

Data and Web Development

CC6012NP

7

Normalisation

Topics

- Introduction
- Anomalies (Insert, Delete, Update)
- Why Normalisation
- Functional and Transitive Dependency
- Normalisation
 - Unnormalized Form (UNF)
 - First Normal Form (1NF)
 - Second Normal Form (2NF)
 - Third Normal Form (3NF)

Introduction

- Normalization is the process **to get data into simpler form** that truly reflects separate entity types, their attributes and relationships between them to **avoid unnecessary duplication (redundancy) of data**
- Starts from pre-documented sets of attributes and tries to group and regroup them without causing **data inconsistencies** in such a way that **Anomalies are avoided**

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Anomalies

- **Anomalies** are undesirable side effects or problems that can occur if relations/tables are not in proper normal form.
- Anomalies fall into three categories:
 - Insertion Anomaly
 - Deletion Anomaly
 - Update Anomaly

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Anomalies

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| Employee_id | Employee_name | Employee_Address | Department_id | De |
|-------------|---------------|------------------|---------------|-----|
| Emp1 | John | Kathmandu | Dep1 | IT |
| Emp2 | Alice | Kathmandu | Dep2 | Fin |
| Emp3 | David | Dharan | Dep1 | IT |
| Emp4 | Jeffery | Biratnagar | Dep1 | IT |
| Emp5 | Martha | Chitwan | Dep3 | Sal |
| Emp6 | Claudia | Kathmandu | Dep3 | Sal |

Anomalies

- **Insertion Anomaly:**

- Adding new rows forces user to create duplicate data or occurs when we cannot insert new row into relation because some or all of Primary Key value is not known.

- **Deletion Anomaly:**

- Deleting rows may cause loss of data that would be needed for other future rows

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Anomalies

- **Update Anomaly:**

- Changing data in row forces changes to other rows because of duplication.
- Update: occurs when we have unnecessary redundancy in the data and we are forced to update several rows.

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Why Normalisation

what are other words for normalisation?



standardization,
standardisation, normalization,
calibration, regularization,
regularisation, stabilisation



Thesaurus.plus

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Why Normalisation

- Database Design must be efficient (performance-wise).
- Amount of data should be reduced if possible.
- Design should be free of **Update, Insertion and Deletion** Anomalies.
- Design must comply with rules regarding Relational Databases.
- Design has to show relevant Relationship between Entities.
- Design should permit simple retrieval, simplify data maintenance and reduce need to restructure data.

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Functional Dependencies (FD)

- Normalisation is based on analysis of Functional Dependence.
- Functional Dependency is particular Relationship between two Attributes.

Functional Dependency

$$A \rightarrow B$$

B - functionally dependent on A

A - determinant set

B - dependent attribute

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Functional Dependencies (FD)

- Attribute B is Functionally Dependent upon Attribute A (or a collection of attributes) if a value of A determines a single value of B at any one time.
- Value of one Attribute (collection of attributes) determines value of another Attribute

The following table illustrates $A \rightarrow B$:

| A | B |
|---|----|
| 1 | 1 |
| 2 | 4 |
| 3 | 9 |
| 4 | 16 |
| 2 | 4 |
| 7 | 9 |

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Functional Dependencies (FD)

- Notation for this Functional Dependency is: $A \rightarrow B$
- Notation is read “A determines B” or “B is Functionally Dependent on A”.
- A is called Determinant and B is called object of Dependent.
- Composite Determinant is made up of more than one attribute: $X, Y \rightarrow Z$

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Functional Dependencies (FD)

- Two terms relevant with Composite Determinants

- Full Functional Dependency (FFD)

- If it is necessary to use all attributes of Composite Determinant to identify its object uniquely, we have Full Functional Dependency.

- Partial Functional Dependency (PFD)

- Dependency exists if it is necessary to use only subset of Attributes of a Composite Determinant to identify object uniquely.

