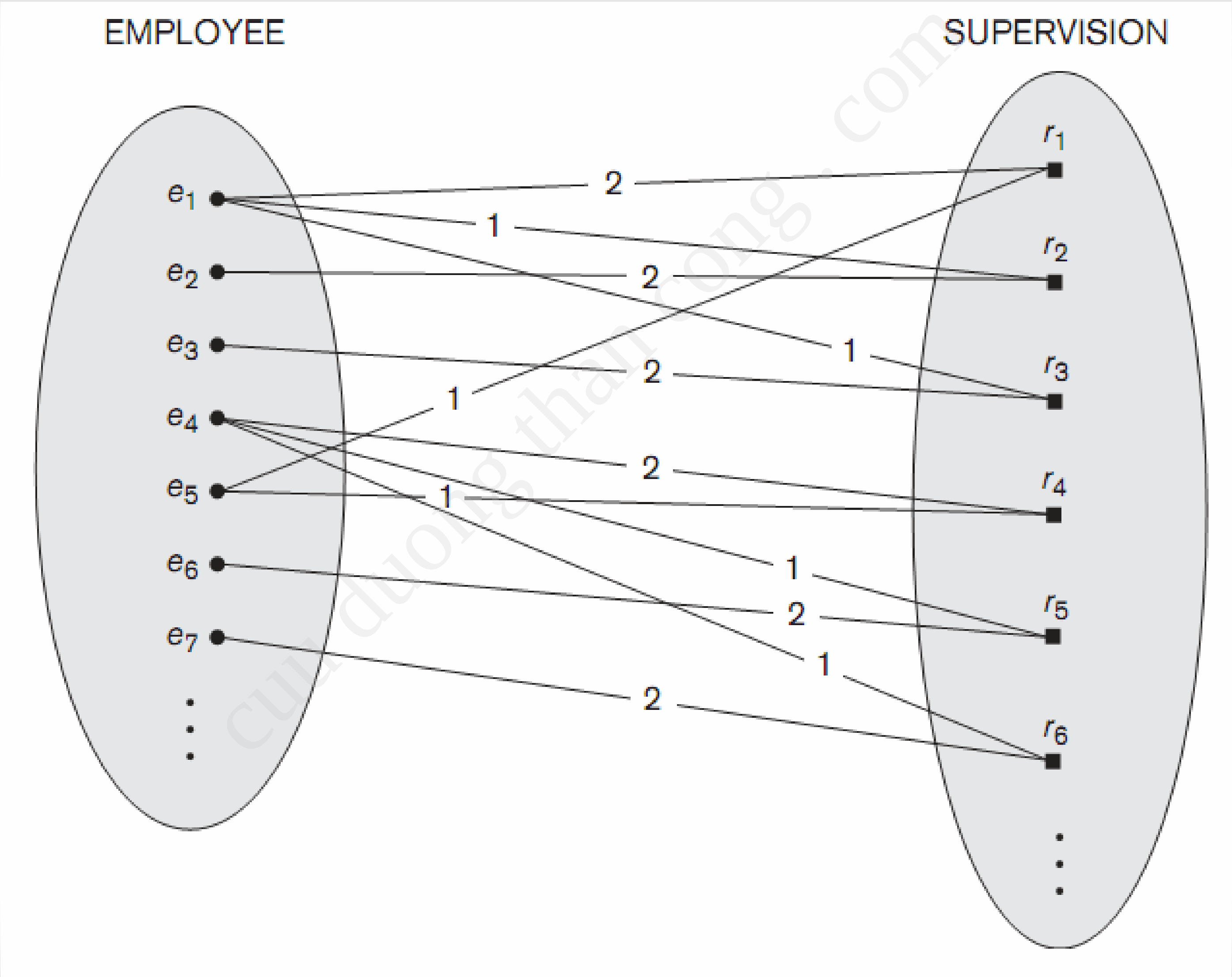
Relationship

Relationships

- **Recursive** relationships
  - Same entity type participates more than once in a relationship type in different roles
  - Must specify role that a participating entity plays in each relationship instance
  - Ex: SUPERVISION relationships between EMPLOYEE (in role of supervisor or boss) and (another) EMPLOYEE (in role of subordinate or worker)

