


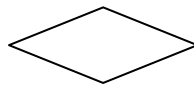

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# INFO90002 Database Systems & Information Modelling

## Lecture 04 Logical & Physical Modelling

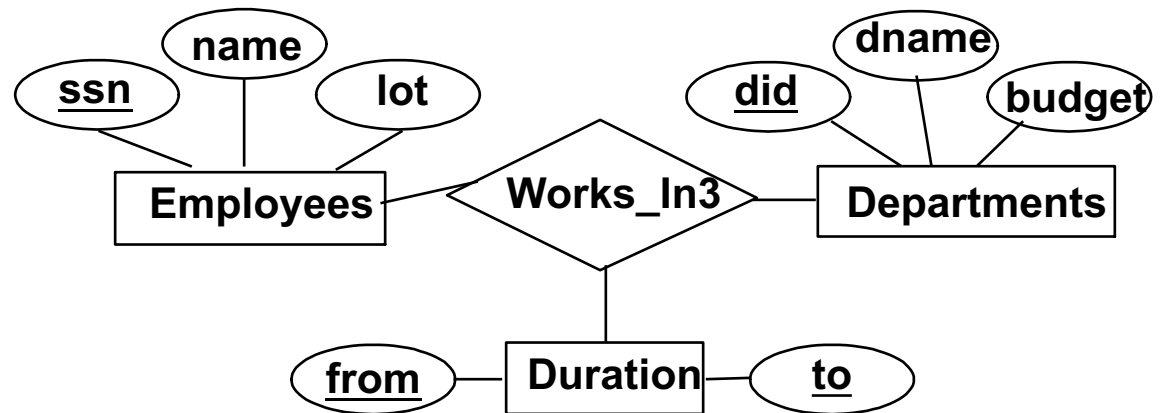
- Basic ER modeling concepts

- Entities, 
- Relationships 
- Attributes (Key Attributes) 

- Constraints

- Key Constraints M:M 1:M 1:1
- Participation Constraints
  - Total
  - Partial

- Conceptual Design



- Relational Model
- Keys & Integrity Constraints
- Translating ER to Logical and Physical Model

*Readings: Chapter 3, Ramakrishnan & Gehrke, Database Systems*



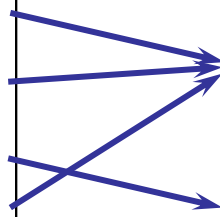
- **Data Model** allows us to translate real world things into structures that a computer can store
- Many models: Relational, ER, O-O, Network, Hierarchical, etc.
- **Relational Model:**
  - Rows & Columns (Tuples and Attributes/fields)
  - Keys & Foreign Keys to link Relations

## Enrolled

sid	cid	grade
53666	Carnatic101	5
53666	Reggae203	5.5
53650	Topology112	6
53666	History105	5

## Student

sid	name	login	age	gpa
53666	Jones	jones@cs	18	5.4
53688	Smith	smith@eecs	18	4.2
53650	Smith	smith@math	19	4.8





- **Relational database**: a set of *relations*.
- **Relation**: made up of 2 parts:
  - **Schema** : specifies name of relation, plus name and type of each column (attribute).  
Example:  
Student(*sid*: string, *name*: string, *login*: string, *age*: integer, *gpa*: real)
  - **Instance** : a **table**, with rows and columns.  
#rows = *cardinality*  
#fields = *degree (or arity)*
- You can think of a relation as a set of *rows* or *tuples*.
  - all rows are *distinct*
  - *no order* among rows

## Students

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@eecs	18	3.2
53650	Smith	smith@math	19	3.8

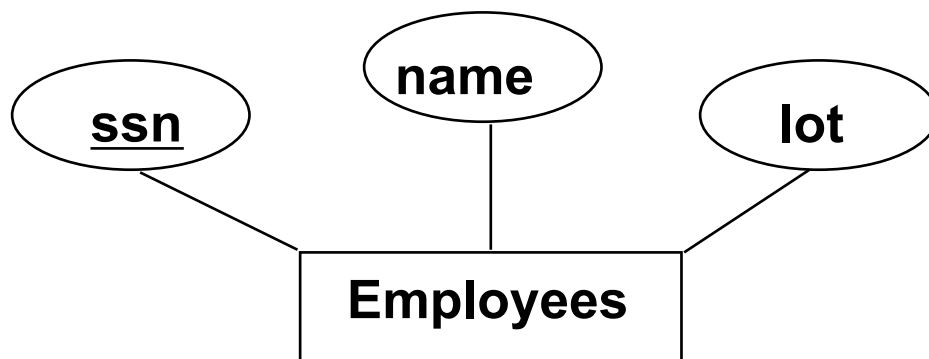
Cardinality = 3, degree (arity) = 5, all rows distinct

In logical design **entity** set becomes a **relation**.  
Attributes become attributes of the relation.

