Database Management Systems

Converting from ER to Relational Model

M. Emre Gürsoy

Assistant Professor
Department of Computer Engineering
www.memregursoy.com

Introduction

- We had modelled our miniworld using an ER diagram
- Now, we will learn how to convert ER diagrams to a set of relations (Relational Model)
- After we obtain the set of relations, in the next weeks we will learn how to work with relations
  - Theoretical: Relational algebra
  - Practical: Relational DBMS and SQL

- **<u>Main goals in ER -> Relational conversion:</u>**
  - (1) Preserve as much information as possible
  - (2) Minimize redundancy and NULL values

Conversion Algorithm

- We will follow a step-by-step algorithm.

- Step 1: Mapping of Regular Entities
- (EER only) Mapping of Subclass/Superclass
- Step 2: Mapping of Weak Entities
- Step 3: Mapping of Binary 1:1 Relationships
- Step 4: Mapping of Binary 1:N Relationships
- Step 5: Mapping of Binary M:N Relationships
- Step 6: Mapping of Multivalued Attributes
- Step 7: Mapping of N-ary Relationships (eg: ternary)

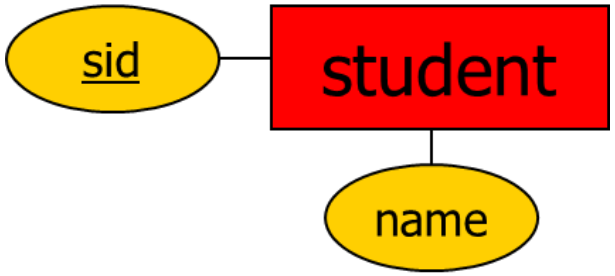
Step 1

- **Regular (non-weak) entities**
- For each regular entity E, create a relation R that includes all the simple attributes of E.
  - If E has a composite attribute, take the simple attributes that make up the composite attribute.
- Choose one of E's keys as the primary key of R
  - If E's key is composite, the set of simple attributes that make up the composite attribute COMBINED becomes the key of R

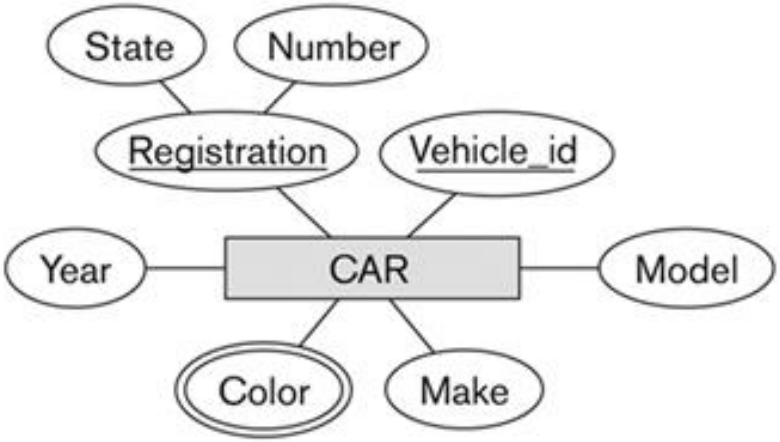
EMPLOYEE (<u>Ssn</u>, Bdate, Fname, Minit, Lname, Address, Salary, Sex)

Step 1 Examples

```
CREATE TABLE Student
        (sid: CHAR(8),
        name: CHAR(30),
        PRIMARY KEY (sid))
```

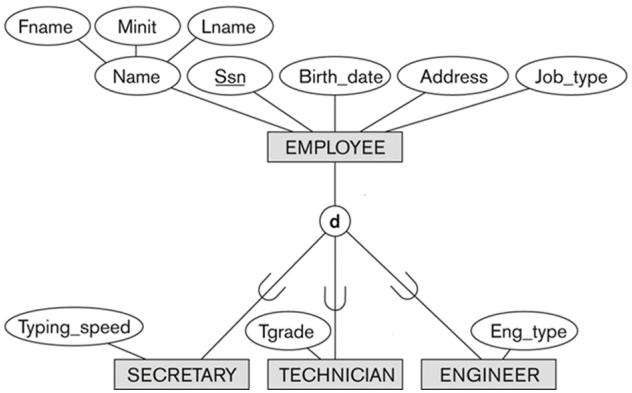



```
CREATE TABLE Car
        (reg_state: CHAR(2),
         reg_number: CHAR(10),
         vehicle_id: CHAR(15),
         model: CHAR(10),
         make: CHAR(15),
         year: INTEGER,
         PRIMARY KEY (reg_state,
                      reg_number))
```



Subclasses/Superclasses

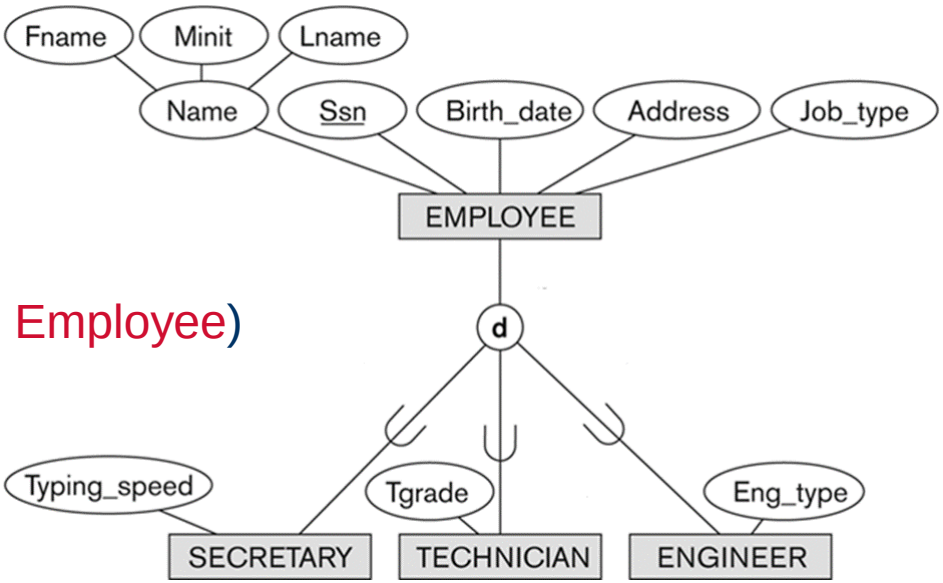
- **Subclasses/Superclasses**
- There are multiple options in the book.
  - Some better for disjoint, some better for overlapping
  - Some better with participation constraint, some not
  - We will study just one (most general) option



- Keep the superclass relation as is.
- For each subclass, create its own relation.
  - Add primary key of superclass to the subclass relation, as a foreign key.
  - Add any other attribute the subclass may have to the subclass relation.
  - Primary key of subclass relation is equal to the primary key of the superclass.

