

Chapter 1

Overview of Systems Analysis and Design

What is System?

A system is a collection of components (subsystems) that work together to realize some objective. For example, the **library system** contains librarians, books, and periodicals as components to provide knowledge for its members.

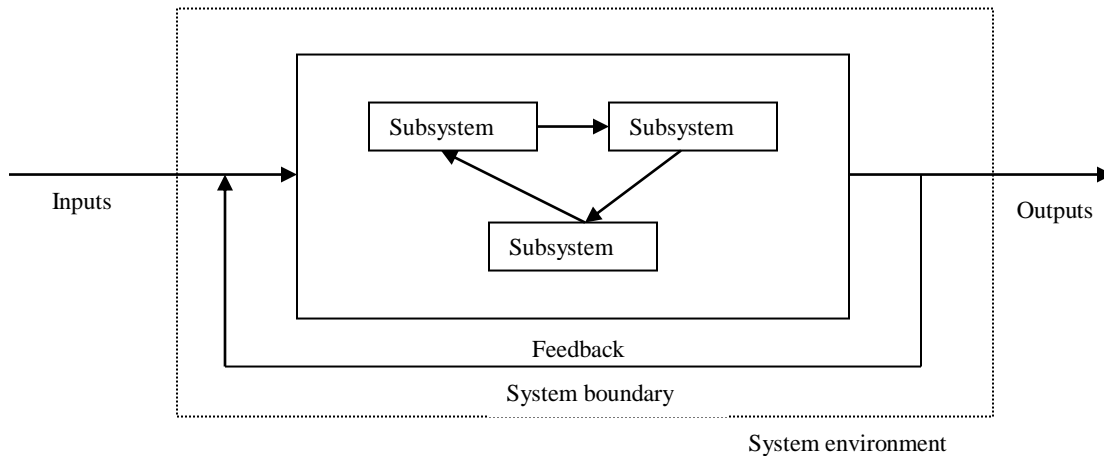


Fig: Basic System Model

Every system has three *activities* or *functions*. These activities are *input*, *processing* and *output*.

- **Input:** It involves capturing and assembling elements that enter the system to be processed. Inputs to the system are anything to be captured by the system from its environment. For example, *raw materials*.
- **Processing:** It involves transformation processes that convert input to output. For example, a *manufacturing process*.
- **Output:** It involves transferring elements that have been produced by a transformation process to their ultimate destinations. Outputs are the things produced by the system and sent into its environment. For example, *finished products*.

The system also includes other two additional activities. These activities include *feedback* and *control*.

- **Feedback:** It is data about the performance of a system. It is the idea of monitoring the current system output and comparing it to the system goal. Any variation from the goal are then fed back in to the system and used to adjust it to ensure that it meets its goal. For example, data about sales performance is feedback to a sales manager.
- **Control:** It involves monitoring and evaluating feedback to determine whether a system is moving toward the achievement of its goals. The control function then makes necessary adjustments to a system's input and processing components to ensure that it produces proper output. For example, a sales manager exercises control

when reassigning salespersons to new sales territories after evaluating feedback about their sales performance.

Theoretical approaches to systems have introduced many generalized *principles*. **Goal setting** is one such principle. It defines exactly what the system is supposed to do. There are principles concerned with system structure and behavior. **System boundary** is one such a principle. This defines the components that make up the system. Anything outside the system boundary is known as **system environment**. A system can be made up of any number of **subsystems**. Each subsystem carries out part of the system function i.e. part of the system goal. The subsystems communicate by passing messages between themselves.

Several systems may share the same environment. Some of these systems may be connected to one another by means of a shared boundary, or **interface**. A system that interacts with other systems in its environment is called **open system**. Finally, a system that has the ability to change itself or environment in order to survive is called an **adaptive system**.

What is an Information System?

In a simplest sense, a system that provides information to people in an organization is called **information system (IS)**.

Information systems in organizations capture and manage data to produce useful information that supports an organization and its employees, customers, suppliers and partners. So, many organizations consider information system to be the essential one.

Information systems produce information by using data about significant *people*, *places*, and *things* from within the organization and/or from the external environment to *make decisions, control operations, analyze problems, and create new products or services*. **Information** is the data shaped into a meaningful form. **Data**, on the other hand, are the collection of raw facts representing events occurring in organizations or the environment before they have been organized and arranged into a form that people can understand and use.

The three activities to produce information in an information system are *input*, *processing*, and *output*. **Input** captures or collects raw data from within the organization or from its external environment for processing. **Processing** converts these raw data into the meaningful information. **Output** transfers this information to the people who will use it or to the activities for which it will be used. Information systems also require **feedback**, which is used to monitor the current information system output and compare it to the system goal.

The two types of information systems are **formal** and **informal**. **Formal information systems** are based on accepted and fixed definitions of data and procedures for collecting, storing, processing, disseminating, and using these data with predefined rules. **Informal information systems**, in contrast, rely on unstated rules.

Formal information systems can be **manual** as well as **computer based**. **Manual information systems** use paper-and-pencil technology. In contrast, **computer-based information systems (CBIS)** rely on computer hardware and software for processing and disseminating information.

Types of Information Systems

In practice there are several classes of information systems in organizations. Each class serves the needs of different types of users. These are *transaction processing system (TPS)*, *management information system (MIS)*, *decision support system (DSS)*, *executive information system (EIS)*, *expert system*, *communication and collaboration system*, and *office automation system*.

Transaction Processing Systems (TPSs)

These are the computerized systems that perform and records the daily routine transactions necessary to conduct business. These systems serve the operational level of the organization. Some examples include sales order entry, hotel reservation systems, payroll, employee record keeping, and shipping.

Transaction processing systems are central to a business. TPS failure for a few hours can cause a firm's demise and perhaps other firms linked to it. Managers need TPS to monitor the status of internal operations and the firm's relations with external environment. TPS are also major producers of information for the other types of systems.

Online transaction processing systems (OLTPS) is an interactive data processing system that involves a direct connection between TPS programs and users. As soon as a single transaction is entered into a computer system, the program interacts immediately with the user for that transaction. It is often known as the live system where there is no time lag between data creation and its processing. A good example of this system is online ticket reservation system.

Management Information Systems (MISs)

These are the information systems at the management level of an organization and serve management-level functions like planning, controlling, and decision-making. These systems provide reports that are usually generated on a predetermined schedule and appear in prearranged format. Typically, these systems use internal data provided by the transaction processing systems. These systems are used for structured decision-making and in some cases for semi-structured decision making as well. Salary analysis and sales reporting are the examples in which MIS can be used.

Decision Support Systems (DSSs)

These systems also serve at the management level of the organization. These systems combine data and sophisticated analytical models or data analysis tools to support semi-structured and unstructured decision-making. These systems use internal information from TPS and MIS, and often information from external sources, such as current stock prices or product prices of competitors. DSS have more analytical power than other systems. Contract cost analysis is an example in which DSS can be used.

Executive Information Systems (EISs)

These systems are also called **executive support systems (ESSs)** and serve the strategic level of the organization. These systems are designed to address unstructured decision making through advanced graphics and communication. These systems incorporate data about external events such as new tax laws or competitors, but they also draw

summarized information from internal MIS and DSS.

These systems are not designed to solve a specific problem but they provide a generalized computing and telecommunication capacity that can be applied to a changing array of problems. 5-year operating plan is an example in which EIS can be used.

Expert Systems

An expert system is an extension of DSS that captures and reproduces the knowledge and expertise of an expert problem solver or decision maker and then simulates the “thinking” or “actions” of that expert. These systems imitate the logic and reasoning of the experts within their respective fields.

Expert systems are implemented with artificial intelligence (AI) technology that captures, stores, and provides access to the reasoning of the experts.

Communication and Collaboration Systems

These systems enable more effective communications between workers, partners, customers and suppliers to enhance their ability to collaborate. These systems use network technology that allows companies to coordinate with other organizations across great distances. These systems create new efficiencies and new relationships between an organization, its customers and suppliers, and business partners redefining organizational boundaries.

Office Automation Systems

Office automation (OA) is more than word processing and spreadsheet applications. Office automation systems support the wide range of business office activities for improved work flow and communication between workers, regardless of whether or not those workers are located in the same office.

Office automation functions include word processing, spreadsheet applications, electronic mails, work group computing, fax processing, work flow management etc.

Office automation systems can be designed to support both individuals and work groups. **Personnel information systems** are those designed to meet the needs of a single user. They are designed to boost an individual’s productivity. **Work group information systems**, on the other hand, are designed to meet the needs of a work group. They are designed to boost the group’s productivity.

Systems Analysis and Design

System analysis and design is a complex, challenging, and simulating organizational process that a team of business and systems professionals uses to develop and maintain computer-based information systems. It is an organizational improvement process. Information systems are built and rebuilt for organizational benefits.

An important (but not the only) result of system analysis and design is **application software** i.e. software designed to support organizational functions or processes such as inventory management, payroll, or mark-sheet analysis. In addition to application software, the total information system includes the hardware and systems software on which the application software runs, documentation and training materials, the specific

job roles associated with the overall system, controls and the people who use the software along with their work methods.

In systems analysis and design, we use various *methodologies*, *techniques* and *tools* that have been developed, tested, and widely used over the years to assist people during system analysis and design.

Methodologies are comprehensive, multistep approaches to systems development that will guide your work and influence the quality of your final product: the information system. Methodologies use a standard set of steps. A methodology adopted by an organization will be consistent with its general management style. Most methodologies incorporate several development techniques.

Techniques are particular processes that will help to ensure that your work is well thought-out, complete, and comprehensible to other on the project team. Techniques also provide support for a wide range of tasks like conducting interviews, planning and managing the activities in a system development project, diagramming the system's logic, and designing the reports that the system will generate.

Tools are typically computer programs that make it easy to use and benefit from the techniques and to faithfully follow the guidelines of the overall development methodology.

To be effective, both techniques and tools must be consistent with an organizations system development methodology. These make easy for system developers to conduct the steps in methodology.

Importance of Systems Analysis and Design

Systems analysis and design is the collection of important activities that takes place when new information systems are being built or existing ones are changed. All the activities are needed to build good information systems. The systems developed by using systems analysis and design activities fulfill the requirements of organizations' personnel.

Furthermore, we can develop information systems easily and rapidly because there are lots of supporting methodologies, tools, and techniques. The information system can be built in the most effective way. The systems also fit into an existing environment and will be very easy to use and maintain. By following the activities involved in systems analysis and design, we can develop high quality information system within allocated budget and time.

Information System Stakeholders

A stakeholder is any person who has an interest in an existing or proposed information system. She/he may be *technical* or *non-technical* and *internal* or *external* worker. Stakeholders are also called **information workers**. An information worker involves in *creating*, *collecting*, *processing*, *distributing* and *using* information.

There are **six groups** of stakeholders and each group has a different role in the same information system. But in practice, any individual person may play more than one role. For example, a system analyst may also work as a system designer. The six groups are: system owners, system users, system designers, system builders, system analysts and

project managers, and information technology vendors and consultants.

System owners

System owners are the information system's sponsors and chief advocates. They are usually responsible for funding the project of development, operate, and maintain the information system. They are interested with-how much will the system cost? And how much value or what benefit will the system return to the business?

Every information system has one or more system owners. They usually come from the ranks of managers to supervisors.

System Users

These are the people who use or are affected by the information system on a regular basis. They are concerned with the system's functionality related with their jobs and the system's ease of learning and use. A system user may capture, validate, enter, respond, store and exchange data and information. System users are also called **clients**. To know business requirements, discussions with most users need to be kept.

System Designers

These are technology specialists who translate system users' business requirements and constraints into technical solutions. These are interested in information technology choices and the design of systems within the constraints of the chosen technology. They design the computer database, inputs, outputs, screens, networks, and programs that will meet the system users' requirements. These designs guide the construction of the final system.

System Builders

These are also technology specialists who construct information systems and components based on the design specifications generated by the system designer.

Systems Analysts and Project Managers

A. Systems Analyst: Although, many people in organizations are responsible for systems analysis and design, in most organizations the systems analyst has the primary responsibility. The primary role of a systems analyst is to study the problems and needs of an organization in order to determine how people, methods and information technology can best be combined to bring about improvements in the organization. System analysts identify and validate problems and needs and ensure that the technical solution fulfills these problems and needs.

Systems analysts study the system and identify and validate its problems and needs for system owners and users and ensure that the technical solution fulfills the business needs.

B. Project Manager: To build a good information system and applications all the stakeholders must work together as a team. Teams require leadership. For this reason, usually one or more of these stakeholders takes on the role of project manager to ensure that systems are developed on time, within budget and acceptable quality. So, project manager is responsible for planning, monitoring, and controlling projects with

respect to schedule, budget, deliverables, customer satisfaction, technical standards and system quality.

Information Technology Vendors and Consultants

Most information systems are dependent on information technology that must be selected, installed and customized, integrated into business, and technically supported. This technology is developed, sold, and supported by IT vendors.

Similarly, many businesses rely on external consultants to help them develop or acquire information systems and technology. The use of consultants may be driven by the need for specialized knowledge or skills or by an immediate need to complete a project.

Preparing Career as a Systems Analyst

System analysts are the key individuals in the information system development process. To succeed as a system analyst, you will need to develop the following skills.