Conceptual Design:



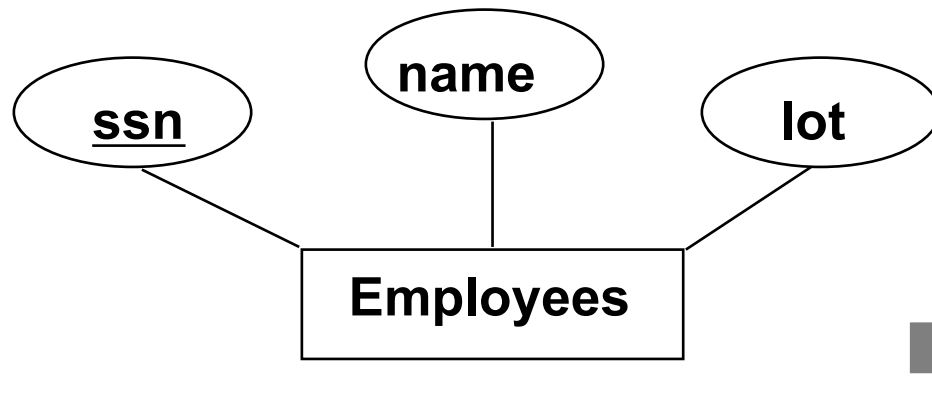
Logical Design:



Employees = (ssn, name, lot)

In physical design we choose **data types**

## 1. Conceptual Design:



## 3. Physical Design:

Employees  
(ssn CHAR(11),  
name CHAR(20),  
lot INTEGER)

## 2. Logical Design:

Employees (ssn, name, lot)



# The Entire Cycle

**1. Conceptual Design**



**2. Logical Design**



**3. Physical Design**

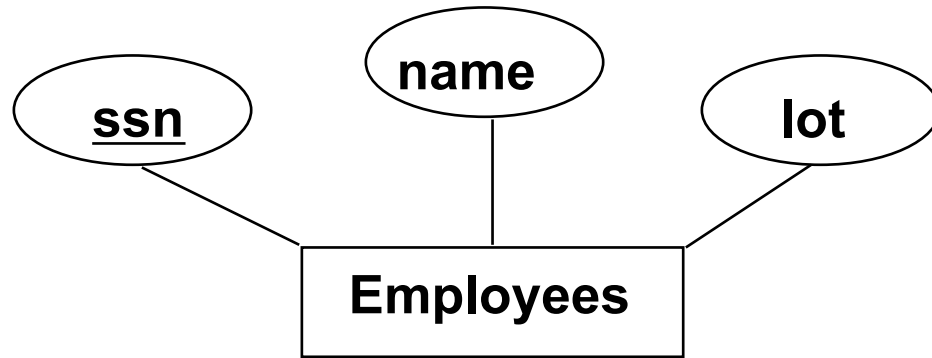


**4. Implementation**



**5. Create Instance**

## 1. Conceptual Design:



## 2. Logical Design:

Employees (ssn, name, lot)

## 3. Physical Design:

Employees  
(ssn CHAR(11),  
name CHAR(20),  
lot INTEGER)

## 4. Implementation:

```
CREATE TABLE Employees  
(ssn CHAR(11),  
name CHAR(20),  
lot INTEGER,  
PRIMARY KEY (ssn))
```

## 5. Instance:

### EMPLOYEES

<u>ssn</u>	name	lot
0983763423	John	10
9384392483	Jane	10
3743923483	Jill	20

## Example: Creating the Student relation

```
CREATE TABLE Student  
  (sid CHAR(20),  
   name CHAR(20),  
   login CHAR(10),  
   age INTEGER,  
   gpa FLOAT,  
   PRIMARY KEY (sid))
```

The type (domain) of each field is *specified*, and *enforced* by the DBMS whenever tuples are *added* or *modified*.

If 27.4 is inserted for field *age* the database will reject the insert --> not the correct type (domain)  
If 'deccles@unimelb.edu.au' is inserted for field *login* the database will reject it --> too long 22 chars

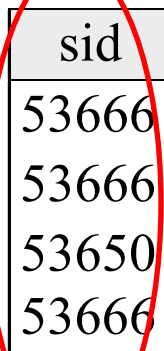
This is the power of databases – much of the error checking is automated by the database.



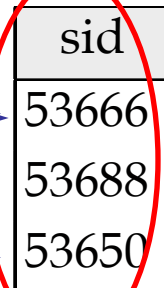
- Relational Model
- **Keys & Integrity Constraints**
- Translating ER to Logical and Physical Model

*Readings: Chapter 3, Ramakrishnan & Gehrke, Database Systems*

- Keys are a way to associate tuples in different relations
- Keys are one form of **integrity constraint (IC)**
- **Example:** *Only students can be enrolled in subjects.*

**Enrolled**

sid	cid	grade
53666	15-101	C
53666	18-203	B
53650	15-112	A
53666	15-105	B

**FOREIGN Key****Students**

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@cs	18	3.2
53650	Smith	smith@math	19	3.8

**PRIMARY Key**

- A set of fields is a **superkey** if no two distinct tuples can have same values in all key fields
- A set of fields is a **key** for a relation if it is a superkey and no subset of the fields is a superkey (minimal subset)
- Out of all keys *one* is chosen to be the **primary key** of the relation. Other keys are called **candidate** keys.
- Each *relation* has a *primary key*.

- **Your turn:**

1. Is *sid* a key for Student?
2. What about *name*?
3. Is the set {*sid*, *gpa*} a superkey? Is the set {*sid*, *gpa*} a key?
4. Find a primary key from this set {*sid*, *login*}

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@cs	18	3.2
53650	Smith	smith@math	19	3.8

## Superkeys



## Keys



## Candidate Keys



## Primary Key

- Superkey – a set of fields that contains the key
- Keys are columns that in combination or alone can uniquely identify the tuple (row)
- Candidate keys are all the possible key combinations that could be the Primary Key
- Of all candidate keys the database designer *identifies* the primary key. The primary key is the *fewest number of columns* that can uniquely identify a key
- N.B.\* Not all relations will have a key. In those cases the database designer will add a *surrogate key*

\*N.B. means Nota Bene latin for "Note well" or in David speak "This information is important!")