Examples

```
CREATE TABLE Secretary
        (SSN: INTEGER,
         TypingSpeed: REAL,
         PRIMARY KEY (SSN),
         FOREIGN KEY SSN
                    REFERENCES Employee)
```



EMPLOYEE

SSN	FName	MInit	LName	BirthDate	Address	JobType

SECRETARY

SSN	TypingSpeed

TECHNICIAN

SSN	TGrade

ENGINEER

SSN	EngType

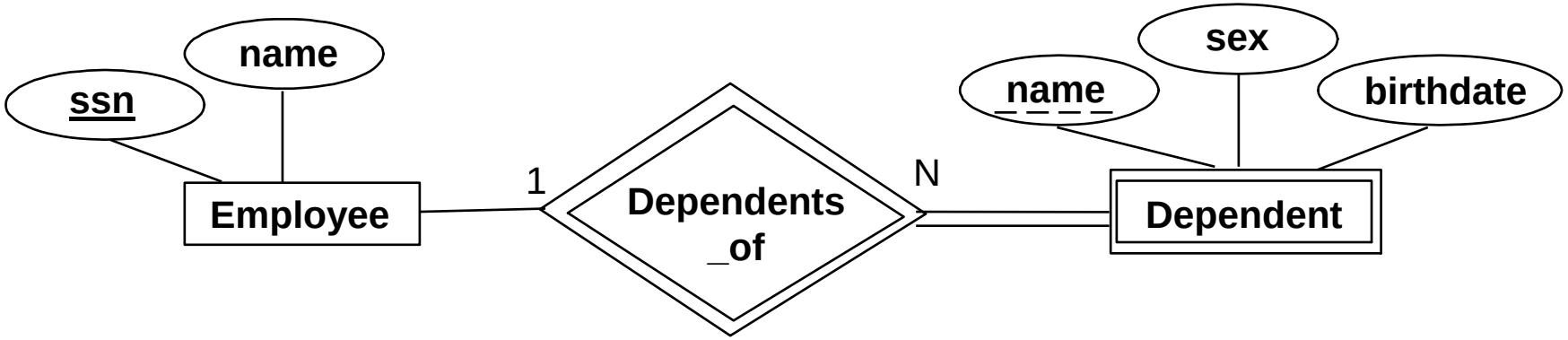
Step 2

- **Weak entities (+ identifying relationships)**
- We handle the weak entity and its identifying relationship together, by creating one new relation R.
- The new relation R contains:
  - Owner (strong) entity's primary key -> foreign key in R
  - All attributes of the weak entity
  - All attributes of the identifying relationship (if any)
- Primary key of R is the **combination** of the primary key of the owner plus the partial key of the weak entity

Step 2 Examples

```
CREATE TABLE Employee
        (ssn: INTEGER,
        name: CHAR(30),
        PRIMARY KEY (ssn))
```

```
CREATE TABLE Emp_Dependents
        (emp_ssn: INTEGER,
         dep_name: CHAR(30),
         dep_sex: CHAR(10),
         dep_birthdate: CHAR(10),
         PRIMARY KEY (emp_ssn, dep_name),
         FOREIGN KEY emp_ssn
                REFERENCES Employee)
```



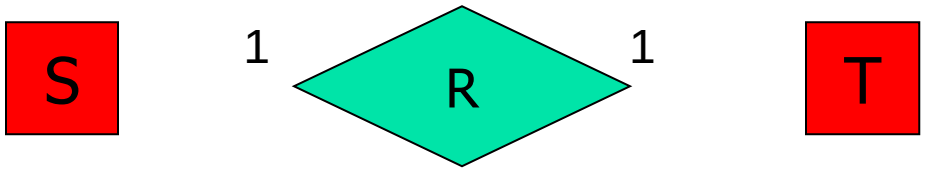
Conversion Algorithm

- We will follow a step-by-step algorithm.

- Step 1: Mapping of Regular Entities
- (EER only) Mapping of Subclass/Superclass
- Step 2: Mapping of Weak Entities
- Step 3: Mapping of Binary 1:1 Relationships
- Step 4: Mapping of Binary 1:N Relationships
- Step 5: Mapping of Binary M:N Relationships
- Step 6: Mapping of Multivalued Attributes
- Step 7: Mapping of N-ary Relationships (eg: ternary)

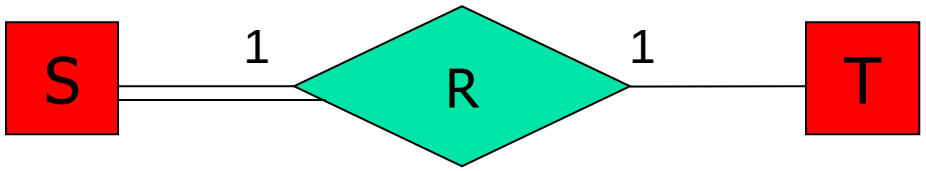
Step 3

- **Binary 1-to-1 Relationships**
- There are 3 cases:
  - (3A) Participation constraint only on one side
  - (3B) Participation constraints on both sides
  - (3C) No participation constraints



Step 3-A

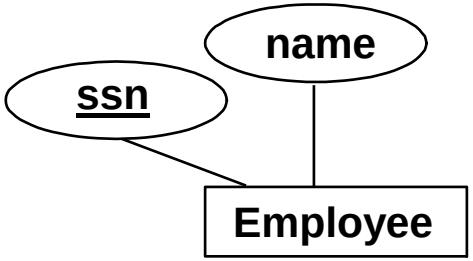
- **Binary 1-to-1 Relationships**
- **Participation constraint only on one side**
- (Note: From Step 1, we already have a relation created for S and one relation created for T.)
- Let S be the fully participating entity
- Add T's primary key to S's relation as foreign key
- Any attribute of relationship R is also added to S

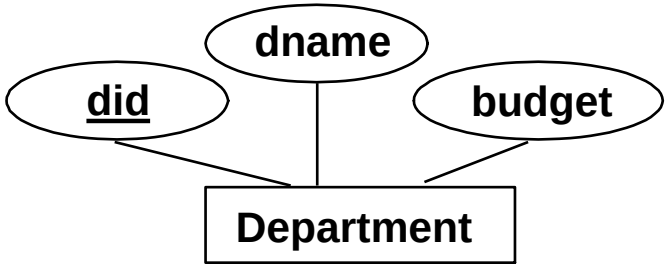


Step 3-A Examples

```
CREATE TABLE Employee
        (ssn: INTEGER,
        name: CHAR(30),
        PRIMARY KEY (ssn))
```

```
CREATE TABLE Department
        (did: INTEGER,
        dname: CHAR(30),
        budget: REAL,
        PRIMARY KEY (did))
```