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FD - Example

| Student-id | Activity | Cost | Proficiency |
|------------|----------|------|-------------|
| 100 | Squash | 200 | A |
| 100 | Swimming | 100 | B |
| 150 | Swimming | 100 | B |
| 175 | Scuba | 300 | L |
| 175 | Aerobics | 200 | I |
| 200 | Squash | 200 | A |
| 200 | Swimming | 100 | A |

- FFD = student-id, activity → proficiency
- PFD = activity → cost

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FD - Example

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| Booking_id | Room_id | Guest-name | Roomtype | Price_per_night |
|------------|---------|------------|----------|-----------------|
| B101 | R01 | John | Deluxe | 5000 |
| B102 | R01 | Minnie | Deluxe | 5000 |
| B103 | R02 | Manon | Suite | 9000 |

- ❑ FFD = $\text{Booking_id}, \text{Room_id} \rightarrow \text{Price_per_night}$
- ❑ PFD = $\text{Room_id} \rightarrow \text{Roomtype}$

Transitive Dependency (TD)

- Transitive Dependency exists when there is an intermediate dependency. Assume three attributes A, B and C. Further assume that the following functional dependencies exist
 - $A \rightarrow B$, $B \rightarrow C$
- Then it can be stated that the following transitive dependency also holds
 - $A \rightarrow B \rightarrow C$

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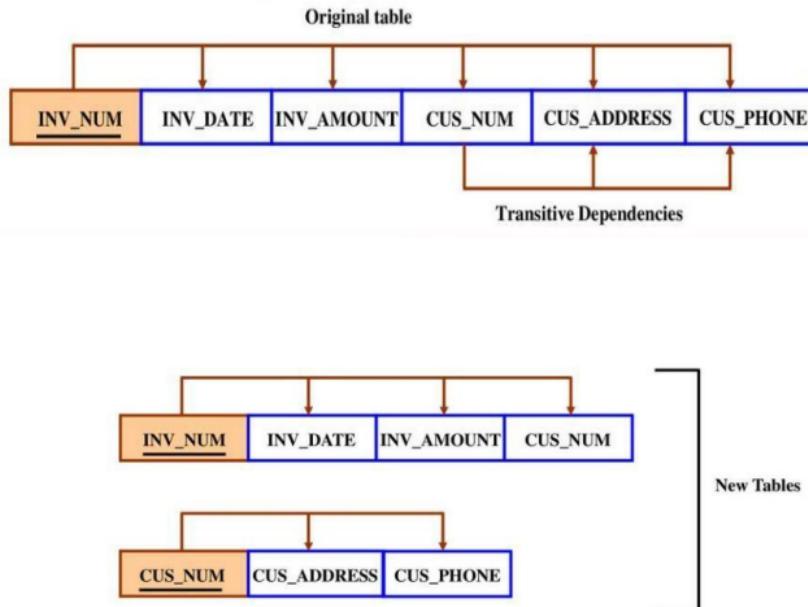
Transitive Dependency (TD)

| Student-id | Accommodation | Fee |
|------------|---------------|------|
| 100 | Perkin | 1100 |
| 150 | Gatehouse | 1200 |
| 200 | Gatehouse | 1200 |
| 250 | Perkin | 1100 |
| 300 | Ingleside | 1500 |

- FD = student-id → accommodation
- FD = student-id → fee
- FD = accommodation → fee
- TD = student-id → accommodation → fee

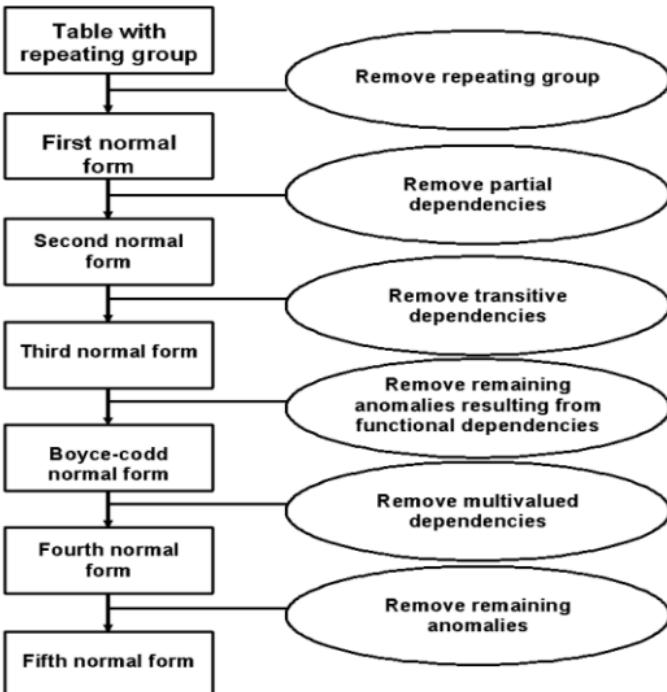
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Transitive Dependency (TD)



