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DATA STRUCTURES
ALGORITHMS
COMPUTER NETWORKS
DATABASE SYSTEMS

Unit-I


DATA STRUCTURES
ALGORITHMS
COMPUTER NETWORKS
DATABASE SYSTEMS
#include <iostream>
using nameepace std;
int main()
{
cout << "Hello, World!";
return 0;
}

INTRODUCTION TO SOFTWARE ENGINEERING

CHARACTERISTICS OF SOFTWARE

Software Engineering is an engineering discipline that applies systematic, disciplined and quantifiable approaches to the development, operation and maintenance of software.

What is Software?

Software is a collection of programs, procedures, data and related documentation that instructs a computer to perform specific tasks.

Characteristics of Software

01 Intangible (Invisibility)
Software is not a physical entity. It cannot be seen or touched like hardware.

02 Developed, Not Manufactured
Software is engineered or developed through coding and design. It does not have a manufacturing process.

03 Does Not Wear Out
Software does not physically deteriorate with use. However, it may become obsolete due to changes in requirements or technology.

04 Complexity
Software systems are highly complex due to large number of components, interactions and dependencies.

05 Changeability
Software must adapt to changing requirements and environments, so it is designed to be flexible and modifiable.

06 Conforms to Requirements
The quality of software depends on how well it satisfies the needs and expectations of users.

07 Custom Built
Most software is tailored for specific users or organizations rather than produced for a single generic use.

08 Maintenance is Essential
A significant portion of software cost is in its maintenance due to bug fixes, enhancements and adaptation to changes.

09 Copying is Easy
Software can be copied perfectly and distributed at nearly zero additional cost.

10 Mostly Logical, Not Physical
Software deals with logic, rules and information processing rather than physical materials.

In Short: Software is intangible, developed with effort and creativity, easy to copy, constantly evolving, and must meet user needs with high reliability and efficiency.

> "Good software is not just about working code, but about meeting real needs with quality and reliability."

TYPES OF SOFTWARE

Software can be broadly classified into the following main types

Software is a collection of programs, procedures and related documentation that instructs a computer to perform specific tasks.

1. SYSTEM SOFTWARE

System software manages computer hardware and provides a platform for running application software.

1.1 Operating System

Manages hardware resources and provides common services for computer programs.

Examples:
Windows, Linux, macOS, Android, iOS

1.2 Language Processors

Translates source code written in a programming language into machine language.

Examples:
Assembler, Compiler, Interpreter

1.3 Utility Programs

Performs maintenance and supports system operations for better performance.

Examples:
Antivirus, Disk Cleanup, Backup, Compression tools

1.4 Device Drivers

Acts as an interface between the operating system and hardware devices.

Examples:
Printer driver, Graphics driver, Network driver

2. APPLICATION SOFTWARE

Application software is designed to perform specific tasks for end users. It can be further divided into the following types.

2.1 General Purpose Application Software

Designed to perform common tasks that are useful to a wide range of users.

Examples:
MS Word, MS Excel, Web Browsers, Media Players

2.2 Specific Purpose Application Software

Designed for a specific task or to meet the requirements of a particular user or field.

Examples:
Payroll System, Inventory Management System, Billing Software

2.3 Customized (Tailor-made) Software

Developed specifically for a particular organization or individual as per their requirements.

Examples:
School Management System, Hospital Management System

2.4 Web and Mobile Application Software

Runs on web browsers or mobile devices to perform specific tasks.

Examples:
Online Banking, E-commerce Apps, Social Media Apps

In Short: System software runs the computer and supports other software, while application software helps users perform useful tasks.

"Good software makes the computer powerful, but the right software makes it useful."

NEED OF SOFTWARE ENGINEERING

Software Engineering provides a systematic, disciplined and quantifiable approach to the development of software.

What is it?

Software Engineering is an engineering discipline that applies engineering principles and methods to the design, development, testing, deployment and maintenance of software.

Why is Software Engineering Needed?

01 Manages Complexity

Software systems are becoming larger and more complex. Software Engineering provides structured methods to handle this complexity effectively.

02 Improves Quality

It ensures high quality software through proper design, coding standards, testing and reviews which reduces errors and improves reliability.

03 Timely Delivery

With proper planning, estimation and project management, software can be delivered on time, meeting deadlines.

04 Cost Effectiveness

Well-engineered software reduces rework, avoids defects and ensures efficient use of resources, which lowers the overall development and maintenance cost.

05 Meets User Requirements

It focuses on understanding user needs and delivering software that satisfies those needs and adds value to the users.

06 Easier Maintenance

Software Engineering produces well-structured and well-documented software that is easier to modify, enhance and maintain.

07 Scalability and Flexibility

It allows software to adapt to changing requirements and supports future growth and expansion.

08 Better Risk Management

It identifies potential risks early and applies risk management strategies to minimize failures and project uncertainties.

09 Increases Productivity

Using proven tools, techniques and processes improves team productivity and efficiency.

