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## Normalization

## Why does a good database design need Normalization?

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### Objectives

- The purpose of normalization.
- The problems associated with redundant data.
- The identification of various types of update anomalies such as insertion, deletion, and modification anomalies.

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### Data Redundancy

- Major aim of relational database design is to group attributes into relations to:
  - minimize data redundancy and
  - reduce file storage space required by base relations.

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### Objectives

- The concept of functional dependency.
- How functional dependencies can be used to group attributes into relations that are in a known normal form.
- How to undertake the process of normalization.

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### Data Redundancy

Staff\_Branch Relation

| Staff_No | SName       | SAddress                 | Position  | Salary | Branch_No | BAddress               | Tel_No        |
|----------|-------------|--------------------------|-----------|--------|-----------|------------------------|---------------|
| SL21     | Joim White  | 19 Taylor St, London     | Manager   | 30000  | B5        | 22 Deer Rd, London     | 0171-886-1212 |
| SG37     | Ann Beech   | 81 George St, Glasgow    | Str Asst  | 12000  | B3        | 165 Main St, Glasgow   | 0141-339-2178 |
| SG14     | David Ford  | 63 Ashby St, Glasgow     | Deputy    | 18000  | B3        | 165 Main St, Glasgow   | 0141-339-2178 |
| SA9      | Mary Howe   | 2 Elm Pl, Aberdeen       | Assistant | 9000   | B7        | 16 Argyll St, Aberdeen | 01224-67125   |
| SG5      | Susan Brand | 5 Gr Western Rd, Glasgow | Manager   | 24000  | B3        | 165 Main St, Glasgow   | 0141-339-2178 |
| SLA1     | Julie Lee   | 28 Malvern St, Kilburn   | Assistant | 9000   | B5        | 22 Deer Rd, London     | 0171-886-1212 |

## *Data Redundancy*

- **Staff\_Branch relation has redundant data; the details of a branch are repeated for every member of staff.**

## *Deletion Anomaly*

Staff\_Branch Relation

**Mary is resigned:  
information loss**
**Ann is resigned**

| Staff_No | SName       | SAddress                 | Position  | Salary | Branch_No | BAddress               | Tel_No        |
|----------|-------------|--------------------------|-----------|--------|-----------|------------------------|---------------|
| SL21     | John White  | 19 Taylor St, London     | Manager   | 30000  | B5        | 22 Deer Rd, London     | 0171-886-1212 |
| SG37     | Ann Beech   | 81 George St, Glasgow    | Str Asst  | 12000  | B3        | 163 Main St, Glasgow   | 0141-339-2178 |
| SG14     | David Ford  | 63 Ashby St, Glasgow     | Deputy    | 18000  | B3        | 163 Main St, Glasgow   | 0141-339-2178 |
| SA9      | Mary Howe   | 2 Elm Pl, Aberdeen       | Assistant | 9000   | B7        | 16 Argyll St, Aberdeen | 01224-67125   |
| SG5      | Susan Brand | 5 Gr Western Rd, Glasgow | Manager   | 24000  | B3        | 163 Main St, Glasgow   | 0141-339-2178 |
| SLA1     | Julie Lee   | 28 Malvern St, Kilburn   | Assistant | 9000   | B5        | 22 Deer Rd, London     | 0171-886-1212 |

## *Update Anomalies*

- **Relations that contain redundant information may potentially suffer from update anomalies.**
- **Types of update anomalies include**
  - Insertion
  - Deletion
  - Modification

## *Modification Anomaly*

Staff\_Branch Relation

**Change Address of B3**

| Staff_No | SName       | SAddress                 | Position  | Salary | Branch_No | BAddress               | Tel_No        |
|----------|-------------|--------------------------|-----------|--------|-----------|------------------------|---------------|
| SL21     | John White  | 19 Taylor St, London     | Manager   | 30000  | B5        | 22 Deer Rd, London     | 0171-886-1212 |
| SG37     | Ann Beech   | 81 George St, Glasgow    | Str Asst  | 12000  | B3        | 163 Main St, Glasgow   | 0141-339-2178 |
| SG14     | David Ford  | 63 Ashby St, Glasgow     | Deputy    | 18000  | B3        | 163 Main St, Glasgow   | 0141-339-2178 |
| SA9      | Mary Howe   | 2 Elm Pl, Aberdeen       | Assistant | 9000   | B7        | 16 Argyll St, Aberdeen | 01224-67125   |
| SG5      | Susan Brand | 5 Gr Western Rd, Glasgow | Manager   | 24000  | B3        | 163 Main St, Glasgow   | 0141-339-2178 |
| SLA1     | Julie Lee   | 28 Malvern St, Kilburn   | Assistant | 9000   | B5        | 22 Deer Rd, London     | 0171-886-1212 |