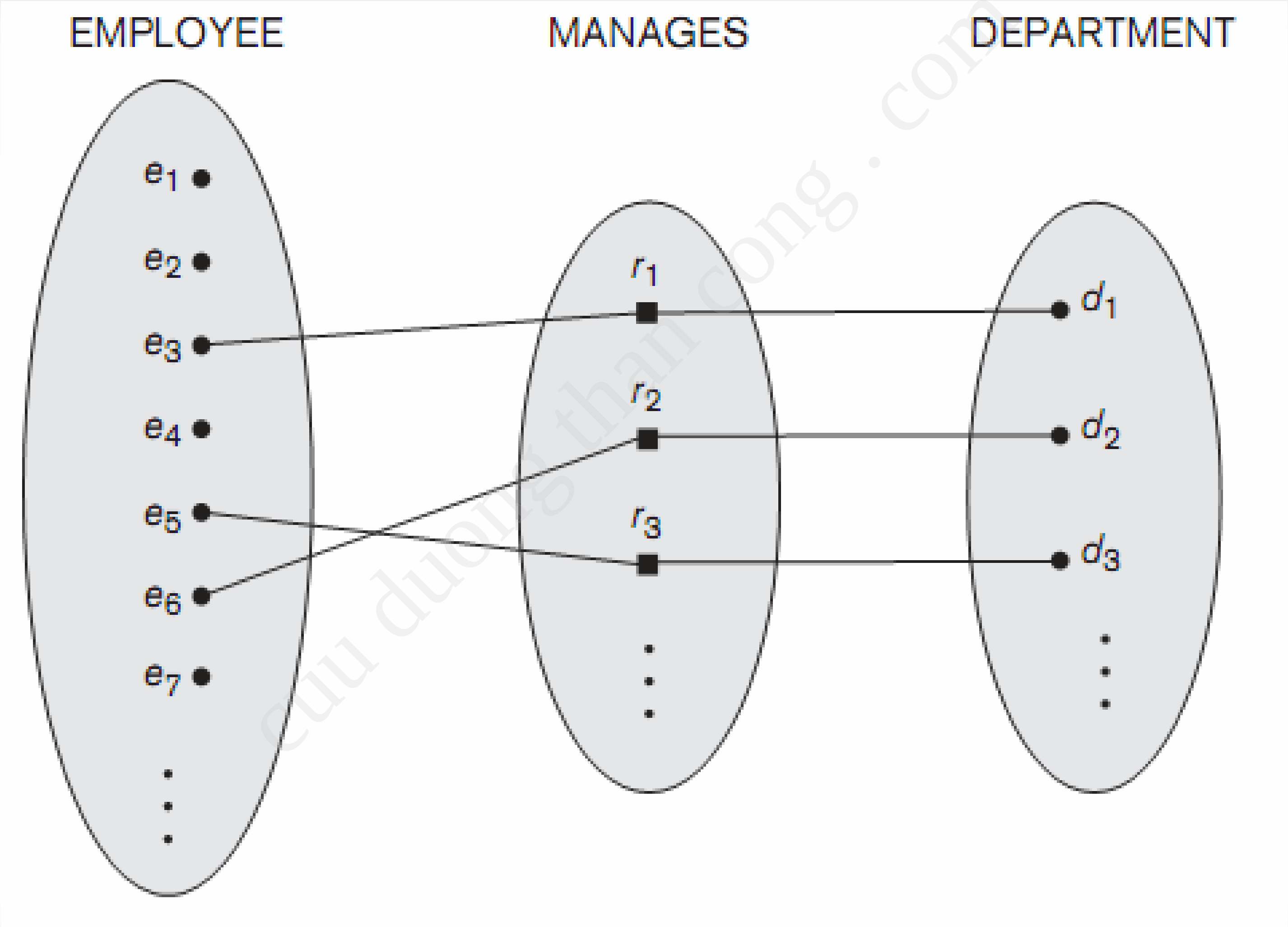
Recursive Relationship: Example



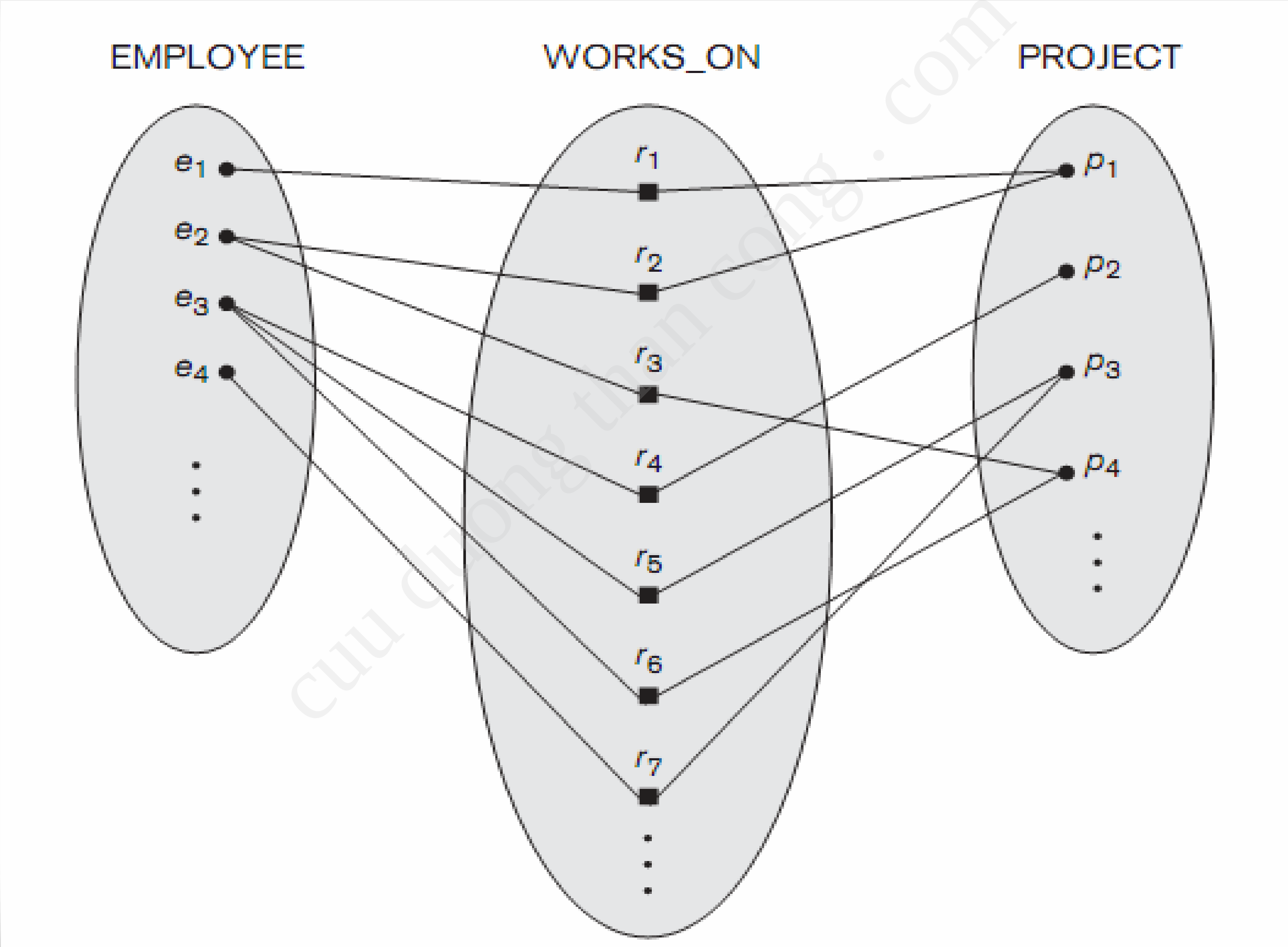
Constraints on Binary Relationship Type

- **Structural constraints**: one way to express semantics of relationship: cardinality ratio and membership class
- **Cardinality ratio**: specifies maximum number of relationship instances that entity can participate in a binary relationship.
  - one-to-one (1:1)
  - one-to-many (1:M) or many-to-one (M:1)
  - many-to-many (M:N)

