What is Data Modeling?

Determining and structuring data elements and their connections in an ordered manner is called data modeling. It gives developers insight into the storage, retrieval and manipulation of data in a system and acts as a guide for database design.

Types of Data Models

1. **Conceptual Data Model**
   This high level model defines the entities and also their attributes and the relationships between them. It focuses on the business concepts and is independent of any specific database technology.
2. **Logical Data Model**
   This model includes the information like data types, primary keys and constraints. It act as the bridge between the conceptual model and the physical implementation.
3. **Physical Data Model**
   This model deals with the actual implementation details on a specific database management system. It includes considerations like indexing, partitioning and optimization for performance.

Data Modeling Techniques

1. **ER Diagrams**
   An illustration of the relationships between entities using shapes and lines is called an entity relationship diagram. It is a commonly used method to see a database's structure.
2. **UML Class Diagrams**
   The Unified Modeling Language includes class diagrams which are used to represent the classes, attributes and relationships in an object oriented system.
3. **Normalization**
   This technique involves organizing data in a database to reduce redundancy and dependency by organizing fields and table of a database.
4. **Dimensional Modeling**
   Business intelligence and data warehousing environments frequently use dimensional modelling. Data is arranged into two categories of tables which are dimension tables and fact tables. Fact tables hold numerical data whereas dimension tables hold descriptive information. Reporting and querying can be done efficiently with this method.
5. **Denormalization**
   Normalisation diminishes redundancy but denormalization has the reverse effect. To enhance query performance it entails merging tables or adding unnecessary data especially in systems where read operations greatly outweigh write operations. To prevent inconsistent data it should be used cautiously though.

Emerging Trends in Data Modeling

1. **Graph Database Modeling**
   With the rise of graph databases the data modeling techniques specific to graph structures are gaining importance. This allows for efficient representation and querying of complex relationships.
2. **Machine Learning Data Modeling**
   ML algorithms are being employed to assist in the creation of data models. They can analyze large datasets to identify patterns and relationships and aiding in the modeling process.

3. **Temporal Data Modeling**
   As the need to track and analyze data over time increases and temporal data modeling is becoming more relevant. This involves capturing and managing historical data and changes over time.

Advantages

1. **Clarity and Understanding:** Data modeling provides a clear visual representation of the data structure which facilitates understanding of the system's data requirements by developers, stakeholders and even non-technical individuals.
2. **Consistency and Integrity:** Data consistency and integrity are ensured by solid data models. By doing this irregularities, duplications and errors in the information that is kept are avoided.
3. **Efficiency:** Database operations are more efficient when data is properly organised. This can shorten the time it takes to retrieve or update information and greatly enhance query performance.
4. **Scalability:** A well-designed data model can accommodate growth and changes in data requirements over time. It provides a flexible structure that can adapt to evolving business needs.
5. **Collaboration:** Data models provide developers, analysts and stakeholders with a consistent language. This encourages teamwork and efficient communication throughout the development process.
6. **Saves Time and Resources:** Having a well-defined data model upfront can save time in the long run. It reduces the chances of costly redesigns or restructuring later in the development process.
7. **Facilitates Maintenance and Updates:** It is simpler to recognise and apply modifications to the database structure with a defined data model without completely upsetting the system.

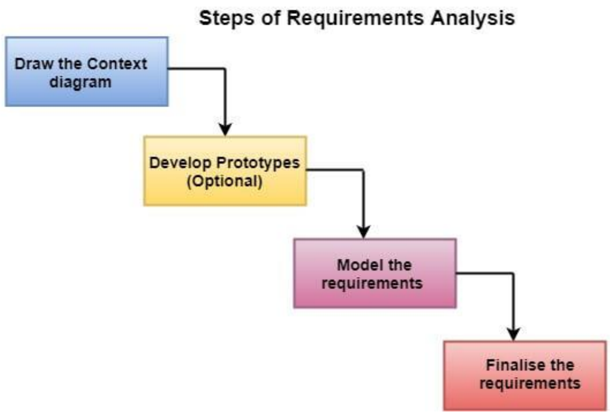
Disadvantages

1. **Time Consuming:** For big and complex systems making an understandable data model can be time taking process. This initial cost might be seen as a disadvantage and particularly in development situations which progress fast.
2. **Over Engineering:** The data model runs the danger of becoming too complex and particularly if developers attempt to take into consideration every eventuality that can arise in the future. System performance may suffer and needless complexity may result from this
3. **Inflexibility:** A rigidly designed data models can find it difficult to adapt the unexpected changes and new requirements. This technique may lead to difficulties in accommodating and evolving business needs.
4. **Requires Expertise:** A thorough understanding of database administration and the business area are prerequisites for creating an efficient data model. Untrained or inexperienced workers could produce inadequate models.
5. **Maintenance Overheads:** If not managed appropriately an efficiently built data model can become a source of overhead and be simple to maintain. Modifications in specifications or technology necessitate substantial updates.
6. **Resource Intensive:** In terms of computational resources and complex data models can demand more from the underlying hardware. This could lead to higher infrastructure costs.
7. **Potential for Incomplete Modeling:** A slight risk of missing important data elements or relationships is there if not approached carefully. This may create differences in function or accuracy of system.