## *Insertion Anomaly*

Staff\_Branch Relation    How do you add an empty branch?    Needs consistency checks

| Staff_No | SName       | SAddress                 | Position  | Salary | Branch_No | BAddress               | Tel_No        |
|----------|-------------|--------------------------|-----------|--------|-----------|------------------------|---------------|
| SL21     | John White  | 19 Taylor St, London     | Manager   | 30000  | B5        | 22 Deer Rd, London     | 0171-886-1212 |
| SG37     | Ann Beech   | 81 George St, Glasgow    | Str Asst  | 12000  | B3        | 163 Main St, Glasgow   | 0141-339-2178 |
| SG14     | David Ford  | 63 Ashby St, Glasgow     | Deputy    | 18000  | B3        | 163 Main St, Glasgow   | 0141-339-2178 |
| SA9      | Mary Howe   | 2 Elm Pl, Aberdeen       | Assistant | 9000   | B7        | 16 Argyll St, Aberdeen | 01224-67125   |
| SG5      | Susan Brand | 5 Gr Western Rd, Glasgow | Manager   | 24000  | B3        | 163 Main St, Glasgow   | 0141-339-2178 |
| SLA1     | Julie Lee   | 28 Malvern St, Kilburn   | Assistant | 9000   | B5        | 22 Deer Rd, London     | 0171-886-1212 |
| SS55     | Nikki       | 1111 St. John            | Janitor   | 500    |           |                        |               |

**Essence of Solution:  
Decomposition**

## Decomposition

Staff\_Branch Relation

| Staff_No | SName       | SAddress                 | Position  | Salary | Branch_No | BAddress               | Tel_No        |
|----------|-------------|--------------------------|-----------|--------|-----------|------------------------|---------------|
| SL21     | John White  | 19 Taylor St, London     | Manager   | 30000  | B5        | 22 Deer Rd, London     | 0171-886-1212 |
| SG37     | Ann Beech   | 81 George St, Glasgow    | Snr Asst  | 12000  | B3        | 163 Main St, Glasgow   | 0141-339-2178 |
| SG14     | David Ford  | 63 Ashby St, Glasgow     | Deputy    | 18000  | B3        | 163 Main St, Glasgow   | 0141-339-2178 |
| SA9      | Mary Howe   | 2 Elm Pl, Aberdeen       | Assistant | 9000   | B7        | 16 Argyll St, Aberdeen | 01224-67125   |
| SG5      | Susan Brand | 5 Gt Western Rd, Glasgow | Manager   | 24000  | B3        | 163 Main St, Glasgow   | 0141-339-2178 |
| SLA1     | Julie Lee   | 28 Malvern St, Kilburn   | Assistant | 9000   | B5        | 22 Deer Rd, London     | 0171-886-1212 |

## Insertion

Staff Relation

| Staff_No | SName       | SAddress                 | Position  | Salary | Branch_No |
|----------|-------------|--------------------------|-----------|--------|-----------|
| SL21     | John White  | 19 Taylor St, London     | Manager   | 30000  | B5        |
| SG37     | Ann Beech   | 81 George St, Glasgow    | Snr Asst  | 12000  | B3        |
| SG14     | David Ford  | 63 Ashby St, Glasgow     | Deputy    | 18000  | B3        |
| SA9      | Mary Howe   | 2 Elm Pl, Aberdeen       | Assistant | 9000   | B7        |
| SG5      | Susan Brand | 5 Gt Western Rd, Glasgow | Manager   | 24000  | B3        |
| SLA1     | Julie Lee   | 28 Malvern St, Kilburn   | Assistant | 9000   | B5        |
| SS55     | Nikki       | 1111 St. John            | Janitor   | 500    |           |