- There are possibly many candidate keys (specified using UNIQUE), one of which is chosen as the *primary key*. Keys must be chosen carefully.

## Example:

*For a given student and course, there is a single grade.*

```
CREATE TABLE Enrolled  
(sid CHAR(20)  
  cid CHAR(20),  
  grade CHAR(2),  
  PRIMARY KEY (sid,cid))
```

VS.

```
CREATE TABLE Enrolled  
(sid CHAR(20)  
  cid CHAR(20),  
  grade CHAR(2),  
  PRIMARY KEY (sid),  
  UNIQUE (cid, grade))
```

*“Students can take only one course,  
and no two students in a course  
receive the same grade.”*



- **Foreign key** : A set of fields in one relation that is used to 'refer' to a tuple in another relation. The foreign key must correspond to the primary key of the other relation.
- If all foreign key constraints are enforced in a DBMS, we say a **referential integrity** is achieved.



**Example:** *Only students listed in the Students relation should be allowed to enroll in courses.*

- sid* is a foreign key referring to Students

```
CREATE TABLE Enrolled
```

```
(sid CHAR(20),
```

```
cid CHAR(20),
```

```
grade CHAR(2),
```

```
PRIMARY KEY (sid.cid),
```

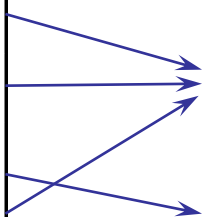
```
FOREIGN KEY (sid) REFERENCES Students (sid))
```

**Enrolled**

sid	cid	grade
53666	15-101	C
53666	18-203	B
53650	15-112	A
53666	15-105	B

**Students**

sid	name	login	age	gpa
53666	Jones	jones@cs	18	3.4
53688	Smith	smith@cs	18	3.2
53650	Smith	smith@math	19	3.8



- Consider Students and Enrolled; *sid* in Enrolled is a foreign key that references Students.
- What should be done if an Enrolled tuple with a non-existent student id is inserted? (*Reject it!*)
- What should be done if a Students tuple is deleted?
  - Also delete all Enrolled tuples that refer to it?
  - Disallow deletion of a Students tuple that is referred to?
  - Set *sid* in Enrolled tuples that refer to it to a *default sid*?
  - (In SQL, also: Set *sid* in Enrolled tuples that refer to it to a special value *null*, denoting '*unknown*' or '*inapplicable*'.)
- Note: Similar issues arise if primary key of Students tuple is updated.

- **IC**: condition that must be true for *any* instance of the database; e.g., domain constraints.
  - ICs are specified when schema is defined.
  - ICs are checked when relations are modified.
- A **legal** instance of a relation is one that satisfies all specified ICs.
  - DBMS should not allow illegal instances.
- This is also known as Schema on Write



- Relational Model
- Keys & Integrity Constraints
- **Translating ER to Logical and Physical Model**

*Readings: Chapter 3, Ramakrishnan & Gehrke, Database Systems*

- Multi-valued attributes need to be unpacked (flattened) when converting to logical design.

## Example:

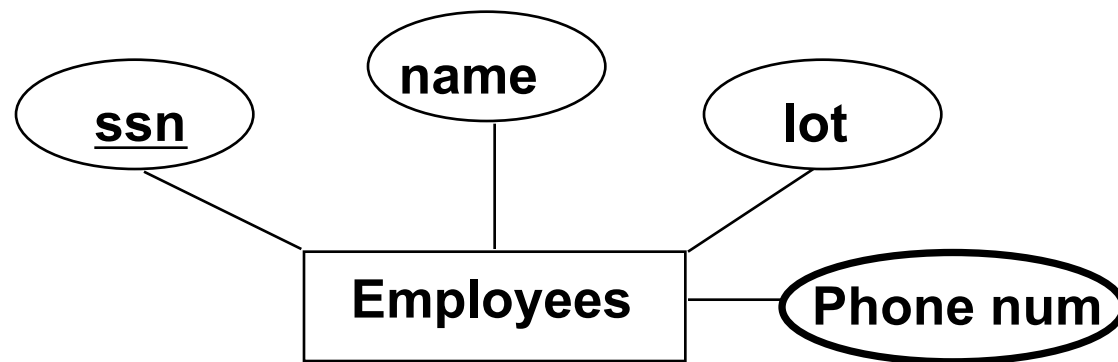
*For employees we need to capture home phone number and work phone number.*