10 Supports Large Projects

Software Engineering techniques help in managing large teams and large-scale projects successfully.

In Short

Software Engineering is needed to build high-quality, reliable, scalable and cost-effective software that meets user needs and can adapt to future changes.

"Good software is not just about working code, it is about solving real problems in the best possible way."

SOFTWARE DEVELOPMENT LIFE CYCLE (SDLC)

A Systematic Approach to Build Quality Software

SDLC (Software Development Life Cycle) is a structured process used by software development teams to design, develop, test, deploy and maintain high-quality software.

OBJECTIVE

- Deliver high-quality software that meets user requirements.
- Complete projects on time and within budget.
- Ensure continuous improvement and customer satisfaction.

SDLC is an iterative process.

BENEFITS

- Provides a well-defined structure.
- Improves quality and productivity.
- Reduces risk and rework.
- Enhances communication and documentation.

PHASES OF SDLC

1 REQUIREMENT ANALYSIS

The requirements are gathered and analyzed in detail. This phase understands what the system should do.

Output: SRS Document

2 SYSTEM DESIGN

The system architecture, database, interfaces and modules are designed based on the requirements.

Output: Design Document

3 IMPLEMENTATION

The actual coding is done based on the design. The developers build the software modules.

Output: Source Code

4 TESTING

The software is tested to find defects and ensure it meets the requirements and quality standards.

Output: Tested Software

5 DEPLOYMENT

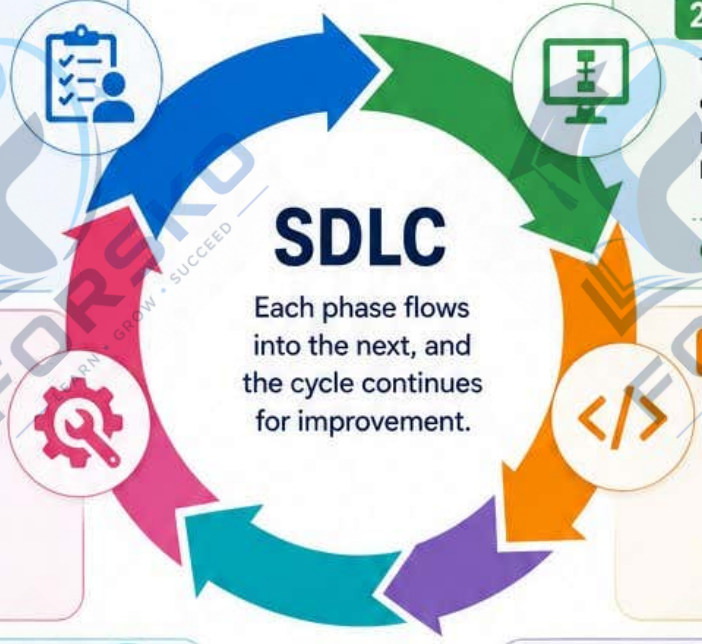
The tested software is deployed to the production environment for users to use.

Output: Deployed System

6 MAINTENANCE

The software is monitored and maintained. Bugs are fixed and updates are made as per user needs or environment changes.

Output: Updated System



KEY POINTS

- SDLC brings order and structure to software projects.
- It ensures quality, timely delivery and cost efficiency.
- It is an iterative process and allows continuous feedback and improvement.
- SDLC models can vary (Waterfall, Agile, Spiral, Iterative, etc.) based on project needs.

In Short: SDLC is the backbone of software engineering that ensures the right software is built in the right way, at the right time.

PHASES OF SDLC

The SDLC (Software Development Life Cycle) consists of a series of well-defined phases that guide the software from an idea to a fully functional and maintained product.

01 REQUIREMENT ANALYSIS

The goal is to understand what the system should do. Collect and analyze all requirements from users and stakeholders.

Key Activities
- Elicit requirements
- Analyze and document
- Feasibility study
- Validate requirements

Output
SRS Document (Software Requirements Specification)

02 SYSTEM DESIGN

The system is designed based on the requirements. It defines the architecture, modules, interfaces, and data flow.

Key Activities
- System architecture design
- Database design
- Interface design
- Detailed design

Output
Design Document (Architecture, HLD, LLD, Database Schema)

03 IMPLEMENTATION (CODING)

The actual coding is done as per the design. Developers write, build and integrate the code to form software modules.

Key Activities
- Write and compile code
- Follow coding standards
- Unit programming
- Code integration

Output
Source Code (Program Modules)

04 TESTING

The software is tested to find defects and ensure it meets the requirements and quality standards.

Key Activities
- Test planning
- Execute test cases
- Find and report defects
- Verify and validate

Output
Test Reports (Defect Reports, Test Summary)

05 DEPLOYMENT

The tested software is deployed to the production environment so that users can use it.

Key Activities
- Prepare deployment plan
- Install and configure
- Data migration
- Go-live and release

Output
Deployed System (Production Environment)

06 MAINTENANCE

The software is maintained after deployment. Issues are fixed and enhancements are made as per user needs or environment changes.