- **Working Knowledge of Information Technology:** This is the technical skill. The analyst must be aware of both existing and emerging information technology. Such knowledge can be acquired by college courses, seminars and training programs.
- **Computer Programming Experience and Expertise:** This is also a technical skill needed by systems analysts. Most system analyst need to be proficient in one or more high level programming language.
- **General Knowledge of Business Processes and Terminology:** Most of the systems today are business related and the systems analysts must be able to communicate with business experts to gain understanding of their problems and needs. So, this skill is must. To develop this skill, the system analyst should have knowledge about the courses like accounting, finance, business law and ethics, economics, manufacturing, marketing, operations management, human resource management, organizational behavior etc.
- **General Problem Solving Skill:** The systems analyst must be able to take a large business problem, break down that problem into its component parts, analyze the various aspects of the problem, and then assemble into an improved system to solve the problem. To develop this skill, a system analyst should have knowledge about critical thinking and reasoning.
- **Good Interpersonal Communication Skill:** To know the user requirements, an analyst must be able to communicate orally and in writing. To develop this skill, the courses like business and technical writing, business and technical speaking, interviewing and listening will be effective.
- **Good Interpersonal Relations Skill:** The systems analysts should interact with all the stakeholders in the information system development project. To do this they must have this skill. To improve this skill, the analyst should have knowledge about the courses like teamwork, principles of persuasion, managing change and conflict, and leadership.
- **Flexibility and Adaptability:** No two projects are alike. So, a successful system analyst must learn to be flexible and to adapt to unique challenges and situations.

- **Character and Ethics:** The system analyst should have strong character and a sense of right and wrong. This is needed to hide the sensitive and confidential facts and information of an organization.
- **System Analysis and Design Skill:** All systems analysts should know concepts and principles, tools, and techniques of information systems development.

Developing Information Systems and System Development Life Cycle (SDLC)

Most organizations use a standard set of steps, called a **systems development methodology** to develop and support their information systems. It is a standard process followed in an organization to conduct all the steps necessary to analyze, design, implement, and maintain information systems. And **systems development life cycle (SDLC)** is the traditional methodology used to develop, maintain, and replace information systems. It includes different phases as shown in the figure below. This representation of SDLC is sometimes referred to as the **waterfall model** or **classic life cycle**.

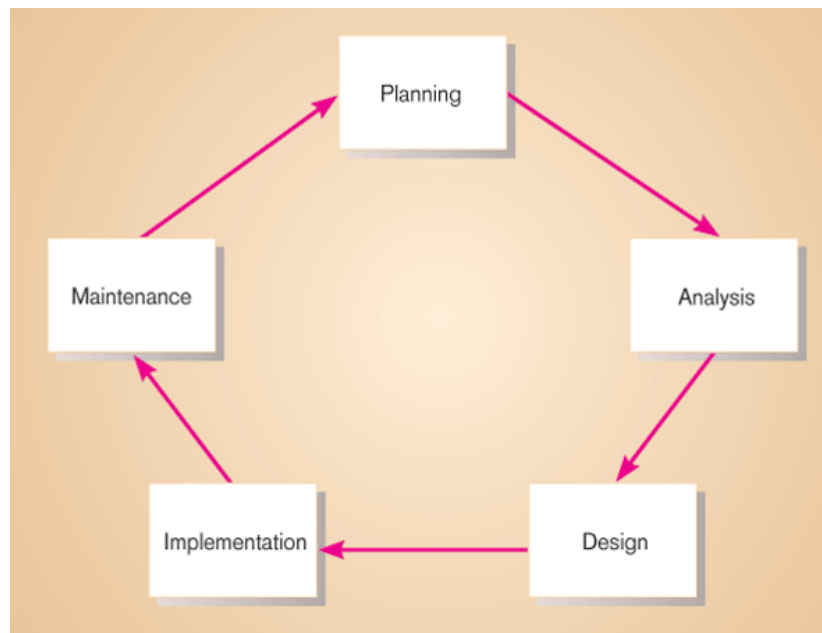


Fig: The systems development life cycle

The first phase is called **planning**. In this phase, someone identifies the need for a new or enhanced system. These needs are then analyzed, prioritized and arranged into a plan for the IS department. Here, a potential information systems project is explained and an argument for continuing or not continuing with the project is presented; a detailed plan is also developed for conducting the remaining phases or the SDLC for the proposed system.

The next phase is called **analysis**. During this phase, the analyst studies the current system and proposes alternative replacement systems. Here, the analyst thoroughly

studies the organization's current procedures and the information systems used to perform organizational tasks. The analyst work with users to determine what the users want from a proposed system. The analyst carefully studies any current systems, manual and computerized, that might be replaced or enhanced as part of this project. The analyst studies the requirements and structures them according to their interrelationships and eliminates any redundancies; generates alternative initial designs to match the requirements; compare these alternatives to determine which best meets the requirements within the cost, labor, and technical levels the organization is willing to commit to the development process. The output of this phase is a description of the recommended alternative solution. Once the recommendation is accepted by owners, you can begin to make plans to acquire any hardware and system software necessary to build or operate the system as proposed.

The next phase is called **design**. During this phase, you convert the description of the recommended alternative solution into logical and then physical system specification. Here, you must design all aspects of the system from input and output screens to reports, databases, and computer processes. **Logical design** is the part of the design process that is independent of any specific hardware or software platform. Theoretically, the system could be implemented on any hardware and systems software. **Physical design** is the part of the design phase in which the logical specifications of the system from logical design are transformed into technology-specific details from which all programming and system construction can be accomplished.

The next phase is called **implementation**. In this phase, the information system is coded, tested, installed, and supported in the organization. During coding, programmers write the programs that make up the information system. During testing, programmers and analysts test individual programs and the entire system in order to find and correct errors. During installation, the new system becomes a part of the daily activities of the organization. Implementation activities also include initial user support such as the finalization of documentation, training programs, and ongoing user assistance.

The final phase of SDLC is called **maintenance**. In this phase, information system is systematically repaired and improved. When a system is operating in an organization, users sometimes find problems with how it works and often think of better ways to perform its functions. Also the organization's needs with respect to the system change over time. In maintenance, you make the changes that users ask for and modify the system to reflect changing business conditions.

Waterfall model is the oldest and the most widely used paradigm for information systems development. While it does have weaknesses, it is significantly better than a haphazard approach. This model is suitable for the projects in which user requirements are certain and precise. The problems that are sometimes encountered with the linear sequential model are:

- Changes can cause confusion as the project team proceeds.
- It is often difficult for the customer to state all requirements explicitly. The linear sequential model requires this and makes difficulty to respond to changing customer requirements.

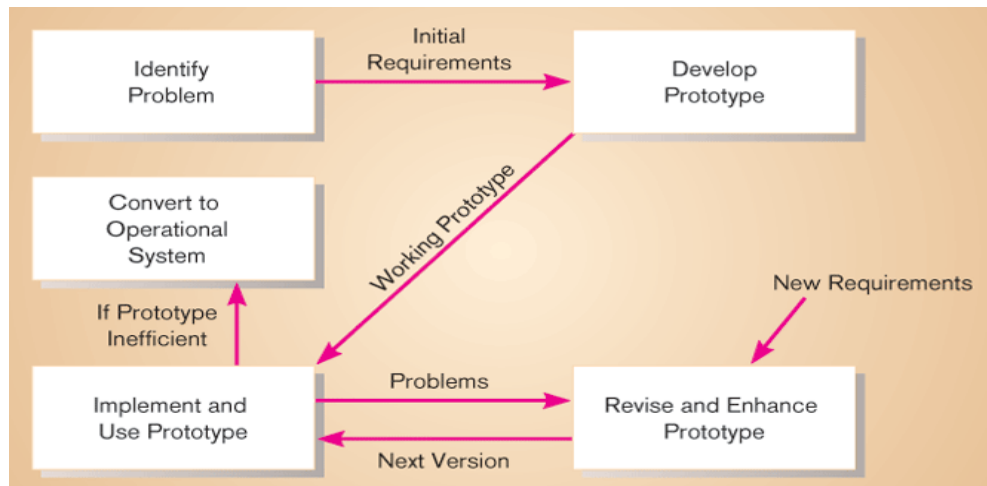
- A working version of the system will be available to customers late in the project time-span. A major blunder, if undetected until the working program is reviewed, can be disastrous.
- The linear nature of the classic life cycle leads to “blocking states” in which some project team members must wait for other members of the team to complete dependent tasks.
- User involvement is limited.

Different Approaches to Improving Information Systems Development

Several different approaches have been developed in the continuous effort to improve the systems analysis and design process. The two important approaches are **prototyping** and **joint application development (JAD)**.

Prototyping

Prototyping is a form of **rapid application development (RAD)**. Prototyping is a *rapid, iterative, and incremental* process of systems development in which requirements are converted to a working system that is continually revised through close work between the development team and the users. We can build a prototype with any computer language or development tool, but special prototyping tools have been developed to simplify the process. A prototype can be developed with some fourth-generation language (4GL), with the query and screen and report design tools of a database management system, and with tools called *computer-aided software engineering (CASE)* tools.



In prototyping, the analyst works with users to determine the initial or basic requirements for the system. The analyst then quickly builds a prototype. When the prototype is completed, the users work with it and tell the analyst what they like and do not like about it. The analyst uses this feedback to improve the prototype and takes the new version back to the users. This iterative process continues until the users are relatively satisfied with what they have seen.

Ideally, the prototype serves as a mechanism for identifying information system requirements. In this case, we throw away the prototype (also called **throwaway prototype**) after identifying requirements. The actual information system is developed with an eye toward quality and maintainability based on the requirements.

◆ **Advantages:**

- Useful for projects in which user requirements are uncertain or imprecise.
- It encourages active user and management participation.
- Projects have higher visibility and support because of the extensive user involvement.
- Users and management see working, software based solutions more rapidly.
- Errors and omissions tend to be detected earlier in prototypes.
- Testing and training are natural by-products.
- It is more natural process.
- It is most popular for small to medium-size projects.

◆ **Disadvantages:**

- It increases lifetime cost to operate, support and maintain the system.
- It can solve the wrong problems since problem analysis is abbreviated or ignored.
- The product may have less quality because of speed in development.

Joint Application Development (JAD)

It is used for collecting information system requirements and reviewing system designs. It is a structured process in which users, managers, and analysts work together for several days in a series of intensive structured meetings run by a JAD session leader to specify or review system requirements. Here, people work together to agree on system requirements and design details, time and organizational resources are better managed. Group members are more likely to develop a shared understanding of what the IS is supposed to do.

Computer-aided Software Engineering (CASE) Tools

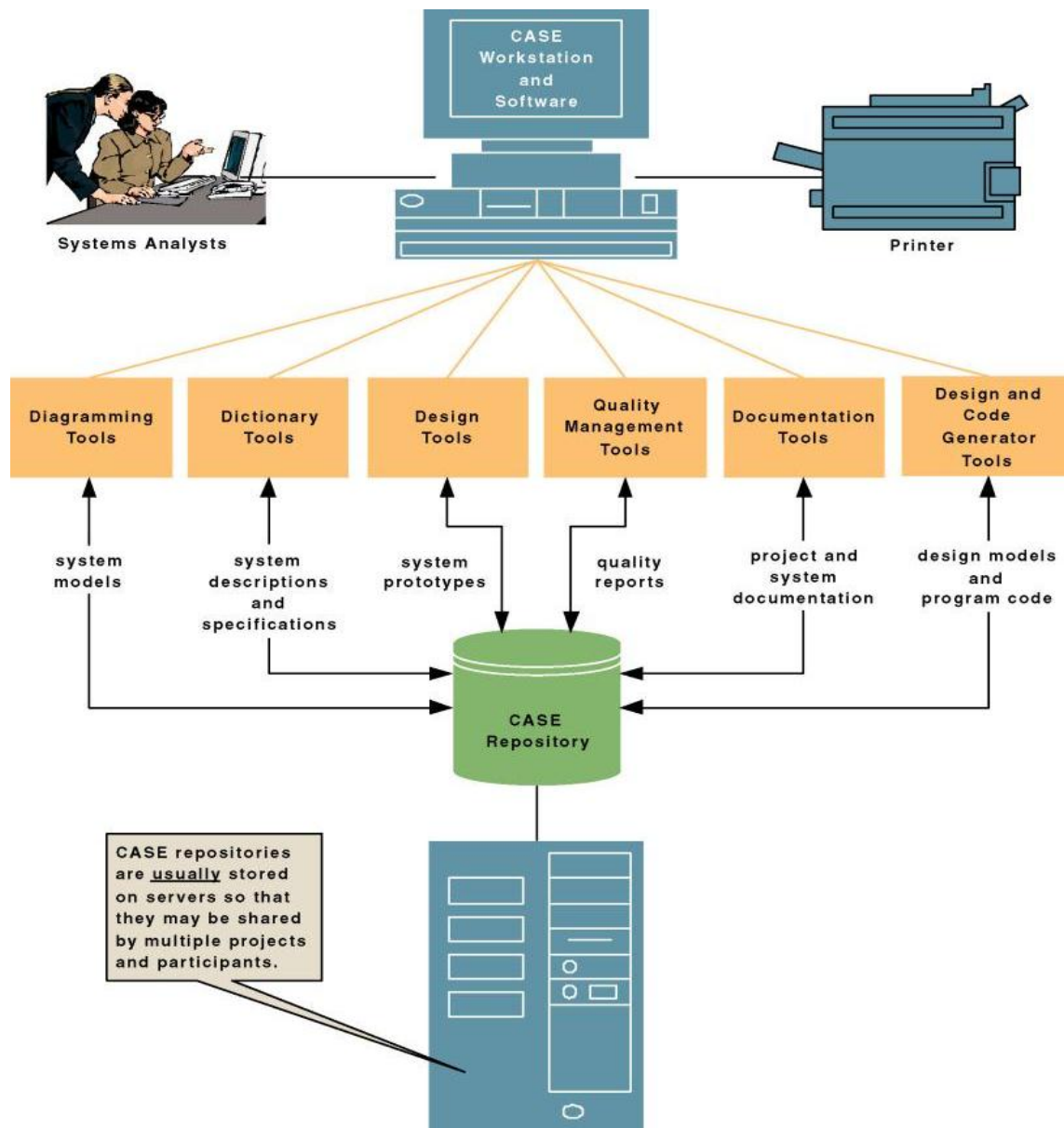
Computer-aided systems engineering (CASE) tools are the software programs that help the development team do their jobs more efficiently and more effectively. These tools support the drawing and analysis of system models. Some CASE tools also provide prototyping and code generation capabilities. Some examples are: Oracle's Designer 2000, Rational's Rose, Platinum's Erwin, Popkin's System Architect 2001, and Visible System's Visible Analyst.