### Conceptual Design:



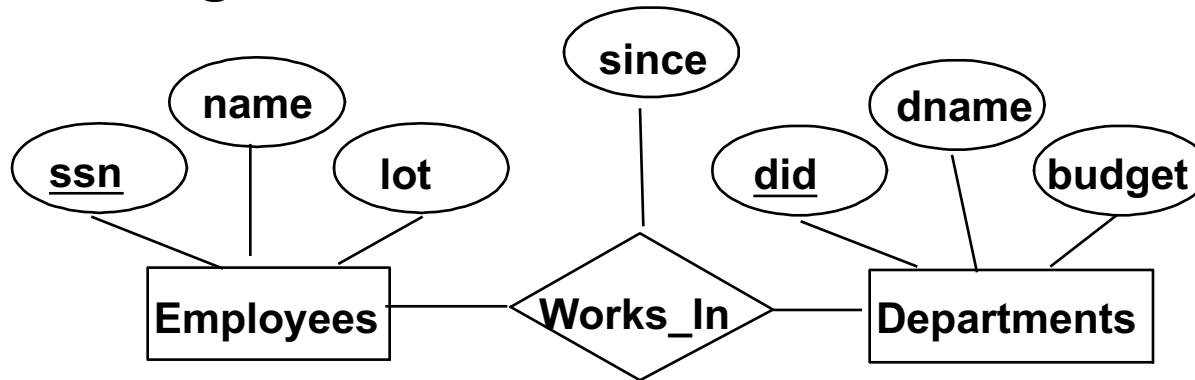
### Logical Design:

Employees = (ssn,  
name,  
lot,  
home\_num,  
work\_num)



Multi-valued attribute

## Conceptual Design:

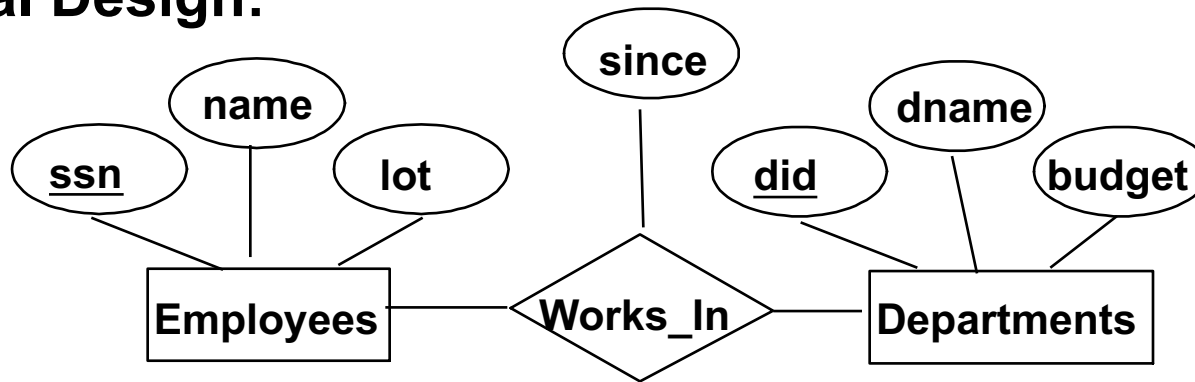


## Logical Design:

In translating a **many-to-many** relationship set to a relation, attributes of a *new* relation must include:

1. Keys for each participating entity set (as foreign keys). This set of attributes forms a **superkey** of the relation.
2. All descriptive attributes.

## Conceptual Design:



## Logical Design:

Employees = (ssn,  
name  
lot)

Departments = (did,  
dname,  
budget)

Works\_In = (ssn,  
did,  
since)

Keys from connecting  
entities become PFK

Note:  
Underline = PK,  
Italic = FK,  
Underline + Italic = PFK



## Logical Design:

Employees = (ssn, name, lot)

Departments = (did, dname, budget)

Works\_In = (ssn, *did*, since)

Note: Underline = PK,  
italic = FK,  
underline and italic = PFK

## Physical Design:

Employees  
(ssn CHAR(11),  
name CHAR(20),  
lot INTEGER)

Departments  
(did INTEGER,  
dname CHAR(20),  
budget FLOAT)

Works\_In(  
ssn CHAR(11),  
*did* INTEGER,  
since DATE)

## Logical Design:

Employees = (ssn, name, lot)

Departments = (did, dname, budget)

Works\_In = (ssn, did, since)

Note: Underline = PK

Italic = FK,

Underline and Italic = PFK

## Implementation:

```
CREATE TABLE Employees
  (ssn CHAR(11),
   name CHAR(20),
   lot INTEGER,
   PRIMARY KEY (ssn))
```

```
CREATE TABLE Departments
  (did INTEGER,
   dname CHAR(20),
   budget FLOAT,
   PRIMARY KEY (did))
```

```
CREATE TABLE Works_In(
  ssn CHAR(11),
  did INTEGER,
  since DATE,
  PRIMARY KEY (ssn, did),
  FOREIGN KEY (ssn) REFERENCES Employees(ssn),
  FOREIGN KEY (did) REFERENCES Departments(did))
```