Key Activities
- Correct defects
- Improve performance
- Add new features
- Ongoing support

Output
Updated System (Maintained and Enhanced Software)

07 RETIREMENT (OPTIONAL)

When the software is no longer needed, it is safely retired or replaced.

Key Activities
- Plan retirement
- Backup important data
- Decommission system
- Document closure

Output
Retired System (Archived and Closed)

SDLC FLOW

01 Requirement Analysis → 02 System Design → 03 Implementation (Coding) → 04 Testing → 05 Deployment → 06 Maintenance → 07 Retirement (Optional)

In Short: SDLC phases provide a structured approach to build high-quality software in the right way, at the right time.

SOFTWARE DEVELOPMENT MODELS

Software Development Models are structured approaches or frameworks that define the process of developing software. They help in **planning, organizing, managing** and **controlling** the software projects effectively.

WHY USE SOFTWARE DEVELOPMENT MODELS?

- Provides a structured approach
- Improves quality and reliability
- Ensures timely delivery
- Helps in better planning and cost management
- Enhances communication and team coordination

01 WATERFALL MODEL

A linear and sequential approach where each phase must be completed before the next phase begins.

PHASES / FLOW

Requirements Analysis → System Design → Implementation (Coding) → Testing → Deployment → Maintenance

ADVANTAGES

- Simple and easy to understand
- Well defined phases and deliverables
- Easy to manage
- Works well when requirements are stable and clear

BEST SUITED FOR

Projects with well-defined and stable requirements.

02 ITERATIVE MODEL

The software is developed in repeated cycles (iterations). Each iteration adds more functionality to the system.

PHASES / FLOW

Plan → Design & Build → Test → Review

Repeat for next iteration

ADVANTAGES

- Early delivery of working software
- Easy to incorporate changes
- Continuous feedback and improvement
- Reduces risk

BEST SUITED FOR

Projects where requirements may change or are not fully known.

03 INCREMENTAL MODEL

The software is developed in small increments. Each increment adds a part of the functionality.

PHASES / FLOW

Increment 1	Increment 2	Increment 3	...	Increment n
Requirements	Requirements	Requirements		Requirements
Design	Design	Design		Design
Build	Build	Build		Build
Test	Test	Test		Test

Each increment delivers a working part of the software

ADVANTAGES

- Early and partial delivery
- Easy to manage and prioritize
- Accommodates changing requirements
- Better risk management

BEST SUITED FOR

Large projects where requirements can be divided into smaller modules.

04 SPIRAL MODEL

A risk-driven model that combines iterative development with systematic aspects of the waterfall model.

PHASES / FLOW

1. Determine Objectives — Define goals, alternatives and constraints
2. Identify & Resolve Risks — Evaluate risks and propose solutions
3. Development & Testing — Develop and verify the next level product
4. Plan the Next Iteration — Review and plan the next cycle

ADVANTAGES

- Effective risk management
- Handles complex projects well
- Flexible and adaptable
- Suitable for large-scale projects

BEST SUITED FOR

Large, complex and high-risk projects.

05 AGILE MODEL

An iterative and incremental approach that focuses on customer collaboration, flexibility and fast delivery.

PHASES / FLOW

Plan → Design → Develop → Test → Review → Plan (Continuous Iteration) → Release

Deliver working software frequently

ADVANTAGES

- Fast delivery and early feedback
- Welcomes changing requirements
- High customer satisfaction
- Continuous improvement

BEST SUITED FOR

Projects with changing requirements and need for quick delivery.

IN SHORT: Different models suit different types of projects. The right model helps in delivering the right software, in the right way, at the right time.

INTRODUCTION TO PROCESS MODELS

A process model is a simplified representation of a software process. It defines the order of activities, their dependencies, and the flow of the development process.

WHY DO WE NEED PROCESS MODELS?

- They provide a structured approach to software development.
- Help in planning, estimating, scheduling and monitoring.
- Improve quality, productivity and control.
- Facilitate effective communication among stakeholders.
- Help in managing risks and changing requirements.
- Act as a guide for the software development team.

CHARACTERISTICS OF A GOOD PROCESS MODEL

Understandable
Easy to understand and follow.

Complete
Covers all activities of the process.

Flexible
Allows changes to accommodate real-world needs.

Visible
Defines milestones and deliverables clearly.

Cost Effective
Provides good results within available resources.

Quality Focused
Ensures high quality products and process improvement.

TYPES / CLASSIFICATION OF PROCESS MODELS

1. Generic Process Models

Applicable to all types of software projects.

- Waterfall Model
- V-Model
- Incremental Model
- Iterative Model
- Spiral Model
- RAD Model
- Agile Models (Scrum, XP, Kanban, etc.)

2. Specialized Process Models

Designed for specific types of applications or domains.