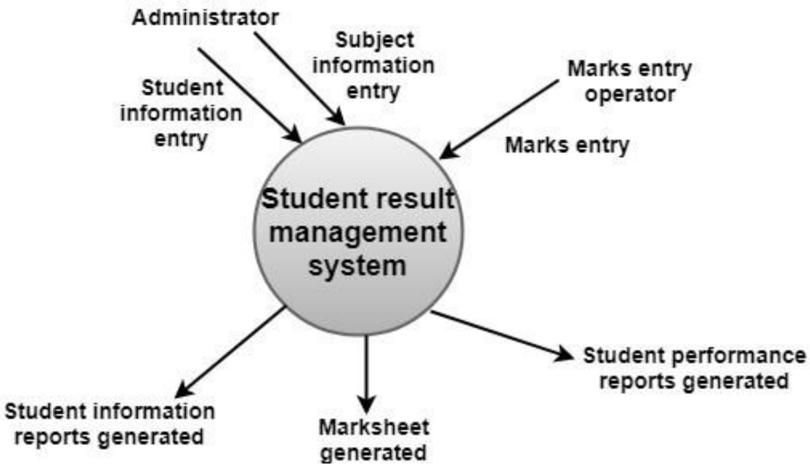
Requirements Analysis

Requirement analysis is significant and essential activity after elicitation. We analyze, refine, and scrutinize the gathered requirements to make consistent and unambiguous requirements. This activity reviews all requirements and may provide a graphical view of the entire system. After the completion of the analysis, it is expected that the understandability of the project may improve significantly. Here, we may also use the interaction with the customer to clarify points of confusion and to understand which requirements are more important than others.

The various steps of requirement analysis are shown in fig:



(i) Draw the context diagram: The context diagram is a simple model that defines the boundaries and interfaces of the proposed systems with the external world. It identifies the entities outside the proposed system that interact with the system. The context diagram of student result management system is given below:



(ii) Development of a Prototype (optional): One effective way to find out what the customer wants is to construct a prototype, something that looks and preferably acts as part of the system they say they want.

We can use their feedback to modify the prototype until the customer is satisfied continuously. Hence, the prototype helps the client to visualize the proposed system and increase the understanding of the requirements. When developers and users are not sure about some of the elements, a prototype may help both the parties to take a final decision.

Some projects are developed for the general market. In such cases, the prototype should be shown to some representative sample of the population of potential purchasers. Even though a person who tries out a prototype may not buy the final system, but their feedback may allow us to make the product more attractive to others.

The prototype should be built quickly and at a relatively low cost. Hence it will always have limitations and would not be acceptable in the final system. This is an optional activity.

(iii) Model the requirements: This process usually consists of various graphical representations of the functions, data entities, external entities, and the relationships between them. The graphical view may help to find incorrect, inconsistent, missing, and superfluous requirements. Such models include the Data Flow diagram, Entity-Relationship diagram, Data Dictionaries, State-transition diagrams, etc.

(iv) Finalise the requirements: After modeling the requirements, we will have a better understanding of the system behavior. The inconsistencies and ambiguities have been identified and corrected. The flow of data amongst various modules has been analyzed. Elicitation and analyze activities have provided better insight into the system. Now we finalize the analyzed requirements, and the next step is to document these requirements in a prescribed format.

Data Flow Diagrams

A Data Flow Diagram (DFD) is a traditional visual representation of the information flows within a system. A neat and clear DFD can depict the right amount of the system requirement graphically. It can be manual, automated, or a combination of both.

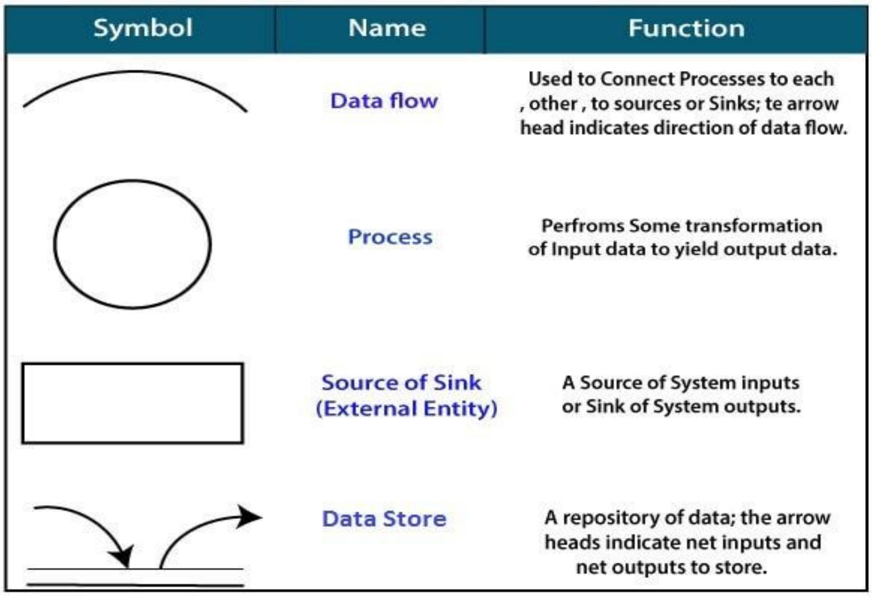
It shows how data enters and leaves the system, what changes the information, and where data is stored.