Branch Relation

| Branch_No | BAddress               | Tel_No        |
|-----------|------------------------|---------------|
| B5        | 22 Deer Rd, London     | 0171-886-1212 |
| B7        | 16 Argyll St, Aberdeen | 01224-67125   |
| B3        | 163 Main St, Glasgow   | 0141-339-2178 |

## Decomposition

Staff Relation

| Staff_No | SName       | SAddress                 | Position  | Salary | Branch_No |
|----------|-------------|--------------------------|-----------|--------|-----------|
| SL21     | John White  | 19 Taylor St, London     | Manager   | 30000  | B5        |
| SG37     | Ann Beech   | 81 George St, Glasgow    | Snr Asst  | 12000  | B3        |
| SG14     | David Ford  | 63 Ashby St, Glasgow     | Deputy    | 18000  | B3        |
| SA9      | Mary Howe   | 2 Elm Pl, Aberdeen       | Assistant | 9000   | B7        |
| SG5      | Susan Brand | 5 Gt Western Rd, Glasgow | Manager   | 24000  | B3        |
| SLA1     | Julie Lee   | 28 Malvern St, Kilburn   | Assistant | 9000   | B5        |

Branch Relation

| Branch_No | BAddress               | Tel_No        |
|-----------|------------------------|---------------|
| B5        | 22 Deer Rd, London     | 0171-886-1212 |
| B7        | 16 Argyll St, Aberdeen | 01224-67125   |
| B3        | 163 Main St, Glasgow   | 0141-339-2178 |

## Deletion

Mary is resigned

Staff Relation

| Staff_No | SName       | SAddress                 | Position  | Salary | Branch_No |
|----------|-------------|--------------------------|-----------|--------|-----------|
| SL21     | John White  | 19 Taylor St, London     | Manager   | 30000  | B5        |
| SG37     | Ann Beech   | 81 George St, Glasgow    | Snr Asst  | 12000  | B3        |
| SG14     | David Ford  | 63 Ashby St, Glasgow     | Deputy    | 18000  | B3        |
| SA9      | Mary Howe   | 2 Elm Pl, Aberdeen       | Assistant | 9000   | B7        |
| SG5      | Susan Brand | 5 Gt Western Rd, Glasgow | Manager   | 24000  | B3        |
| SLA1     | Julie Lee   | 28 Malvern St, Kilburn   | Assistant | 9000   | B5        |

Branch Relation

| Branch_No | BAddress               | Tel_No        |
|-----------|------------------------|---------------|
| B5        | 22 Deer Rd, London     | 0171-886-1212 |
| B7        | 16 Argyll St, Aberdeen | 01224-67125   |
| B3        | 163 Main St, Glasgow   | 0141-339-2178 |

## Data Redundancy

- The branch information appears only once for each branch in the Branch relation and
- Only the branch number (Branch\_No) is repeated in the Staff relation, to represent where each member of staff is located.

## Modification

Staff Relation

| Staff_No | SName       | SAddress                 | Position  | Salary | Branch_No |
|----------|-------------|--------------------------|-----------|--------|-----------|
| SL21     | John White  | 19 Taylor St, London     | Manager   | 30000  | B5        |
| SG37     | Ann Beech   | 81 George St, Glasgow    | Snr Asst  | 12000  | B3        |
| SG14     | David Ford  | 63 Ashby St, Glasgow     | Deputy    | 18000  | B3        |
| SA9      | Mary Howe   | 2 Elm Pl, Aberdeen       | Assistant | 9000   | B7        |
| SG5      | Susan Brand | 5 Gt Western Rd, Glasgow | Manager   | 24000  | B3        |
| SLA1     | Julie Lee   | 28 Malvern St, Kilburn   | Assistant | 9000   | B5        |

Branch Relation

| Branch_No | BAddress               | Tel_No        |
|-----------|------------------------|---------------|
| B5        | 22 Deer Rd, London     | 0171-886-1212 |
| B7        | 16 Argyll St, Aberdeen | 01224-67125   |
| B3        | 163 Main St, Glasgow   | 0141-339-2178 |

# Functional Dependency

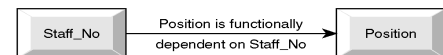
## *Functional Dependency*

- B is functionally dependent on A
- $A \rightarrow B$ : A determines B
- If you know the value of A, you can know the value of B
- A = Key (Primary Key)

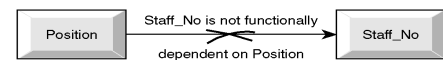
## *Functional Dependency*

- Describes the relationship between attributes in a relation.
- For example, if A and B are attributes of relation R,
  - B is functionally dependent on A (denoted  $A \rightarrow B$ ), if:
  - each value of A in R is associated with exactly one value of B in R.