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Steps in Normalisation



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Steps in Normalisation

- **Step 1: Un-Normalised Form (UNF)**

- All attributes with repeating groups are included.

- **Step 2: First Normal Form (1NF)**

- Any repeating groups have been separated, so that there is a single valued attribute at the intersection of each row and column of the table.

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Steps in Normalisation

- **Step 3: Second Normal Form (2NF)**

- Any Partial Functional Dependencies have been separated.

- **Step 4: Third Normal Form (3NF)**

- Any Transitive Dependencies have been separated.

Note: If Relation meets the criteria for 3NF, it also meets criteria for 2NF and 1NF. Most design problems can be avoided if Relations are in 3NF.)

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Un-normalised Normal Form (UNF)

- Relation is un-normalised if it has not had any normalisation rules applied to it and if it suffers from various anomalies.
- **Sources of un-normalised data are:**
 - Computer Screen Layouts
 - Reports
 - Computer Programs
 - User Manuals

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An Order Form – Example



Customer number: 1489
Name: Arthur Smith
Address: 1 Lime Avenue
Anytown
ZZ52 5QA

Order number: 0057435
Order date: 11-Jan-06

Secure Parts Ltd

| product number | product description | unit price | order quantity | line total |
|----------------|---------------------|------------|----------------|------------|
| T5060 | Lock | 5.00 | 5 | 25.00 |
| PT42 | Alarm | 20.00 | 1 | 20.00 |
| QZE248 | Key | 2.50 | 10 | 25.00 |

Order total: 70.00

Collection of orders

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Un-normalized Form (UNF)

| Order-no | Order-date | Cust-no | Cust-name | Cust-address | Prod-no | Prod-desc | Unit-price | Ord-qty | Line-total | Order-total |
|----------|------------|---------|--------------|--------------------------------------|---------|-----------|------------|---------|------------|-------------|
| 0057435 | 11-JAN-06 | 1489 | Arthur Smith | 1 Lime Avenue Anytown ZZ52 5QA | T5060 | Lock | 5.00 | 5 | 25 | 70.00 |
| 0057435 | 11-JAN-06 | 1489 | Arthur Smith | 1 Lime Avenue Anytown ZZ52 5QA | PT42 | Alarm | 20.00 | 1 | 20.00 | 70.00 |
| 0057435 | 11-JAN-06 | 1489 | Arthur Smith | 1 Lime Avenue Anytown ZZ52 5QA | QZE248 | Key | 2.50 | 10 | 25.00 | 70.00 |

Un-normalised Form (UNF)

Multi-valued

| Order-no | Order-date | Cust- no | Cust-name | Cust-address | Prod-no | Prod-desc | Unit-price | Ord-qty | Line-total | Order-total |
|----------|------------|----------|--------------|--------------------------------|---------------------|-----------------|------------|---------|------------|-------------|
| 0057435 | 11-JAN-06 | 1489 | Arthur Smith | 1 Lime Avenue Anytown ZZ52 5QA | T5060, PT42, QZE248 | Lock, Alarm,key | 5,20,2.5 | 5,1,10 | 25,20,25 | 70.00 |

Un-normalised Normal Form(UNF)

Multi-valued attribute group = repeating group

| Order-no | Order-date | Cust-no | Cust-name | Cust-address | Prod-no | Prod-desc | Unit-price | Ord-qty | Line-total | Order-total |
|----------|------------|---------|--------------|--------------------------------------|----------------------------|--------------------|--------------|---------|------------|-------------|
| 0057435 | 11-JAN-06 | 1489 | Arthur Smith | 1 Lime Avenue Anytown ZZ52 5QA | T5060,P T4 2, QZE248 | Lock, Alarm,key | 5,20.2. 5 | 5,1,10 | 25,20,25 | 70.00 |

Repeating Group = prod-no, prod-desc, unit-price, ord-qty, line-total

A repeating group is an attribute (or set of attributes) that can have multiple values for a single occurrence of the key (single or composite) in a table.