- Component-Based Development
- Aspect-Oriented Development
- Formal Methods Model
- Concurrent Development Model
- Big Bang Model
- Prototyping Model

KEY POINTS

- No single process model is best for all projects.
- The choice of model depends on project size, requirements, complexity, risk, time and resources.
- Process models are the backbone of Software Engineering and the foundation for successful software development.

IN SHORT

Process models provide a roadmap for software development. They define the sequence of activities, help in better planning and control, and lead to the delivery of high-quality software.

> *"A well-chosen process model leads to the right product, delivered in the right way, at the right time."*

WATERFALL MODEL

A linear and sequential software development model where each phase must be completed before the next phase begins.

DEFINITION

The Waterfall Model is the earliest software process model. It is simple to understand and easy to manage because of its linear flow of control.

KEY FEATURES

- Sequential flow – one phase follows another.
- Well-defined stages and deliverables.
- Easy to understand and manage.
- Works best when requirements are stable and clearly defined.
- Suitable for small to medium projects.
- Each phase has specific inputs and outputs.

PHASES OF WATERFALL MODEL

1. **Requirements Analysis**
   All possible requirements of the system to be developed are captured in this phase and documented in the SRS document.
2. **System Design**
   The requirements are studied and the system design is prepared. It includes architecture, database design, interface design, etc.
3. **Implementation (Coding)**
   The actual coding is done based on the design document. The code is written, tested at unit level and integrated.
4. **Testing**
   The complete system is tested to find defects and ensure it meets the requirements and quality standards.
5. **Deployment**
   The tested software is deployed in the production environment for end users.
6. **Maintenance**
   After deployment, the software is maintained. Bugs are fixed, and improvements are made as per user needs.
7. **Retirement (Optional)**
   When the software is no longer useful, it is phased out and the system is retired or replaced.

ADVANTAGES

- Simple and easy to understand.
- Clearly defined stages and deliverables.
- Easy to manage due to rigid structure.
- Works well when requirements are stable and clear.
- Each stage has review points (milestones) which ensure quality.

LIMITATIONS

- Not flexible – changes are difficult once a phase is completed.
- Working software is not produced until late in the development.
- High risk and cost if requirements change.
- Not suitable for large and complex projects.
- Customer feedback is limited until later stages.

CHARACTERISTICS

- Linear and sequential flow.
- Phase begins only after the previous phase is completed.
- Documentation is heavily emphasized.
- Best suited for projects with well-defined and is not requirements.

WHEN TO USE?

- Requirements are clear, complete and stable.
- Technology and tools are well known.
- Project scope is well defined.
- Short duration projects.
- Small to medium-sized projects.
- Low-risk projects.

EXAMPLE

Payroll System, Inventory Management System, Student Information System, Library Management System, etc.

IN SHORT

The Waterfall Model is a traditional and straightforward approach. It is effective when requirements are fixed and unlikely to change. However, it lacks flexibility and is not ideal for complex and dynamic projects.

WATERFALL FLOW AT A GLANCE

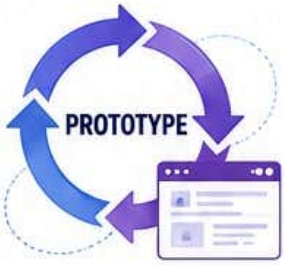
1 Requirements Analysis → 2 System Design → 3 Implementation (Coding) → 4 Testing → 5 Deployment → 6 Maintenance → 7 Retirement (Optional)

"Plan well, start well, finish well – that's the Waterfall way!"

PROTOTYPE MODEL

The Prototype Model is an iterative approach in software development used when requirements are not clearly understood.

A quick prototype is built, reviewed by the user, and refined until the final system meets the user's needs.



DEFINITION

The Prototype Model is a type of software development model in which a working prototype of the system is built, tested and refined repeatedly based on user feedback until an acceptable solution is achieved.

KEY CHARACTERISTICS

- Iterative process
- User involvement is high
- Early working model (prototype) is created
- Flexible to changes
- Focus on user satisfaction

WHEN TO USE?

- Requirements are unclear or incomplete
- New or innovative projects
- When user interface and user experience are critical
- When regular feedback from users is possible
- Small to medium-sized projects

PHASES OF PROTOTYPE MODEL

1 Requirement Gathering
Basic requirements are gathered from users.

2 Quick Design
A quick design is created for the prototype focusing on key features.

3 Build Prototype
A working prototype is developed quickly with limited functionality.

4 User Evaluation
Users evaluate the prototype and provide feedback.

5 Refine Prototype
The prototype is refined based on user feedback and requirements.

6 Engineer Product
Once the prototype is accepted, the complete system is built and tested.

Iterate until user is satisfied

ADVANTAGES

- Helps to clarify requirements.
- User involvement improves the end product.
- Early detection of problems.
- Reduces risk of project failure.
- Provides a better understanding of user needs.
- Flexible and easy to accommodate changes.

LIMITATIONS

- Not suitable for large and complex projects.
- Users may focus on the prototype and ignore the final product.
- Can lead to unclear goals if not managed well.
- Documentation may be insufficient.
- May increase cost and time if iterations are many.