## *Example - Functional Dependency*



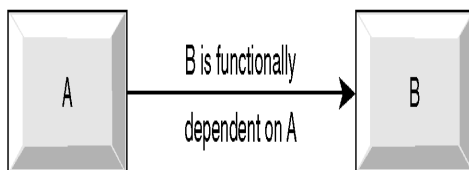
Staff number SL21 → Manager  
(a)



Manager → Staff number SL21  
Manager → Staff number SG5  
(b)

## *Functional Dependency*

- Diagrammatic representation.



# Normalization

## *Normalization*

- Formal technique for analyzing a relation based on its
  - primary key and
  - the functional dependencies between the attributes of that relation.
  
- A relation can be normalized to a specific form to prevent the possible occurrence of update anomalies.

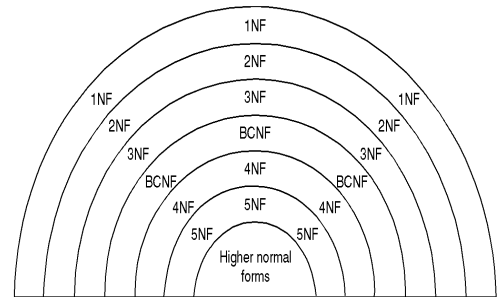
## *The Process of Normalization*

- As normalization proceeds, the relations become progressively more restricted (stronger) in format and also less vulnerable to update anomalies.

## *The Process of Normalization*

- Normalization is often executed as a series of steps. Each step corresponds to a specific normal form, which has known properties.

## *Relationship Between Normal Forms*



## *The Process of Normalization*

- Most commonly used normal forms are:
  - first (1NF),
  - second (2NF),
  - third (3NF) and
  - Boyce-Codd (BCNF) normal forms

## *Normalization Report*

| Page 1 <span style="float: right;">DreamHome</span><br>Customer Rental Details <span style="float: right;">Date 7-Oct-98</span> |                        |            |                             |      |              |             |
|---|------------------------|------------|-----------------------------|------|--------------|-------------|
| Customer Name <i>John Kay</i>   |                        |            | Customer Number <i>CR76</i> |      |              |             |
| Property Number   | Property Address       | Rent Start | Rent Finish                 | Rent | Owner Number | Owner Name  |
| PG4   | 6 Lawrence St, Glasgow | 1-Jul-94   | 31-Aug-96                   | 350  | CO40         | Tina Murphy |
| PG16  | 5 Novar Dr, Glasgow    | 1-Sep-96   | 1-Sep-98                    | 450  | CO93         | Tony Shaw   |

## *Unnormalized Form (UNF)*

- A table that contains one or more repeating groups.
- To create an unnormalized table
  - Transform the data from the information source (e.g. form) into table format with columns and rows.

## *UNF to INF*

- Remove the repeating group by
- Entering appropriate data into the empty columns of rows containing the repeating data ('flattening' the table).

## *Unnormalized Form (UNF)*

Customer\_Rental Table

| Customer_No | CName         | Property_No | PAddress               | RentStart | RentFinish | Rent | Owner_No | OName       |
|-------------|---------------|-------------|------------------------|-----------|------------|------|----------|-------------|
| CR76        | John Kay      | PG4         | 6 Lawrence St, Glasgow | 1-Jul-94  | 31-Aug-96  | 350  | CO40     | Tina Murphy |
|             |               | PG16        | 5 Novar Dr, Glasgow    | 1-Sep-96  | 1-Sep-98   | 450  | CO93     | Tony Shaw   |
| CR56        | Aline Stewart | PG4         | 6 Lawrence St, Glasgow | 1-Sep-92  | 10-June-94 | 350  | CO40     | Tina Murphy |
|             |               | PG36        | 2 Manor Rd, Glasgow    | 10-Oct-94 | 1-Dec-95   | 375  | CO93     | Tony Shaw   |
|             |               | PG16        | 5 Novar Dr, Glasgow    | 1-Jan-96  | 10-Aug-96  | 450  | CO93     | Tony Shaw   |