One-to-one (1:1) Relationship

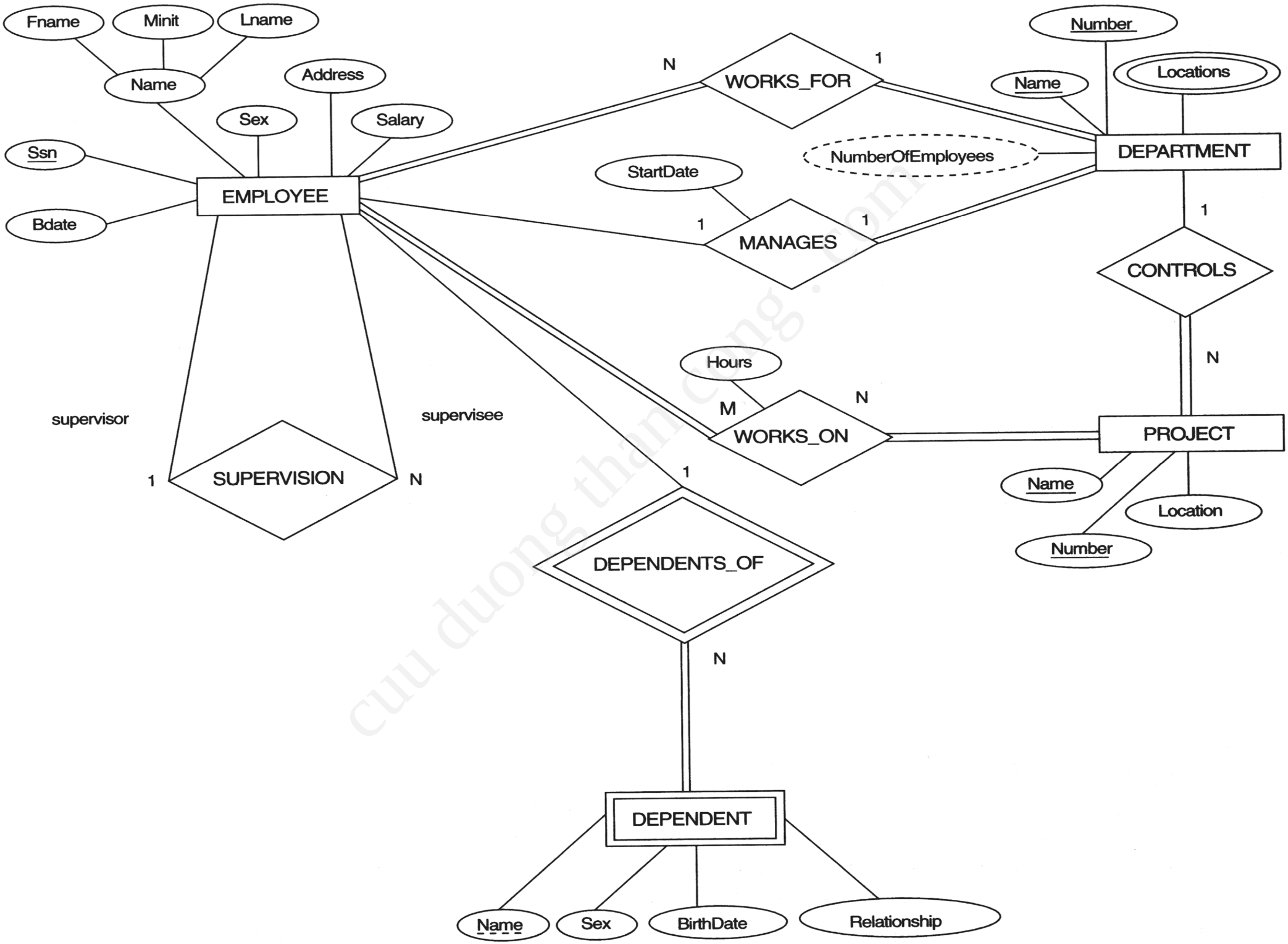


Many-to-many (M:N) Relationship



Constraints on Binary Relationship Type

- **Membership class (or participation constraint):** specifies if existence of entity depends on its being related to another entity
  - **Mandatory (total participation)** - every instance of a participating entity type must participate in the relationship. (double line)
  - **Optional (partial participation)** - not every instance of a participating entity type must participate in the relationship. (single line)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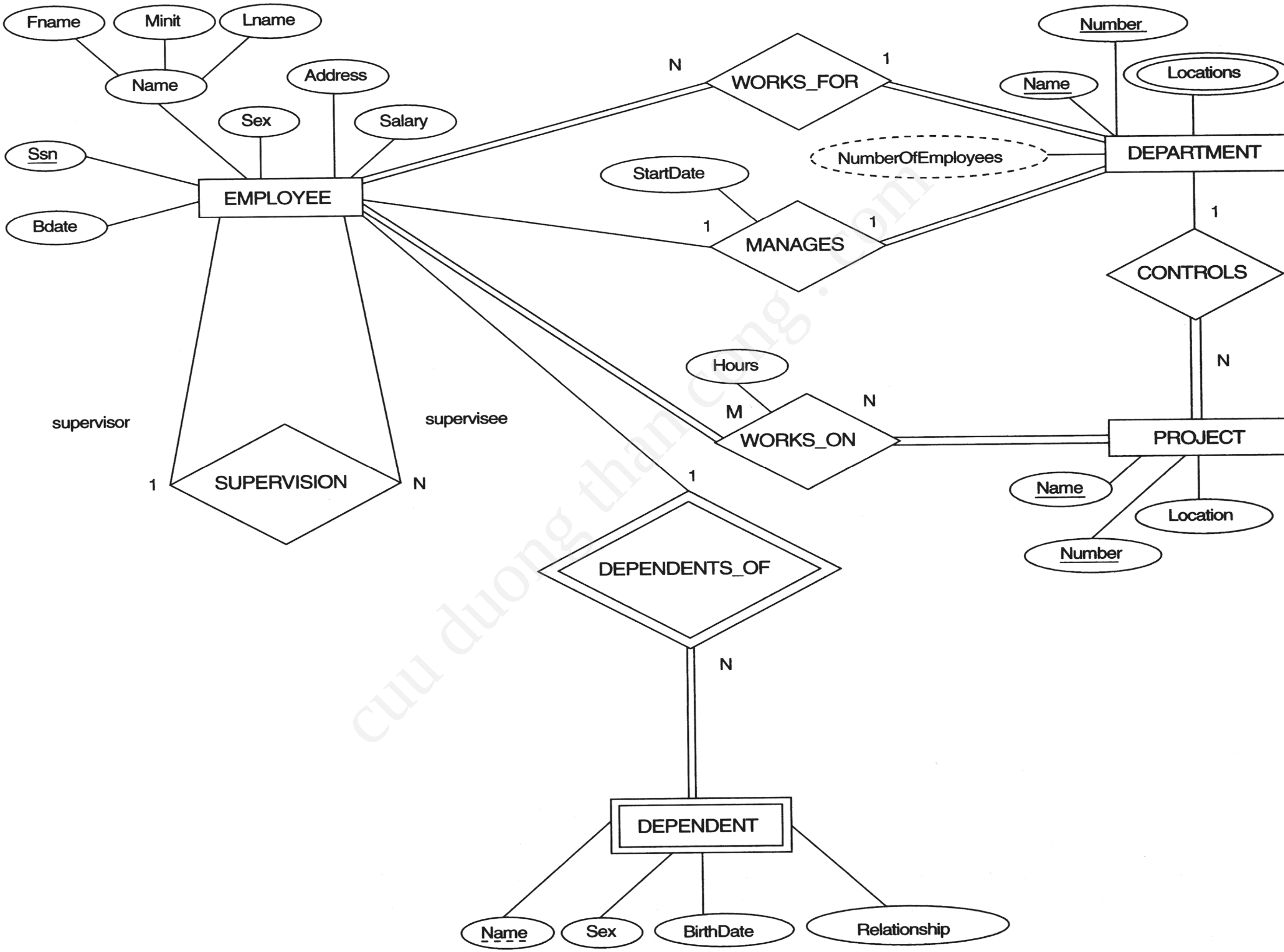
Relationship

Attributes of Relationship Types

- A relationship type can have attributes.
  - Ex: HoursPerWeek of WORKS_ON
- Attributes of 1:1 or 1:N relationship types can be migrated to one entity type
  - For a 1:N relationship type: relationship attribute can be migrated only to entity type on N-side of relationship
  - For M:N relationship types: must be specified as relationship attributes

Weak Entity Types

- Do not have key attributes of their own
  - Identified by being related to specific entities from another entity type
- **Identifying relationship**
  - Relates a weak entity type to its owner
- Always has a total participation constraint
- Entities are identified by the combination of:
  - A partial key of the weak entity type
  - The particular entity they are related to in the identifying entity type



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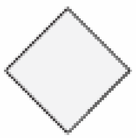
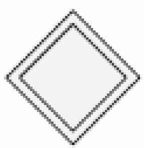
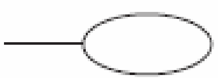
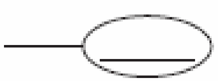
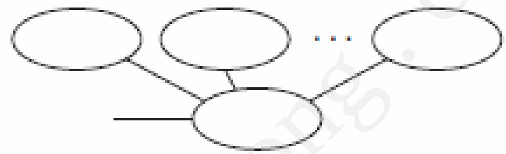
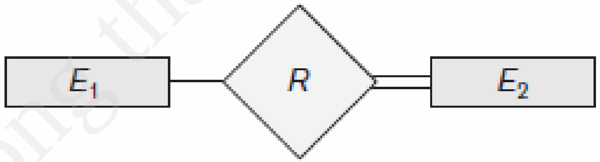
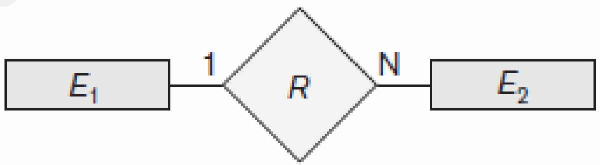
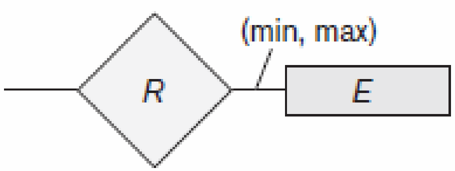
ER Diagram and Naming Conventions