The objective of a DFD is to show the scope and boundaries of a system as a whole. It may be used as a communication tool between a system analyst and any person who plays a part in the order that acts as a starting point for redesigning a system. The DFD is also called as a data flow graph or bubble chart.

The following observations about DFDs are essential:

1. All names should be unique. This makes it easier to refer to elements in the DFD.
2. Remember that DFD is not a flow chart. Arrows is a flow chart that represents the order of events; arrows in DFD represents flowing data. A DFD does not involve any order of events.
3. Suppress logical decisions. If we ever have the urge to draw a diamond-shaped box in a DFD, suppress that urge! A diamond-shaped box is used in flow charts to represents decision points with multiple exists paths of which the only one is taken. This implies an ordering of events, which makes no sense in a DFD.
4. Do not become bogged down with details. Defer error conditions and error handling until the end of the analysis.

Standard symbols for DFDs are derived from the electric circuit diagram analysis and are shown in fig:



Symbol	Name	Function
	Data flow	Used to Connect Processes to each , other , to sources or Sinks; te arrow head indicates direction of data flow.
	Process	Perfroms Some transformation of Input data to yield output data.
	Source of Sink (External Entity)	A Source of System inputs or Sink of System outputs.
	Data Store	A repository of data; the arrow heads indicate net inputs and net outputs to store.

Symbols for Data Flow Diagrams

Circle: A circle (bubble) shows a process that transforms data inputs into data outputs.

Data Flow: A curved line shows the flow of data into or out of a process or data store.

Data Store: A set of parallel lines shows a place for the collection of data items. A data store indicates that the data is stored which can be used at a later stage or by the other processes in a different order. The data store can have an element or group of elements.

Source or Sink: Source or Sink is an external entity and acts as a source of system inputs or sink of system outputs.

Levels in Data Flow Diagrams (DFD)

The DFD may be used to perform a system or software at any level of abstraction. Infact, DFDs may be partitioned into levels that represent increasing information flow and functional detail. Levels in DFD are numbered 0, 1, 2 or beyond. Here, we will see primarily three levels in the data flow diagram, which are: 0-level DFD, 1-level DFD, and 2-level DFD.

0-level DFDM

It is also known as fundamental system model, or context diagram represents the entire software requirement as a single bubble with input and output data denoted by incoming and outgoing arrows. Then the system is decomposed and described as a DFD with multiple bubbles. Parts of the system represented by each of these bubbles are then decomposed and documented as more and more detailed DFDs. This process may be repeated at as many levels as necessary until the program at hand is well understood. It is essential to preserve the number of inputs and outputs between levels, this concept is called leveling by DeMacro. Thus, if bubble "A" has two inputs x_1 and x_2 and one output y, then the expanded DFD, that represents "A" should have exactly two external inputs and one external output as shown in fig:

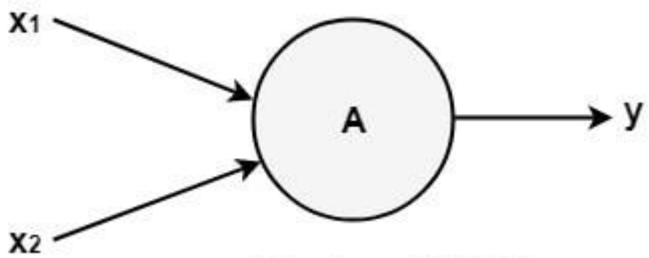


Fig: Level-0 DFD.

The Level-0 DFD, also called context diagram of the result management system is shown in fig. As the bubbles are decomposed into less and less abstract bubbles, the corresponding data flow may also be needed to be decomposed.

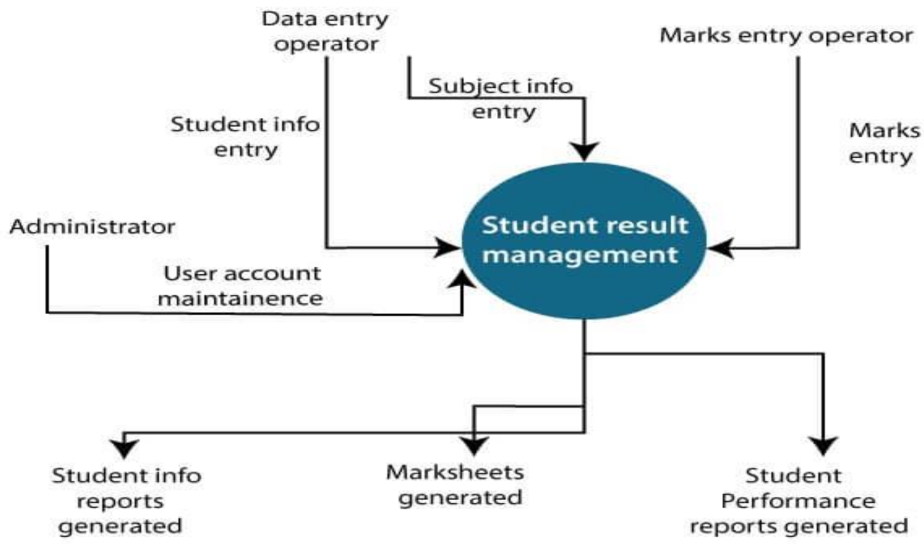


Fig: Level-0 DFD of result management system

1-level DFD

In 1-level DFD, a context diagram is decomposed into multiple bubbles/processes. In this level, we highlight the main objectives of the system and breakdown the high-level process of 0-level DFD into subprocesses.