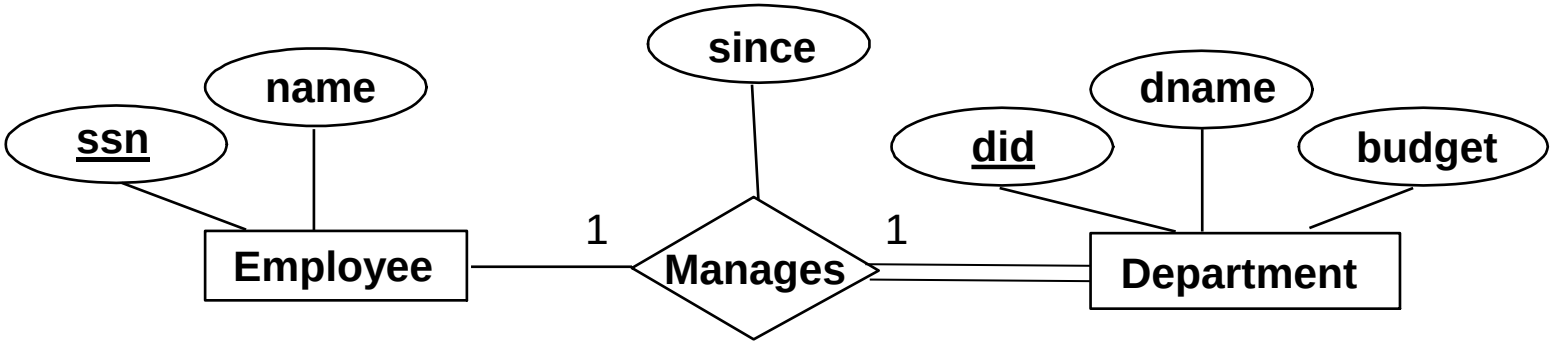




Step 3-A Examples

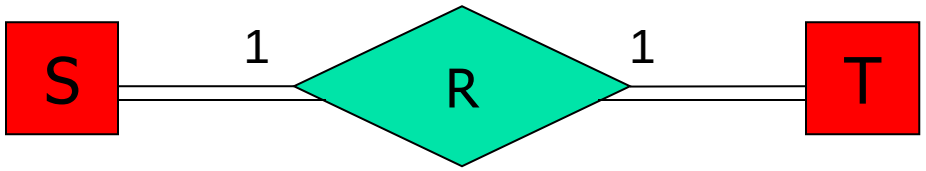
```
CREATE TABLE Employee
        (ssn: INTEGER,
        name: CHAR(30),
        PRIMARY KEY (ssn))
```

```
CREATE TABLE Department
        (did: INTEGER,
        dname: CHAR(30),
        budget: REAL,
        PRIMARY KEY (did),
        manager_ssn: INTEGER,
        FOREIGN KEY(manager_ssn)
            REFERENCES Employee
        manager_since: CHAR(10))
```



Step 3-B

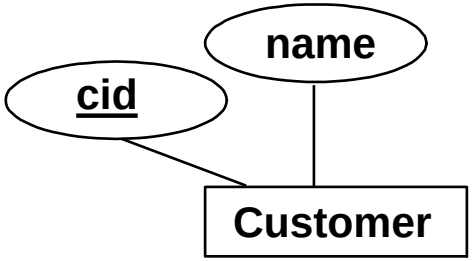
- **Binary 1-to-1 Relationships**
- **Participation constraints on both sides**
- (Note: From Step 1, we already have a relation created for S and one relation created for T.)
- Merge the relations for S and T into a single relation.

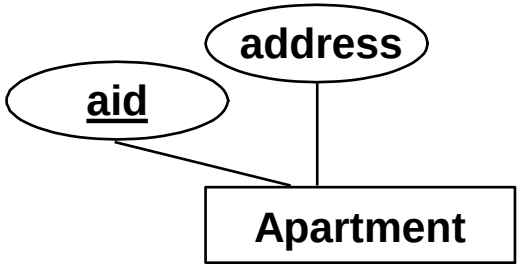


Step 3-B Examples

```
CREATE TABLE Customer
        (cid: INTEGER,
        name: CHAR(30),
        PRIMARY KEY (cid))
```

```
CREATE TABLE Apartment
        (aid: INTEGER,
        address: CHAR(30),
        PRIMARY KEY (aid))
```

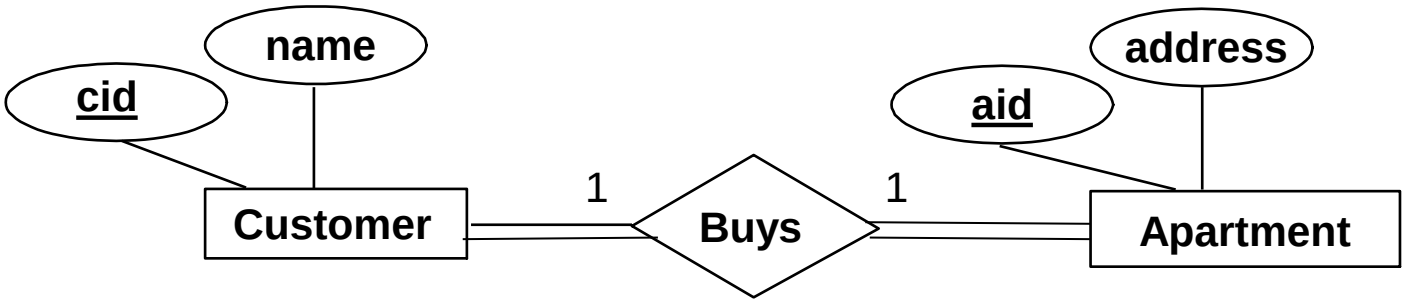




Step 3-B Examples

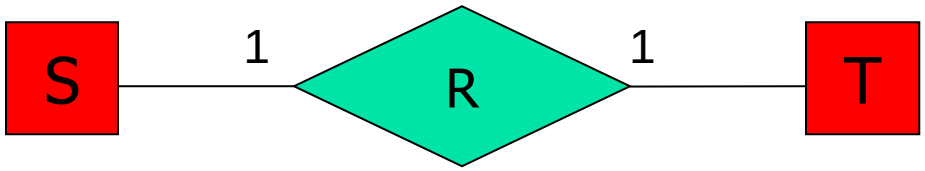
First, get rid of the Customer and Apartment relations.
Then, create the following relation:

```
CREATE TABLE Customer_Apartment
        (cid: INTEGER,
        name: CHAR(30),
        aid: INTEGER,
        address: CHAR(30),
        PRIMARY KEY (cid))
```



Step 3-C

- **Binary 1-to-1 Relationships**
- **No participation constraints**
- (Note: From Step 1, we already have a relation created for S and one relation created for T.)
- Relations for S and T stay the way they are.
- Create a new relation for relationship R, use S and T's primary keys as foreign keys in R.