HOW IT WORKS

Discuss with users → Build quick prototype → Get user feedback → Refine and improve → Final product

The cycle of build → evaluate → refine continues until the user is fully satisfied.

EXAMPLE

A College Management System Prototype: Login screen, student details form, fee payment page. User feedback: Add scholarship module. Refined prototype is updated. After approval, the complete system is developed.

PROTOTYPE MODEL FLOW AT A GLANCE

1. Requirement Gathering → 2. Quick Design → 3. Build Prototype → 4. User Evaluation → 5. Refine Prototype → 6. Engineer Product → Goal: User Satisfaction

IN SHORT: Prototype Model is all about **"Build – Show – Refine – Repeat"** until the right solution is achieved.

SPIRAL MODEL

The Spiral Model is a **risk-driven** software development model that combines iterative development with systematic aspects of the waterfall model.

DEFINITION

The Spiral Model is an iterative process model that emphasizes risk assessment and reduction. It is especially useful for large, complex and high-risk projects.

KEY CHARACTERISTICS

- Risk-driven approach
- Iterative and incremental
- Strong focus on risk analysis and mitigation
- Flexibility to accommodate changes
- Suitable for large and complex projects

WHEN TO USE?

- Large and complex projects
- High risk and uncertain requirements
- New or innovative projects
- Requirements are likely to change
- When risk assessment is critical for success

PHASES OF SPIRAL MODEL

1 Determine Objectives

- Identify objectives, alternatives and constraints.
- Plan the next iteration.

2 Identify and Resolve Risks

- Evaluate alternatives.
- Identify and analyze risks.
- Develop strategies to reduce or eliminate risks.

3 Development and Testing

- Develop the product based on the chosen approach.
- Verify and test the product.

4 Plan the Next Iteration

- Review the results of the iteration.
- Plan the next cycle based on feedback.

ADVANTAGES

- Effective risk management.
- Accommodates changes easily.
- High flexibility.
- Improves product quality.
- Customer satisfaction is high.
- Suitable for large, complex and high-risk projects.

LIMITATIONS

- Complex and difficult to manage.
- Requires risk assessment expertise.
- More costly and time-consuming.
- Not suitable for small or low-risk projects.

HOW IT WORKS?

1. Determine Objectives → 2. Identify & Resolve Risks → 3. Develop & Test → 4. Plan Next Iteration → Repeat until complete

Each cycle (spiral loop) results in a more complete and refined version of the software.

EXAMPLE

A Banking System:

Each spiral iteration may deliver a module such as Account Management, Fund Transfer, or Reporting. Risks like security, performance, or integration are analyzed and resolved in every cycle before moving forward.

SPIRAL MODEL FLOW AT A GLANCE

1 Determine Objectives → 2 Identify & Resolve Risks → 3 Development & Testing → 4 Plan Next Iteration → Repeat until project is complete

IN SHORT The Spiral Model is a cyclic and risk-driven approach that ensures continuous improvement, flexibility, and better handling of risks in software development.

Unit - II


DATA STRUCTURES
ALGORITHMS
COMPUTER NETWORKS
DATABASE SYSTEMS
#include <iostream>
using namespace std;
int main()
{
cout << "Hello, World!";
return 0;
}

SOFTWARE REQUIREMENTS

Software Requirements are the capabilities, features, functions, and constraints that a software system must satisfy.
They define **WHAT** the system should do, not **HOW** it will do it.

1. WHAT ARE SOFTWARE REQUIREMENTS?

Software requirements are the descriptions of services that the system should provide and the constraints under which it must operate.

Purpose

- Guide the development process
- Basis for planning, estimation and design
- Help in testing and validation
- Act as a contract between customer and developer

2. TYPES OF SOFTWARE REQUIREMENTS

A. Functional Requirements

Define what the system should do.
They describe the system's behavior or functionality.

Examples:

- User login
- Generate reports
- Add, update, delete records

B. Non-Functional Requirements

Define how well the system should perform certain functions.
They describe the quality attributes or constraints.

Examples:

- Performance (e.g., response time < 2 sec)
- Reliability (99.9% availability)
- Usability (easy to use)
- Security (data encryption)
- Maintainability, Scalability, Portability

3. USER REQUIREMENTS vs SYSTEM REQUIREMENTS

User Requirements	System Requirements
• Expressed in the user's own words	• Detailed and precise
• High-level and general	• Describe the system in detail
• Focus on what the user needs	• Define what the system must do and the constraints
• Used during the requirement elicitation phase	• Used for design, development, and testing

VS

User Requirements are transformed into System Requirements.

4. REQUIREMENTS ENGINEERING PROCESS

1. Elicitation
Gather requirements from stakeholders using techniques like interviews, questionnaires, observation, etc.

→

2. Analysis
Study and analyze requirements for consistency, completeness, feasibility, and prioritization.

→

3. Specification
Document requirements in a clear, precise and structured manner (SRS – Software Requirements Specification).