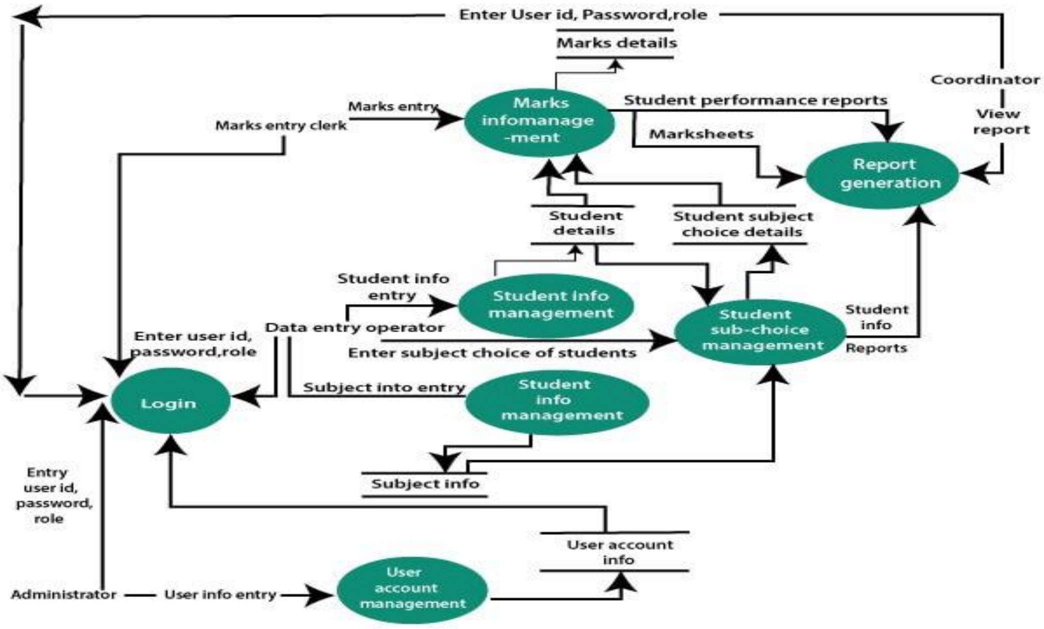
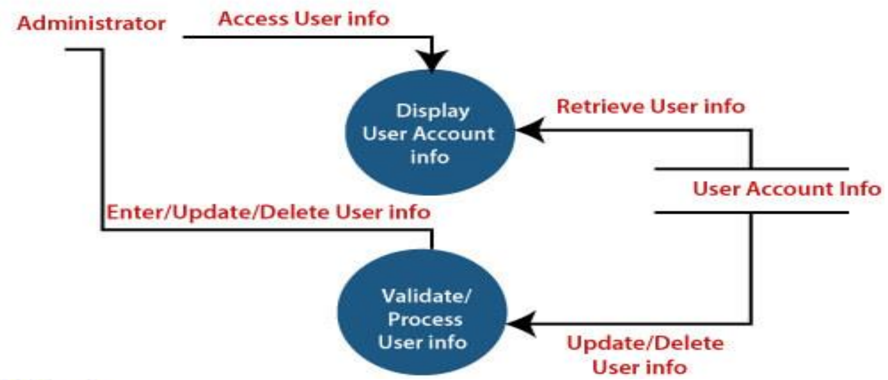


Fig: Level-1 DFD of result management system

2-Level DFD

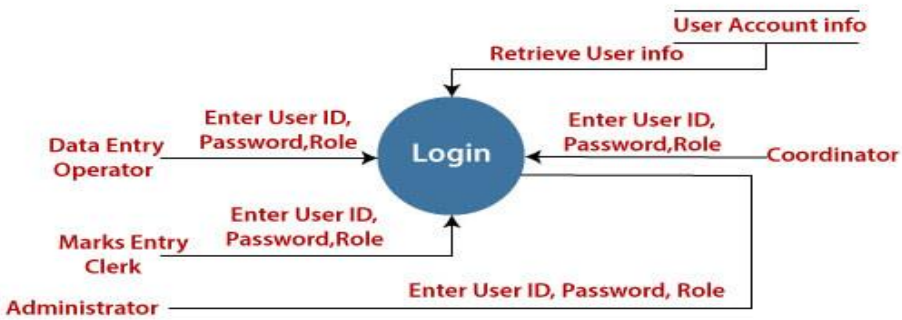
2-level DFD goes one process deeper into parts of 1-level DFD. It can be used to project or record the specific/necessary detail about the system's functioning.