Applying UNF

1. Write down all attributes from above and name this entity.
 2. Choose suitable unique identifier for this entity
 3. Show Repeating Group within { }.

ORDER

ORDER (order-no, order-date, cust-no, cust-name,
cust-address, {prod-no, prod-desc, unit-price, ord-qty,
line-total}, order-total)

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First Normal Form (1NF)

A table is said to be in 1NF if each column has atomic (single) values.

- Repeating groups should be removed to separate Relation
- 1NF restriction is built into Relational Model
- Advantages of 1NF are simplicity and uniform access

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Applying 1NF

ORDER (order-no, order-date, cust-no, cust-name, cust-address, {prod-no, prod-desc, unit-price, ord-qty, line-total}, order-total)



ORDER-1 (order-no, order-date, cust-no, cust-name, cust-address, order-total)

ORDER-LINE-1 (order-no*, prod-no, prod-desc, unit-price, ord-qty, line-total)



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Second Normal Form (2NF)

- **Relation is in 2NF if**
 - It is in 1NF, and
 - All non-key attributes are Fully Functionally Dependent on Primary Key and not on only a part (portion) of Primary Key.
 - Attributes that are wholly dependent on only part of Composite identifier should be removed to a separate Relation
 - Prohibits situation where each row represents single-valued facts about more than one object.
 - Partial FDs on an identifier should be avoided because they result in data redundancy.

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Second Normal Form (2NF)

- **Steps to transform into 2NF**

- Identify all Functional Dependencies in 1NF.
- Make each Determinant Primary Key of new Relation.
- Place all attributes that depend on given Determinant in Relation with that Determinant as non-key attributes.

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Identifying PFDs

- List all combination of Composite Determinant (Primary Key) and Part of Composite Determinant (Primary Key)
 - How are non-key attributes dependent on determinants?
-

- order-no, prod-no → ord-qty, line-total
 - prod-no → prod-desc, unit-price
 - order-no →
-

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Applying 2NF

ORDER-1 (order-no, order-date, cust-no, cust-name, cust-address, order-total)

ORDER-LINE-1 (order-no, prod-no, prod-desc, unit-price, ord-qty, line-total)



ORDER-2 (order-no, order-date, cust-no, cust-name, cust-address, order-total)

ORDER-LINE-2 (order-no*, prod-no*, ord-qty, line-total)

PRODUCT-2 (prod-no, prod-desc, unit-price)

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Second Normal Form (2NF)

- Relation with only *single attribute* key are already in 2NF
 - A → b, c, d
- Relation with Composite key may not be in 2NF, as there may be some PDs
 - X, Y → l, m, n
- Relation that is in First Normal Form will be in Second Normal Form if any one of following conditions apply:
 - Primary Key consists of only one attribute (such as the attribute ORDER-NO in ORDER).
 - No non-key attributes exist in Relation.
 - Every non-key attribute is Functionally Dependent on full set of Primary Key attributes

Third Normal Form (3NF)

- Relation is in 3NF if
- It is in 2NF, and
 - No Transitive Dependencies.
 - Transitive Dependencies are when
 - $A \rightarrow B \rightarrow C$
 - Thus it can be split into
 - $A \rightarrow B$
and
 - $B \rightarrow C$.

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Third Normal Form (3NF)

- Attributes that are wholly dependent upon another attribute should be removed to separate Relation.
- Like 2NF, but now we consider FDs on non-key attributes only and do not worry about Key.
- Transitive Dependencies should be avoided because they result in data redundancy.