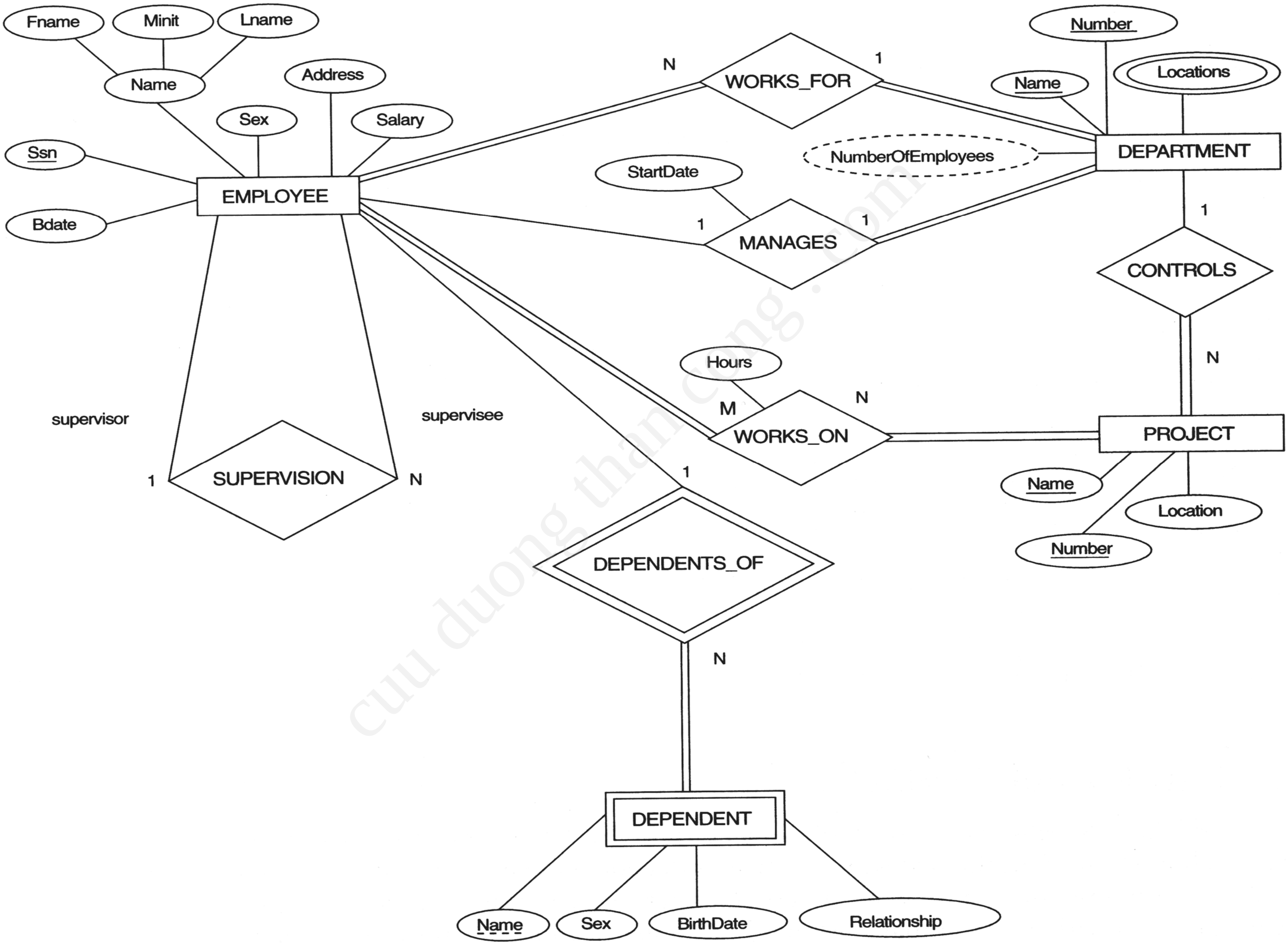
ER Diagram and Naming Conventions

- An ER model can be expressed in the form of the ER diagram.
- Proper Naming of Schema Constructs:
  - Choose names that convey meanings attached to different constructs in schema
  - Nouns give rise to entity type names
  - Verbs indicate names of relationship types
  - Choose binary relationship names to make ER diagram readable from left to right and from top to bottom

ER Diagram: Summary

Symbol	Meaning
	Entity
	Weak Entity
	Relationship
	Indentifying Relationship
	Attribute
	Key Attribute
	Multivalued Attribute

Symbol	Meaning
	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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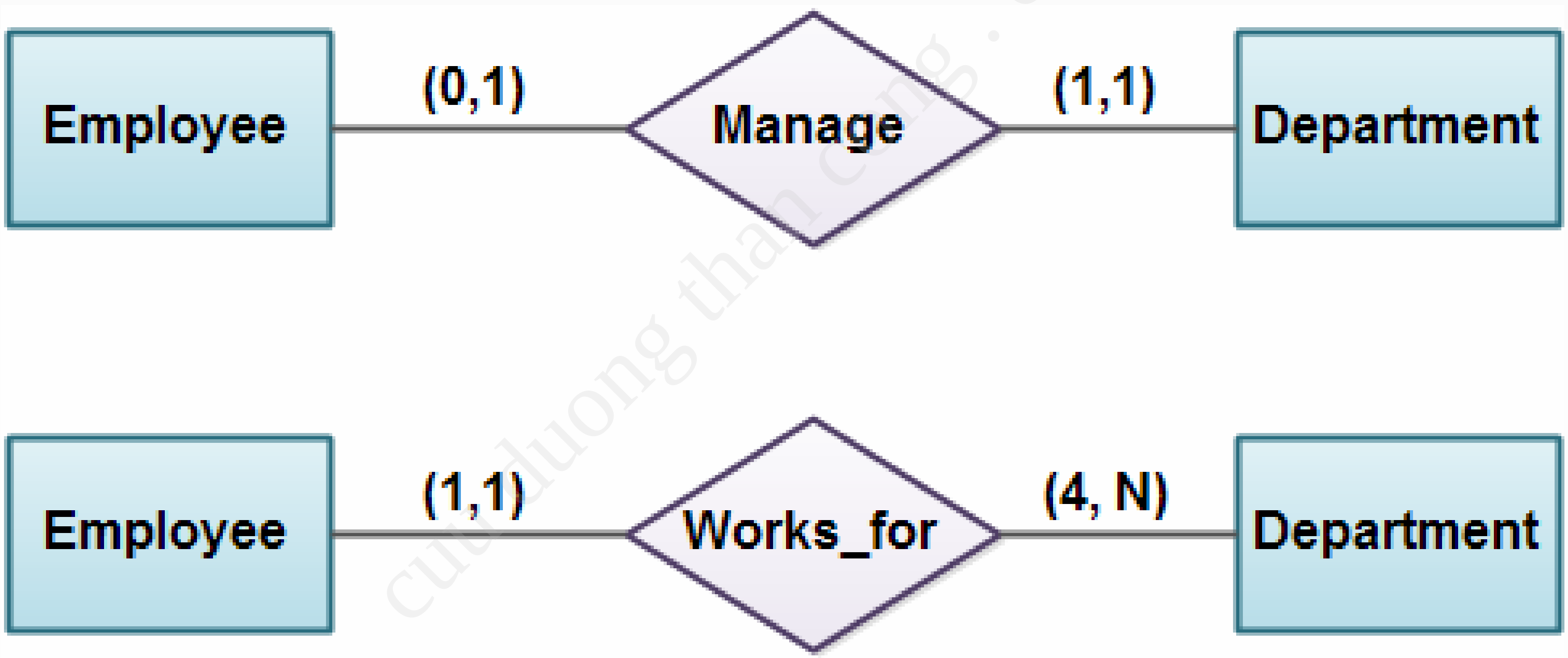
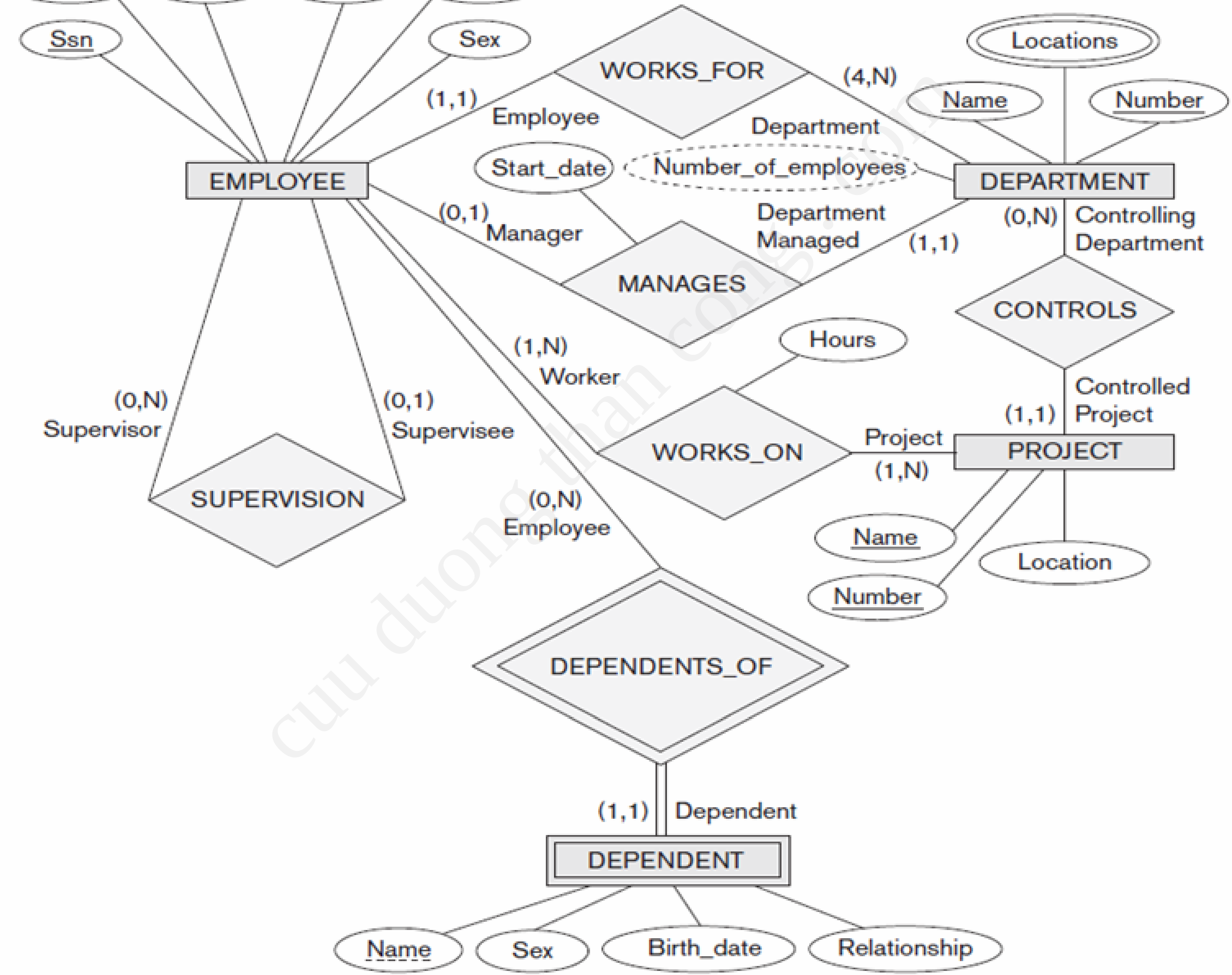
Alternative Diagrammatic Notations