1.User Account Maintenance

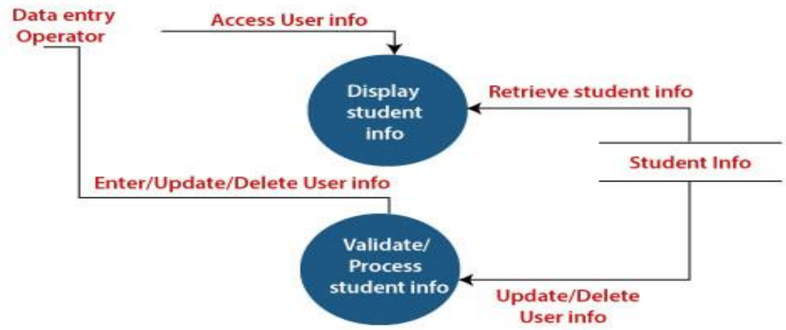


2. Login

The level 2 DFD of this process is given below:

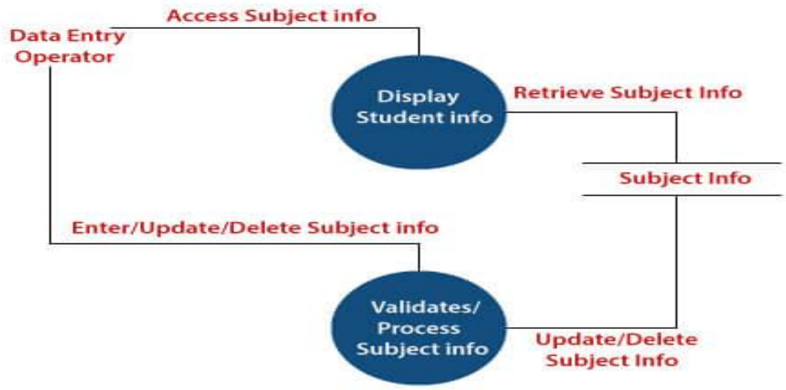


3. Student Information Management



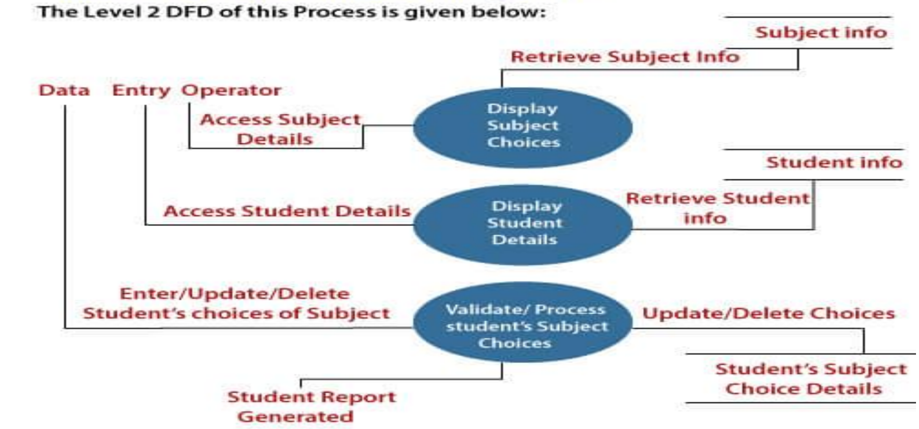
4. Subject Information Management

The level 2 DFD of this process is given below:



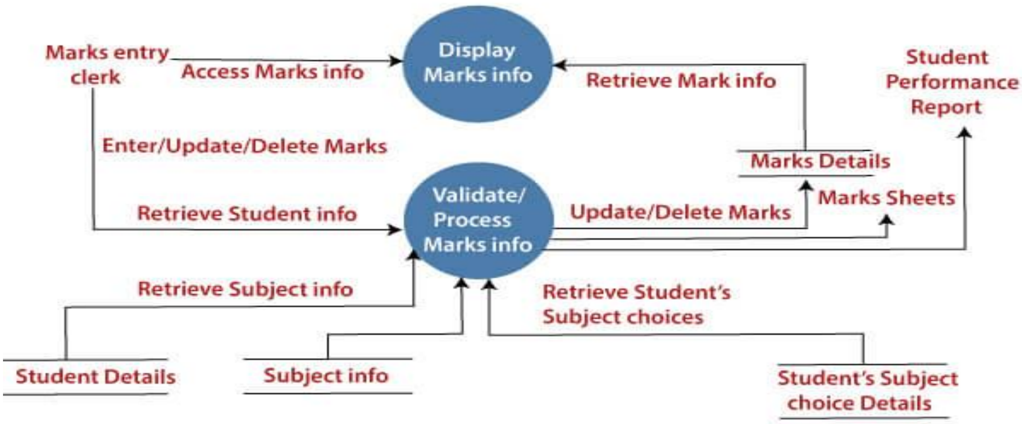
5. Student's Subject Choice Management

The Level 2 DFD of this Process is given below:



6. Marks Information Managment

The Level 2 DFD of this Process is given below:



Data Dictionaries

A data dictionary is a file or a set of files that includes a database's metadata. The data dictionary hold records about other objects in the database, such as data ownership, data relationships to other objects, and other data. The data dictionary is an essential component of any relational database. Ironically, because of its importance, it is invisible to most database users. Typically, only database administrators interact with the data dictionary.

The data dictionary, in general, includes information about the following:

- Name of the data item
- Aliases
- Description/purpose
- Related data items
- Range of values
- Data structure definition/Forms

The **name of the data item** is self-explanatory.