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Third Normal Form (3NF)

- Steps to transform into 3NF
 - Create one relation for each Determinant in Transitive Dependency.
 - Make Determinants Primary Keys in their respective relations.
 - Include as non-key attributes those attributes that depend on Determinant
 - $\text{order-no} \rightarrow \text{cust-no} \rightarrow \text{cust-name}, \text{cust-address}$
 - $\text{order-no} \rightarrow \text{order-date}, \text{cust-no}, \text{order-total}$
 - $\text{cust-no} \rightarrow \text{cust-name}, \text{cust-address}$

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Applying 3NF

ORDER-2 (order-no, order-date, cust-no, cust-name, cust-address, order-total)

ORDER-LINE-2 (order-no, prod-no, ord-qty, line-total)

PRODUCT-2 (prod-no, prod-desc, unit-price)

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ORDER-3 (order-no, order-date, cust-no*, order-total)

ORDER-LINE-3 (order-no*, prod-no*, ord-qty, line-total)

PRODUCT-3 (prod-no, prod-desc, unit-price)

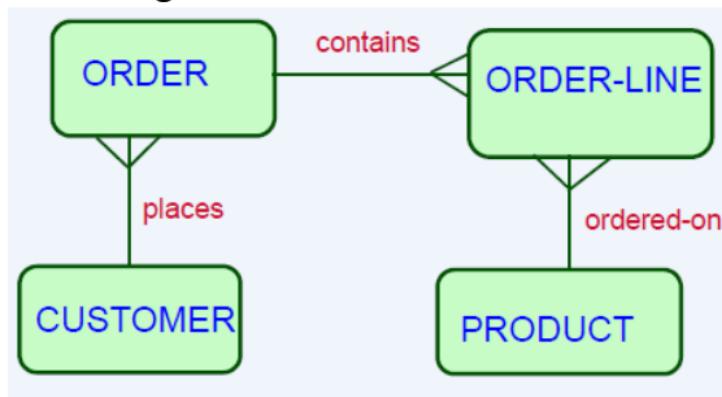
CUSTOMER-3 (cust-no, cust-name, cust-address)

Third Normal Form (3NF)

- Entities which are *all-key* OR have only *single non-key* attribute are already in 3NF
 - $A, B \rightarrow$
 - $A \rightarrow b$
- Entities with more than one non-key attribute may not be in 3NF, as there may be some TDs
 - $X, Y \rightarrow l, m, n$
 - $X \rightarrow l, m$

ER Model Representation

- Final list of 3NF entities can be represented by following ER model:



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Eliminating Redundancy

| Order-no | Order-date | Cust-no | Cust-name | Cust-add | Prod-no | Prod-desc | Price | Qty |
|----------|------------|---------|-----------|-----------|---------|-----------|-------|-----|
| 0057435 | 11-01-02 | 1489 | Smith | Anytown | Q2E | Spanner | 20.00 | 5 |
| 0057435 | 11-01-02 | 1489 | Smith | Anytown | PT42 | Bolt | 2.50 | 10 |
| 0057435 | 11-01-02 | 1489 | Smith | Anytown | T5060 | Hook | 5.00 | 1 |
| 0057436 | 12-01-02 | 1489 | Smith | Anytown | T5060 | Hook | 5.00 | 4 |
| 0057437 | 12-01-02 | 1500 | Jones | Somewhere | T5060 | Hook | 5.00 | 2 |