→

4. Validation
Check whether the requirements are correct, consistent, complete and testable.

→

5. Requirements Management
Manage changes to requirements and ensure traceability throughout the software lifecycle.

5. ATTRIBUTES OF GOOD REQUIREMENTS

- **Correct** – Reflect the real needs of stakeholders
- **Unambiguous** – Clear and have only one interpretation
- **Complete** – All necessary requirements are included
- **Consistent** – No conflicts among requirements
- **Feasible** – Achievable within constraints
- **Necessary** – Only essential requirements
- **Prioritized** – Ranked by importance and stability
- **Verifiable** – Testable to ensure they are met
- **Traceable** – Forward and backward traceable

6. IMPORTANCE OF REQUIREMENTS

- Reduces cost and time
- Improves quality of the software
- Helps in risk management
- Provides a baseline for project planning
- Ensures better communication among stakeholders
- Reduces scope creep (uncontrolled changes)
- Forms the basis for testing and validation

IN SHORT

Software Requirements define what a system should do and the constraints under which it must operate.
Good requirements lead to successful software.

EXAMPLES

- ATM System: Withdraw cash, check balance (Functional)
- Website: Page load time < 3 sec, secure login (Non-Functional)
- Library System: Add book, issue book (Functional)
- Library System: Easy to use, data backup (Non-Functional)

FUNCTIONAL REQUIREMENTS

Functional requirements define **WHAT** the system should do. They describe the features, services and functions that the system must provide to the users.

DEFINITION

Functional requirements specify the behavior of the system. They describe the tasks or functions the system must perform, the inputs it must accept, the outputs it must produce, and the conditions under which it must operate.

KEY POINTS

- Focus on the system's behavior and functions.
- Written from the user's point of view.
- Describe WHAT the system should do, not HOW it will do it.
- Can be measured and tested.
- Used by developers for design and implementation.

EXAMPLES OF FUNCTIONAL REQUIREMENTS

Domain	Functional Requirement	Description
Login	User Authentication	The system shall allow registered users to log in using username and password.
Student Management	Add Student	The system shall allow admin to add new student details.
Library System	Search Book	The system shall allow users to search books by title, author or ISBN.
Banking System	Fund Transfer	The system shall allow customers to transfer funds between accounts.
E-Commerce	Place Order	The system shall allow customers to place an order for selected products.

TYPICAL CHARACTERISTICS

- Describe system services or functions.
- Specify inputs, processing and outputs.
- Describe system behavior for various conditions.
- State system responses to specific inputs.
- Independent of any particular technology.
- Usually expressed in clear, simple language.

Template

The system shall <function> <object> in order to <achieve result>.

Example:

The system shall allow the user to reset password in order to regain account access.

TYPES OF FUNCTIONAL REQUIREMENTS

1. User Functional Requirements

Describes the functions from the end user's perspective.

Example:

The user shall be able to generate a sales report.

2. System Functional Requirements

Describes the functions in detail, used by developers.

Example:

The system shall generate a sales report based on date range selected by user.

SOURCES OF FUNCTIONAL REQUIREMENTS

- User interviews
- Questionnaires and surveys
- Observation of current system
- Business documents and policies
- Stakeholder meetings and discussions

IMPORTANCE

- Helps in understanding user needs clearly.
- Forms the basis for system design and development.
- Enables accurate estimation of cost and time.
- Provides a basis for testing and validation.
- Ensures the developed system meets user expectations.

GOOD PRACTICES

- Use simple and clear language.
- Be complete, consistent and unambiguous.
- Avoid technical jargon (in user requirements).
- Write testable and verifiable requirements.
- Review and validate with stakeholders.

IN SHORT: Functional requirements define the functions and services a system must provide. They answer the question "What should the system do?"

NON-FUNCTIONAL REQUIREMENTS

Non-functional requirements (NFRs) define **HOW WELL** the system should perform rather than what the system should do. They specify the quality attributes, constraints and standards under which the system must operate.

1. DEFINITION

Non-functional requirements are constraints on the services or functions offered by the system. They describe the quality attributes, performance, reliability, security, usability and other characteristics of the system.

2. KEY POINTS

- Focus on the quality and behavior of the system.
- Define how well the system should work.
- Apply to the entire system, not to a specific function.
- Often measurable and testable.
- Important for user satisfaction and system success.

3. EXAMPLES (IN GENERAL)

- System should respond in less than 2 seconds.
- System should provide 99.9% availability.
- Data should be encrypted during transmission.
- System should be easy to use and understand.

