# MODULE 4

## Informal Design Guidelines for Relation Schemas

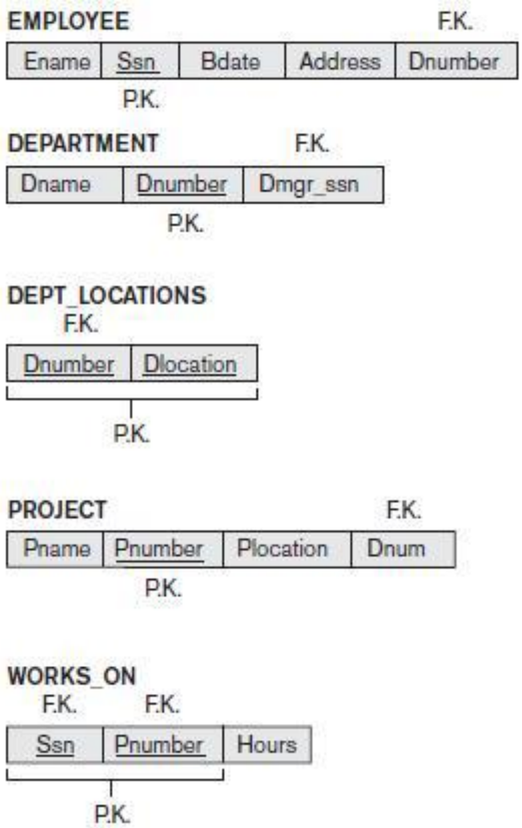
Before discussing the formal theory of relational database design, we discuss four *informal guidelines* that may be used as *measures to determine the quality* of relation schema design:

- Making sure that the semantics of the attributes is clear in the schema
- Reducing the redundant information in tuples
- Reducing the NULL values in tuples
- Disallowing the possibility of generating spurious tuples

## Semantics to Attributes in Relations

The **semantics** of a relation refers to its meaning resulting from the interpretation of attribute values in a tuple. systematically, the relational schema design should have a clear **meaning**.

**Guideline**




**Guideline 1**: Design a relation schema so that it is easy to explain its meaning.
Do not combine attributes from multiple entity types and relationship types into a single relation.
if a relation schema corresponds to one entity type or one relationship type, it is straightforward to interpret and to explain its meaning. Otherwise, if the

relation corresponds to a mixture of multiple entities and relationships, semantic ambiguities will result and the relation cannot be easily explained.

## Redundant Information in Tuples and Update Anomalies

One goal of schema design is to minimize the storage space used by the base relations . Grouping attributes into relation schemas has a significant effect on storage space.

For example, compare the space used by the two base relations EMPLOYEE and DEPARTMENT in Figure with that for an EMP_DEPT base relation in Figure , which is the result of applying the NATURAL JOIN operation to EMPLOYEE and DEPARTMENT.

In EMP_DEPT, the attribute values pertaining to a particular department (Dnumber, Dname, Dmgr_ssn) are repeated for *every employee who works for that department.* In contrast, each department's information appears only once in the DEPARTMENT relation in Figure Storing

**EMPLOYEE**

| Ename | Ssn | Bdate | Address | Dnumber |
|---|---|---|---|---|
| Smith, John B. | 123456789 | 1965-01-09 | 731 Fondren, Houston, TX | 5 |
| Wong, Franklin T. | 333445555 | 1955-12-08 | 638 Voss, Houston, TX | 5 |
| Zelaya, Alicia J. | 999887777 | 1968-07-19 | 3321 Castle, Spring, TX | 4 |
| Wallace, Jennifer S. | 987654321 | 1941-06-20 | 291Berry, Bellaire, TX | 4 |
| Narayan, Ramesh K. | 666884444 | 1962-09-15 | 975 Fire Oak, Humble, TX | 5 |
| English, Joyce A. | 453453453 | 1972-07-31 | 5631 Rice, Houston, TX | 5 |
| Jabbar, Ahmad V. | 987987987 | 1969-03-29 | 980 Dallas, Houston, TX | 4 |
| Borg, James E. | 888665555 | 1937-11-10 | 450 Stone, Houston, TX | 1 |