- **(Min-max) notation for relationships**
  - Specify structural constraints on relationships
  - Replaces cardinality ratio (1:1, 1:N, M:N) and single/double line notation for participation constraints
  - Associate a pair of integer numbers (min, max) with each participation of an entity type *E* in a relationship type *R*, where $0 \le min \le max$ and $max \ge 1$

(min, max) Notation



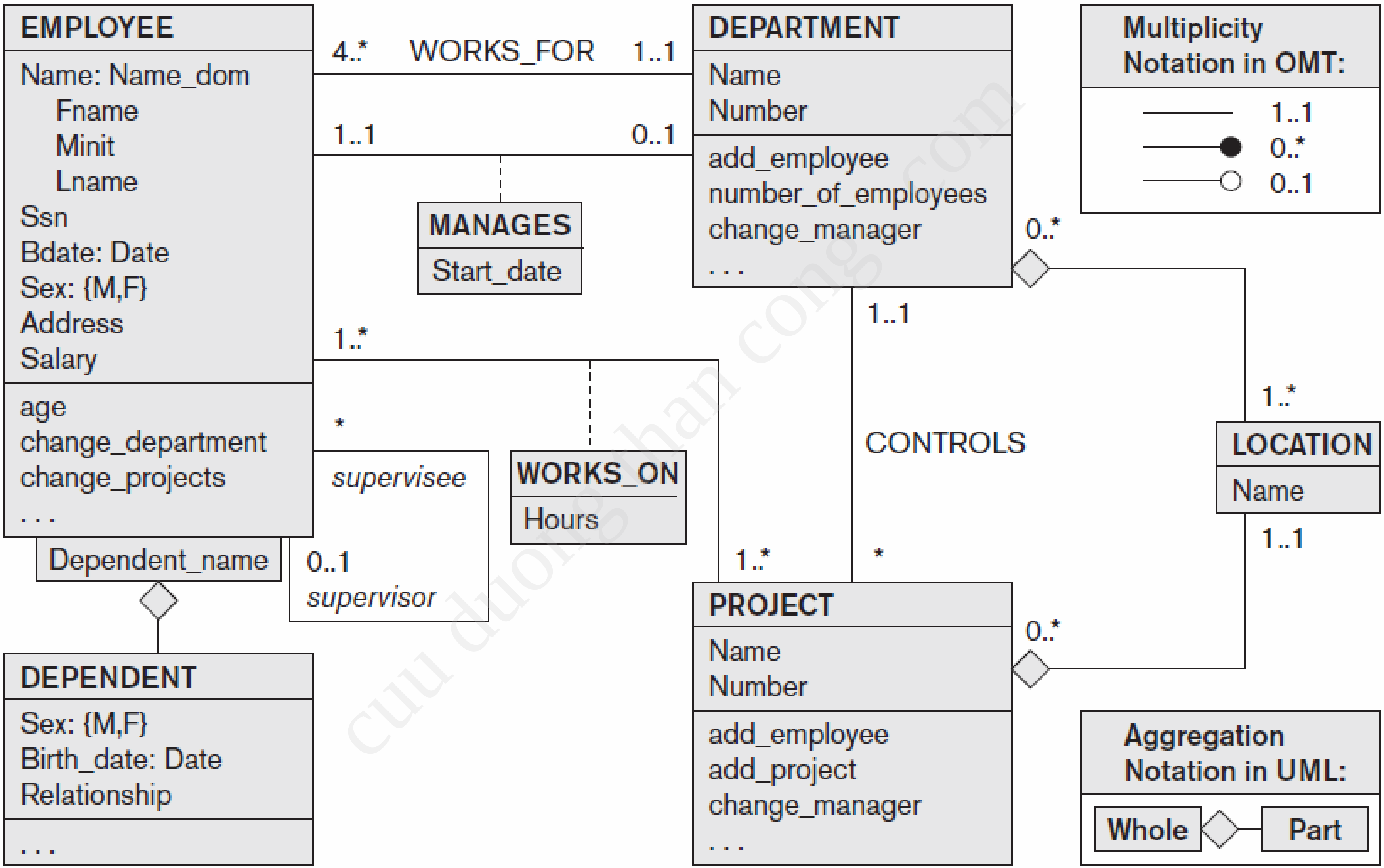
ER diagrams for the company schema, with structural constraints specified using (min, max) notation and role names.



Alternative Diagrammatic Notations

- UML methodology
  - Used extensively in software design
  - Many types of diagrams for various software design purposes
- **UML class diagrams**
  - Entity in ER corresponds to an object in UML

The COMPANY conceptual schema
in UML class diagram notation.



Alternative Diagrammatic Notations

- **UML class diagrams**
  - **Class** includes three sections:
    - Top section gives the class name
    - Middle section includes the attributes;
    - Last section includes operations that can be applied to individual objects
  - **Associations**: relationship types
  - **Relationship instances**: links

Alternative Diagrammatic Notations

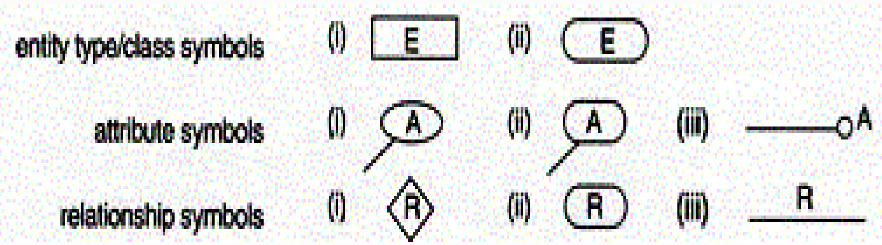
- **UML class diagrams**
  - Binary association
    - Represented as a line connecting participating classes
    - May optionally have a name
  - Link attribute
    - Placed in a box connected to the association's line by a dashed line