4. COMMON NON-FUNCTIONAL REQUIREMENTS AND EXAMPLES

Category	Description	Example
Performance	Defines speed, response time, throughput, resource usage.	• Page load time < 2 seconds • System should handle 1000 users simultaneously
Reliability	Defines availability, fault tolerance, recoverability.	• System availability should be 99.9% • System should recover from failure automatically
Security	Defines protection of data and system from unauthorized access and attacks.	• Users must authenticate to access system • Data should be encrypted • Role-based access control
Usability	Defines ease of use, user interface and user experience.	• System should be easy to navigate • New users should learn system within 30 minutes
Maintainability	Defines ease of modification, testing and support.	• Code should follow standard coding guidelines • System should be modular and well documented
Scalability	Defines capability to handle growth in users, data or transactions.	• System should support 10,000 users in future • System should allow easy addition of new modules
Compatibility	Defines ability to work with other systems, platforms or devices.	• System should work on Windows, Linux and macOS • System should be compatible with modern browsers
Portability	Defines ease of installation and deployment in different environments.	• System should be deployable on cloud and on-premise • Minimal changes for new environment setup

5. CHARACTERISTICS

- Applies to the whole system.
- Independent of specific functionalities.
- Measurable and testable (where possible).
- Important for quality and user satisfaction.
- Influences design and implementation.
- Often more critical than functional requirements for system success.

6. SOURCES OF NON-FUNCTIONAL REQUIREMENTS

- Stakeholder interviews
- Quality standards and regulations
- Organizational policies
- Existing system performance reports
- Market and competitor analysis
- Best practices and domain knowledge

7. IMPORTANCE

- Ensures high quality of the system.
- Improves user satisfaction.
- Helps in risk reduction.
- Differentiates the system from competitors.
- Ensures the system meets business and technical standards.

8. DIFFERENCE BETWEEN FUNCTIONAL AND NON-FUNCTIONAL REQUIREMENTS

Functional Requirements	Non-Functional Requirements
Define what the system should do.	Define how well the system should do it.
Focus on behavior and functions.	Focus on quality attributes and constraints.
Usually expressed as actions.	Usually expressed as quality criteria or constraints.
Example: User login, Add product.	Example: Response time < 2 sec, 99.9% availability.

IN SHORT

Functional requirements answer **"What should the system do?"**

Non-functional requirements answer **"How well should the system do it?"**

USER REQUIREMENTS

User requirements are high-level statements of what the users need from the system. They describe the system from the user's point of view in simple and natural language.

1. DEFINITION

User requirements are the needs and expectations of the users for a system. They are expressed in the user's own words, without using technical terms. They describe WHAT the system should do, not HOW it will do it.

2. KEY POINTS

- Focus on the needs of the end users.
- Written in simple, non-technical language.
- Describe what the user wants the system to do.
- Do not describe how developers will implement the system.
- Form the basis for system requirements.
- Help in understanding the problem clearly.

3. CHARACTERISTICS

- High-level and general.
- Easy to understand by users.
- Expressed in natural language.
- Focus on user goals and tasks.
- Independent of technology.
- May be incomplete and change during development.

4. EXAMPLES OF USER REQUIREMENTS

Application Domain	User Requirements (Examples)
Banking System	• The system shall allow users to withdraw cash. • The system shall allow users to check account balance. • The system shall allow users to transfer money.
E-Commerce System	• The system shall allow customers to search for products. • The system shall allow customers to add items to the cart. • The system shall allow customers to place an order.
Student Management System	• The system shall allow teachers to enter student marks. • The system shall allow students to view their results. • The system shall allow the admin to manage student records.
Hospital Management System	• The system shall allow patients to book appointments. • The system shall allow doctors to view patient history. • The system shall allow staff to manage patient records.

5. SOURCES OF USER REQUIREMENTS

- User interviews
- Questionnaires and surveys
- Observation of current system
- User meetings and discussions
- Feedback and suggestions
- Business documents
- User manuals of existing system

6. USER REQUIREMENTS vs SYSTEM REQUIREMENTS

User Requirements		System Requirements
Expressed in the user's own words.	VS	Written in technical and precise terms.
High-level and general.	VS	Detailed and specific.
Focus on what users need.	VS	Focus on what the system must do and the constraints.
Used during requirement elicitation.	VS	Used for design, development, testing and validation.
May change during development.	VS	Should be stable and measurable.
Example: "The system shall allow users to book tickets."	VS	Example: "The system shall allow users to book tickets and store them in the database."

7. IMPORTANCE OF USER REQUIREMENTS

- Helps in understanding user needs clearly.
- Provides a clear direction for system development.
- Acts as a starting point for requirement analysis.
- Improves communication between users and developers.
- Helps in creating a system that meets user expectations.
- Reduces the chances of misunderstanding.
- Increases user satisfaction.

8. HOW USER REQUIREMENTS ARE USED

1. Elicit User Requirements
2. Analyze and Understand
3. Document as User Requirements
4. Convert to System Requirements
5. Use for Design, Development and Testing

IN SHORT

User requirements describe what the users want from the system in their own words. They are the foundation for building a successful system that satisfies the users.

SYSTEM REQUIREMENTS

System requirements are detailed statements that describe **what** the system **must do** and the **constraints** under which it must operate. They are derived from user requirements and are more precise and technical.

1. DEFINITION

System requirements are precise, detailed and structured descriptions of the system's functions, services, performance and constraints. They define in detail WHAT the system must do and the conditions under which it must operate.