At the center of any CASE tool's architecture is a developer's database called a *CASE repository*. **CASE repository** is a system developer's database where developers can store system models, detailed description and specification, and other products of system development. It is also called **dictionary** or **encyclopedia**.

Around the CASE repository is a collection of tools or facilities for creating system models and documentation. These facilities generally include:

- **Diagramming tools** – These tools are used to draw system models.
- **Dictionary tools** – These tools are used to record, delete, edit, and output detailed documentation and specification.

- **Design tools** – These tools are used to construct system components including system inputs and outputs. These are also called **prototyping tools**.
- **Documentation tools** – These tools are used to assemble, organize, and report on



system models, descriptions and specifications, and prototypes.

- **Quality management tools** – These tools are used to analyze system models, descriptions and specifications, and prototypes for completeness, consistency, and conformance to accepted rules of methodologies.
- **Design and code generator tools** – These tools automatically generate database designs and application programs or significant portions of those programs.

Today's CASE tools provide two distinct ways to develop system models – *forward engineering* and *reverse engineering*. **Forward engineering** requires the system analyst to draw system models, either from scratch or from templates. The resulting models are

subsequently transformed into program code. **Reverse engineering**, on the other hand, allows a CASE tool to read existing program code and transform that code into a representative system model that can be edited and refined by the systems analyst. CASE tools that allow for bi-directional, forward and reverse engineering are said to provide for “round-trip engineering”. The figure below shows CASE tool architecture.

Chapter 2

Modeling Tools for Systems Analyst

Entity Relationship Diagram (E-R Diagram)

During *analysis* phase, a systems analyst uses **entity relationship data model (E-R model)** as a **conceptual data model**. A **conceptual data model** is a detailed model that captures the overall structure of organizational data while being independent of any database management system or other implementation consideration. And an **E-R model** is a detailed, logical representation of the data for an organization or for a business area. The E-R model is expressed in terms of entities in the business environment, the relationships or associations among those entities, and the attributes or properties of both the entities and their relationships. An E-R model is normally expressed as an **entity relationship diagram (E-R diagram)**, which is a graphical representation of an E-R model. It has three basic concepts: **entities**, **attributes**, and **relationships**.

Entities

An entity is a person, place, object, event, or concept in the user environment about which the organization wishes to capture and store data. An **entity type** (sometimes called an **entity class** or **entity set**) is a collection of entities that share common properties or characteristics. An **entity instance** (or **instance**) is a single occurrence of an entity type.

Each entity type in E-R diagram is given a name. When naming entity types, we should use the following guidelines:

- An entity type name is a *singular noun* like CUSTOMER, STUDENT, or AUTOMOBILE.
- An entity type name should be *descriptive and specific to the organization* like PURCHASE ORDER for orders placed with suppliers to distinguish it from CUSTOMER ORDER for orders placed by customers.
- An entity type name should be *concise* like REGISTRATION for the event of a student registering for a class rather than STUDENT REGISTRATION FOR CLASS.
- *Event entity types* should be named for the *result of the event*, not the activity or process of the event like the event of a project manager assigning an employee to work on a project results in an ASSIGNMENT.

Each entity type in E-R diagram should be defined. When defining entity types, we should use the following guidelines:

- An entity type definition should include a statement of *what the unique characteristic(s) is (are) for each instance*.
- An entity type definition should make clear *what entity instances are included and not included* in the entity type.
- An entity type definition often includes a description of *when an instance of the entity type is created or deleted*.
- For some entity types the definition must specify *when an instance might change into an instance of another entity type*. For example, a bid for a construction company

becomes a contract once it is accepted.

- For some entity types the definition must specify *what history is to be kept about entity instances*.

An entity type in E-R diagram is drawn using **rectangle**. This shape represents all instances of the named entity. We place entity type name inside the rectangle. For example, the figure below shows STUDENT entity type.



Attributes

Each entity type has a set of attributes associated with it. An attribute is a property or characteristic of an entity that is of interest to the organization. For example, STUDENT entity type may have Student_ID, Student_Name, Home_Address, Phone_Number, and Major as its attributes. Similarly, EMPLOYEE entity type may have Employee_ID, Employee_name, and Skill, Address as its attributes.

Each attribute in E-R diagram is given a name. When naming attributes, we should use the following guidelines:

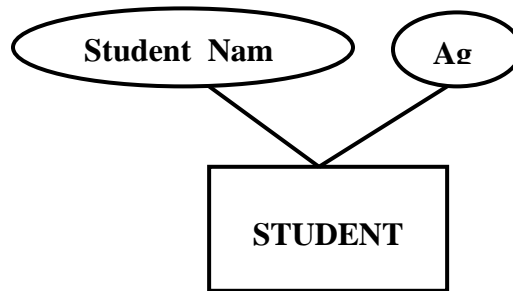
- An attribute is a *noun* like Customer_ID, Age, or Skill.
- An attribute name should be *unique*. No two attributes of the same entity type may have the same name, and it is desirable, for clarity purposes, that no two attributes across all entity types have the same name.
- To make an attribute unique and clear, *each attribute name should follow a standard form*. For example, Student_GPA as opposed to GPA_of_Students.
- Similar attributes of different entity types should use the similar but distinguishing names. For example, Student_Residence_City_Name for STUDENT entity type and Faculty_Residence_City_Name for FACULTY entity type.

Each attribute in E-R diagram should be defined. When defining attributes, we should use the following guidelines:

- An attribute definition states *what the attribute is and possibly why it is important*.
- An attribute definition should make it clear *what is included and what is not included* in the attributes value. For example, Employee_Monthly_Salary_Amount is the amount paid each month exclusive of any benefits, bonuses, or special payments.
- An attribute definition may contain any *aliases* or alternative names.
- An attribute definition may state *the source of values for the attribute to make the meaning clearer*.
- An attribute definition should indicate *if a value for the attribute is required or optional* (to maintain data integrity).
- An attribute definition may indicate *if a value for the attribute may change* (to maintain data integrity).
- An attribute definition may also indicate any *relationships that an attribute has with other attributes*. For example, Age is determined from Date_of_Birth.

An attribute in E-R diagram is drawn using an **ellipse**. We place attribute name inside the ellipse with a line connecting it to the associated entity type. For example, the figure

below shows Student_Name and Age attributes of STUDENT entity type.

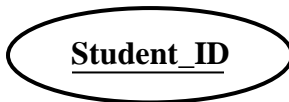


Every entity type must have an attribute or set of attributes that distinguishes one instance from other instances of the same type. A **candidate key** is an attribute or combination of attributes that uniquely identifies each instance of an entity type. For example, a candidate key for a STUDENT entity type might be Student_ID.

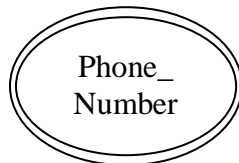
Some entity type may have more than one candidate key. In such a case, we must choose one of the candidate keys as the identifier. An **identifier** (or **primary key**) is a candidate key that has been selected to be used as the unique characteristic for an entity type. We can use the following selection rules to select identifiers:

- Choose a candidate key that will not change its value over the life of each instance of the entity type.
- Choose a candidate key that will never be null.
- Avoid using *intelligent keys*.
- Consider substituting single value *surrogate keys* for large composite keys.

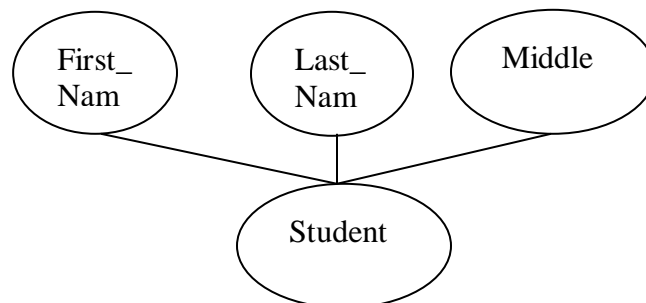
The name of the identifier is underlined on an E-R diagram. For example, the figure below shows Student_Id as an identifier for a STUDENT entity type.



A **multivalued attribute** may take more than one value for each entity instance. For example Phone_Number attribute of STUDENT entity type. We use a double-lined ellipse to represent multivalued attribute.



An attribute that has meaningful component parts is called **composite attribute**. For example, Student_Name attribute of STUDENT entity type has First_Name, Middle_Name, and Last_Nmae as its component parts.



An attribute whose value can be computed from related attribute values is called **derived attribute**. For example, value of Age attribute is computed from Date_of_Birth attribute. We use dashed ellipse to denote derived attribute.



Relationships

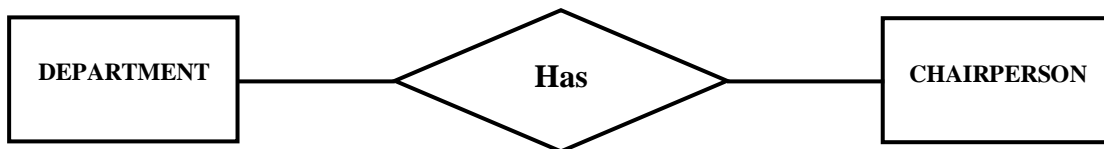
A **relationship** is an association between the instances of one or more entity types that is of interest to the organization. We use **diamond** to denote relationships. Relationships are labeled with *verb phrases*. For example, if a training department in a company is interested in tracking with training courses each of its employees has completed, this leads to a relationship (called Completes) between the EMPLOYEE and COURSE entity types as shown in the figure below.



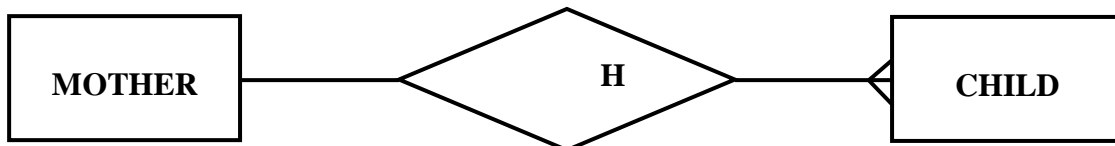
As indicated by arrows, the *cardinality* of this relationship is many-to-many since each employee may complete more than one course, and each course may be completed by more than one employee.

The **cardinality** of a relationship is the number of instances of one entity type that can (or must) be associated with each instance of another entity type. The cardinality of a relationship can be in one of the following four forms: *one-to-one*, *one-to-many*, *many-to-one*, and *many-to-many*.

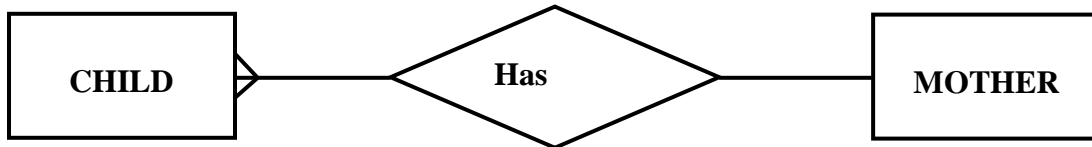
- **One-to-one:** An instance in entity type **A** is associated with at most one instance in entity type **B**, and an instance in entity type **B** is associated with at most one instance in entity type **A**. For example, cardinality between DEPARTMENT and CHAIRPERSON.



- **One-to-many:** An instance in entity type **A** is associated with any number (zero or more) of instances in entity type **B**, and an instance in entity type **B**, however, can be associated with at most one instance in entity type **A**. For example, cardinality between MOTHER and CHILD.



- **Many-to-one:** An instance in entity type **A** is associated with at most one instance in entity type **B**, and an instance in entity type **B**, however, can be associated with any number (zero or more) of instances in entity type **A**. For example, cardinality between CHILD and MOTHER.



- **Many-to-many:** An instance in entity type **A** is associated with any number (zero or more) of instances in entity type **B**, and an instance in entity type **B** is associated with any number (zero or more) of instances in entity type **A**. For example, cardinality between STUDENT and COURSE.



The **degree** of a relationship is the number of entity types that participate in the relationship. The three most common relationships in E-R models are *unary* (degree one), *binary* (degree two), and *ternary* (degree three). Higher degree relationships are also possible, but they are rarely encountered.