Aliases include other names by which this data item is called DEO for Data Entry Operator and DR for Deputy Registrar.

Description/purpose is a textual description of what the data item is used for or why it exists.

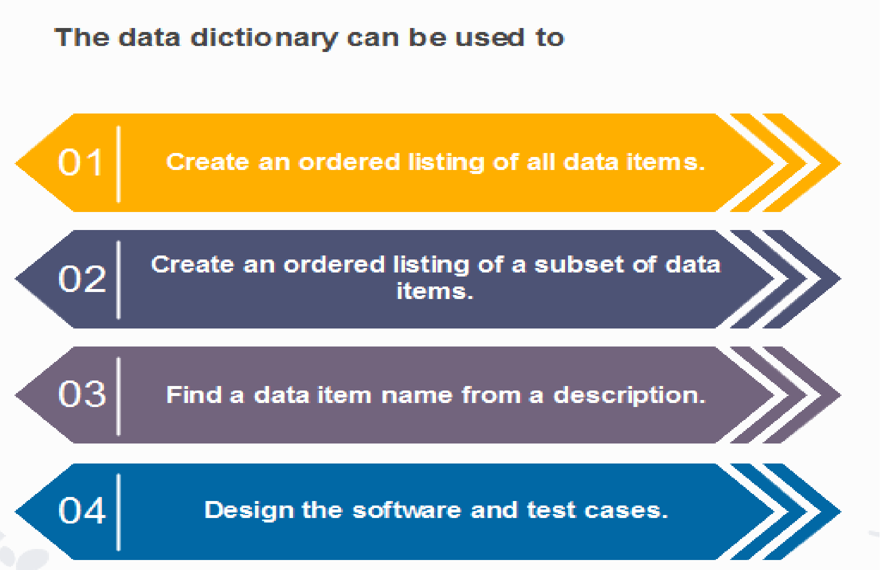
Related data items capture relationships between data items e.g., total_marks must always equal to internal_marks plus external_marks.

Range of values records all possible values, e.g. total marks must be positive and between 0 to 100.

Data structure Forms: Data flows capture the name of processes that generate or receive the data items. If the data item is primitive, then data structure form captures the physical structures of the data item. If the data is itself a data aggregate, then data structure form capture the composition of the data items in terms of other data items.

The mathematical operators used within the data dictionary are defined in the table:

x=a+b	x includes of data elements a and b.
x=[a/b]	x includes of either data elements a or b.
x=a x	includes of optimal data elements a.
x=y[a]	x includes of y or more occurrences of data element a
x=[a]z	x includes of z or fewer occurrences of data element a
x=y[a]z	x includes of some occurrences of data element a which are between y and z.



Entity-Relationship Diagrams

ER-modeling is a data modeling method used in software engineering to produce a conceptual data model of an information system. Diagrams created using this ER-modeling method are called Entity-Relationship Diagrams or ER diagrams or ERDs.

Purpose of ERD

- The database analyst gains a better understanding of the data to be contained in the database through the step of constructing the ERD.
- The ERD serves as a documentation tool.
- Finally, the ERD is used to connect the logical structure of the database to users. In particular, the ERD effectively communicates the logic of the database to users.

Components of an ER Diagrams

1. Entity

An entity can be a real-world object, either animate or inanimate, that can be merely identifiable. An entity is denoted as a rectangle in an ER diagram. For example, in a school database, students, teachers, classes, and courses offered can be treated as entities. All these entities have some attributes or properties that give them their identity.

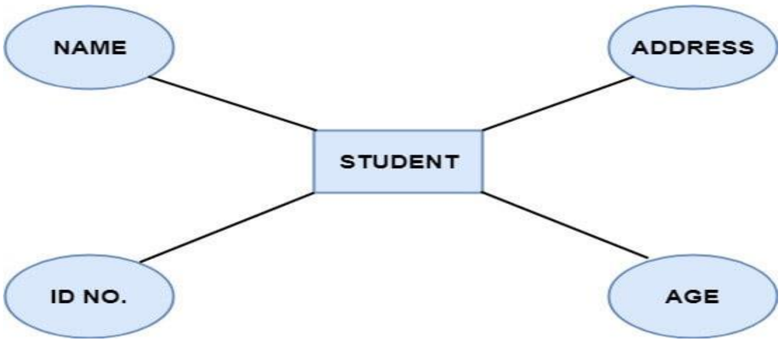
Entity Set

An entity set is a collection of related types of entities. An entity set may include entities with attribute sharing similar values. For example, a Student set may contain all the students of a school; likewise, a Teacher set may include all the teachers of a school from all faculties. Entity set need not be disjoint.

2. Attributes

Entities are denoted utilizing their properties, known as attributes. All attributes have values. For example, a student entity may have name, class, and age as attributes.