Alternative Diagrammatic Notations

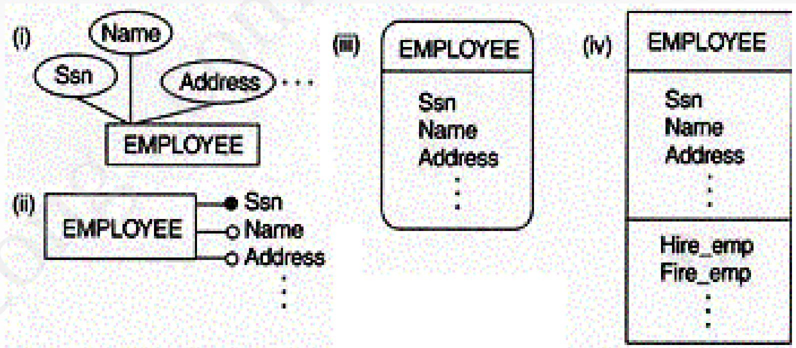
- **UML class diagrams**
  - **Multiplicities**: min..max, asterisk (*) indicates no maximum limit on participation
  - Types of relationships: **association** and **aggregation**
  - Distinguish between **unidirectional** and **bidirectional** associations
  - Model weak entities using **qualified association**

Alternative Diagrammatic Notations

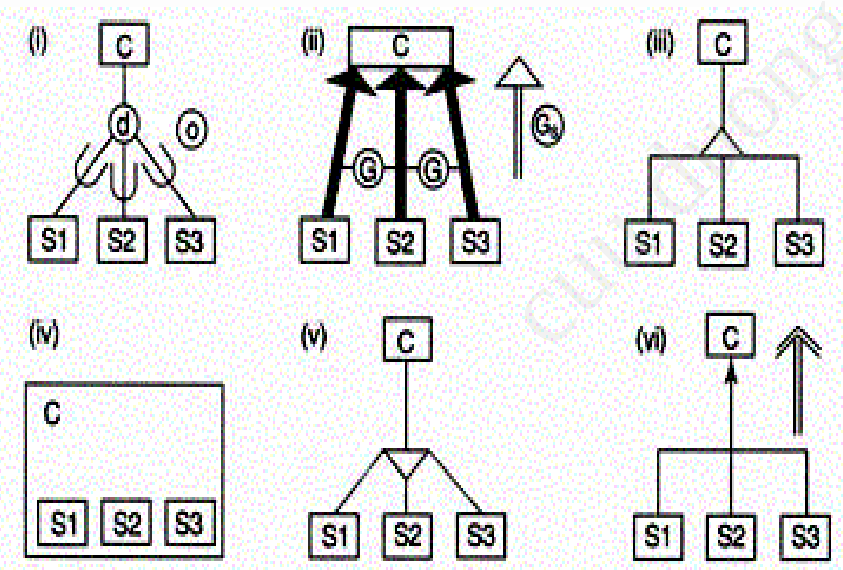
Symbols for entity type / class, attribute and relationship



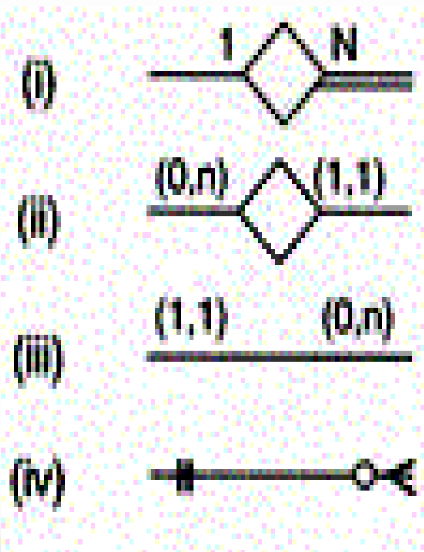
Displaying attributes



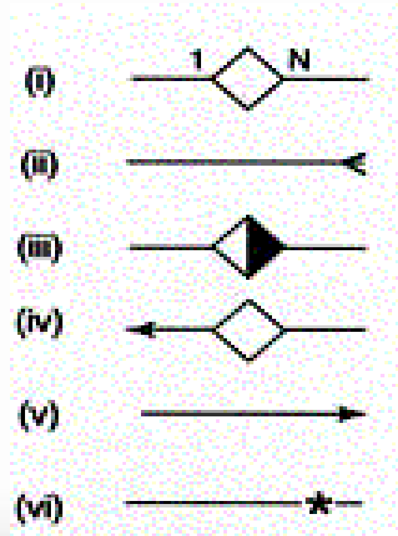
Notations for displaying specialization / generalization



Various (min, max) notations



Displaying cardinality ratios

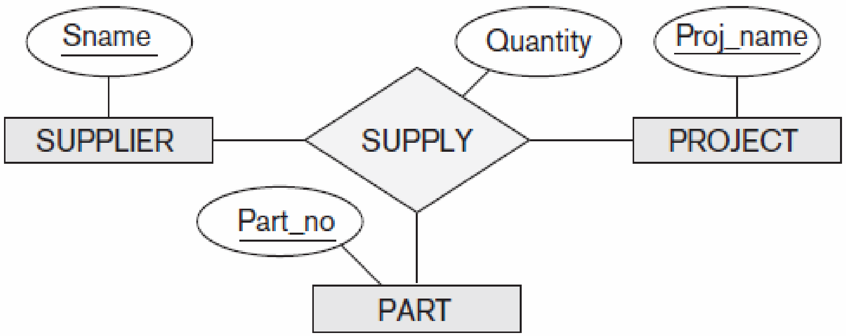


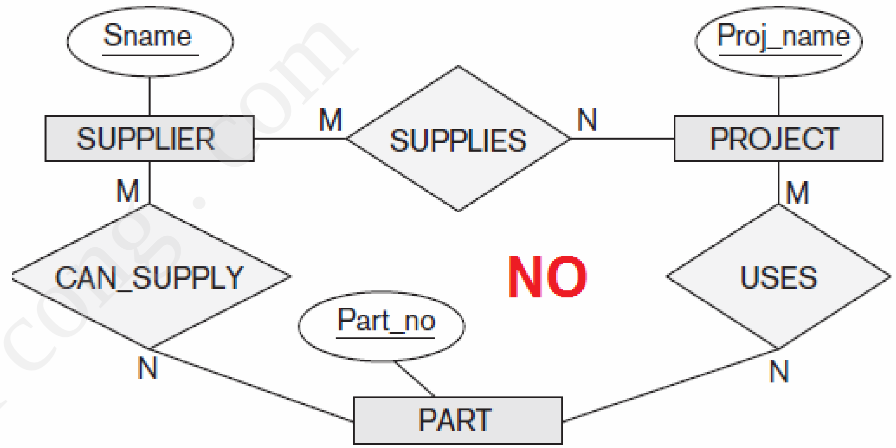
Higher Degree Relationship Types

Binary vs. Ternary Relationships

- Some database design tools permit only binary relationships
  - Ternary relationship must be represented as a weak entity type
  - No partial key and three identifying relationships
- Represent ternary relationship as a regular entity type
  - By introducing an artificial or surrogate key

Binary vs. Ternary Relationships





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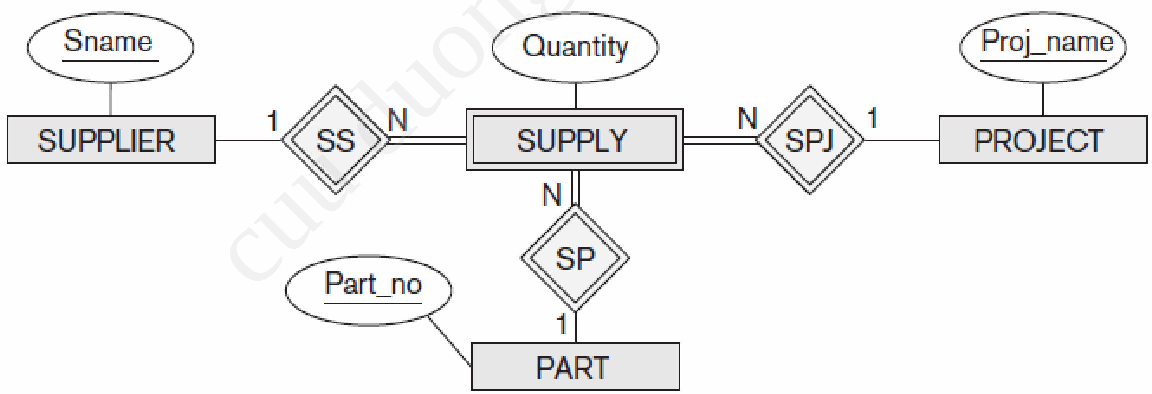