**DEPARTMENT**

| Dname | Dnumber | Dmgr_ssn |
|---|---|---|
| Research | 5 | 333445555 |
| Administration | 4 | 987654321 |
| Headquarters | 1 | 888665555 |

**DEPT_LOCATIONS**

| Dnumber | Dlocation |
|---|---|
| 1 | Houston |
| 4 | Stafford |
| 5 | Bellaire |
| 5 | Sugarland |
| 5 | Houston |

Storing natural joins of base relations leads to an additional problem referred to as **update anomalies**.

These can be classified into insertion anomalies, deletion anomalies, and modification anomalies Anomalies that cause redundant work to be done during insertion into and modification of a relation, and that may cause accidental loss of information during a deletion from a relation

**Guideline 2**

Design the base relation schemas so that no insertion, deletion, or modification anomalies are present in the relations.

Reducing redundant values in tuples. Save storage space and avoid update Anomalies

## NULL Values in Tuples

In some schema designs we may group many attributes together into a "fat" relation. If many of the attributes do not apply to all tuples in the relation, we end up with many NULLs in those tuples. This can waste space at the storage level and may also lead to problems with understanding the meaning of the attributes and with specifying JOIN operations at the logical level.

**Guideline 3**

As far as possible, avoid placing attributes in a base relation whose values may frequently be NULL. If NULLs are unavoidable, make sure that they apply in exceptional cases only and do not apply to a majority of tuples in the relation.

Waste of storage space due to NULLs and the difficulty of performing elections, aggregation operations, and joins due to NULL values

**Generation of Spurious Tuples**

Generation of invalid and spurious data during joins on base relations with matched attributes that may not represent a proper (foreign key, primary key) relationship

**Guideline 4**

Design relation schemas so that they can be joined with equality conditions on attributes that are appropriately related (primary key, foreign key) pairs in a way that guarantees that no spurious tuples are generated. Avoid relations that contain matching attributes that are not (foreign key, primary key) combinations because joining on such attributes may produce spurious tuples

**Functional Dependencies**

A functional dependency is a constraint between two sets of attributes from the database. Suppose that our relational database schema has $n$ attributes $A1$, $A2$, ..., $An$;

**Definition.** A **functional dependency**, denoted by $X \rightarrow Y$, between two sets of attributes $X$ and $Y$ that are subsets of $R$ specifies a *constraint* on the possible tuples that can form a relation state $r$ of $R$.

The constraint is that, for any two tuples $t1$ and $t2$ in $r$ that have $t1[X] = t2[X]$, they must also have $t1[Y] = t2[Y]$.

This means that the values of the $Y$ component of a tuple in $r$ depend on, or are *determined by,* the values of the $X$ component; alternatively, the values of the $X$ component of a tuple uniquely (or **functionally**) *determine* the values of the $Y$

component.
There is a functional dependency from $X$ to $Y$, or that $Y$ is **functionally dependent** on $X$. The abbreviation for functional dependency is **FD** or **f.d.** The
set of attributes $X$ is called the **left-hand side** of the FD, and $Y$ is called the **right-hand side**.

a. Ssn→Ename
b. Pnumber →{Pname, Plocation}
c. {Ssn, Pnumber}→Hours

**Inference Rules for Functional Dependencies**
An FD $X \rightarrow Y$ is **inferred from** a set of dependencies $F$ specified on $R$ if $X \rightarrow Y$
holds in *every* legal relation state $r$ of $R$; that is, whenever $r$ satisfies all the dependencies in $F$, $X \rightarrow Y$ also holds in $r$. The closure $F+$ of $F$ is the set of all functional dependencies that can be inferred from $F$.
The following six rules IR1 through IR6 are well-known inference rules for functional dependencies:
IR1 (reflexive rule)1: If $X$ $Y$, then $X \rightarrow Y$.
IR2 (augmentation rule)2: $\{X \rightarrow Y\} \mid= XZ \rightarrow YZ$.
IR3 (transitive rule): $\{X \rightarrow Y, Y \rightarrow Z\} \mid= X \rightarrow Z$.
IR4 (decomposition, or projective, rule): $\{X \rightarrow YZ\} \mid= X \rightarrow Y$.
IR5 (union, or additive, rule): $\{X \rightarrow Y, X \rightarrow Z\} \mid= X \rightarrow YZ$.
IR6 (pseudotransitive rule): $\{X \rightarrow Y, WY \rightarrow Z\} \mid= WX \rightarrow Z$.
**Proof of IR1.** Suppose that $X \supseteq Y$ and that two tuples $t1$ and $t2$ exist in some
relation
instance $r$ of $R$ such that $t1\ [X] = t2\ [X]$. Then $t1[Y] = t2[Y]$ because $X \supseteq Y$; hence, $X \rightarrow$Y must hold in $r$.
**Proof of IR2 (by contradiction).** Assume that $X \rightarrow Y$ holds in a relation instance
$r$ of $R$ but that $XZ \rightarrow YZ$ does not hold. Then there must exist two tuples $t1$ and
$t2$ in $r$ such that
(1) $t1\ [X] = t2\ [X]$,
(2) $t1\ [Y] = t2\ [Y]$,
(3) $t1\ [XZ] = t2\ [XZ]$, and
(4) $t1\ [YZ] \neq t2\ [YZ]$. This is not possible because from (1) and (3) we deduce
(5) $t1\ [Z] = t2\ [Z]$, and from (2) and (5) we deduce (6) $t1\ [YZ] = t2\ [YZ]$, contradicting (4).
**Proof of IR3.** Assume that (1) $X \rightarrow Y$ and (2) $Y \rightarrow Z$ both hold in a relation $r$. Then for any two tuples $t1$ and $t2$ in $r$ such that $t1\ [X] = t2\ [X]$, we must have (3)
$t1\ [Y] = t2\ [Y]$, from assumption (1); hence we must also have (4) $t1\ [Z] = t2\ [Z]$

from (3) and assumption (2); thus $X \rightarrow Z$ must hold in $r$.

**Proof of IR4 (Using IR1 through IR3).**

1. $X \rightarrow YZ$ (given).
2. $YZ \rightarrow Y$ (using IR1 and knowing that $YZ \supseteq Y$).
3. $X \rightarrow Y$ (using IR3 on 1 and 2).

**Proof of IR5 (using IR1 through IR3).**

1. $X \rightarrow Y$ (given).
2. $X \rightarrow Z$ (given).
3. $X \rightarrow XY$ (using IR2 on 1 by augmenting with $X$; notice that $XX = X$).
4. $XY \rightarrow YZ$ (using IR2 on 2 by augmenting with $Y$).
5. $X \rightarrow YZ$ (using IR3 on 3 and 4).

**Proof of IR6 (using IR1 through IR3).**

1. $X \rightarrow Y$ (given).
2. $WY \rightarrow Z$ (given).
3. $WX \rightarrow WY$ (using IR2 on 1 by augmenting with $W$).
4. $WX \rightarrow Z$ (using IR3 on 3 and 2).

**Algorithm to find Closure**

**Definition.** For each such set of attributes $X$, we determine the set $X+$ of attributes
that are functionally determined by $X$ based on $F$; $X+$ is called the **closure of X under F**. Algorithm 16.1 can be used to calculate $X+$.