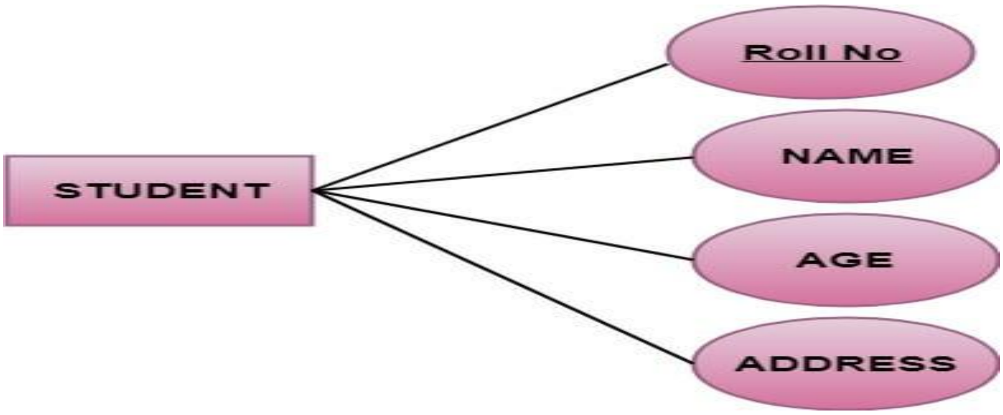
There exists a domain or range of values that can be assigned to attributes. For example, a student's name cannot be a numeric value. It has to be alphabetic. A student's age cannot be negative, etc.



There are four types of Attributes:

1. Key attribute
2. Composite attribute
3. Single-valued attribute
4. Multi-valued attribute
5. Derived attribute

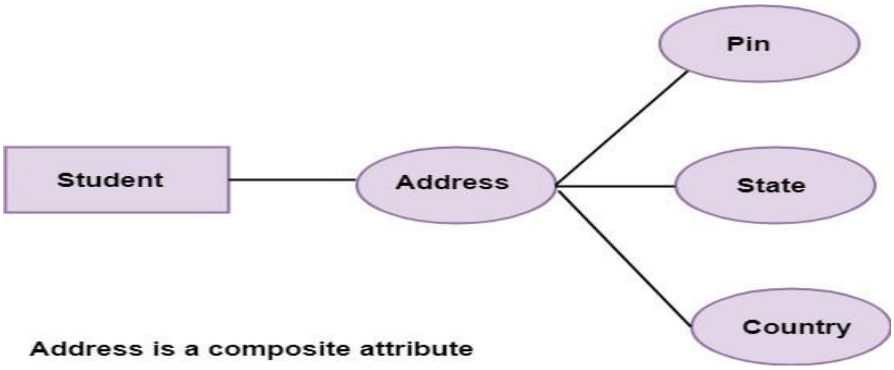
1. Key attribute: Key is an attribute or collection of attributes that uniquely identifies an entity among the entity set. For example, the roll_number of a student makes him identifiable among students.



There are mainly three types of keys:

1. **Super key:** A set of attributes that collectively identifies an entity in the entity set.
2. **Candidate key:** A minimal super key is known as a candidate key. An entity set may have more than one candidate key.
3. **Primary key:** A primary key is one of the candidate keys chosen by the database designer to uniquely identify the entity set.

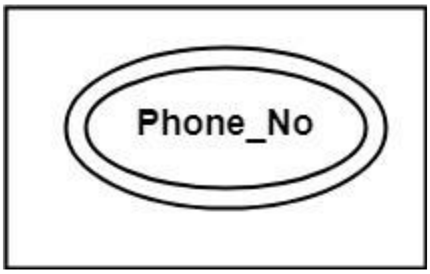
2. Composite attribute: An attribute that is a combination of other attributes is called a composite attribute. For example, In student entity, the student address is a composite attribute as an address is composed of other characteristics such as pin code, state, country.



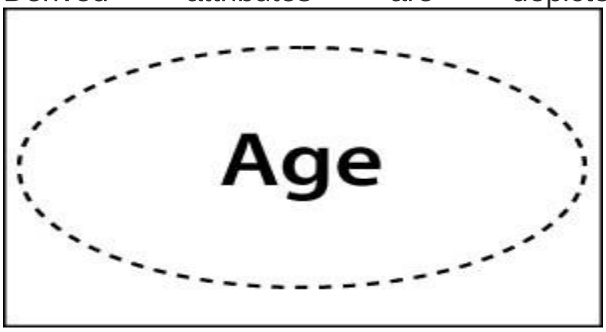
Address is a composite attribute

3. Single-valued attribute: Single-valued attribute contain a single value. For example, Social_Security_Number.

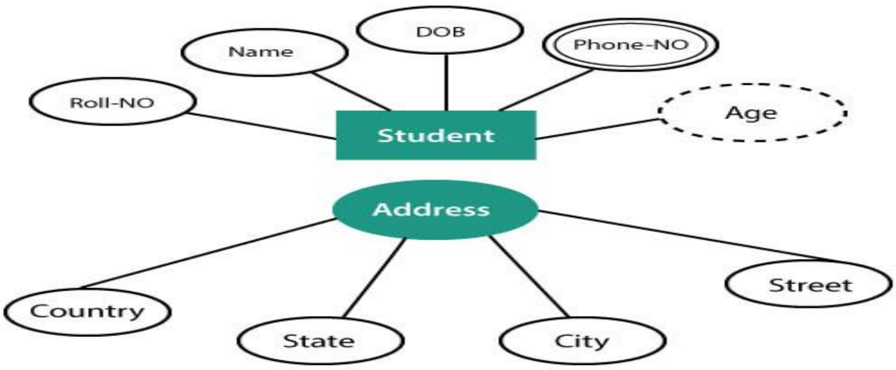
4. Multi-valued Attribute: If an attribute can have more than one value, it is known as a multi-valued attribute. Multi-valued attributes are depicted by the double ellipse. For example, a person can have more than one phone number, email-address, etc.