**Employees**

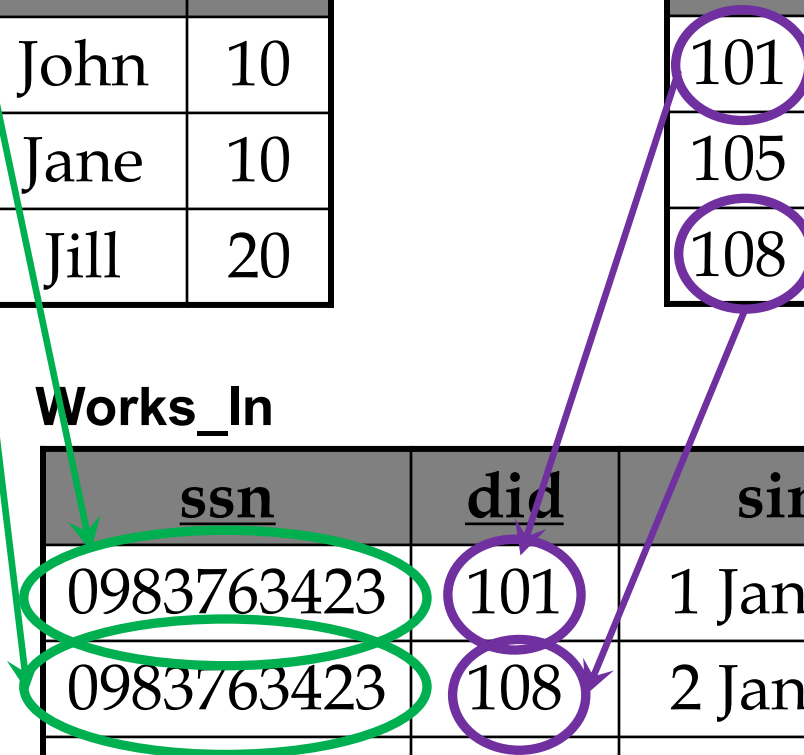
<u>ssn</u>	name	lot
0983763423	John	10
9384392483	Jane	10
3743923483	Jill	20

**Departments**

<u>did</u>	dname	budget
101	Sales	10K
105	Purchasing	20K
108	Databases	1000K

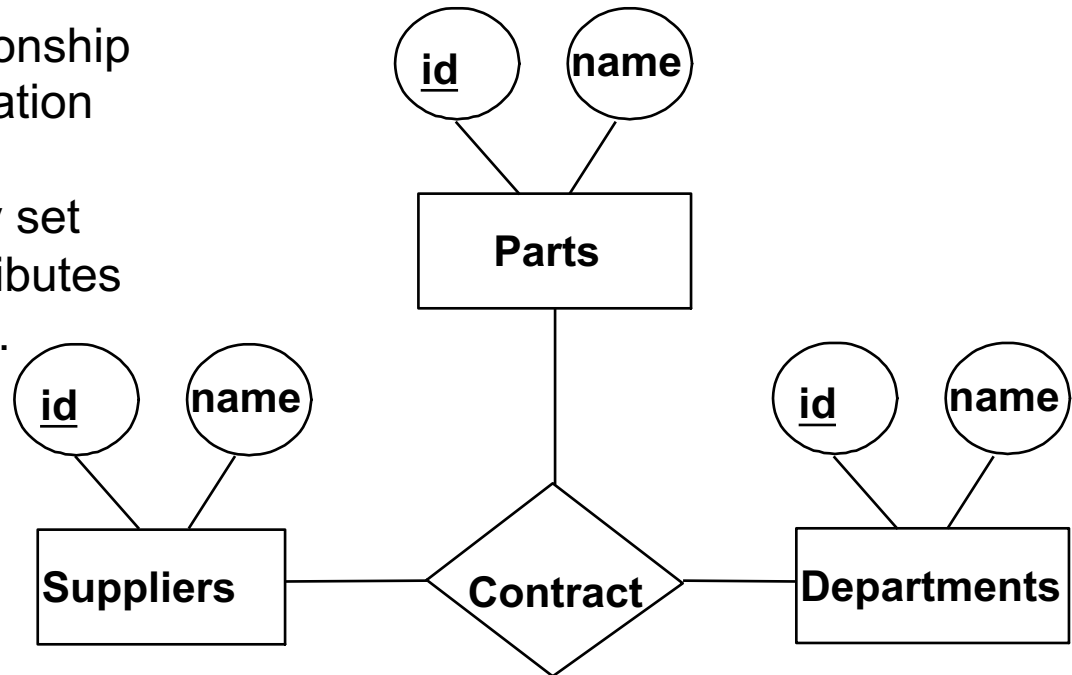
**Works\_In**

<u>ssn</u>	<u>did</u>	since
0983763423	101	1 Jan 2003
0983763423	108	2 Jan 2003
9384392483	108	1 Jun 2002



In translating a **many-to-many** relationship set to a relation, attributes of the relation must include:

- Keys for each participating entity set (as foreign keys). This set of attributes forms a **superkey** for the relation.
- All descriptive attributes.



## Logical Design:

Contracts (  
*supplier\_id*,  
*part\_id*,  
*department\_id*)