**Algorithm** Determining $X^+$, the Closure of $X$ under $F$

**Input:** A set $F$ of FDs on a relation schema R, and a set of attributes $X$, which is a subset of R.

$X^+ := X$;
repeat
  old$X^+ := X^+$;
  for each functional dependency $Y \rightarrow Z$ in $F$ do
    if $X^+ \supseteq Y$ then $X^+ := X^+ \cup Z$;
until ($X^+$ = old$X^+$);

**Minimal Sets of Functional Dependencies**

a **minimal cover** of a set of functional dependencies *E* is a set of functional dependencies *F* that satisfies the property that every dependency in *E* is in the
closure *F*+ of *F*.
In addition, this property is lost if any dependency from the set *F* is removed; *F* must have no redundancies in it, and the dependencies in *F* are in
a standard form. To satisfy these properties, we can formally define a set of functional dependencies *F* to be **minimal** if it satisfies the following conditions:

1. Every dependency in *F* has a single attribute for its right-hand side.
2. We cannot replace any dependency $X \rightarrow A$ in *F* with a dependency $Y \rightarrow A$, where *Y* is a proper subset of *X*, and still have a set of dependencies that is equivalent to *F*.
3. We cannot remove any dependency from *F* and still have a set of dependencies that is equivalent to *F*.

Finding a Minimal Cover *F* for a Set of Functional Dependencies *E*
**Input:** A set of functional dependencies E.
1. Set $F := E$.
2. Replace each functional dependency $X\rightarrow\{A1, A2, \ldots, An\}$ in *F* by the *n* functional dependencies $X\rightarrow A1, X\rightarrow A2, \ldots, X\rightarrow An$.
3. For each functional dependency $X\rightarrow A$ in *F* ,for each attribute *B* that is an element of *X* if $\{ \{F - \{X\rightarrow A\} \} \cup \{ (X - \{B\} ) \rightarrow A\} \}$ is equivalent to *F*, then replace
$X\rightarrow A$ with $(X - \{B\} ) \rightarrow A$ in *F*.
4. For each remaining functional dependency $X\rightarrow A$ in *F* if $\{F - \{X\rightarrow A\} \}$ is equivalent to *F*, then remove $X\rightarrow A$ from *F*.

**Normalization of Relations**

The normalization process, as first proposed by Codd (1972a), takes a relation
schema through a series of tests to *certify* whether it satisfies a certain **normal form**.
The process, which proceeds in a top-down fashion by evaluating each relation

against the criteria for normal forms and decomposing relations as necessary,
can thus be considered as *relational design by analysis.* Initially, Codd proposed three normal forms, which he called first, second, and third normal
form. A stronger definition of 3NF—called Boyce-Codd normal form (BCNF)

**First Normal Form**
**A relation schema R is 1NF if every attribute of R takes only a single value(atomic value)**

Employees

| SSN | Name | Age | Dependents |
|---|---|---|---|
| 1234 | Scott | 40 | {Deepak, Pradeep} |
| 7089 | Pooja | 28 | {Kathy} |
| 1357 | Prasad | 38 | {Kiran, Divya, Vinu} |

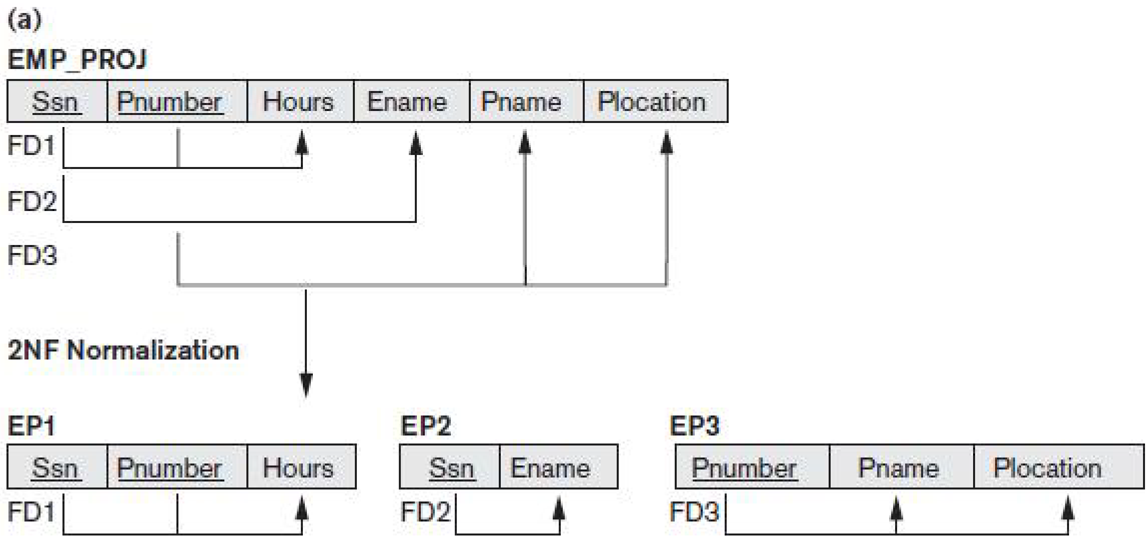
**Employees Table with Multivalue Attribute and not in 1NF**