## *Normalization UNF to INF*

Customer\_Rental Relation

| Customer_No | Property_No | CName         | PAddress               | RentStart | RentFinish | Rent | Owner_No | OName       |
|-------------|-------------|---------------|------------------------|-----------|------------|------|----------|-------------|
| CR76        | PG4         | John Kay      | 6 Lawrence St, Glasgow | 1-Jul-94  | 31-Aug-96  | 350  | CO40     | Tina Murphy |
| CR76        | PG16        | John Kay      | 5 Novar Dr, Glasgow    | 1-Sep-96  | 1-Sep-98   | 450  | CO93     | Tony Shaw   |
| CR56        | PG4         | Aline Stewart | 6 Lawrence St, Glasgow | 1-Sep-92  | 10-Jun-94  | 350  | CO40     | Tina Murphy |
| CR56        | PG36        | Aline Stewart | 2 Manor Rd, Glasgow    | 10-Oct-94 | 1-Dec-95   | 375  | CO93     | Tony Shaw   |
| CR56        | PG16        | Aline Stewart | 5 Novar Dr, Glasgow    | 1-Jan-96  | 10-Aug-96  | 450  | CO93     | Tony Shaw   |

## *INF - Definition*

- A relation in which the intersection of each row and column contains one and only one value.

## *Normalization UNF to INF*

Property\_Inspection Table

| Property_No | PAddress               | IDate     | ITime | Comments                   | Staff_No | SName      | Car_Reg  |
|-------------|------------------------|-----------|-------|----------------------------|----------|------------|----------|
| PG4         | 6 Lawrence St, Glasgow | 18-Oct-96 | 10.00 | need to replace crockery   | SG37     | Ann Beech  | M231 JGR |
|             |                        | 22-Apr-97 | 09.00 | in good order              | SG14     | David Ford | M533 HDR |
|             |                        | 1-Oct-98  | 12.00 | damp rot in bathroom       | SG14     | David Ford | N721 HFR |
| PG16        | 5 Novar Dr, Glasgow    | 22-Apr-96 | 13.00 | replace living room carpet | SG14     | David Ford | M533 HDR |
|             |                        | 24-Oct-97 | 14.00 | good condition             | SG37     | Ann Beech  | N721 HFR |

## Normalization UNF to 1NF

Property\_Inspection Relation

| Property_No | IDate     | ITime | PAddress               | Comments                   | Staff_No | SName      | Car_Reg  |
|-------------|-----------|-------|------------------------|----------------------------|----------|------------|----------|
| PG4         | 18-Oct-96 | 10.00 | 6 Lawrence St, Glasgow | need to replace crockery   | SG37     | Ann Beech  | M231 JGR |
| PG4         | 22-Apr-97 | 09.00 | 6 Lawrence St, Glasgow | in good order              | SG14     | David Ford | M533 HDR |
| PG4         | 1-Oct-98  | 12.00 | 6 Lawrence St, Glasgow | damp rot in bathroom       | SG14     | David Ford | N721 HFR |
| PG16        | 22-Apr-96 | 13.00 | 5 Novar Dr, Glasgow    | replace living room carpet | SG14     | David Ford | M533 HDR |
| PG16        | 24-Oct-97 | 14.00 | 5 Novar Dr, Glasgow    | good condition             | SG37     | Ann Beech  | N721 HFR |

## 1NF to 2NF

- Identify the primary key for the 1NF relation.
- Identify the functional dependencies in the relation.
- If partial dependencies exist on the primary key remove them by placing them in a new relation along with a copy of their determinant.

## Second Normal Form (2NF)

- Based on the concept of full functional dependency.
- Full functional dependency indicates that if
  - A and B are attributes of a relation,
  - B is fully dependent on A if B is functionally dependent on A but not on any proper subset of A.