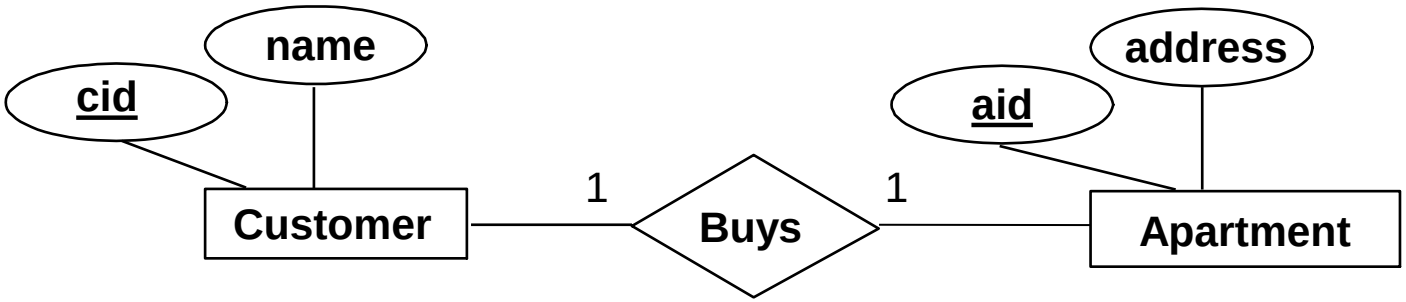


Step 3-C Examples

```
CREATE TABLE Customer
        (cid: INTEGER,
        name: CHAR(30),
        PRIMARY KEY (cid))
```

```
CREATE TABLE Apartment
        (aid: INTEGER,
        address: CHAR(30),
        PRIMARY KEY (aid))
```

```
CREATE TABLE Buys
        (cid: INTEGER,
        aid: INTEGER,
        … (other attributes if any),
        FOREIGN KEY cid REFERENCES Customer,
        FOREIGN KEY aid REFERENCES Apartment,
        PRIMARY KEY (cid))
```



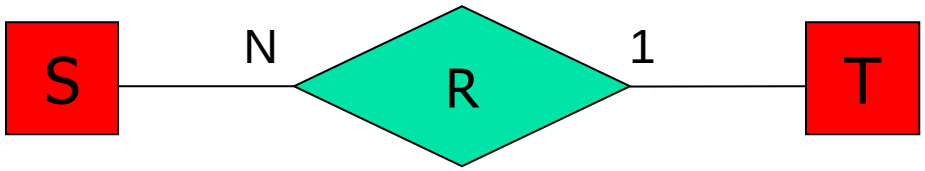
Conversion Algorithm

- We will follow a step-by-step algorithm.

- Step 1: Mapping of Regular Entities
- (EER only) Mapping of Subclass/Superclass
- Step 2: Mapping of Weak Entities
- Step 3: Mapping of Binary 1:1 Relationships
- Step 4: Mapping of Binary 1:N Relationships
- Step 5: Mapping of Binary M:N Relationships
- Step 6: Mapping of Multivalued Attributes
- Step 7: Mapping of N-ary Relationships (eg: ternary)

Step 4

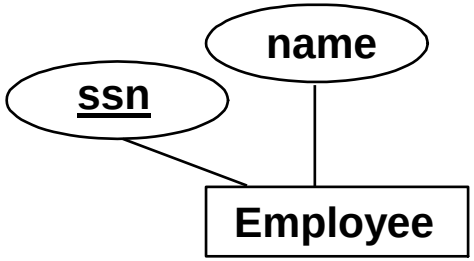
- **Binary 1-to-N Relationships (or N-to-1)**
- (Note: From Step 1, we already have a relation created for S and one relation created for T.)
- To handle relationship R:
  - Let S be the entity on the "N"-side of the relationship.
  - Add the primary key of T as foreign key in S.
  - Add the simple attributes of R to S.

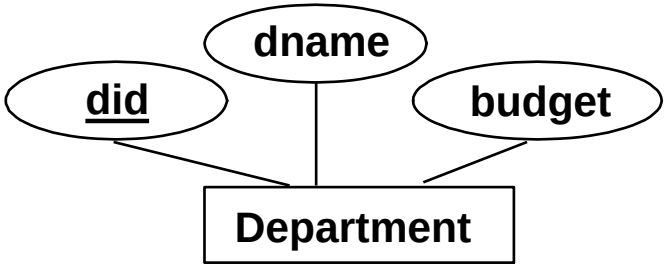


Step 4 Examples

```
CREATE TABLE Employee
        (ssn: INTEGER,
        name: CHAR(30),
        PRIMARY KEY (ssn))
```

```
CREATE TABLE Department
        (did: INTEGER,
        dname: CHAR(30),
        budget: REAL,
        PRIMARY KEY (did))
```