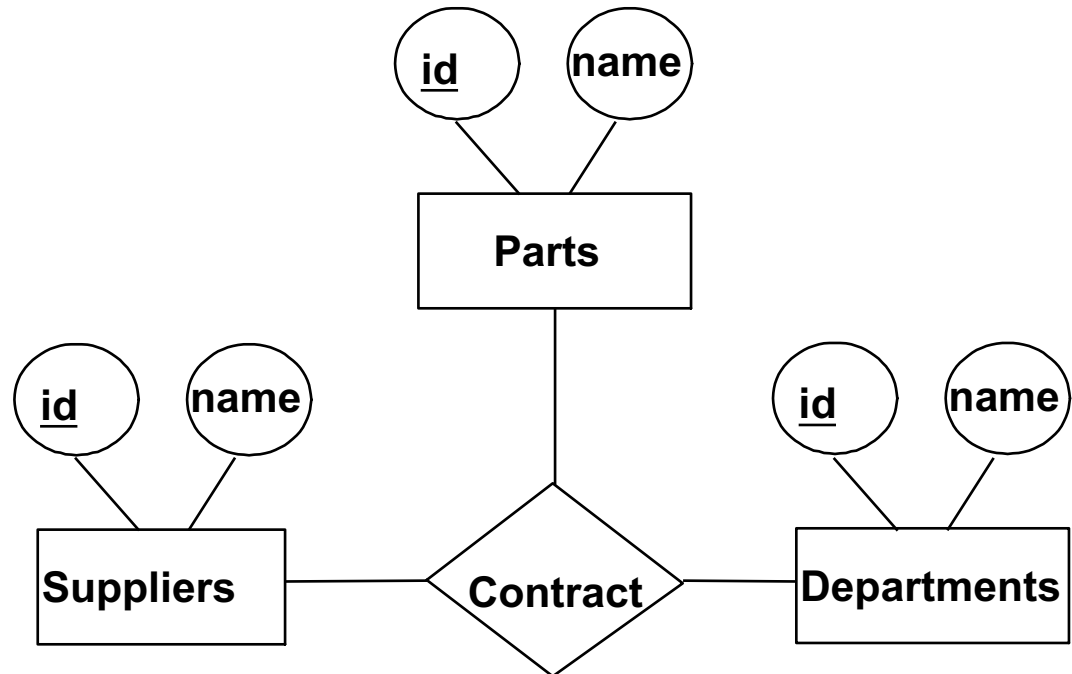
Note:  
Underline = PK,  
Italic = FK,  
Underline and italic = PFK

## Logical Design:

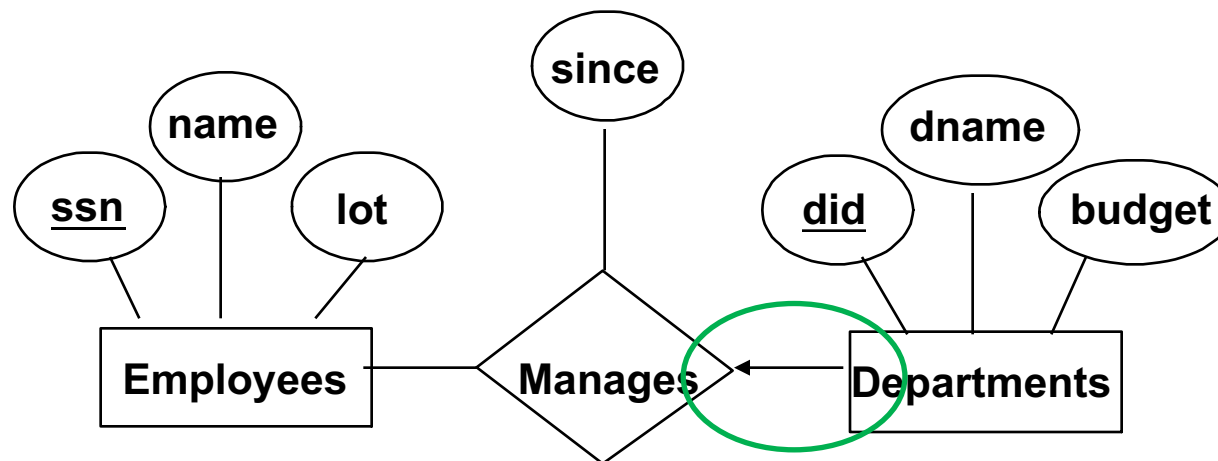
Contracts (  
supplier\_id,  
part\_id,  
department\_id)

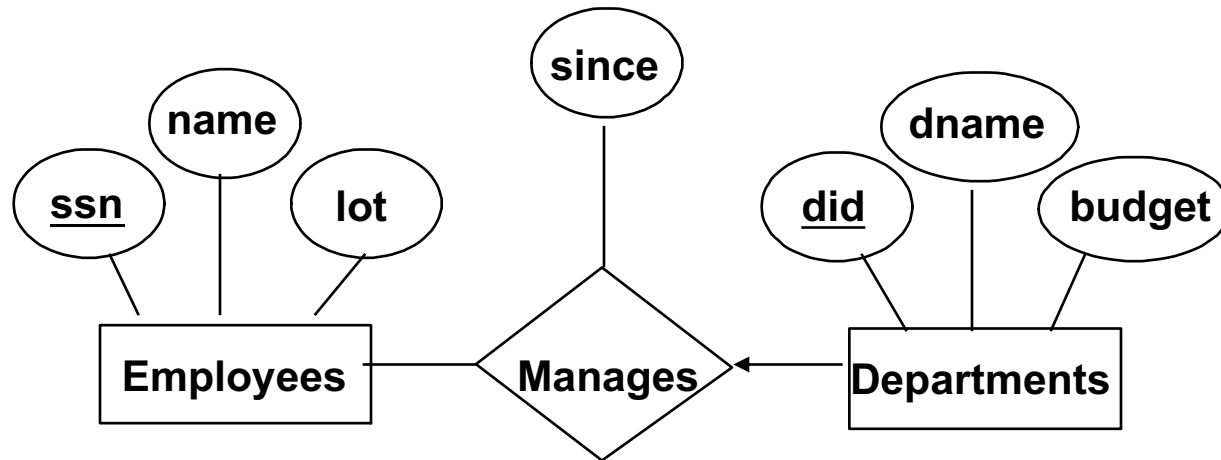
## Implementation:

```
CREATE TABLE Contracts (  
  supplier_id INTEGER,  
  part_id INTEGER,  
  department_id INTEGER,  
  PRIMARY KEY (supplier_id, part_id, department_id),  
  FOREIGN KEY (supplier_id) REFERENCES Suppliers(id),  
  FOREIGN KEY (part_id) REFERENCES Parts(id),  
  FOREIGN KEY (department_id) REFERENCES Departments(id))
```



- Each department has at most one manager, according to the key constraint on Manages.