Employees

| SSN | Name | Age | Dependents |
|---|---|---|---|
| 1234 | Scott | 40 | Deepak |
| 1234 | Scott | 40 | Pradeep |
| 7089 | Pooja | 28 | Kathy |
| 1357 | Prasad | 38 | Kiran |
| 1357 | Prasad | 38 | Divya |
| 1357 | Prasad | 38 | Kiran |

**Fig: Employees Table in 1NF**

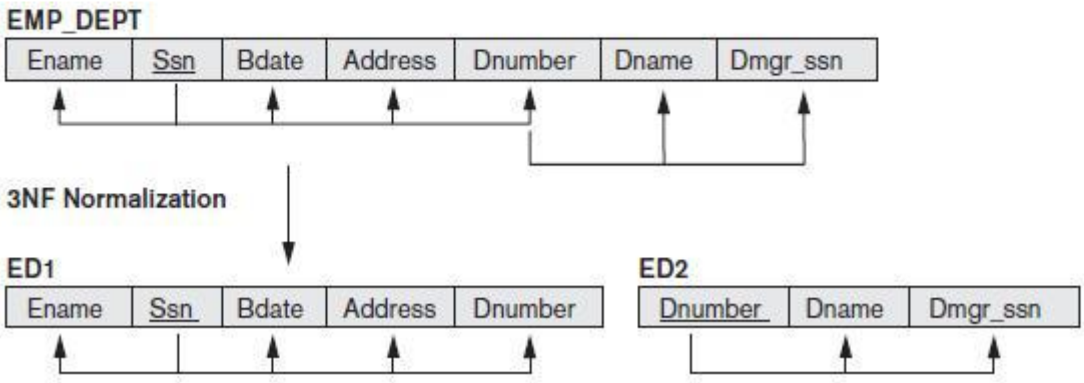
**Second Normal Form**
A relation schema *R* is in 2NF if every nonprime attribute *A* in *R* is *fully functionally dependent* on the primary key of *R*.



If a relation schema is not in 2NF, it can be *second normalized* or *2NF normalized* into a number of 2NF relations in which nonprime attributes are associated only with the part of the primary key on which they are fully functionally dependent.
Therefore, the functional dependencies FD1, FD2, and FD3 in Figure (a) lead to the decomposition of EMP_PROJ into the three relation schemas EP1, EP2,
and EP3 shown in Figure (b)- each of which is in 2NF.

**Third Normal Form**

a relation schema *R* is in **3NF** if it satisfies 2NF *and* no nonprime attribute of *R*
is transitively dependent on the primary key.



The relation schema EMP_DEPT in Figure (a) is in 2NF, since no partial dependencies on a key exist. However, EMP_DEPT is not in 3NF because of the
transitive dependency of Dmgr_ssn (and also Dname) on Ssn via Dnumber.

**Boyce-Codd Normal Form**

**Boyce-Codd normal form (BCNF)** was proposed as a simpler form of 3NF, but
it was found to be stricter than 3NF. That is, every relation in BCNF is also in
3NF; however, a relation in 3NF is *not necessarily* in BCNF.

**Definition.** A relation schema *R* is in **BCNF** if whenever a *nontrivial* functional
dependency $X \rightarrow A$ holds in *R*, then *X* is a superkey of *R*.