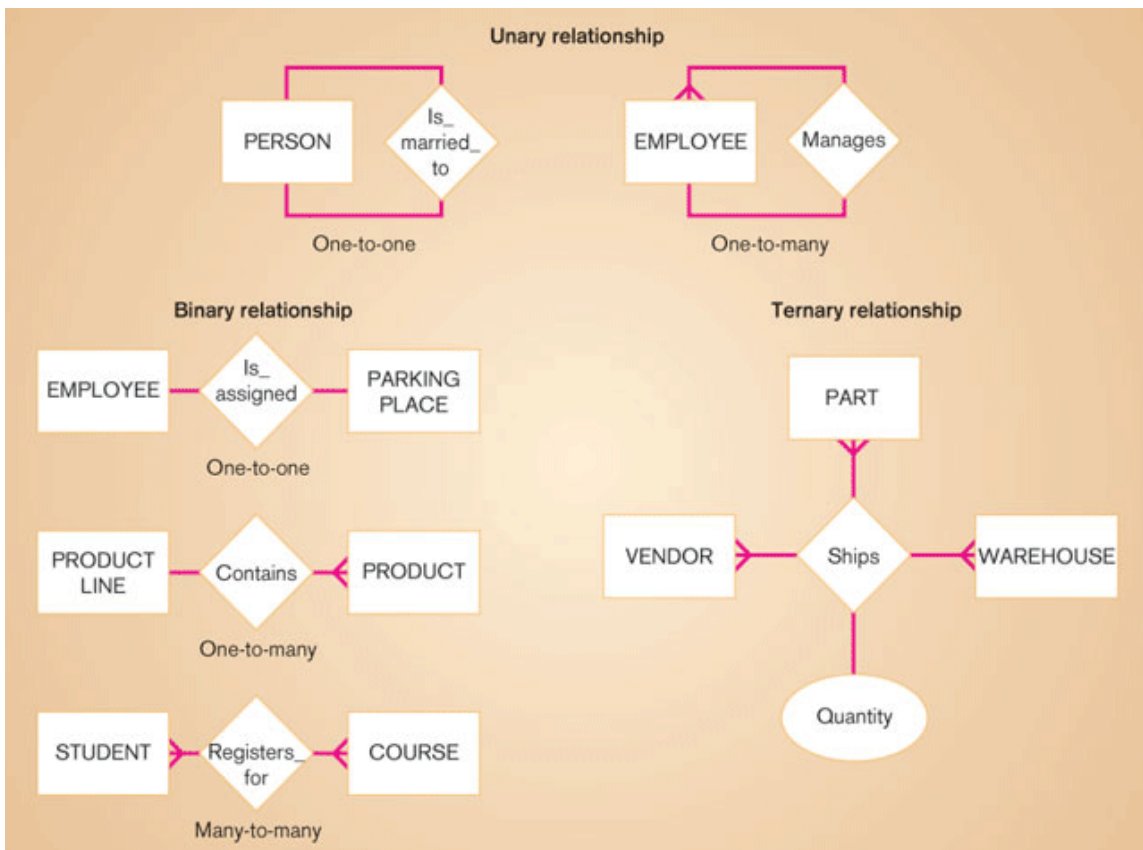


Fig: Example relationships of different degrees

A **unary relationship** is a relationship between the instances of one entity type. It is also called a **recursive relationship**. A **binary relationship** is a relationship between instances of two entity types. This is the most common type of relationship encountered in data modeling. A **ternary relationship** is a simultaneous relationship among the instances of three entity types.

We can also use the concept *minimum* and *maximum* cardinality when we draw E-R diagrams. The **minimum cardinality** of a relationship is the minimum number of instances of an entity type that may be associated with each instance of another entity type. The **maximum cardinality** of a relationship is the maximum number of instances of an entity type that may be associated with each instance of another entity type. For example, suppose a portion of banking database as shown in the figure below. Here, the minimum number of accounts for a customer is one and the maximum number of accounts is many (unspecified number greater than one). Similarly, the minimum number of customers associated with an account is one and the maximum number of customers is many.



When the minimum cardinality of a relationship is zero, then we say that the entity type is an **optional participation** or **partial participation** in the relationship. When the minimum cardinality of a relationship is one, then we say that the entity type is a **mandatory participation** or **total participation** in the relationship. In the figure above, the entity type ACCOUNT is a mandatory participation in the relationship. Similarly, the entity type CUSTOMER is a mandatory participation.

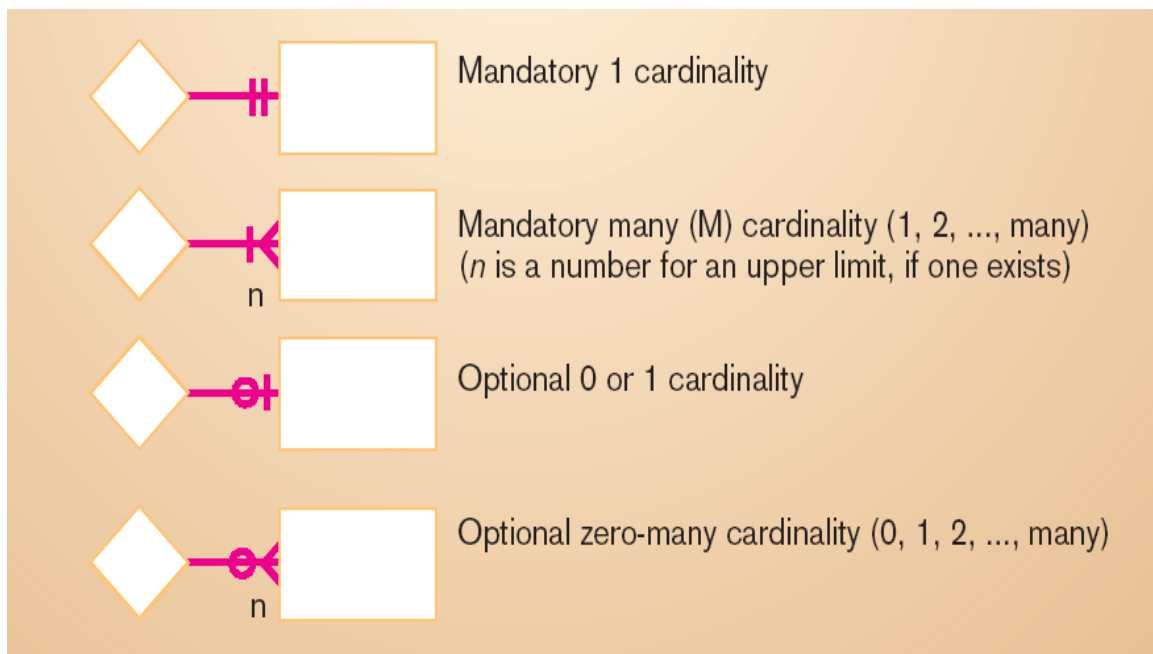


Fig: Cardinality symbols

Each relationship in E-R diagram is given a name. When naming relationships, we should use the following guidelines:

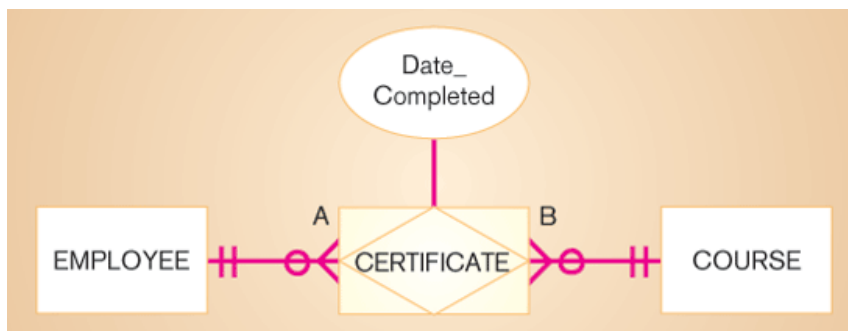
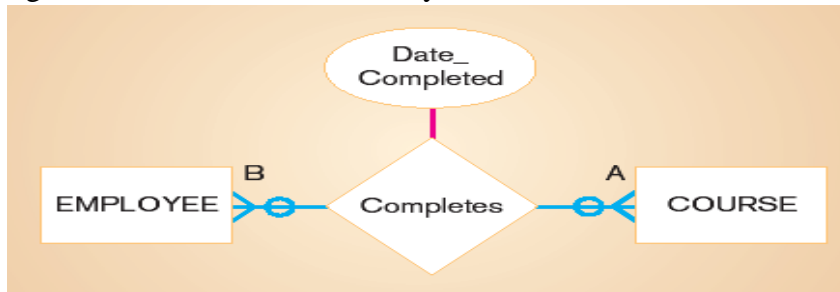
- A relationship name is *verb phrase* like Assigned_to, Supplies, or Teaches. This name represents action taken, not the result of the action, usually in the present tense.
- A relationship name should *avoid vague names*, such as Has or Is_related_to.

Each relationship in E-R diagram should be defined. When defining relationships, we should use the following guidelines:

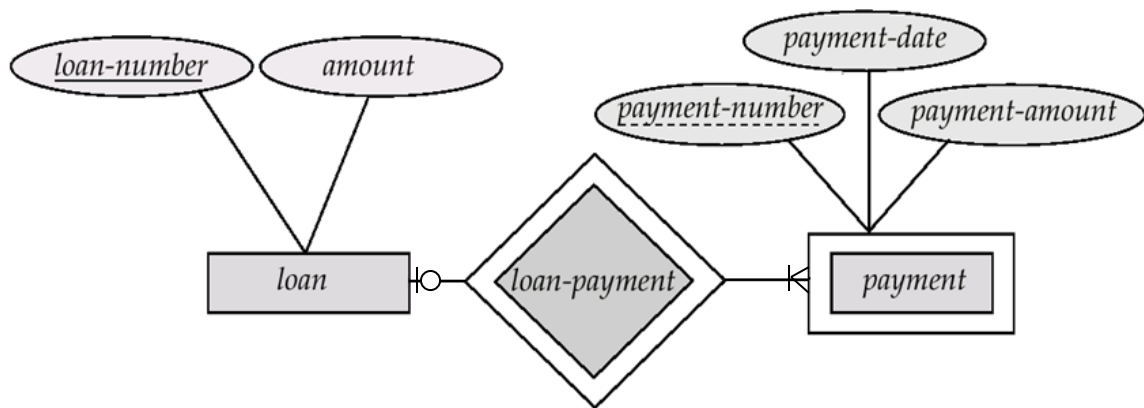
- A relationship definition should explain *what action is being taken and possibly why it is important*.
- It may be important to *give examples to clarify the action*.
- The definition should explain any *optional participation*.
- A relationship definition should *explain any restrictions on participation in the relationship*.
- A relationship definition should *explain the extent of history that is kept in the relationship*.
- A relationship definition should *explain the reason for any explicit maximum cardinality* other than many.
- A relationship definition should *explain whether an entity instance involved in a relationship instance can transfer participation to another relationship instance*.

Other E-R Notations

- **Associative Entity:** An entity type that associates the instances of one or more entity types and contains attributes that are peculiar to the relationship between those entity instances is called **associative entity**. Associative entity is also called a **gerund**. For example, the first figure below shows a relationship with an attribute and the second figure shows an associative entity.



- Weak Entity Type:** An entity type may not have sufficient attributes to form a primary key. Such an entity type is termed as a weak entity type. An entity type that has a primary key is termed as a strong entity type. For a weak entity type to be meaningful, it must be associated with another entity type, called the identifying or owner entity type, using one of the key attribute of owner entity type. The weak entity type is said to be existence dependent on the identifying entity type. The relationship associating the weak entity type with the identifying entity type is called the identifying relationship. The identifying relationship is many-to-one from the weak entity type to the identifying entity type, and the participation of the weak entity type in the relationship is total. Although a weak entity type does not have a primary key, we use discriminator (or partial key) as a set of attributes that allows the distinction to be made among all the entities in the weak entity type.



Supertypes and Subtypes

- Subtype:** Subtype is a subgrouping of the entities in an entity type that is meaningful to the organization and that shares common attributes or relationships distinct from other subgroupings. For example, an entity type STUDENT to GRADUATE STUDENT and UNDERGRADUATE STUDENT.
- Supertype:** Supertype is a generic entity type that has a relationship with one or more subtypes. For example PATIENT with OUTPATIENT and RESIDENTPATIENT.

There are several important business rules for supertype/subtype relationships.

- Total specialization rule:** Specifies that each entity instance of the supertype must be a member of some subtype in the relationship.
- Partial specialization rule:** Specifies that an entity instance of the supertype does not have to belong to any subtype. May or may not be an instance of one of the subtypes.
- Disjoint rule:** Specifies that if an entity instance of the supertype is a member of one subtype, it cannot simultaneously be a member of any other subtype.
- Overlap rule:** Specifies that an entity instance can simultaneously be a member of two (or more) subtypes.

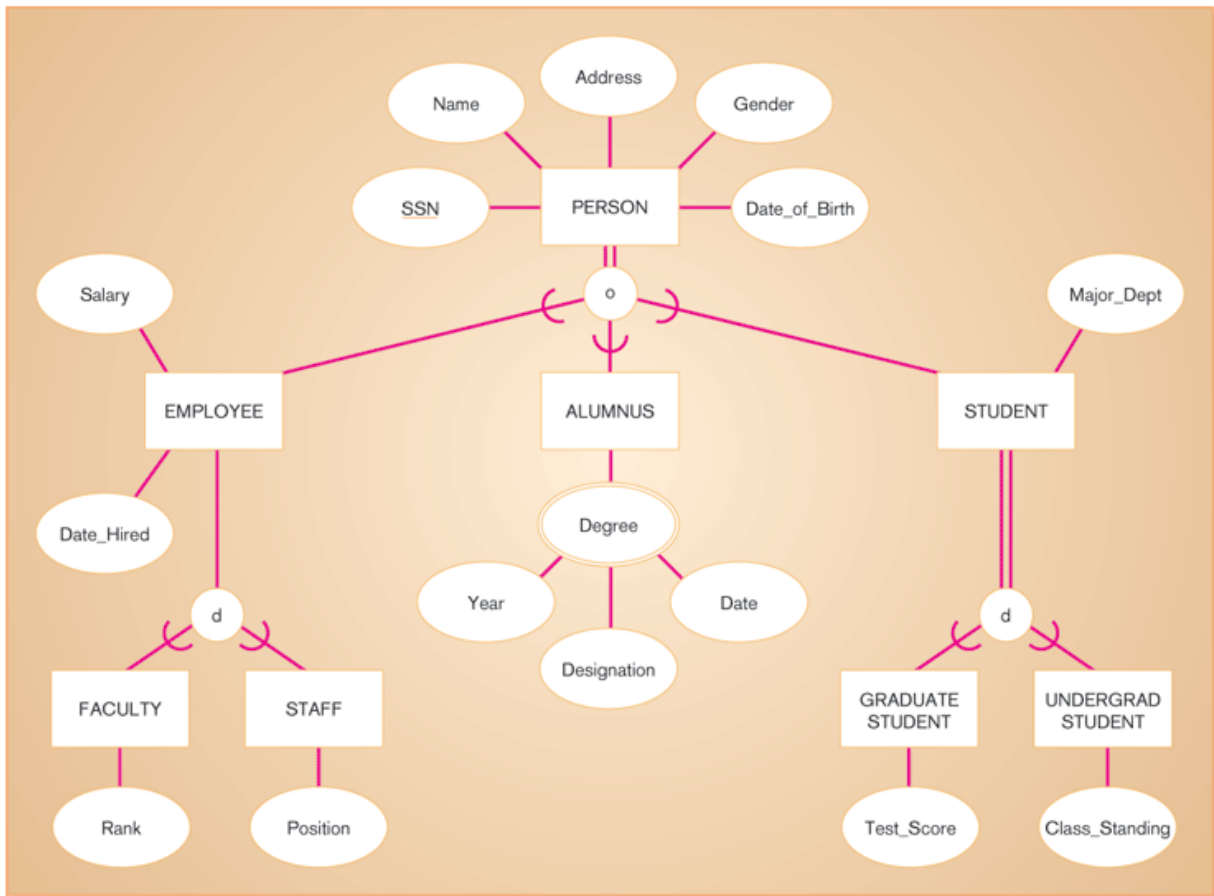


Fig: Example of supertype/subtype hierarchy

In the figure above, PERSON is supertype and EMPLOYEE, ALUMNUS, and STUDENT are subtypes. Similarly, EMPLOYEE is supertype for FACULTY and STAFF subtypes and STUDENT is supertype for GRADUATE STUDENT and UNDERGRADUATE STUDENT subtypes.

Supertype is connected with a line to a circle, which in turn is connected by a line to the subtypes. The U-shaped symbol indicates that the subtype is a subset of the supertype. Total specialization is shown by a double line from the supertype to the circle and partial specialization is shown by a single line. Disjoint versus overlap is shown by a “d” or an “o” in the circle.

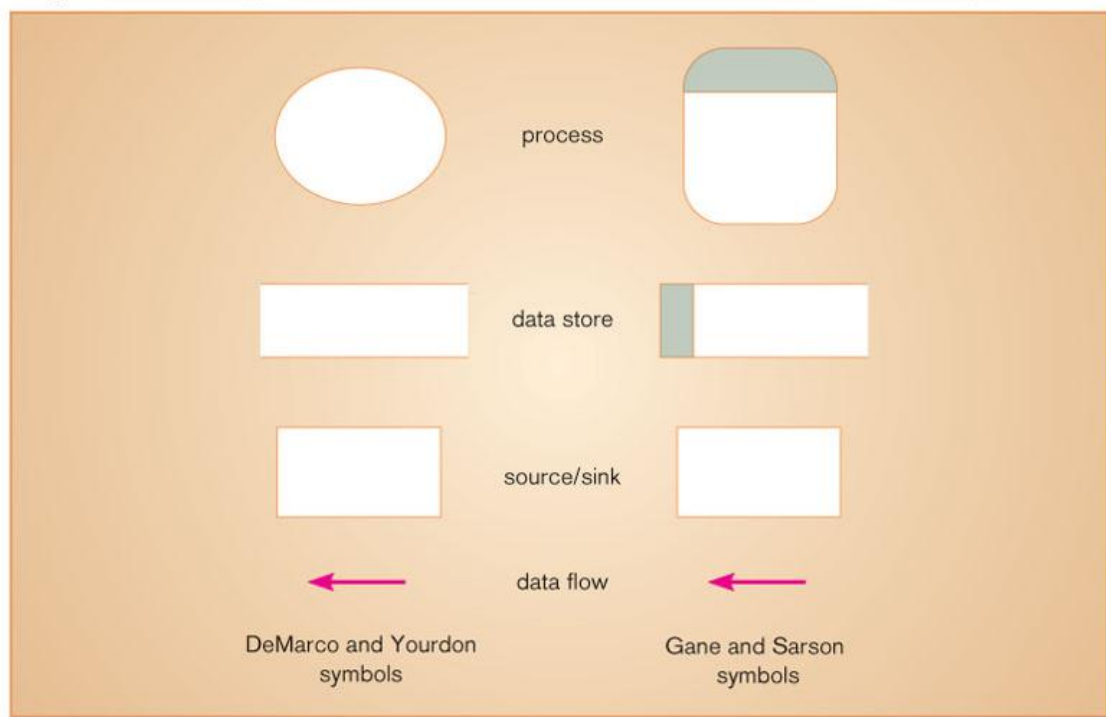
Some Exercises

1. Construct an ER diagram for a car-insurance company whose customers own one or more cars each. Each car has associated with it zero to any number of recorded accidents.
2. Construct an ER diagram for a hospital with a set of patients and a set of doctors. Associate with each patient a log of the various tests and examinations conducted.
3. Construct an ER diagram of the library system in your college.
4. Construct an ER diagram to maintain data about students, instructors, semester, and courses in a college.
5. Construct an ERD to record the marks that students get in different exams of different course offerings.

Data Flow Diagram (DFD)

Process modeling involves graphically representing the functions or processes that capture, manipulate, store, and distribute data between a system and its environment and between components within a system. A common form of a process model is a **data flow diagram (DFD)**.

A **data flow diagram (DFD)** is a tool that depicts the flow of data through a system and the work or processing performed by that system. It is also called **bubble chart**, **transformation graph**, or **process model**. There are two different sets of data flow diagram symbols, but each set consists of four symbols that represent the same things: **data flows**, **data stores**, **processes**, and **sources/sinks** (or **external entities**). The figure below shows two different sets of symbols developed by DeMarco and Yourdon and Gane and Sarson. The set of symbols we will use here was devised by Gane and Sarson.



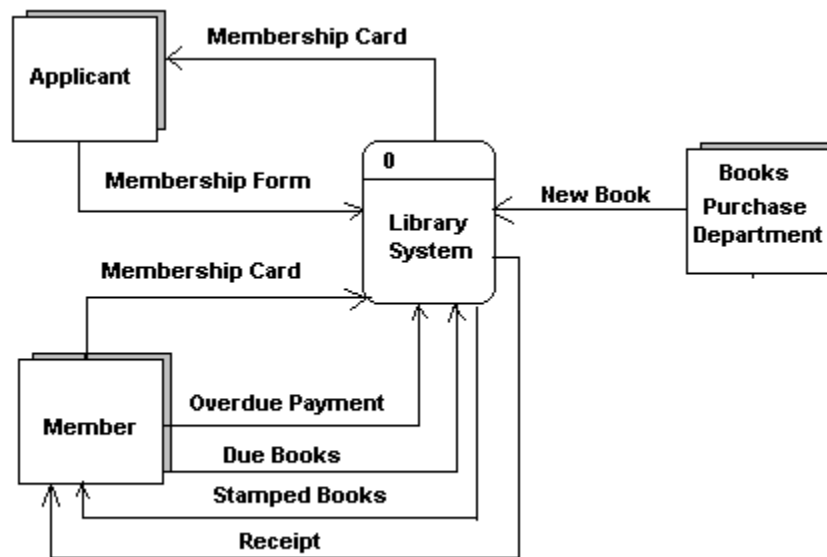
According to *Gane and Sarson*, **rounded rectangles** represent *process* or *work* to be done, **squares** represent *external agents*, **open-ended boxes** represent *data store* (sometimes called *files* or *databases*), and **arrows** represent *data flows* or *inputs* and *outputs* to and from the processes.

Process is the work or actions performed on data so that they are transformed, stored or distributed. *Data store* is the data at rest (inside the system) that may take the form of many different physical representations. External entity (source/sink) is the origin and/or destination of data. Data flow represents data in motion, moving from one place in a system to another.

Developing DFDs

The highest-level view of a system is called **context diagram** or **context DFD**. A context DFD is used to document the scope of the project of development. It is also called **environmental model**.

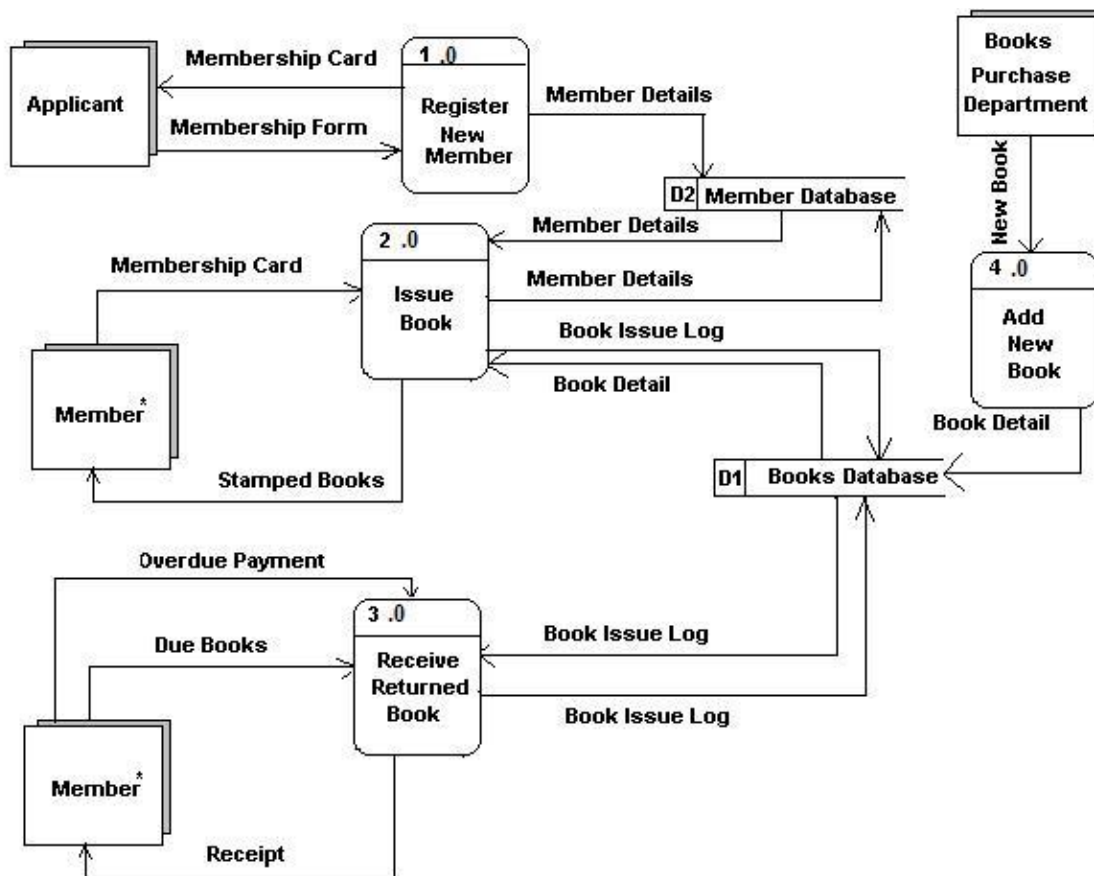
A project's scope defines what aspect of the business, an information system or application is supposed to support and how the system being modeled must interact with other systems and the business as a whole. Because the scope of any project is always subject to change, the context diagram is also subject to constant change. The context DFD contains one and only one process and it has no data storage. Sometimes this process is identified by the number "0". The figure below shows the context diagram of library system.



The next step is to draw a DFD with major processes that are represented by the single process in the context diagram. These major processes represent the major functions of the system. This diagram also includes data stores and called **level-0 diagram** (or **level-0 DFD**). A level-0 diagram is a DFD that represents a system's major processes, data flows, and data stores at a high level of detail. In this diagram, sources/sinks should be same as in the context diagram. Each process has a number that ends in .0. The figure below shows level-0 DFD.

Here, we started with a high-level context diagram. Upon thinking more about the system, we saw that the larger system consisted of four processes. This process is called **functional decomposition**. Functional decomposition is an iterative process of breaking the description or perspective of a system down into finer and finer detail. When we repeat the decomposition until we reached the point where no subprocesses can logically be broken down any further, we get the lowest level of DFD called **primitive DFD**.

When we decompose level-0 DFD, we get level-1 DFD. In level-1 DFD, we label subprocesses of process 1.0 to 1.1, 1.2, and so on. Similarly, subprocesses of process 2.0 to 2.1, 2.2, and so on. In general, a **level-n diagram** is a DFD that is generated from **n** nested decompositions from a level-0 diagram.



Chapter 3

Structured Methodologies

Introduction

Structured methodologies (or structured systems analysis and design) have been used to document, analyze, and design information systems since the 1970s. **Structured** refers to the fact that the techniques are step by step, with each step building on the previous one. Structured methodologies are top-down, progressing from the highest, most abstract level to the lowest level of detail – from the general to the specific.

Structured development methods are process-oriented, focusing primarily on modeling the processes, or actions that capture, store, manipulate, and distribute data as the data flow through a system. These methods separate data from processes.

The primary tool for representing a system's component processes and the flow of data between them is the **data flow diagram (DFD)**. The data flow diagram offers a logical graphic model of information flow, partitioning a system into modules that show manageable levels of detail. It rigorously specifies the processes or transformations that occur within each module and the interfaces that exist between them.

Another tool for structured analysis is a **data dictionary**, which contains information about individual pieces of data and data groupings within a system. The data dictionary defines the contents of data flows and data stores so that systems builders understand exactly what pieces of data they contain. **Process specification** is another tool that describes the transformation occurring within the lowest level of data flow diagrams. They express the logic for each process. We can express the logic using structured English, decision table, decision tree etc.

In structured methodology, software design is modeled using hierarchical structure charts. The **structure chart** is a top-down chart, showing each level of design, its relationship to other levels, and its place in the overall design structure. The design first considers the main function of a program or system, then breaks this function into subfunctions, and decomposes each subfunction until the lowest level of detail has been reached. A structure chart may document one program, one system (a set of programs) or part of one program.

The Need for Structured Methodology

Most information systems development organizations use structured methodology because it offers the following advantages:

- Improve project management & control
- Make more effective use of experienced and inexperienced development staff
- Develop better quality systems with low cost
- Make projects resilient to the loss of staff
- Enable projects to be supported by computer-based tools such as computer-aided software engineering (CASE) systems
- Establish a framework for good communications between participants in a project

- Enable projects to deliver the product on time because it allows to plan, manage and control a project well
- Respond to the changes in the business environment while project progresses
- Improves the overall productivity by encouraging on-time delivery, meeting business requirements, ensuring better quality, and using human resources effectively.

Role of CASE in Data Modeling

Data models are stored in a repository. CASE (computer-aided systems engineering) provides the repository for storing the data models and its detail description. Most CASE tools support computer-assisted data modeling and database design. CASE supports in drawing and maintaining the data models and their underlying details.

Using CASE product, you can easily create professional, readable data models without the use of paper, pencil, erasers, and templates. The models can be easily modified to reflect corrections and changes suggested by end users – you don't have to start over. Also, most CASE products provide powerful analytical tools that can check your models for mathematical errors, completeness, and consistency. Some CASE products can even help you analyze the data models for consistency, completeness, and flexibility.

Also, some CASE tools support reverse engineering of existing files and database structures into data models. The resulting data models represent physical data models that can be revised and reengineered into a new file or database, or they may be translated into their equivalent logical models. The logical data models could then be edited and forward engineered into a revised physical data model and subsequently a file or database implementations.

Chapter 4

Systems Analysis

Systems Planning and Initial Investigation

The primary purpose of systems planning is to identify problem's nature and its scope. It also includes preliminary (or initial) investigation and feasibility study. Initial investigation is used to understand the problem, define the project scope and constraints, identify the benefits, estimate the time and costs, and interact with managers and users. Feasibility study is used to determine some feasibility (economic, operational, technical feasibility etc) of the system.

The purpose of this phase is twofold. First, it answers the question, "Is this project worth looking at?" Second, assuming that the problem is worth looking at, it establishes the size and boundaries of the project, the project vision, any constraints or limitations, the required project participants, and the budget and schedule.

Information Gathering Techniques

To develop an information system, we first must be able to correctly identify, analyze, and understand what the users' requirements are or what the user wants the system to do. To know users' requirements, we use information gathering techniques. Information gathering techniques are also called **requirements discovery techniques** or **fact finding techniques** or **data collection techniques**. Information gathering includes those techniques to be used by system analysts to identify or extract system problems and solution requirements from the user community. Systems analysts need an organized method for information gathering. Some information gathering techniques are discussed below:

Sampling of Existing Documentation, Forms, and Files

When we are studying an existing system, we can develop a good feel for the system by studying existing documentation, forms, and files. A good analyst always gets facts from the existing documentation rather than from people.

Because it would be impractical to study every occurrence of every form or record in a file or database, system analysts normally use sampling techniques to determine what can happen in the system.

Sampling is the process of collecting a representative sample of documents, forms, and records. The most commonly used sampling techniques are **randomization** and **stratification**.

Randomization is a sampling technique in which there is no predetermined pattern or plan for selecting sample data.

Stratification is a systematic sampling technique that attempts to reduce the variance of the estimates by spreading out the sampling.

Research and Site Visits

In this technique, we perform site visits at systems they know have experienced similar problems. If these systems are willing to share, valuable information can be obtained that

may save tremendous time and cost in the development process.

Computer trade journals and reference books are also a good source of information. They can provide us with information how others have solved similar problems. Also, through the Internet we can collect immeasurable amounts of information.

Observation of the Work Environment

Observation is an effective data-collection technique for obtaining an understanding of a system. In this technique, the systems analyst either participates in or watches a person performing activities to learn about the system.

Advantages:

- Data gathered can be highly reliable. Sometimes observations can be conducted to check the validity of data obtained directly from individuals.
- The systems analyst is able to see exactly what is being done.
- It is relatively inexpensive compared to other fact-finding techniques, because other techniques usually require more employees.
- It allows the system analyst to do work measurement.

Disadvantages:

- People usually feel uncomfortable when being watched to their work.
- Some system activities may take place at odd times, causing a scheduling inconvenience for the system analyst.
- It may cause interruption.
- Some tasks may not always be performed by observation.

Questionnaires

This technique is used to conduct surveys through questionnaires. **Questionnaires** are special purpose documents that allow the analyst to collect information and opinions from the respondents. The document can be mass-produced and distributed to respondents, who can then complete the questionnaire on their own time. Questionnaires allow the analyst to collect facts from a large number of people.

Types of Questionnaires

There are two formats of questionnaire, **free-format** and **fixed-format**. Free-format questionnaire offer the respondent to record the answer in the space provided after the questionnaire.

Fixed-format questionnaire contain questions that require selection of predefined responses. In this format, the respondent must choose from the available answer. There are three types of fixed-format questions:

- **Multiple Choice Questions:** - The respondent is given several answers of a question. The respondent should be told if more than one answer can be selected.
- **Rating Questions:** - The respondent is given a statement and asked to use supplied responses to state an opinion.
- **Ranking questions:** - The respondent is given several possible answers, which are to be ranked in the order of preference or experience.

Advantages

- Most questionnaires can be answered quickly.
- Inexpensive for gathering data from a large number of individuals.

- Responses can be tabulated and analyzed quickly.

Disadvantages

- There is no guarantee that an individual will answer or expand on all the questions.
- Questionnaires tend to be inflexible.
- It not possible for the systems analyst to observe and analyze the respondent's body language.
- There is no immediate opportunity to clarify a vague or incomplete answer to questions.
- Good questionnaires are difficult to prepare.
- The number of respondents is often low.

Interviews

The personal **interview** is generally recognized as the most often used fact-finding technique. Interviews are the fact-finding techniques whereby the systems analysts collect information from individuals through face-to-face interaction.

There are two roles assumed in an interview. The systems analyst is the **interviewer**, responsible for organizing and conducting the interview. The system user or system owner is the **interviewee**, who is asked to respond to a series of questions.

Types of Interviews

There are two types of interviews: **unstructured** and **structured**. Unstructured interviews are conducted with only a general goal or subject in mind and with few, if any, specific questions. Structured interviews on the other hand are conducted with a set of specific questions to ask the interviewee.

Types of Questions

There are two types of questions in interview: **open-ended** and **closed-ended**. Open-ended questions allow the interviewee to respond in any way that seems appropriate. But, closed-ended questions restrict answers to either specific choices or short, direct responses.

Advantages

- Interviews give the analyst an opportunity to motivate the interviewee to respond freely and openly to questions.
- Interviews allow more feedback from the interviewee.
- Interviews give the analyst an opportunity to observe the interviewee's nonverbal communication.

Disadvantages

- Interviewing is a very time-consuming and therefore costly fact-finding approach.
- Success of interviews is highly dependent on the systems analyst's human relational skills.
- Interviewing may be impractical due to the location of interviewees.

Discovery Prototyping

Discovery prototyping is the act of building a small-scale, representative or working model of the users' requirements to discover or verify the requirements.

Usually only the areas where the requirements are not clearly understood are

prototyped. Creating discovery prototypes enables the developers as well as the users to better understand and refine the requirements involved with developing the system.

Advantages

- Allows users and developers to experiment with the software and develop an understanding of how the system might work.
- Aids in determining the feasibility and usefulness of the system before high development costs are incurred.
- Serves as a training mechanism for users.
- Aids in building system test plans and scenarios to be used last in the system testing process.
- May minimize the time spent for fact-finding and help to define more stable and reliable requirements.

Disadvantages

- Users and developers may need to be trained in the prototyping approach.
- Doing prototyping may extend the development schedule and increase the development costs
- Users may develop unrealistic expectations.

Joint Requirements Planning (JRP)

It is a process whereby highly structured group meeting is conducted to analyze problems and define requirements. JRP is a subset of a more comprehensive *joint application development (JAD)*. The JRP participants are:

- **Sponsor:** - This person is normally an individual who is in top management and has authority that spans the different departments and users who are to be involved in the systems project.
- **Facilitator:** - The JRP facilitator or leader is usually responsible for leading all sessions that are held for a systems project.
- **Users and Managers:** - Users devote themselves to the JRP sessions to effectively communicate business rules and requirements, review design prototypes and make acceptance decisions. Managers approve project objectives, establish project priorities, approve schedules and costs, and approve identified training needs and implementation plans.
- **Scribe(s):** - Scribes are responsible for keeping records pertaining to everything discussed in the meeting.
- **IT Staff:** - IT personnel listen and take notes regarding issues and requirements voiced by the users and managers. Normally, IT personnel do not speak unless invited to do so.

Benefits

- It actively involves users and managers in the development project.
- It reduces the amount of time required to develop systems.
- When JRP incorporates prototyping as a means for conforming requirements and obtaining design approvals, the benefits of prototyping are realized.

Structured Analysis Tools

Structured analysis includes different tools like DFD (data flow diagram), ERD (entity relationship diagram), data dictionary, structured English, decision table, and decision tree.

Feasibility Study

Feasibility is the measure of how beneficial or practical the development of information system will be to an organization. **Feasibility study** is the process by which feasibility is measured. Feasibility analysis is appropriate to the systems analysis phase.

Four Tests for Feasibility

During systems analysis phase, the system analyst identifies different alternate solutions and analyzes those solutions for feasibility. To analyze different alternative solutions, most analysts use four categories of feasibility tests: **operational feasibility**, **technical feasibility**, **schedule feasibility**, and **economic feasibility**.

1. **Operational Feasibility:** It is a measure of how well the solution will work in an organization. It is also a measure of how people feel about the system/project. So, this feasibility is people oriented. Operational feasibility addresses two major issues:

- a. *Is the problem worth solving, or will the solution to the problem work?*
- b. *How do end users and management feel about the problem (solution)?*

When determining operational feasibility, *usability analysis* is often performed with a working prototype of the proposed system. **Usability analysis** is a test of system's user interfaces and is measured in how easy they are to learn and to use and how they support the desired productivity levels of the users. Usability is measured in terms of *ease of learning*, *ease of use*, and *satisfaction*.

2. **Technical Feasibility:** It is a measure of practicality of a specific technical solution and availability of technical resources and expertise. Technical feasibility is computer oriented. This feasibility addresses three major issues:

- a. *Is the proposed technology or solution practical?*
- b. *Do we currently possess the necessary technology?*
- c. *Do we possess the necessary technical expertise, and is the schedule reasonable?*

3. **Schedule Feasibility:** It is a measure of how reasonable the project timetable is. Schedule feasibility is the determination of whether the time allocated for a project seems accurate. Projects are initiated with specific deadlines. It is necessary to determine whether the deadlines are mandatory or desirable. If the deadlines are desirable rather than mandatory, the analyst can propose alternative schedules.

4. **Economic Feasibility:** It is the measure of the cost-effectiveness of a project or solution. This feasibility deals with costs and benefits of the information system. The bottom-line in many projects is economic feasibility. During the early phases of the project, economic feasibility analysis amounts to little more than judging whether the possible benefits of solving the problem are worthwhile. However, as soon as specific requirements and alternative solutions have been identified, the analyst can determine the costs and benefits of each alternative.

Some other feasibility tests are also possible. These are *legal and contractual feasibility* and *political feasibility*. **Legal and contractual feasibility** is the process of assessing potential legal and contractual ramifications due to the construction of a system. **Political feasibility** is the process of evaluating how key stakeholders within the organization view the proposed system.

Cost-Benefit Analysis Techniques

Economic feasibility has been defined as a cost-benefit analysis. Most schools offer courses like *financial management*, *financial decision analysis*, and *engineering economics and analysis* for cost benefit analysis. The cost benefit analysis techniques include:

- *How much will the system costs?*
- *What benefits will the system provide?*
- *Is the proposed system cost-effective?*

How much will the system costs?

Costs fall into two categories: *costs associated with developing the system* and *costs associated with operating the system*. The former costs can be estimated from the start of the project and should be refined at the end of each phase of the project. The later can be estimated only after specific computer-based solution has been defined.

System development costs are usually onetime costs that will not recur after the project has been completed. Many organizations have standard cost categories that must be evaluated. In the absence of such categories, we use the following list:

- **Personnel cost** – The salaries of systems analysts, programmers, consultants, data entry personnel, computer operators, secretaries, and the like who work on the project.
- **Computer usage** – The cost in the use of computer resources.
- **Training** – Expenses for the training of computer personnel or end-users.
- **Supply, duplication, and equipment costs.**
- **Cost of any new computer equipment and software.**

The operating costs tend to recur throughout the lifetime of the system. The costs in this case can be classified as *fixed* or *variable*.

- **Fixed costs** – Fixed costs occur at regular intervals but at relatively fixed rates. Some examples include: lease payments and software license payments, salaries of IS operators and support personnel etc.
- **Variable costs** – Variable costs occur in proportion to some usage factor. Some examples include: costs of computer usage (e.g., CPU time used, storage used), supplies (e.g., printer paper, floppy disks), overhead costs (e.g., utilities, maintenance, and telephone service) etc.

What benefits will the system provide?

Benefits normally increase profits or decrease costs. Benefits can be classified into two categories: *tangible* and *intangible*.

- **Tangible benefits** – Tangible benefits are those that can be easily quantified. These benefits are usually measured in terms of monthly or annual savings or of profit to the firm. Alternatively, these benefits might be measured in terms of unit cost savings or profit. Some examples of tangible benefits are: fewer processing errors, increased throughput, decreased response time, elimination of job steps, increased sales, reduced credit losses, and reduce expenses.
- **Intangible benefits** – Intangible benefits are believed to be difficult or impossible to quantify. Unless these benefits are at least identified, it is entirely possible that many projects would not be feasible. Some examples of intangible benefits are: improved customer goodwill, improved employee morale, better service to community, and better decision making.