Constraints on Higher-Degree Relationships

- Notations for specifying structural constraints on *n*-ary relationships
  - Should both be used if it is important to fully specify structural constraints

ER Models: Problems

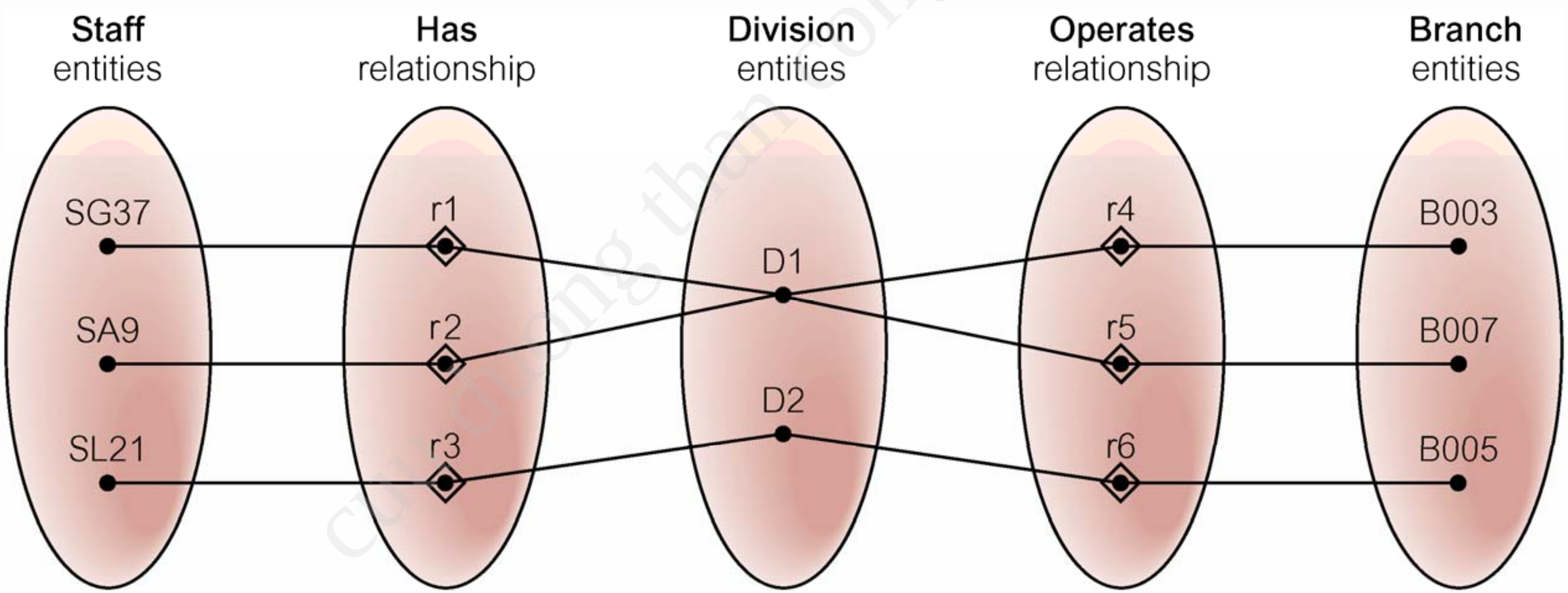
Problems with ER Models

- Problems may arise when designing a conceptual data model called **connection traps**
- Often due to a misinterpretation of the meaning of certain relationships
- Two main types of connection traps are called fan traps and chasm traps

Problems with ER Models

- Fan Trap
  - Where a model represents a relationship between entity types, but pathway between certain entity occurrences is ambiguous
  - Usually: two or more 1:N relationships fan out from the same entity
- Chasm Trap
  - Where a model suggests the existence of a relationship between entity types, but pathway does not exist between certain entity occurrences
  - Usually: optional participation