5. Derived attribute: Derived attributes are the attribute that does not exist in the physical database, but their values are derived from other attributes present in the database. For example, age can be derived from date_of_birth. In the ER diagram, Derived attributes are depicted by the dashed ellipse.



The Complete entity type Student with its attributes can be represented as:



3. Relationships

The association among entities is known as relationship. Relationships are represented by the diamond-shaped box. For example, an employee works_at a department, a student enrolls in a course. Here, Works_at and Enrolls are called relationships.

Fig: Relationships in ERD

Relationship set

A set of relationships of a similar type is known as a relationship set. Like entities, a relationship too can have attributes. These attributes are called descriptive attributes.

Degree of a relationship set

The number of participating entities in a relationship describes the degree of the relationship. The three most common relationships in E-R models are:

1. Unary (degree1)
2. Binary (degree2)
3. Ternary (degree3)

1. Unary relationship: This is also called recursive relationships. It is a relationship between the instances of one entity type. For example, one person is married to only one person.

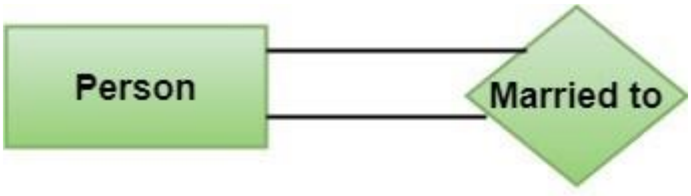


Fig: Unary Relationship

2. Binary relationship: It is a relationship between the instances of two entity types. For example, the Teacher teaches the subject.

Fig: Binary Relationship

3. Ternary relationship: It is a relationship amongst instances of three entity types. In fig, the relationships "**may have**" provide the association of three entities, i.e., TEACHER, STUDENT, and SUBJECT. All three entities are many-to-many participants. There may be one or many participants in a ternary relationship.

In general, "**n**" entities can be related by the same relationship and is known as **n-ary** relationship.

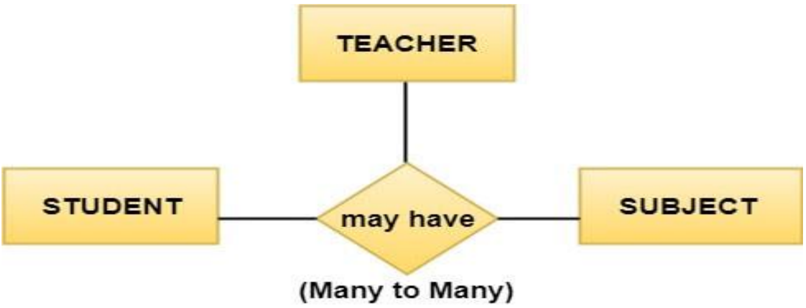


Fig: Ternary Relationship

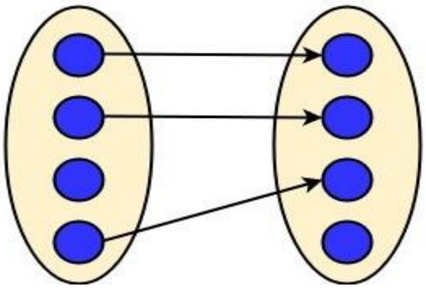
Cardinality

Cardinality describes the number of entities in one entity set, which can be associated with the number of entities of other sets via relationship set.

Types of Cardinalities

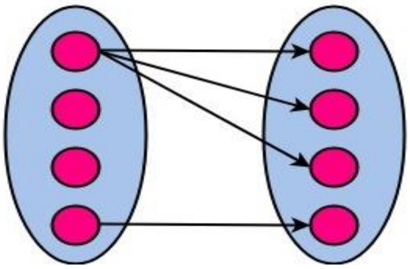
1. One to One: One entity from entity set A can be contained with at most one entity of entity set B and vice versa. Let us assume that each student has only one student ID, and each student ID is assigned to only one person. So, the relationship will be one to one.

Using Sets, it can be represented as:



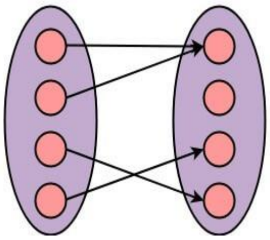
2. One to many: When a single instance of an entity is associated with more than one instances of another entity then it is called one to many relationships. For example, a client can place many orders; a order cannot be placed by many customers.

Using Sets, it can be represented as:



3. Many to One: More than one entity from entity set A can be associated with at most one entity of entity set B, however an entity from entity set B can be associated with more than one entity from entity set A. For example - many students can study in a single college, but a student cannot study in many colleges at the same time.

Using Sets, it can be represented as:



4. Many to Many: One entity from A can be associated with more than one entity from B and vice-versa. For example, the student can be assigned to many projects, and a project can be assigned to many students.

Using Sets, it can be represented as: