

a – d. The relations below have been normalized to 3NF and are validated against user transactions. Constraints are discussed below.

Client (clientNo, fName, lName, address, tel)

Primary Key clientNo

Service (serviceNo, clientNo, startDate, startTime, duration, comments)

Primary Key serviceNo

Foreign Key clientNo **references** Client(clientNo)

Employee (staffNo, fName, lName, address, salary, tel)

Primary Key staffNo

Equipment (equipNo, description, usage, cost)

Primary Key equipNo

Assigned(serviceNo, staffNo)

Primary Key serviceNo, staffNo

Foreign Key serviceNo **references** Service(serviceNo)

Foreign Key staffNo **references** Employee(staffNo)

Needs(serviceNo, equipNo)

Primary Key serviceNo, equipNo

Foreign Key serviceNo **references** Service(serviceNo)

Foreign Key equipNo **references** Equipment(equipNo)

The assigned and needs tables resolve the issues of the many to many relationships.

We validated against some user transactions found below:

1. [List all clients and the details of the services they have requested.](#)

We start at the Client table, and we have a one to many relationship between the Client table and the Service table. That allows us to directly link the services to the clients.

2. [Find the total cost of special equipment used in each service.](#)

This query involves calculating the total cost of special equipment used in each service. There is a many to many relationship between the Equipment and the Service entity which requires the need for the EquipmentRequirements table. This allows us to link specific equipment being used in specific services.

3. Identify employees who are not currently assigned to any service.

There is a many to many relationship between the Employee entity and the Service entity. This requires the Assigned table to capture this relationship. This will allow us to directly link the staff in the Employee table to the services since the Assigned table takes both the staffNo and serviceNo as attributes in the primary key.

4. List clients who have requested cleaning services more than once.

We start at the Client table, and we have a one to many relationship between the Client table and the Service table. That allows us to directly link the services to the clients.

5. Find and list employees that make below the average salary.

This query looks at only one table so it does not depend on other relationships.

All attributes are atomic, and there are no repeating groups. The given entities already satisfy 1NF. The tables are in 2NF if they are in 1NF and there are no partial dependencies. The attributes in the relations do not have partial dependencies so that condition is satisfied. Tables are in 3NF if they are in 2NF and there are no transitive dependencies. Again, these conditions are satisfied.

To maintain referential integrity, all foreign keys must be NOT NULL.

Since we previously assumed that telephone numbers might not be unique to clients or employees, there are no alternate key constraints.

All attributes are required (NOT NULL) with the exception of two: the “usage” attribute in the Equipment and the ‘comments’ attribute in the Service table can both be NULL. This is because neither usage nor comments are necessary to understand every equipment or service provided.

e. The E-R diagram for the logical model is shown below.