## Logical Design:

Employees = (ssn, name, lot)  
 Departments = (did, dname, budget)  
 Manages = (ssn, *did*, since)

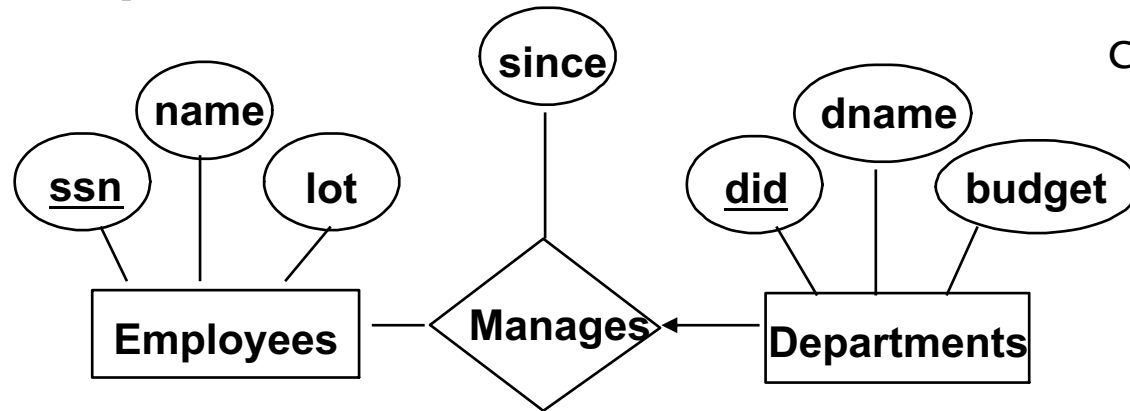
VS.

Employees = (ssn, name, lot)  
 Departments = (did, dname, budget,  
*ssn*, since)

Note: Underline = PK,  
 Italic = FK,  
 Underline and italic = PFK

# Key Constraints in SQL

## Implementation:



```
CREATE TABLE Employees
(ssn CHAR(11),
 name CHAR(20),
 lot INTEGER,
 PRIMARY KEY (ssn))
```

```
CREATE TABLE Manages(
 ssn CHAR(11),
 did INTEGER,
 since DATE,
 PRIMARY KEY (ssn, did),
 FOREIGN KEY (ssn)
 REFERENCES Employees,
 FOREIGN KEY (did)
 REFERENCES Departments)
```

**VS.**

```
CREATE TABLE Departments
(did INTEGER,
 dname CHAR(20),
 budget FLOAT,
 ssn CHAR(11),
 since DATE,
 PRIMARY KEY (did)
 FOREIGN KEY (ssn)
 REFERENCES Employees (ssn))
```