Unfortunately, if a benefit cannot be quantified, it is difficult to accept the validity of an associated cost-benefit analysis that is based on incomplete data.

Is the proposed system cost-effective?

There are three popular techniques to assess economic feasibility, also called cost-effectiveness: *payback analysis*, *return to investment*, and *net present value*.

One concept that is shared by all three techniques is the **time value of money** – a dollar today is worth more than a dollar one-year from now.

Some of the costs of the system will be accrued in after implementation. Before cost-benefit analysis, these costs should be brought back to the current dollars. **Present value** is the current value of a dollar at any time in the future. It is calculated using the formula:

$$PV_n = 1/(1 + i)^n$$

Where PV_n is the present value of \$1.00 n years from now and i is the discount rate.

- **Payback analysis** – It is a technique for determining if and when an investment will pay for itself. Because system development costs are incurred long before benefits begin to occur, it will take some time for the benefits to overtake the costs. After implementation, there will be additional operating expenses that must be recovered. *Payback analysis* determines how much time will lapse before accrued benefits overtake accrued and continuing costs. This period of time is called **payback period**, that is, the period of time that will lapse before accrued benefits overtake accrued costs.
- **Return-on-investment analysis** – This technique compares the lifetime profitability of the solution. It is a percentage rate that measures the relationship between the amounts the business gets back from an investment and the amount invested. It is calculated as follows:

$$\text{Lifetime ROI} = (\text{Estimated lifetime benefits} - \text{Estimated lifetime costs}) / \text{Estimated lifetime costs}$$

- **Net present value** – It is an analysis technique that compares costs and benefits for each year of the system's lifetime. Many managers consider it the preferred cost-benefit analysis technique.

Cost–benefit analysis

Cost–benefit analysis (CBA), sometimes called **benefit–cost analysis (BCA)**, is a systematic approach to estimating the strengths and weaknesses of alternatives that satisfy transactions, activities or functional requirements for a business. It is a technique that is used to determine options that provide the best approach for the adoption and practice in terms of benefits in labor, time and cost savings etc. The CBA is also defined as a systematic process for calculating and comparing benefits and costs of a project, decision or government policy (hereafter, "project").

Broadly, CBA has two purposes:

1. To determine if it is a sound investment/decision (justification/feasibility),
2. To provide a basis for comparing projects. It involves comparing the total expected cost of each option against the total expected benefits, to see whether the benefits outweigh the costs, and by how much.

CBA is related to, but distinct from cost-effectiveness analysis. In CBA, benefits and costs are expressed in monetary terms, and are adjusted for the time value of money, so that all flows of benefits and flows of project costs over time (which tend to occur at different points in time) are expressed on a common basis in terms of their "net present value."

Closely related, but slightly different, formal techniques include cost-effectiveness analysis, cost–utility analysis, risk–benefit analysis, economic impact analysis, fiscal impact analysis, and Social return on investment (SROI) analysis.

Theory

Cost–benefit analysis is often used by governments and other organizations, such as private sector businesses, to appraise the desirability of a given policy. It is an analysis of the expected balance of benefits and costs, including an account of foregone alternatives and the status quo. CBA helps predict whether the benefits of a policy outweigh its costs, and by how much relative to other alternatives (i.e. one can rank alternate policies in terms of the cost–benefit ratio). Generally, accurate cost–benefit analysis identifies choices that increase welfare from a utilitarian perspective. Assuming an accurate CBA, changing the status quo by implementing the alternative with the lowest cost–benefit ratio can improve Pareto efficiency. An analyst using CBA should recognize that perfect appraisal of all present

and future costs and benefits is difficult, and while CBA can offer a well-educated estimate of the best alternative, perfection in terms of economic efficiency and social welfare are not guaranteed.

Process

The following is a list of steps that comprise a generic cost–benefit analysis.

1. List alternative projects/programs.
2. List stakeholders.
3. Select measurement(s) and measure all cost/benefit elements.
4. Predict outcome of cost and benefits over relevant time period.
5. Convert all costs and benefits into a common currency.
6. Apply discount rate.
7. Calculate net present value of project options.
8. Perform sensitivity analysis.
9. Adopt recommended choice.

Unlike net present value method and internal rate of return method, **payback method** does not consider the present value of cash flows. Under this method, an investment project is accepted or rejected on the basis of payback period. Payback period means the period of time that a project requires recovering the money invested in it. The payback period of a project is expressed in years and is computed using the following formula:

Formula of payback period:

$$\text{Payback period} = \frac{\text{Investment required for a project}}{\text{Net annual cash inflow}}$$

According to this method, the project that promises a quick recovery of initial investment is considered desirable. If the payback period of a project computed by the above formula is shorter than or equal to the management's maximum desired payback period, the project is accepted otherwise it is rejected. For example, if a company wants to recoup the cost of a machine within 5 years of purchase, the maximum desired payback period of the company would be 5 years. The purchase of machine would be desirable if it promises a payback period of 5 years or less.

Consider the following example to understand the analysis of a project under this method:

Example 1:

Due to increased demand, the management of Rani Beverage Company is considering to purchase a new equipment to increase the production and revenues. The useful life of the equipment is 10 years and the company's maximum desired payback period is 4 years. The inflow and outflow of cash associated with the new equipment is given below:

The initial cost of equipment \$37,500

Annual cash inflow:

Sales	\$75,000
-------	----------

Annual cash outflow:

Cost of ingredients	\$45,000
---------------------	----------

Salaries expenses	\$13,500
-------------------	----------

Maintenance expenses	\$1,500
----------------------	---------

Non cash expenses:

Depreciation	\$5,000
--------------	---------

Required: Should Rani Beverage Company purchase the new equipment? Use payback method for your answer.

Solution:

Step 1: In order to compute the payback period of the equipment, we need to work out the net annual cash inflow by deducting the total of cash outflow from the total of cash inflow associated with the equipment.

Computation of net annual cash inflow:

$$\begin{aligned} & \$75,000 - (\$45,000 + \$13,500 + \$1,500) \\ & = \$15,000 \end{aligned}$$

Step 2: Now, the amount of investment required to purchase the equipment would be divided by the amount of net annual cash inflow (computed in step 1) to find the payback period of the equipment.

$$\begin{aligned} \text{Payback period} &= \frac{\text{Investment required for a project}}{\text{Net annual cash inflow}} \\ &= \$37,500 / \$15,000 \\ &= 2.5 \text{ years} \end{aligned}$$

Depreciation is a non cash expense and therefore has been ignored.

According to payback method, the equipment should be purchased because the payback period of the equipment is 2.5 years which is shorter than the maximum desired payback period of the company.

Comparison of two or more alternatives – choosing from several alternative projects:

Where funds are limited and several alternative projects are being considered, the project with the shortest payback period is preferred. It is explained with the help of the following example:

Example 2:

The management of Health Supplement Inc. wants to reduce its labor cost by installing a new machine. Two types of machines are available in the market – machine X and machine Y. Machine X would cost \$18,000 where as machine Y would cost \$15,000. Both the machines can reduce annual labor cost by \$3,000.

Required: Which is the best machine to purchase according to payback method?

Solution:

	Machine X	Machine Y
Cost of machine (a)	\$18,000	\$15,000
Annual cost saving (b)	\$3,000	\$3,000
Payback period (a)/(b)	6 years	5 years

According to payback method, machine Y is more desirable than machine X because it has a shorter payback period than machine X.

Payback method and uneven cash flow:

In the above examples we have assumed that the projects generate even cash inflow (same cash inflow during each period) but when projects generate uneven cash inflow (different cash inflow in different periods), the payback period formula given above cannot be used to compute payback period.

To understand the analysis of a project that generates uneven cash inflow, consider the following example:

Example 3:

An investment of \$200,000 is expected to generate the following cash flows in six years:

Net

Cash

Flow

Per

Year

1	\$30,000
2	\$40,000
3	\$60,000
4	\$70,000
5	\$55,000
6	\$45,000

Required: Compute payback period of the investment. Should the investment be made if management wants to recover the initial investment in 3 years or less?

Solution:

(1). Because the cash inflow is uneven, the payback period formula cannot be used to compute the payback period. We can compute the payback period by computing the cumulative net cash flow as follows:

Year	Net cash flow	Cumulative net cash inflow
1	\$30,000	\$30,000
2	\$40,000	\$70,000

3 \$60,000\$130,000

4 \$70,000\$200,000

5 \$55,000\$255,000

6 \$45,000\$300,000

Payback period is 4 years because the cumulative cash flow at the end of 4th year becomes equal to initial amount of investment.

(2). As the payback period is longer than the maximum desired payback period of the management (3 years), the investment should not be made.

Decision Tree

A **decision tree** is a decision support tool that uses a tree-like graph or model of decisions and their possible consequences, including chance event outcomes, resource costs, and utility. It is one way to display an algorithm.

Decision trees are commonly used in operations research, specifically in decision analysis, to help identify a strategy most likely to reach a goal

A decision tree is a flowchart-like structure in which each internal node represents a "test" on an attribute (e.g. whether a coin flip comes up heads or tails), each branch represents the outcome of the test and each leaf node represents a class label (decision taken after computing all attributes). The paths from root to leaf represent classification rules.

In decision analysis a decision tree and the closely related influence diagram are used as a visual and analytical decision support tool, where the expected values (or expected utility) of competing alternatives are calculated.

A decision tree consists of 3 types of nodes:

1. Decision nodes - commonly represented by squares
2. Chance nodes - represented by circles
3. End nodes - represented by triangles

Decision trees are commonly used in operations research, specifically in decision analysis, to help identify a strategy most likely to reach a goal. If in practice decisions have to be taken online with no recall under incomplete knowledge, a decision tree should be paralleled by a probability model as a best choice model or online selection model algorithm. Another use of decision trees is as a descriptive means for calculating conditional probabilities.

Decision rules

The decision tree can be liberalized into **decision rules**, where the outcome is the contents of the leaf node, and the conditions along the path form a conjunction in the if-clause. In general, the rules have the form:

if condition1 and condition2 and condition3 then outcome.

Decision tree using flowchart symbols

Commonly a decision tree is drawn using flowchart symbols as it is easier for many to read and understand.

Advantages and disadvantages

Among decision support tools, decision trees (and influence diagrams) have several advantages. Decision trees:

- Are simple to understand and interpret. People are able to understand decision tree models after a brief explanation.
- Have value even with little hard data. Important insights can be generated based on experts describing a situation (its alternatives, probabilities, and costs) and their preferences for outcomes.
- Allow the addition of new possible scenarios
- Help determine worst, best and expected values for different scenarios

- Use a white box model. If a given result is provided by a model.
- Can be combined with other decision techniques.

Disadvantages of decision trees:

- For data including categorical variables with different number-of levels, information gain in decision trees are biased in favor of those attributes with more levels.
- Calculations can get very complex particularly if many values are uncertain and/or if many outcomes are linked.

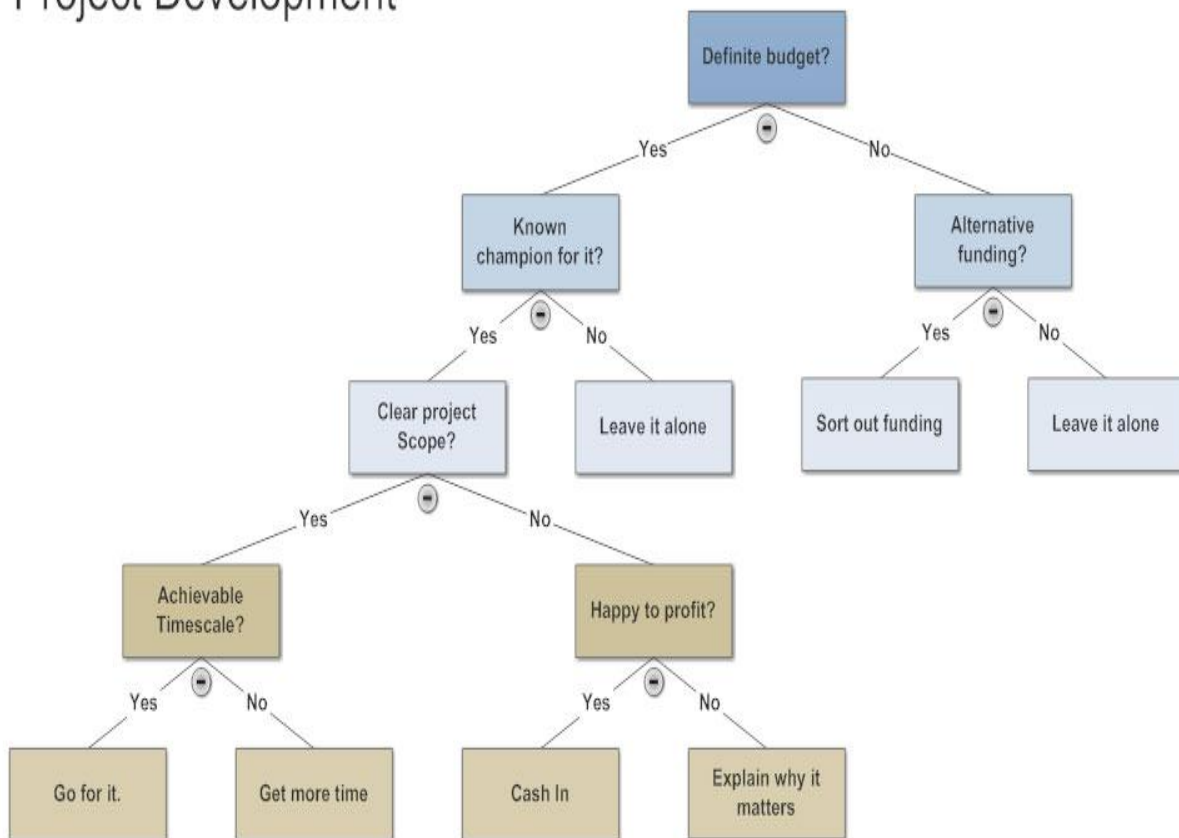
Decision Tree

A decision tree is a flowchart-like structure that shows the various outcomes from a series of decisions. It can be used as a decision-making tool, for research analysis, or for planning strategy. A primary advantage for using a decision tree is that it is easy to follow and understand.