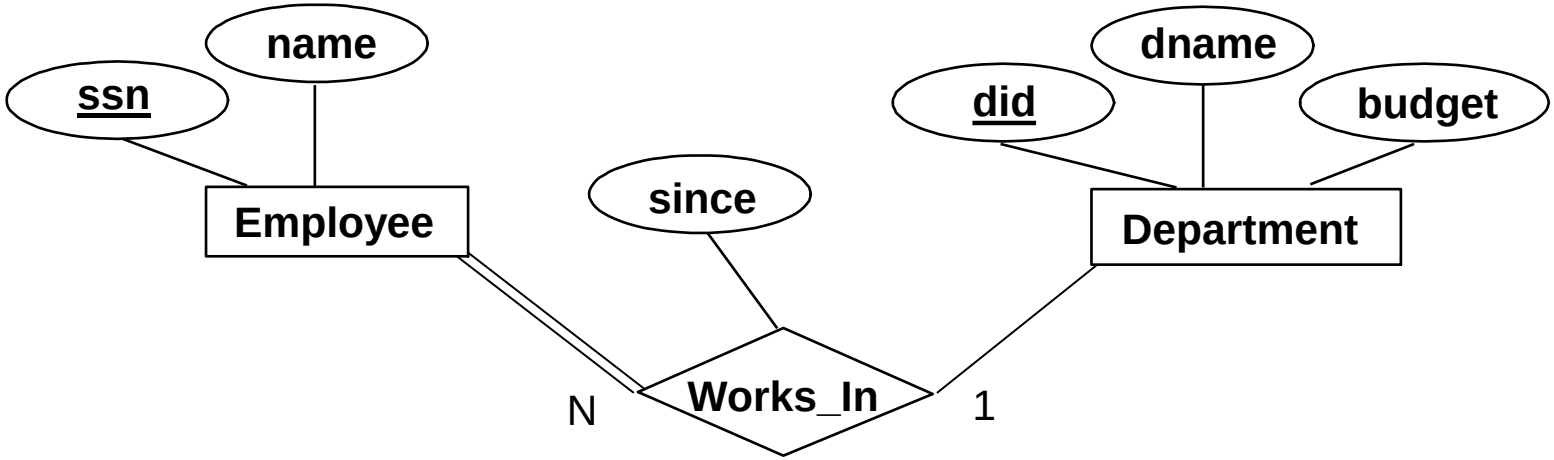




Step 4 Examples

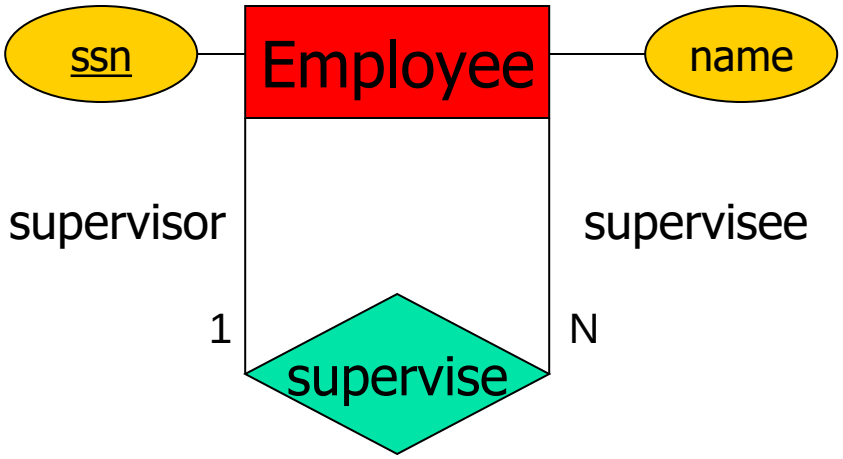
```
CREATE TABLE Employee
        (ssn: INTEGER,
        name: CHAR(30),
        PRIMARY KEY (ssn),
        in_deptid: INTEGER,
        FOREIGN KEY in_deptid
                REFERENCES Department,
        since: CHAR(10))
```

```
CREATE TABLE Department
        (did: INTEGER,
        dname: CHAR(30),
        budget: REAL,
        PRIMARY KEY (did))
```



Step 4 Examples

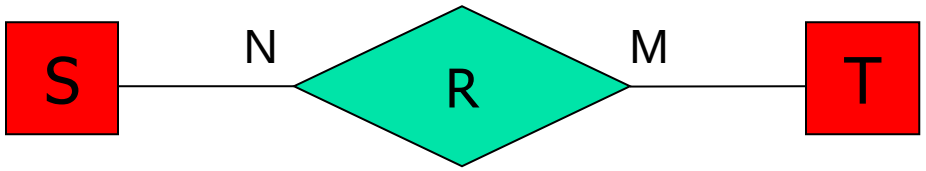
```
CREATE TABLE Employee
        (ssn: INTEGER,
        name: CHAR(30),
        PRIMARY KEY (ssn))
```




```
CREATE TABLE Employee
        (ssn: INTEGER,
        name: CHAR(30),
        PRIMARY KEY (ssn),
        supervisor_ssn: INTEGER,
        FOREIGN KEY supervisor_ssn
                REFERENCES Employee)
```

Step 5

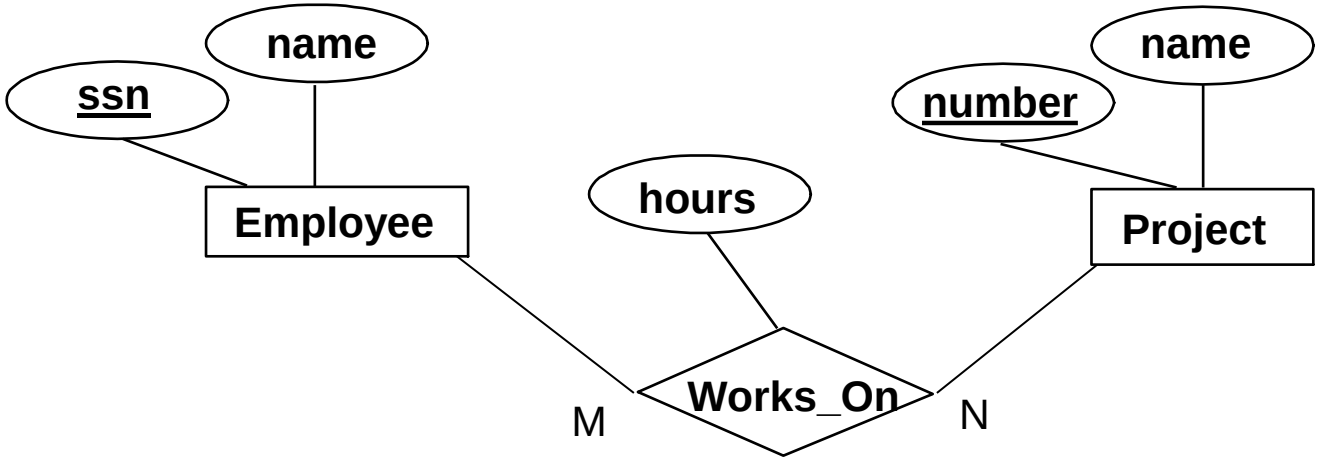
- **Binary M-to-N Relationships**
- (Note: From Step 1, we already have a relation created for S and one relation created for T.)
- To handle the many-to-many relationship:
  - Create a new relation R for this relationship
  - Add S and T's primary keys as foreign key in R, and add any attributes R may have
  - The combination of S and T's primary keys is the primary key of R



Step 5 Examples

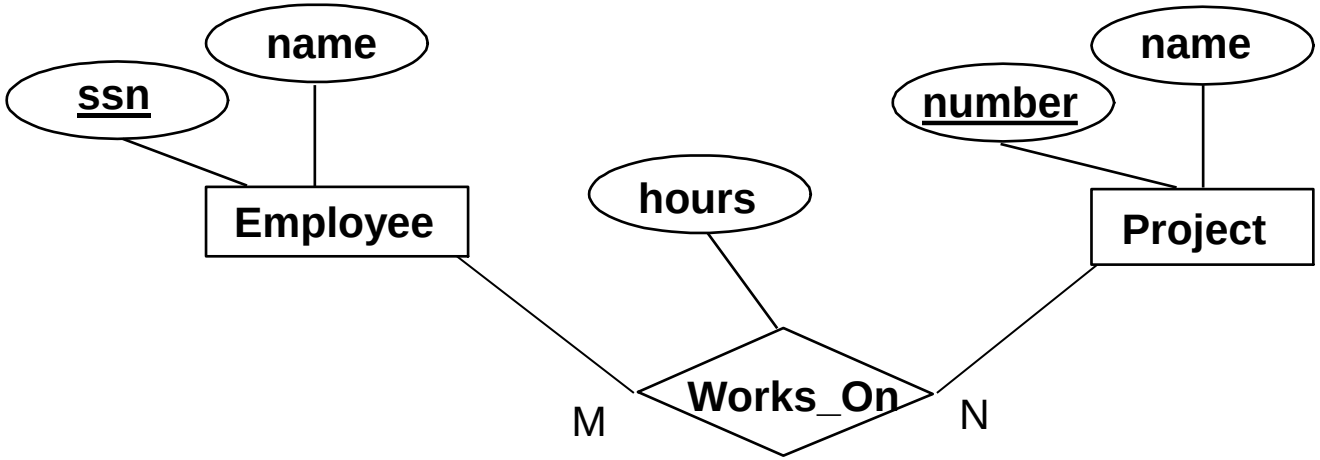
```
CREATE TABLE Employee
        (ssn: INTEGER,
        name: CHAR(30),
        PRIMARY KEY (ssn),
        in_deptid: INTEGER,
        FOREIGN KEY in_deptid
                REFERENCES Department,
        since: CHAR(10),
        superv_ssn: INTEGER,
        FOREIGN KEY superv_ssn
                REFERENCES Employee)
```

```
CREATE TABLE Project
        (pnumber: INTEGER,
        pname: CHAR(30),
        PRIMARY KEY (pnumber))
```



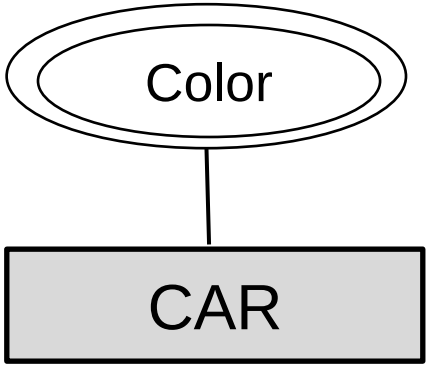
Step 5 Examples

```
CREATE TABLE Works_On
        (essn: INTEGER,
        pno: INTEGER,
        hours: INTEGER,
        FOREIGN KEY essn
                REFERENCES Employee,
        FOREIGN KEY pno
                REFERENCES Project,
        PRIMARY KEY (essn, pno))
```



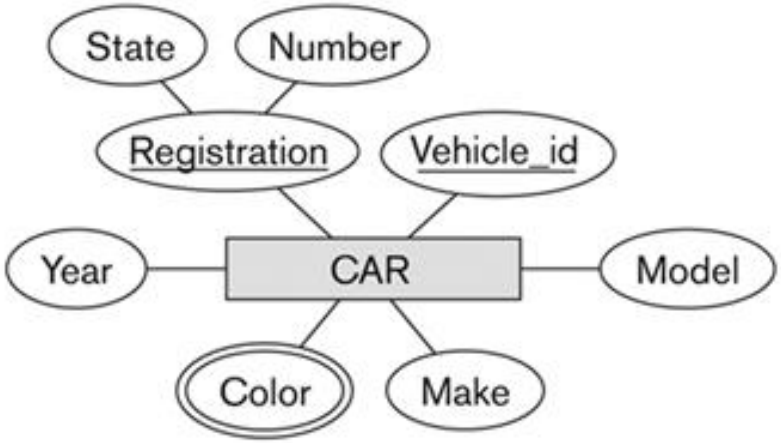
Step 6

- **Multivalued Attributes**
- Create a new relation R for each multivalued attribute.
  - Add primary key of entity to R, as foreign key
  - Primary key of R is the combination of the multi-valued attribute + the added foreign key



Step 6 Examples

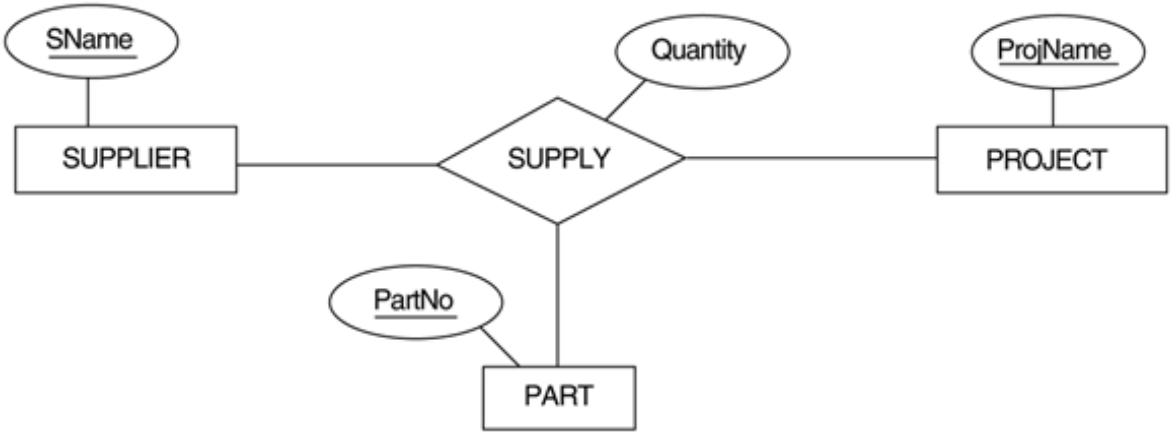
```
CREATE TABLE Car
        (reg_state: CHAR(2),
         reg_number: CHAR(10),
         vehicle_id: CHAR(15),
         model: CHAR(10),
         make: CHAR(15),
         year: INTEGER,
         PRIMARY KEY (vehicle_id))
```



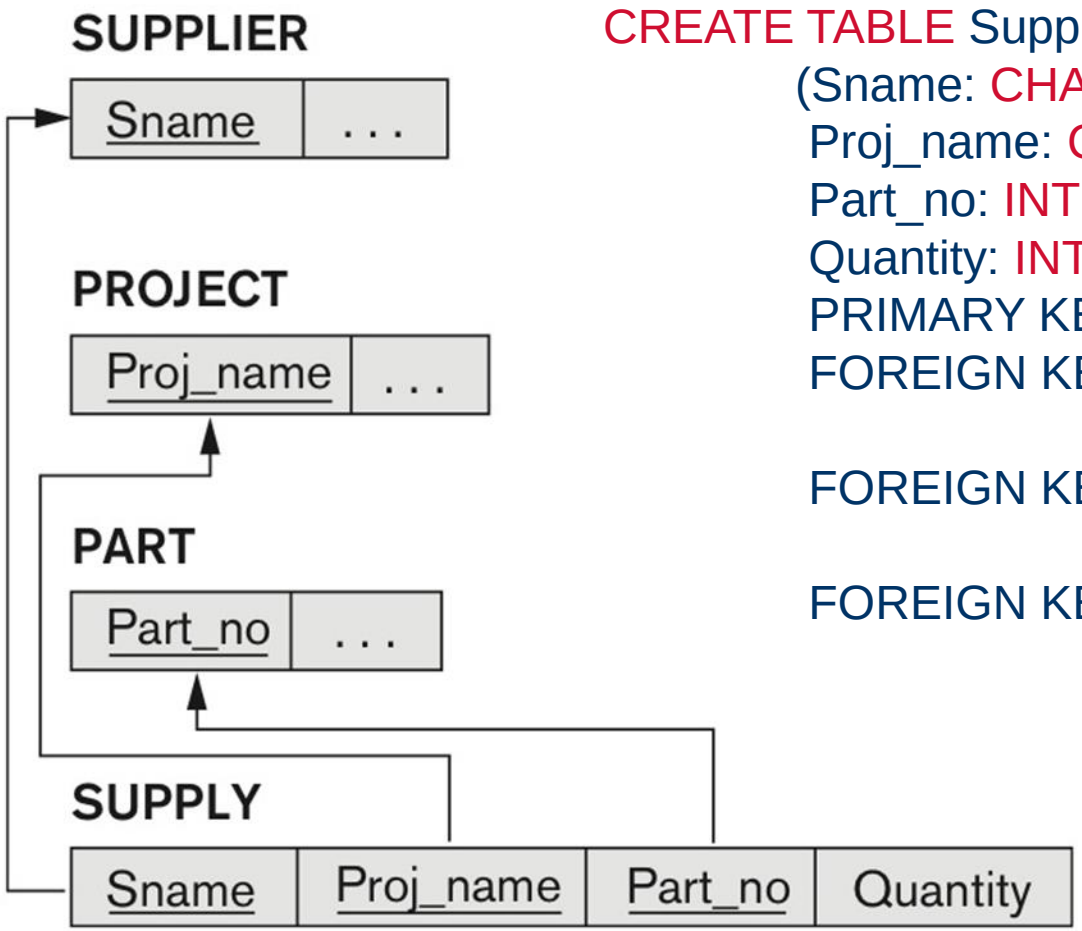

```
CREATE TABLE CarColors
        (veh_id: CHAR(15),
         color: CHAR(10),
         PRIMARY KEY (veh_id, color),
         FOREIGN KEY veh_id REFERENCES Car)
```

Step 7

- **N-ary Relationships (3-ary, 4-ary, etc.)**
- Create a new relation R to represent the relationship.
  - Add the primary keys of all participating entities to R, as foreign keys.
  - Add any attribute the relationship itself may have.
  - Primary key of R is typically the combination of all foreign keys added in the first step.



Step 7 Examples



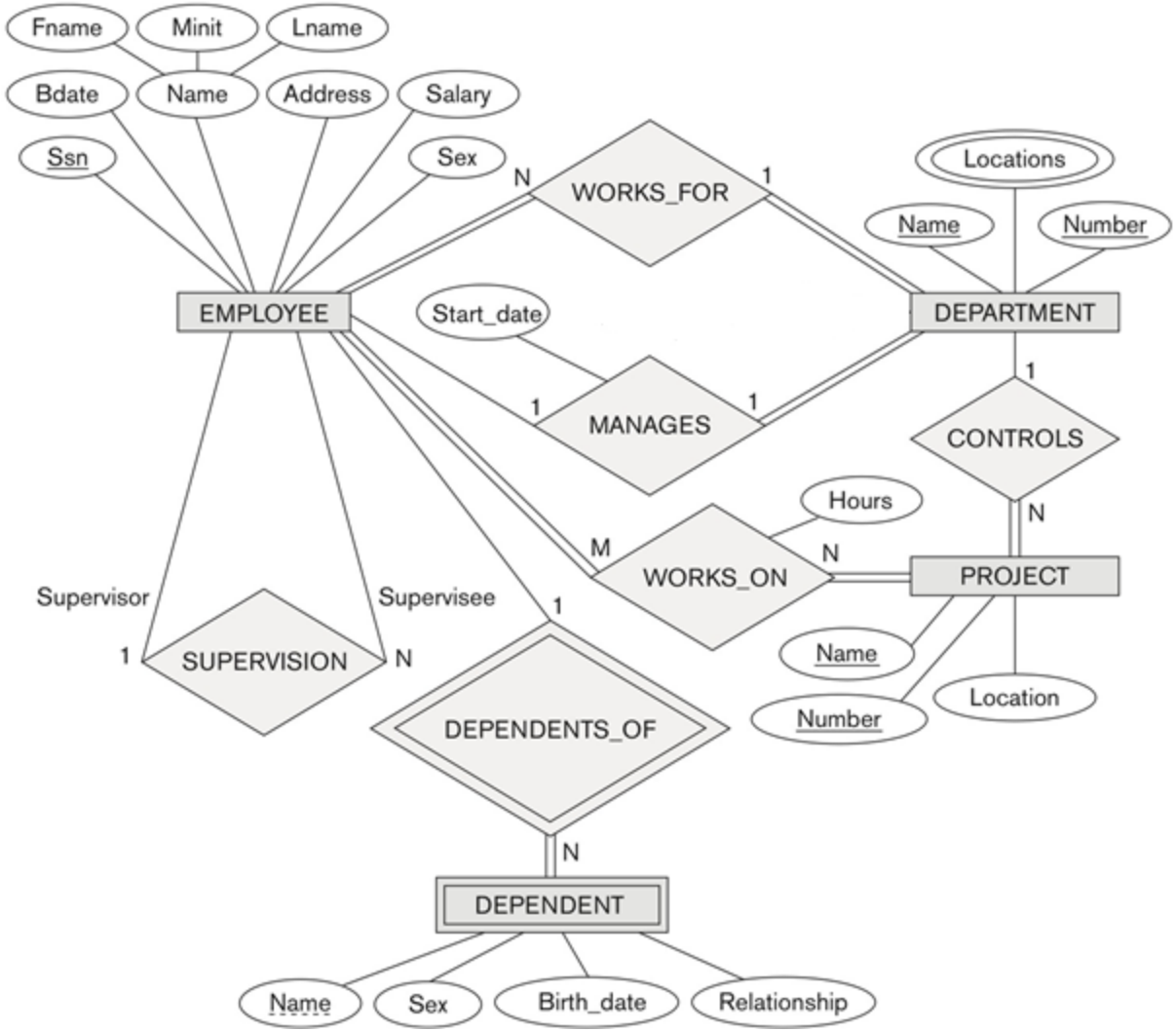

```
CREATE TABLE Supply
        (Sname: CHAR(20),
         Proj_name: CHAR(10),
         Part_no: INTEGER,
         Quantity: INTEGER,
         PRIMARY KEY (Sname, Proj_name, Part_no),
         FOREIGN KEY Sname
                        REFERENCES Supplier,
         FOREIGN KEY Proj_name
                        REFERENCES Project,
         FOREIGN KEY Part_no
                        REFERENCES Part)
```

Done!

- Step 1: Mapping of Regular Entities
- (EER only) Mapping of Subclass/Superclass
- Step 2: Mapping of Weak Entities
- Step 3: Mapping of Binary 1:1 Relationships
- Step 4: Mapping of Binary 1:N Relationships
- Step 5: Mapping of Binary M:N Relationships
- Step 6: Mapping of Multivalued Attributes
- Step 7: Mapping of N-ary Relationships (eg: ternary)

- Final checks:
  - Check all information in ER is captured in the relational database (entity, relationship, attributes)
  - Check existence and correctness of all primary keys
  - Check existence and correctness of all foreign keys

Company Database



Step 1

- Handle EMPLOYEE, DEPARTMENT, PROJECT
  - Note: Locations of DEPARTMENT are not handled yet since it is multi-valued

```
CREATE TABLE Employee
        (Ssn: INTEGER,
         Bdate: CHAR(10),
         Fname: CHAR(20),
         Minit: CHAR(1),
         Lname: CHAR(20),
         Address: CHAR(100),
         Salary: REAL,
         Sex: CHAR(10),
         PRIMARY KEY (Ssn))
```

```
CREATE TABLE Department
        (Dname: CHAR(20),
         Dnumber: INTEGER,
         PRIMARY KEY (Dnumber))
```

```
CREATE TABLE Project
        (Pname: CHAR(20),
         Pnumber: INTEGER,
         Plocation: CHAR(50),
         PRIMARY KEY (Pnumber))
```

Step 2

- Handle DEPENDENT, DEPENDENTS_OF

```
CREATE TABLE Emp_Dependents
        (emp_ssn: INTEGER,
         dep_name: CHAR(30),
         dep_sex: CHAR(10),
         dep_birthdate: CHAR(10),
         dep_relationship: CHAR(10),
         PRIMARY KEY (emp_ssn, dep_name),
         FOREIGN KEY emp_ssn
                REFERENCES Employee)
```

Step 3

- Convert MANAGES relationship
  - Which option? → 3A
  - That means I must change the Department relation

```
CREATE TABLE Department
        (Dname: CHAR(20),
         Dnumber: INTEGER,
         PRIMARY KEY (Dnumber))
```

```
CREATE TABLE Department
        (Dname: CHAR(20),
         Dnumber: INTEGER,
         Manager_SSN: INTEGER,
         Manager_startdate: CHAR(10),
         PRIMARY KEY (Dnumber),
         FOREIGN KEY Manager_SSN REFERENCES Employee)
```

Step 4

- Handle WORKS_FOR, SUPERVISION, CONTROLS
  - I must change EMPLOYEE to handle WORKS_FOR

```
CREATE TABLE Employee
        (S      INTEG
                C      ,
        F              (20),
        Mi             1),
        L              (20),
                       (100),
        S      : RE
        Se     : CHAR(      ),
        PRIMARY KEY (Ssn))
```

```
CREATE TABLE Employee
        (Ssn: INTEGER,
         Bdate: CHAR(10),
         Fname: CHAR(20),
         Minit: CHAR(1),
         Lname: CHAR(20),
         Address: CHAR(100),
         Salary: REAL,
         Sex: CHAR(10),
         Works_In_Dno: INTEGER,
         PRIMARY KEY (Ssn),
         FOREIGN KEY Works_In_Dno
                REFERENCES Department)
```

Step 4

- Handle WORKS_FOR, SUPERVISION, CONTROLS
  - I must change EMPLOYEE to handle WORKS_FOR
  - I must change EMPLOYEE to handle SUPERVISION

```
CREATE TABLE Employee
        INTEGER
        CHAR
        L
  Au        0),
  S
                R,
        Y F
        GN KE      _Dno
            REFER      ES Department)
```

```
CREATE TABLE Employee
        (Ssn: INTEGER,
         Bdate: CHAR(10),
         Fname: CHAR(20),
         Minit: CHAR(1),
         Lname: CHAR(20),
         Address: CHAR(100),
         Salary: REAL,
         Sex: CHAR(10),
         Works_In_Dno: INTEGER,
         Supervisor_SSN: INTEGER,
         PRIMARY KEY (Ssn),
         FOREIGN KEY Works_In_Dno
                REFERENCES Department,
         FOREIGN KEY Supervisor_SSN
                REFERENCES Employee)
```

Step 4

- Handle WORKS_FOR, SUPERVISION, CONTROLS
  - I must change PROJECT to handle CONTROLS

~~CREATE TABLE Project~~
~~(Pname: CHAR(20),~~
~~Pnumber: INTEGER,~~
~~Plocation: CHAR(50),~~
~~PRIMARY KEY (Pnumber))~~

```
CREATE TABLE Project
        (Pname: CHAR(20),
         Pnumber: INTEGER,
         Plocation: CHAR(50),
         Control_Dno: INTEGER,
         PRIMARY KEY (Pnumber),
         FOREIGN KEY Control_Dno
                 REFERENCES Department)
```

Step 5

- Handle WORKS_ON

```
CREATE TABLE Works_On
        (Emp_Ssn: INTEGER,
         Proj_Pnum: INTEGER,
         Hours: INTEGER,
         PRIMARY KEY (Emp_Ssn, Proj_Pnum),
         FOREIGN KEY Emp_Ssn
                REFERENCES Employee,
         FOREIGN KEY Proj_Pnum
                REFERENCES Project)
```

Steps 6+7

- Step 6: Handle Locations attribute of DEPARTMENT

```
CREATE TABLE Dept_Locations
        (Dnum: INTEGER,
         Location: CHAR(30),
         PRIMARY KEY (Dnum, Location),
         FOREIGN KEY Dnum
                REFERENCES Department)
```

- Step 7: No action

Final Result

- Dept_Locations (Dnum, Location)
- Works_On (Emp_Ssn, Proj_Pnum, Hours)
- Employee (Ssn, Bdate, Fname, Minit, Lname, Address, Salary, Sex, Works_In_Dno, Supervisor_Ssn)
- Department (Dname, Dnumber, Manager_Ssn, Manager_startdate)
- Emp_Dependents (Emp_ssn, Dep_name, Dep_sex, Dep_Birthdate, Dep_Relationship)
- Project (Pname, Pnumber, Plocation, Control_Dno)

Final Result