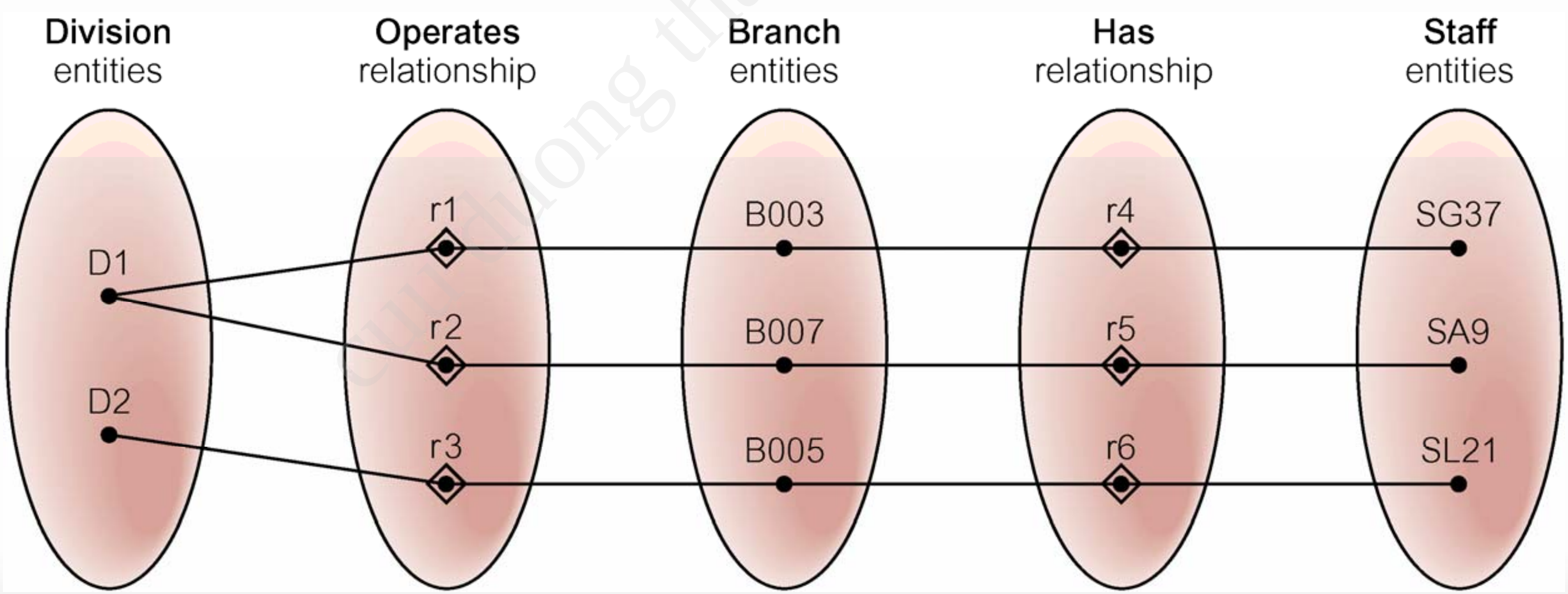
An Example of a Fan Trap



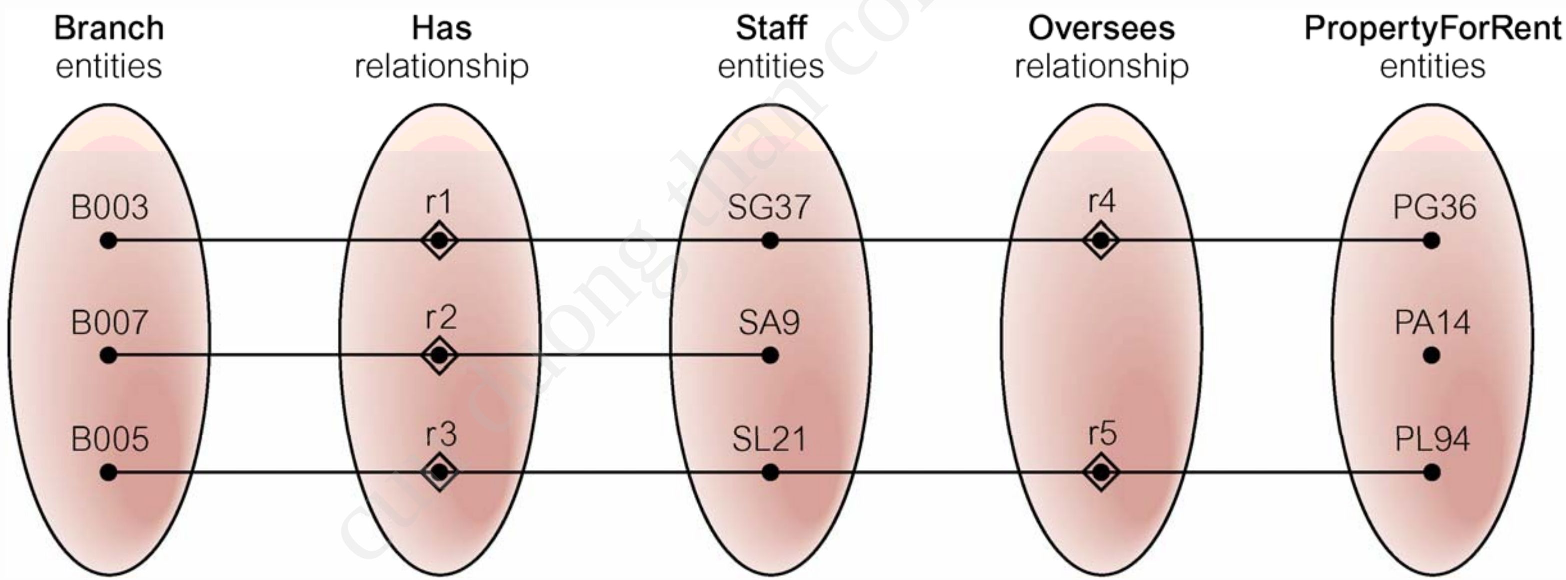
At which branch office does staff number SG37 work?

Restructuring ER Model to Remove Fan Trap

- SG37 works at branch B003

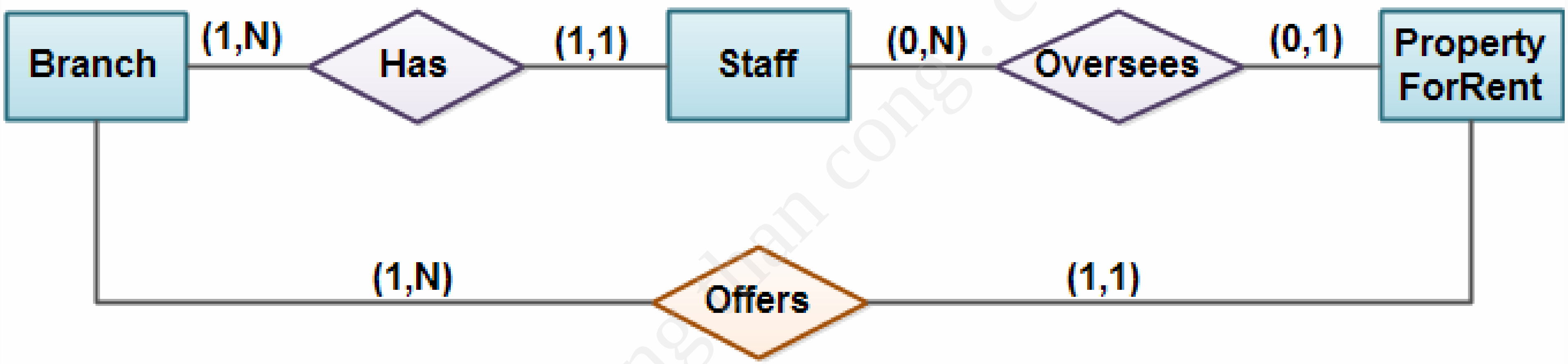


An Example of a Chasm Trap



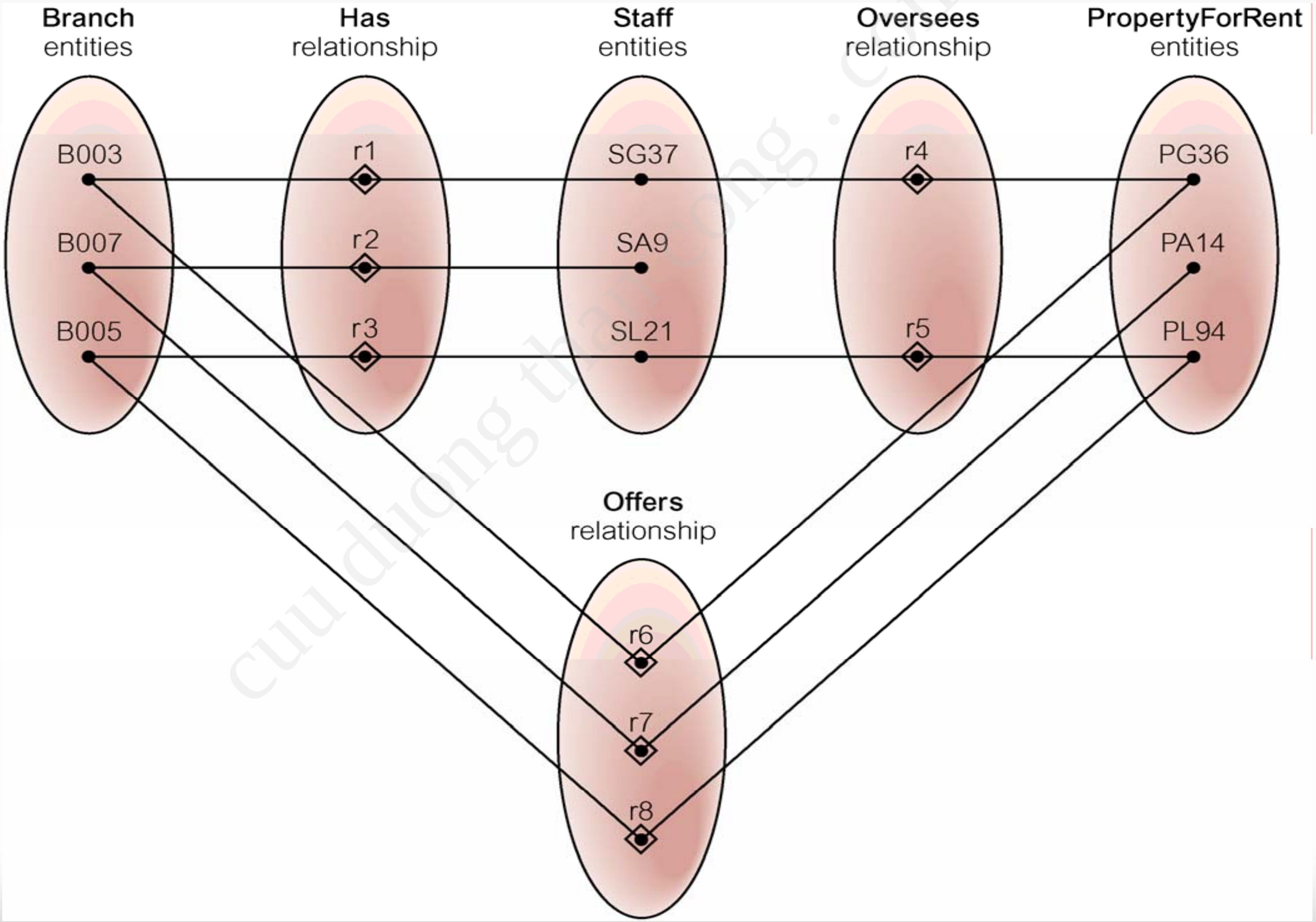
At which branch office is property PA14 available?

ER Model Restructured to Remove Chasm Trap



- Adding the ***Offers*** relationship resolves the chasm trap

ER Model Restructured to Remove Chasm Trap



Summary

1	Overview of Database Design Process
2	What is ER Model? And Why?
3	A Sample Database Application
4	ER Model Concepts
5	ER Diagram and Naming Conventions
6	Alternative Diagrammatic Notations
7	Relationship Types of Degree Higher than Two
8	Problems with ER Models