Structure of a Decision Tree

Decision trees have three main parts: a root node, leaf nodes and branches. The root node is the starting point of the tree, and both root and leaf nodes contain questions or criteria to be answered. Branches are arrows connecting nodes, showing the flow from question to answer. Each node typically has two or more nodes extending from it. For example, if the question in the first node requires a "yes" or "no" answer, there will be one leaf node for a "yes" response, and another node for "no."

Project Development



Decision Tree Uses

A decision tree can be used in either a predictive manner or a descriptive manner. In either instance they are constructed the same way and are always used to visualize all possible outcomes and decision points that occur chronologically. Decision trees are most commonly used in the financial world for areas such as loan approval, portfolio management, and spending. A decision tree can also be helpful when examining the viability of a new product or defining a new market for an existing product.

Seven Tips for Creating a Decision Tree

Here are some best practice tips for creating a decision tree diagram:

- **Start the tree.** Draw a rectangle near the left edge of the page to represent the first node. In this rectangle, write the first question, main idea, or criterion that will lead to a decision.
- **Add branches.** For every possible alternative draw a separate line that begins at the node and moves away toward the right of the page. Using a loan approval process as an example, the first node may have been "Income", and the associated branches might be <\$50K, \$51K - \$100K, >\$101K.

- **Add leaves.** The bulk of the decision tree will be leaf nodes. At the end of each branch add a leaf node. Fill each of these leaf nodes with another question or criterion.
- **Add more branches.** Repeat the process of adding a branch for each possible alternative leading from a leaf. Label each branch just as before.
- **Complete the decision tree.** Continue adding leaves and branches until every question or criterion has been resolved and an outcome has been reached.
- **Terminate a branch.** Continue adding leaves and branches until every question or criterion has been resolved and an outcome has been reached.
- **Verify accuracy.** Consult with all stakeholders to verify accuracy.

Structured English

What does *Structured English* mean?

- Structured English is a narrative form of English written as a series of blocks that use indentation and capitalization to represent a hierarchical structure of logic specifications.
- **Structured English** is the use of the English Language with the syntax of structured programming to communicate the design of a computer program to non-technical users by breaking it down into logical steps using straightforward English words. Structured English aims to get the benefits of both the programming logic and natural language: program logic helps to attain precision, whilst natural language helps with the familiarity of the spoken word.
- This method does not show any decisions or rules, but it states the rules and is used when an individual or an organization is trying to overcome the problems of an ambiguous language by stating the actions and conditions used when making decisions and formulating procedures.
- Structured English is based on structured logic; it is used when process logic involves formulas or iteration, or when structured decisions are not too complex.
- Structured English is used to express all logic in terms of sequential structures, decision structures, iterations and case structures.

- This modified form of English is used to specify the logic of information processes by using a subset of English vocabulary to express process procedures.

Structured English

- ✚ Structured English derives from structured programming and its use of logical construction and imperative statements.
- ✚ This process is designed to carry out instructions for actions by creating decision statements that use structured programming terms, such as "IF", "ELSE" and "THEN".
- ✚ Structure statements are developed and defined by using the following types of statements:

Structured English is a limited form "pseudocode" and consists of the following elements:

- ✚ Operation statements written as English phrases executed from the top down
 - ✚ Conditional blocks indicated by keywords such as IF, THEN, and ELSE
1. Repetition blocks indicated by keywords such as DO, WHILE, and UNTIL OR
 2. Sequence Structure: This is the single step or action included in the sequence process; it does not depend on the existence of other conditions.
 3. Decision Structure: This occurs when two or more actions rely on the value of a specific condition. The condition is expanded and the necessary decisions are made.

4. Iteration/Repetition Structure: Certain conditions will only occur after specific conditions are executed. Iterative instructions help an analyst describe these specific cases.
5. Structured English is a form of narrative English written as a series of blocks that uses capitalization and indentation to represent the hierarchical structure of the logic specifications.
6. Unlike Decision Tables and Decision Trees which show only branching logic, Structured English contains complete step by step statements.

Structured English Constructs

Structured English uses the three logic constructs:

Sequence where statements are executed from top to bottom.

For example:

```
PLACE CUSTOMER ORDER
  Obtain customer details
  IF (item in stock)
    Subtract one from items on hand
    Update INVENTORY record
    Print customer invoice
  ENDIF
EXIT PLACE CUSTOMER ORDER
```

Repetition where a set of statements is executed multiple times. The repetition condition may be at the beginning of the set of items or at the end of the set of items. For example:

```
REPEAT UNTIL (end of file)
```

Update CUSTOMER record

ENDREPEAT

Condition where a statement or a set of statements is executed only if a certain condition applies. A CASE statement may be used to represent mutually exclusive conditions.

For example:

IF (quantity ordered is GE 10)

Apply five percent discount to order price

ELSE IF (quantity ordered is GE 5 AND LE 9)

Apply two percent discount to order price

ENDIF

Guidelines for Writing Structured English

Apply the following guidelines when writing Structured English:

1. Express all logic in terms of sequential, repetition, and condition statements.
2. Ensure statements are not ambiguous.
3. Indent statements to show the logical hierarchy.
4. Place each sequence statement on a separate line. When the statement requires more than one line, the next line is indented.
5. Capitalize keywords.
6. Group blocks of statements together and give them a name that describes their function. Block names are capitalized. Blocks end with an EXIT item.
7. Underline words or phrases defined in a data dictionary.
8. Mark comment lines with an asterisk.
9. Use parentheses to clarify AND/OR meanings and condition statements.

RECOMMENDED KEYWORD CAPITALIZATION FOR LOGIC SPECIFICATION

Below is the recommended set of keywords that should be capitalized when specifying logic:

AND, CASE, CLOSE, CREATE, DELETE, DO, DOWHILE, DOUNTIL, ELSE, END, ENDIF, ENDWHILE, EQUAL, EOF, EXIT, FILE, GET, GE, GT, IF, LE, LT, OPEN, OR, READ, REPEAT, SO, THEN, UNTIL, UPDATE, WHILE, WRITE.

The following guidelines are used when writing Structured English

1. All logic should be expressed in operational, conditional, and repetition blocks
2. Statements should be clear and unambiguous
3. Logical blocks should be indented to show relationship and hierarchy
4. Use one line per logical element, or indent the continuation line
5. Keywords should be capitalized
6. Group blocks of statements together, with a capitalized name that describes their function and end with an EXIT.
7. Underline words or phrases defined in a data dictionary
8. Mark comment lines with an asterisk

Example of Structured English

A bank will grant loan under the following conditions

1. If a customer has an account with the bank and had no loan outstanding, loan will be granted.
2. If a customer has an account with the bank but some amount is outstanding from previous loans then loan will be granted if special approval is given.
3. Reject all loan applications in all other cases.

APPROVE LOAN

IF customer has a Bank Account THEN

IF Customer has no dues from previous account THEN

Allow loan facility

ELSE

IF Management Approval is obtained THEN

Allow loan facility

ELSE

Reject

ENDIF

ENDIF

ELSE

Reject

ENDIF

EXIT

Unit 5

Computer Animation

Introduction

Although we tend to think of **animation** as implying object motions, the term computer animation generally refers to any time sequence of visual changes in a scene. In addition to changing object position with translations or rotations, a computer-generated animation could display time variations in object size, color, transparency, or surface texture.

Some typical applications of computer-generated animation are entertainment (motion pictures and cartoons), advertising, scientific and engineering studies, and training and education. Advertising animations often transition one object shape into another: for example, transforming a can of motor oil into an automobile engine.

Computer animations can also be generated by changing camera parameters, such as position, orientation, and focal length. And we can produce computer animations by changing lighting effects or other parameters and procedures associated with illumination and rendering.

Design of animation sequences

In general, an animation sequence is designed with the following steps:

1. Storyboard layout
2. Object definitions
3. Key-frame specifications
4. Generation of in-between frames

This standard approach for animated cartoons is applied to other animation applications as well, although there are many special applications that do not follow this sequence. Real-time computer animations produced by flight simulators, for instance, display motion sequences in response to settings on the aircraft controls. For frame-by-frame animation, each frame of the scene is separately generated and stored. Later, the frames can be recorded on film or they can be consecutively displayed in "real-time playback" mode.

1. **Storyboard** is an outline of the action. It defines the motion sequence as a set of basic events that are to take place. Depending on the type of animation to be produced, the storyboard could consist of a set of rough sketches or it could be a list of the basic ideas for the motion.
2. An **object definition** is given for each participant in the action. Objects can be defined in terms of basic shapes, such as polygons or splines. In addition, the associated movements for each object are specified along with the shape.
3. A **key frame** is a detailed drawing of the scene at a certain time in the animation sequence. Within each key frame, each object is positioned according to the time for that frame. Some key frames are chosen at extreme positions in the action; others are spaced so that the time interval between key frames is not too great. More key frames are specified for intricate motions than for simple, slowly varying motions.
4. **In-betweens** are the intermediate frames between the key frames. The number of in-betweens needed is determined by the media to be used to display the animation. Film requires 24 frames per second, and graphics terminals are refreshed at the rate of 30 to 60 frames per second.

Typically, time intervals for the motion are set up so that there are from three to five in-betweens for each pair of key frames. Depending on the speed specified for the motion, some key frames can be duplicated. For a 1-minute film sequence with no duplication, we would need 1440 frames. With five in-betweens for each pair of key frames, we would need 288 key frames. If the motion is not too complicated, we could space the key frames a little farther apart.

There are several other tasks that may be required, depending on the application. They include motion verification, editing, and production and synchronization of a soundtrack. Many of the functions needed to produce general animations are now computer-generated.

Virtual Reality

What is VR?

- A believable computer-generated experience
 - A perfect (?) illusion
 - Artificial sensations
 - Deceiving the senses
 - Entering the image
 - Substitute for LSD
 - Obfuscated word

Visual environment

Auditory environment

Haptic/kinesth. enviro.

VR

SHARDA UNIVERSITY OF TECHNOLOGY

Introduction to VR

Virtual Reality

- Also known as artificial reality, virtual environment / presence, augmented / mixed reality, cyberspace, ...
- A believable experience
- A perfect illusion
- Artificial sensation, deceiving the senses
- A very powerful human-computer interface
- "Real life sucks... ..try VIRTUAL REALITY" ©

SHARDA UNIVERSITY OF TECHNOLOGY

Introduction to VR

Virtual Reality

- Virtual Reality (VR) is an environment that is simulated by a computer, trying to imitate the real thing
- Most virtual reality environments are primarily visual experiences
 - Displayed either on a computer screen, through special stereoscopic displays or other displays
 - Sound through speakers or headphones
- Some simulations include additional sensory information
 - Limited tactile feedback etc.

SHARDA UNIVERSITY OF TECHNOLOGY

Introduction to VR

Virtual Reality

- "Virtual reality" originally denoted a fully immersive system
- It has since been used to describe non-orthodox systems lacking wired gloves etc.
- The most immersive experiences I have seen:
 - 3D IMAX (non-VR), Real-D movies (non-VR), CAVE (VR)
 - All of them are very impressive if well done
- In practice, it is very difficult to create a fully convincing virtual reality experience
 - Technical limitations on processing power and image resolution
 - Input/output-devices far from perfect
 - Perfectionism usually not even needed



SHARADH UNIVERSITY OF TECHNOLOGY

Introduction to VR

VR definition

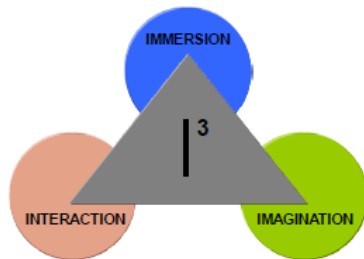
- A simulation in which computer graphics is used to create a realistic-looking world
- Can be a completely synthetic environment without any real counterpart
- Virtual Reality is a high-end user - computer interface that involves real-time simulation and interaction through multiple sensory channels
 - Sensory information may include visual, auditory, haptic, tactile, smell, taste...
 - Visual is dominating



SHARADH UNIVERSITY OF TECHNOLOGY

Introduction to VR

Virtual Reality Triangle



SHARADH UNIVERSITY OF TECHNOLOGY

Introduction to VR

The Three I's of Virtual Reality

- **Immersion**
 - The feeling of presence, being there
 - The amount and quality of stimuli and sensations
 - Real time: very little latency accepted
 - around 50 ms is a threshold of visual noticability, but varies for all senses
- **Interaction**
 - Not just passive watching
 - Moving in the virtual world
 - Doing all kind of things there
- **Imagination**
 - The applications
 - The ideas
 - The virtual worlds



SHARADH UNIVERSITY OF TECHNOLOGY

Introduction to VR

Properties of VR

- Synthetically generated environment
 - Computers, 3D, real-time
- Sensory feedback
 - I/O devices
- Interaction, moving
 - In time
 - In space
 - In scale
- Immersion
 - Being there

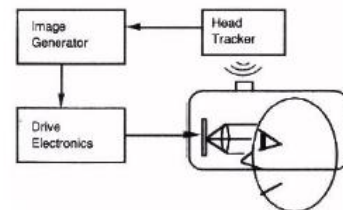


SHARADH UNIVERSITY OF TECHNOLOGY

Introduction to VR

The Basic Components of VR

- Computing
- Displays (visual, audio, haptics, etc)
- Tracking
- Input



SHARADH UNIVERSITY OF TECHNOLOGY

Introduction to VR