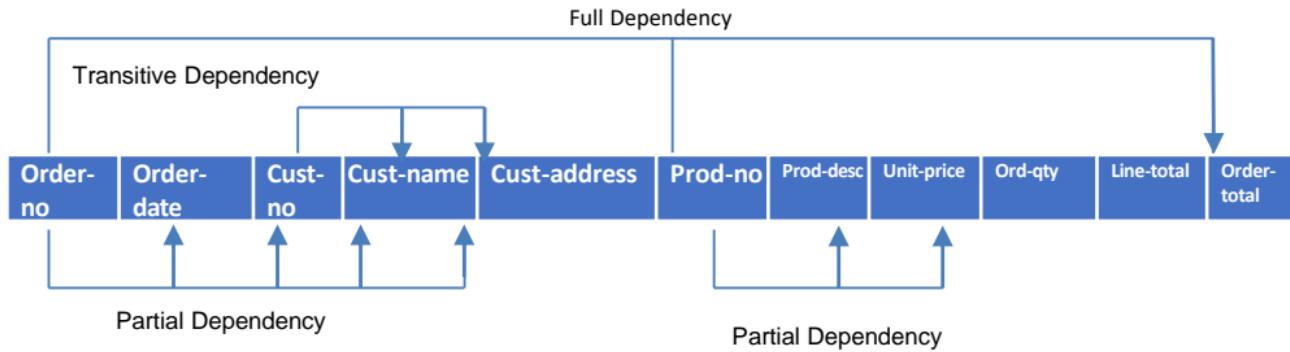
1NF

3NF

2NF

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Eliminating Redundancy



Project Allocation Example

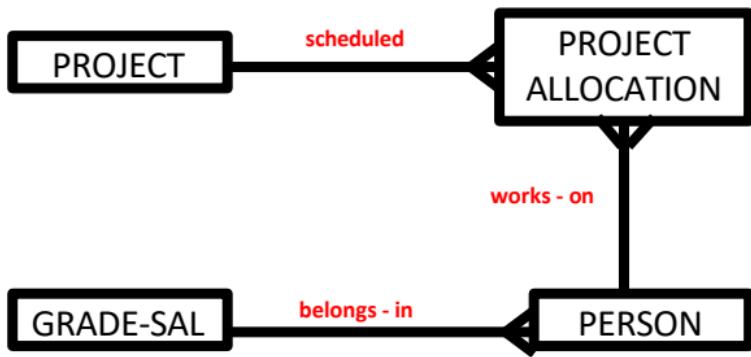
| Project Code | Project Type | Description | Person Number | Name | Grade | Salary Scale | Date-join Project | Alloc-time |
|--------------|--------------|-----------------------|---------------|-------|-------|--------------|-------------------|------------|
| IC5001 | New Dev | Develop Claims System | 2146 | Jones | A1 | 4 | 1/11/20xx | 24 |
| IC5001 | New Dev | Develop Claims System | 3145 | Smith | A2 | 4 | 2/10/20xx | 24 |
| IC5001 | New Dev | Develop Claims System | 6126 | Black | B1 | 9 | 7/11/20xx | 18 |
| IC5001 | New Dev | Develop Claims System | 1214 | Brown | A2 | 4 | 3/10/20xx | 12 |
| IC5001 | New Dev | Develop Claims System | 8191 | Green | A1 | 4 | 12/11/20xx | 18 |
| PAY22 | Maint | Maintain Payments | 6142 | Jacks | A2 | 4 | 9/11/20xx | 6 |
| PAY22 | Maint | Maintain Payments | 3169 | White | B2 | 10 | 4/11/20xx | 12 |
| PAY22 | Maint | Maintain Payments | 6145 | Dean | B3 | 10 | 8/10/20xx | 6 |

Normalisation from UNF to 3NF

| UNF | 1 NF | 2 NF | 3 NF |
|---|---|---|--|
| Project <u>Project-code</u> Project-type Description {Person-number Name Grade Salary-scale Date-join-project Alloc-time} | Project <u>Project-code</u> Project-type Description Project-Allocation <u>Project-code*</u> <u>Person-number</u> Name Grade Salary-scale Date-join-project Alloc-time | Project <u>Project-code</u> Project-type Description Project-Allocation <u>Project-code*</u> <u>Person-number*</u> Date-join-project Alloc-time Person <u>Person-number</u> Name Grade Salary-scale | Project <u>Project-code</u> Project-type Description Project-Allocation <u>Project-code*</u> <u>Person-number*</u> Date-join-project Alloc-time Person <u>Person-number</u> Name Grade* Grade-Sal <u>Grade</u> Salary-scale |

Project Allocation - ER Model

- Final list of 3NF Relation can be represented by following ER model



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Summary of Dependencies

Types of dependency between attributes

| Attributes | | | Dependency |
|-------------|--|-----------|--------------------|
| Key | | Non - Key | Functional |
| Part of Key | | Non - Key | Partial Functional |
| Non - Key | | Non - Key | Transitive |

- Our aim is for key to determine all other non-key attributes.
- Therefore, only first type of dependency is desirable.
- Normalisation ensures that entities are decomposed so that there is only Functional Dependency.

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Any Questions?