**Which one is better?**

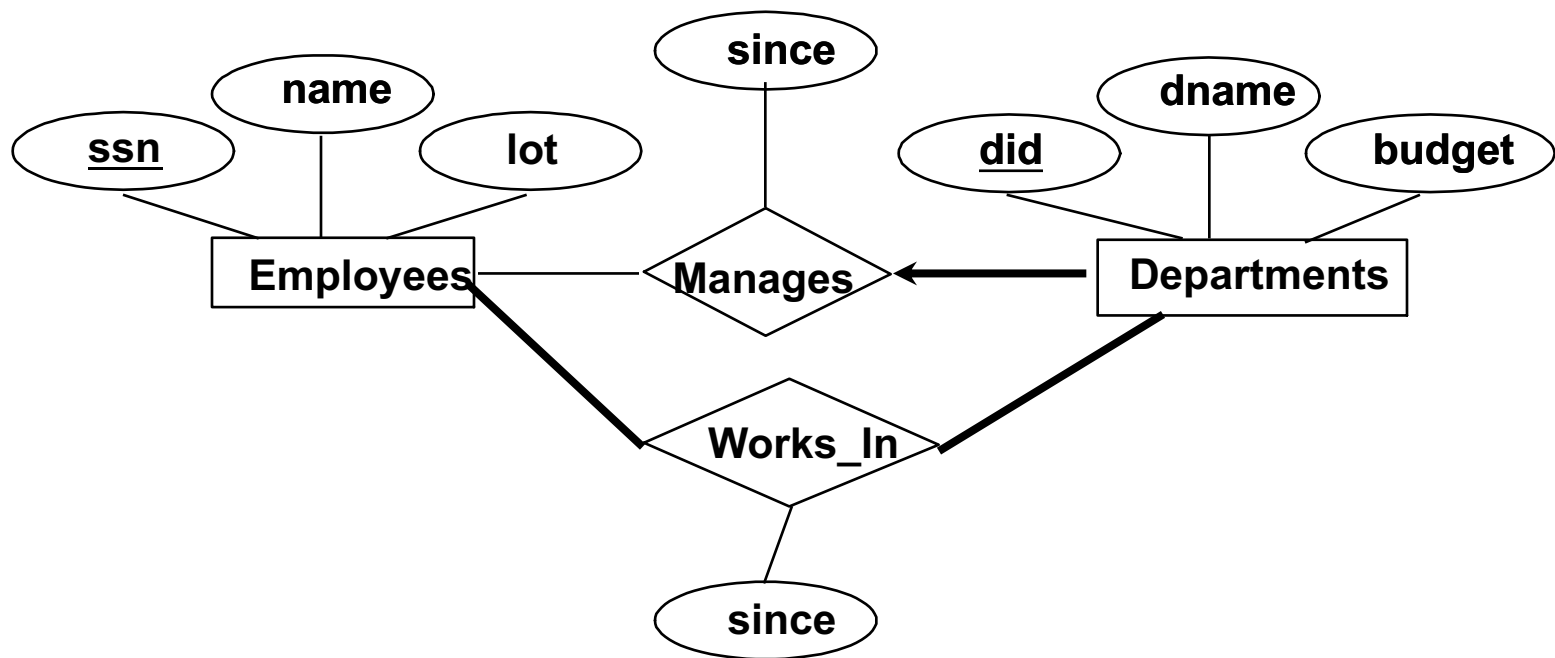


- RULE: Primary key from the many side becomes a foreign key on the one side
- This is the way to ensure that the key constraint holds

```
CREATE TABLE Departments
  (did INTEGER,
   dname CHAR(20),
   budget FLOAT,
   ssn CHAR(11),
   since DATE,
   PRIMARY KEY (did),
   FOREIGN KEY (ssn)
     REFERENCES Employees(ssn))
```

Each department will  
have a *single* manager

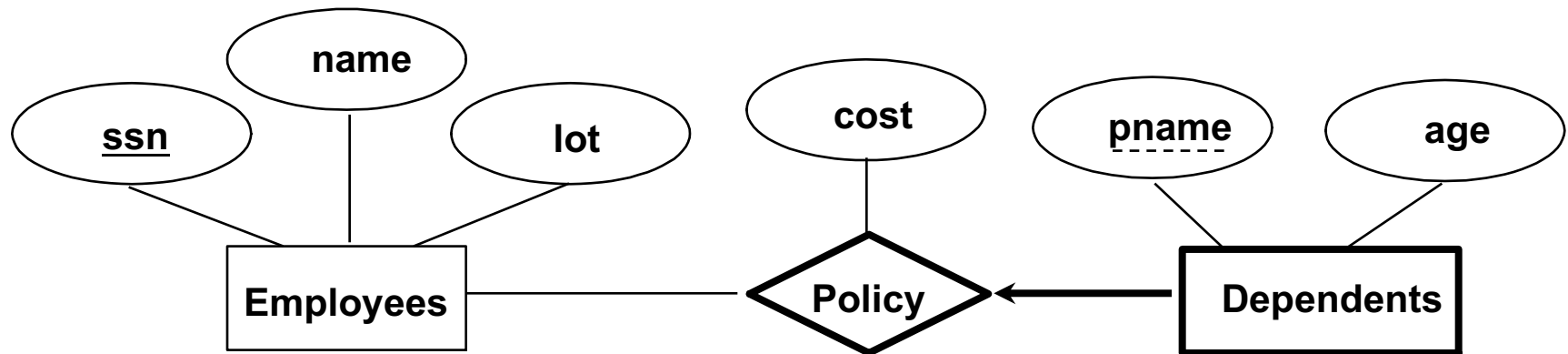
- Does every department have a manager?
  - If so, this is a participation constraint: the participation of Departments in Manages is said to be *total* (vs. *partial*).



- We specify total participation with key words NOT NULL
  - NOT NULL = this field cannot be empty

```
CREATE TABLE Departments(  
    did    INTEGER NOT NULL,  
    dname  CHAR(20),  
    budget REAL,  
    ssn    CHAR(11) NOT NULL,  
    since  DATE,  
    PRIMARY KEY (did),  
    FOREIGN KEY (ssn) REFERENCES Employees(ssn),  
    ON DELETE NO ACTION)
```

- A **weak entity** can be identified uniquely only by considering the primary key of another (*owner*) entity.



- Weak entity set and identifying relationship set are translated into a single table.
  - When the owner entity is deleted, all owned weak entities must also be deleted.

### Logical Design:

Dependents = (pname, age, cost, **ssn**)

Note: Underline = PK,  
italic and underline = FK,  
underline and bold = PFK

### Implementation:

```
CREATE TABLE Dependents(  
  pname CHAR(20),  
  age INTEGER,  
  cost REAL,  
  ssn CHAR(11) NOT NULL,  
  PRIMARY KEY (pname, ssn),  
  FOREIGN KEY (ssn) REFERENCES Employees(ssn),  
  ON DELETE CASCADE)
```

- A tabular representation of data.
- Simple and intuitive, currently the most widely used.
- Integrity constraints can be specified based on application semantics. DBMS checks for violations.
  - Two important ICs: primary and foreign keys
  - In addition, we *always* have domain constraints.
- Rules to translate ER to logical design (relational model)



- Be able to model a case study from conceptual to instance and all stages in between (conceptual, logical, physical, implementation and instance)
- Translate conceptual (ER) into logical & physical design
- Understand integrity constraints
- Use DDL of SQL to create tables with constraints

\* All material is examinable – these are the suggested key skills you would need to demonstrate in an exam scenario