## Normalization 1NF to 2NF

Customer\_Rental Relation

| Customer_No | Property_No | CName         | PAddress               | RentStart | RentFinish | Rent | Owner_No | OName       |
|-------------|-------------|---------------|------------------------|-----------|------------|------|----------|-------------|
| CR76        | PG4         | John Kay      | 6 Lawrence St, Glasgow | 1-Jul-94  | 31-Aug-96  | 350  | CO40     | Tina Murphy |
| CR76        | PG16        | John Kay      | 5 Novar Dr, Glasgow    | 1-Sep-96  | 1-Sep-98   | 450  | CO93     | Tony Shaw   |
| CR56        | PG4         | Aline Stewart | 6 Lawrence St, Glasgow | 1-Sep-92  | 10-Jun-94  | 350  | CO40     | Tina Murphy |
| CR56        | PG36        | Aline Stewart | 2 Manor Rd, Glasgow    | 10-Oct-94 | 1-Dec-95   | 375  | CO93     | Tony Shaw   |
| CR56        | PG16        | Aline Stewart | 5 Novar Dr, Glasgow    | 1-Jan-96  | 10-Aug-96  | 450  | CO93     | Tony Shaw   |

## 2NF - Definition

- A relation that is in 1NF and every non-primary-key attribute is fully functionally dependent on the primary key.

## Normalization 1NF to 2NF

Customer\_Rental Relation

| Customer_No | Property_No | CName         | PAddress               | RentStart | RentFinish | Rent | Owner_No | OName       |
|-------------|-------------|---------------|------------------------|-----------|------------|------|----------|-------------|
| CR76        | PG4         | John Kay      | 6 Lawrence St, Glasgow | 1-Jul-94  | 31-Aug-96  | 350  | CO40     | Tina Murphy |
| CR76        | PG16        | John Kay      | 5 Novar Dr, Glasgow    | 1-Sep-96  | 1-Sep-98   | 450  | CO93     | Tony Shaw   |
| CR56        | PG4         | Aline Stewart | 6 Lawrence St, Glasgow | 1-Sep-92  | 10-Jun-94  | 350  | CO40     | Tina Murphy |
| CR56        | PG36        | Aline Stewart | 2 Manor Rd, Glasgow    | 10-Oct-94 | 1-Dec-95   | 375  | CO93     | Tony Shaw   |
| CR56        | PG16        | Aline Stewart | 5 Novar Dr, Glasgow    | 1-Jan-96  | 10-Aug-96  | 450  | CO93     | Tony Shaw   |

## Normalization 1NF to 2NF

Customer\_Rental Relation

| Customer_No | Property_No | CName         | PAddress               | RentStart | RentFinish | Rent | Owner_No | OName       |
|-------------|-------------|---------------|------------------------|-----------|------------|------|----------|-------------|
| CR76        | PG4         | John Kay      | 6 Lawrence St, Glasgow | 1-Jul-94  | 31-Aug-96  | 350  | CO40     | Tina Murphy |
| CR76        | PG16        | John Kay      | 5 Novar Dr, Glasgow    | 1-Sep-96  | 1-Sep-98   | 450  | CO93     | Tony Shaw   |
| CR56        | PG4         | Aline Stewart | 6 Lawrence St, Glasgow | 1-Sep-92  | 10-Jun-94  | 350  | CO40     | Tina Murphy |
| CR56        | PG36        | Aline Stewart | 2 Manor Rd, Glasgow    | 10-Oct-94 | 1-Dec-95   | 375  | CO93     | Tony Shaw   |
| CR56        | PG16        | Aline Stewart | 5 Novar Dr, Glasgow    | 1-Jan-96  | 10-Aug-96  | 450  | CO93     | Tony Shaw   |

## 3NF - Definition

- A relation that is in 1NF and 2NF and in which **NO non-primary-key attribute is transitively dependent on the primary key.**

## Normalization Customer\_Rental to 2NF Relations

| Customer Relation |               | Rental Relation |             |           |            |
|-------------------|---------------|-----------------|-------------|-----------|------------|
| Customer_No       | CName         | Customer_No     | Property_No | RentStart | RentFinish |
| CR76              | John Kay      | CR76            | PG4         | 1-Jul-94  | 31-Aug-96  |
| CR56              | Aline Stewart | CR76            | PG16        | 1-Sep-96  | 1-Sep-98   |
|                   |               | CR56            | PG4         | 1-Sep-92  | 10-Jun-94  |
|                   |               | CR56            | PG36        | 10-Oct-94 | 1-Dec-95   |
|                   |               | CR56            | PG16        | 1-Jan-96  | 10-Aug-96  |

| Property_Owner Relation |                        |      |          |             |
|-------------------------|------------------------|------|----------|-------------|
| Property_No             | PAddress               | Rent | Owner_No | OName       |
| PG4                     | 6 Lawrence St, Glasgow | 350  | CO40     | Tina Murphy |
| PG16                    | 5 Novar Dr, Glasgow    | 450  | CO93     | Tony Shaw   |
| PG36                    | 2 Manor Rd, Glasgow    | 375  | CO93     | Tony Shaw   |

## 2NF to 3NF

- Identify the primary key in the 2NF relation.
- Identify functional dependencies in the relation.
- If transitive dependencies exist on the primary key remove them by placing them in a new relation along with a copy of their dominant.

## Third Normal Form (3NF)

- Based on the concept of transitive dependency.
- Transitive Dependency is a condition where
  - A, B and C are attributes of a relation such that if  $A \rightarrow B$  and  $B \rightarrow C$ ,
  - then C is transitively dependent on A through B. (Provided that A is not functionally dependent on B or C).

## Normalization Customer\_Rental to 2NF Relations

| Customer Relation |               | Rental Relation |             |           |            |
|-------------------|---------------|-----------------|-------------|-----------|------------|
| Customer_No       | CName         | Customer_No     | Property_No | RentStart | RentFinish |
| CR76              | John Kay      | CR76            | PG4         | 1-Jul-94  | 31-Aug-96  |
| CR56              | Aline Stewart | CR76            | PG16        | 1-Sep-96  | 1-Sep-98   |
|                   |               | CR56            | PG4         | 1-Sep-92  | 10-Jun-94  |
|                   |               | CR56            | PG36        | 10-Oct-94 | 1-Dec-95   |
|                   |               | CR56            | PG16        | 1-Jan-96  | 10-Aug-96  |

| Property_Owner Relation |                        |      |          |             |
|-------------------------|------------------------|------|----------|-------------|
| Property_No             | PAddress               | Rent | Owner_No | OName       |
| PG4                     | 6 Lawrence St, Glasgow | 350  | CO40     | Tina Murphy |
| PG16                    | 5 Novar Dr, Glasgow    | 450  | CO93     | Tony Shaw   |
| PG36                    | 2 Manor Rd, Glasgow    | 375  | CO93     | Tony Shaw   |

### Normalization Property\_Owner to 3NF Relations

| Property_for_Rent Relation |                        |      |          | Owner Relation |             |
|----------------------------|------------------------|------|----------|----------------|-------------|
| Property_No                | PAddress               | Rent | Owner_No | Owner_No       | OName       |
| PG4                        | 6 Lawrence St, Glasgow | 350  | CO40     | CO40           | Tina Murphy |
| PG16                       | 5 Novar Dr, Glasgow    | 450  | CO93     | CO93           | Tony Shaw   |
| PG36                       | 2 Manor Rd, Glasgow    | 375  | CO93     |                |             |

### Normalization Summary of 3NF Relations

| Customer Relation |               | Rental Relation |             |           |            |
|-------------------|---------------|-----------------|-------------|-----------|------------|
| Customer_No       | CName         | Customer_No     | Property_No | RentStart | RentFinish |
| CR76              | John Kay      | CR76            | PG4         | 1-Jul-94  | 31-Aug-96  |
| CR56              | Aline Stewart | CR76            | PG16        | 1-Sep-96  | 1-Sep-98   |
|                   |               | CR56            | PG4         | 1-Sep-92  | 10-Jun-94  |
|                   |               | CR56            | PG36        | 10-Oct-94 | 1-Dec-95   |
|                   |               | CR56            | PG16        | 1-Jan-96  | 10-Aug-96  |

| Property_for_Rent Relation |                        |      |          | Owner Relation |             |
|----------------------------|------------------------|------|----------|----------------|-------------|
| Property_No                | PAddress               | Rent | Owner_No | Owner_No       | OName       |
| PG4                        | 6 Lawrence St, Glasgow | 350  | CO40     | CO40           | Tina Murphy |
| PG16                       | 5 Novar Dr, Glasgow    | 450  | CO93     | CO93           | Tony Shaw   |
| PG36                       | 2 Manor Rd, Glasgow    | 375  | CO93     |                |             |