2. KEY POINTS

- Derived from user requirements.
- More detailed, complete and precise.
- Describe system behavior, features, performance and constraints.
- Written in technical language.
- Used by developers, testers and other technical team members.
- Serve as a contract between customer and developer.

3. CHARACTERISTICS

- Precise and unambiguous.
- Complete.
- Consistent.
- Verifiable and testable.
- Feasible.
- Necessary.
- Ranked for importance and stability.

4. TYPES / CATEGORIES OF SYSTEM REQUIREMENTS

Type	Description	Examples
Functional Requirements	Define the functions and services that the system must provide.	• User login • Generate reports • Add, update, delete records
Non-Functional Requirements	Define the quality attributes and constraints on the system.	• Response time < 2 seconds • Availability 99.9% • Security and reliability
External Interface Requirements	Define the interfaces between the system and external entities.	• User interface • Hardware interfaces • Software interfaces (APIs)
Data Requirements	Define the data that the system must use, store and manage.	• Database tables and fields • Data formats • Data retention rules
Constraints	Define the limitations or constraints that the system must follow.	• Budget • Legal or regulatory rules • Technology limitations

5. EXAMPLES OF SYSTEM REQUIREMENTS

User Management System
The system shall allow an admin to add, update, delete and view users.

Performance Requirement
The system shall respond to any request within 2 seconds under normal load.

Security Requirement
The system shall encrypt all sensitive data during transmission.

Data Requirement
The system shall store user data in the database for a minimum of 5 years.

Interface Requirement
The system shall provide a web interface that is compatible with Chrome, Firefox and Edge browsers.

6. USER REQUIREMENTS vs SYSTEM REQUIREMENTS

User Requirements		System Requirements
Expressed in the user's own words.	VS	Expressed in technical and precise terms.
High-level and general.	VS	Detailed and specific.
Focus on what the user wants.	VS	Focus on what the system must do and the constraints.
Used during requirement elicitation.	VS	Used for design, development, testing and validation.
May change frequently.	VS	Should be stable and measurable.
Example: "I want to transfer money."	VS	Example: "The system shall allow users to transfer money between accounts and show confirmation."

7. IMPORTANCE OF SYSTEM REQUIREMENTS

- Provide a clear and precise understanding of the system.
- Guide the design and implementation.
- Help in accurate estimation of cost and time.
- Form the basis for testing and validation.
- Ensure the system meets user needs and business goals.
- Reduce the risk of misunderstanding.
- Act as a reference throughout the software development.

8. HOW SYSTEM REQUIREMENTS ARE USED

1. Gather User Requirements
2. Analyze and Refine User Requirements
3. Convert to System Requirements
4. Use for Design, Development and Testing
5. Validate and Verify the System

IN SHORT

System requirements describe in detail what the system must do and the constraints under which it must operate. They are the foundation for building a reliable, efficient and user-friendly system.

REQUIREMENTS ENGINEERING PROCESS

Requirements Engineering is the process of discovering, analyzing, documenting, validating and managing the requirements of a system.
It ensures that the **right system** is built.

1. DEFINITION

Requirements Engineering Process is a systematic approach to find, analyze, document, validate and manage the requirements of a software system.

2. OBJECTIVES

- Understand the needs of stakeholders.
- Define complete and unambiguous requirements.
- Ensure requirements are feasible and testable.
- Manage changes in requirements.
- Reduce risk and cost.
- Ensure customer satisfaction.

3. ACTIVITIES INVOLVED

- Requirements Elicitation
- Requirements Analysis
- Requirements Specification
- Requirements Validation
- Requirements Management

4. REQUIREMENTS ENGINEERING PROCESS (PHASES)

1. Requirements Elicitation

Discover and gather requirements from stakeholders.
Identify needs, expectations and constraints.

Techniques
- Interviews
- Questionnaires
- Observation
- Document Study
- Brainstorming

2. Requirements Analysis

Analyze and refine the gathered requirements.
Resolve conflicts, remove ambiguity, and check feasibility.

Outputs
- Use case model
- Data flow diagrams
- Domain model
- Feasibility report
- Prototypes

3. Requirements Specification

Document the requirements in a clear, precise and structured manner.
Serves as a contract between customer and developer.

Outputs
- SRS (Software Requirements Specification)
- Supplementary Specifications

4. Requirements Validation

Validate that the requirements are correct, complete, consistent, realistic and testable.

Techniques
- Reviews
- Prototyping
- Walkthroughs
- Test case generation

5. Requirements Management

Manage changes to requirements throughout the software development lifecycle.

Activities
- Change tracking
- Version control
- Impact analysis
- Traceability

5. ELICITATION TECHNIQUES (DETAILS)

Technique	Description
Interviews	Direct conversation with stakehdders to understand needs.
Questionnaires	Set of written questions to gather from many stakeholders.
Observation	Observe users while they perform their tasks in their environment.
Document Study	Study existing documents, reports, manuals, policies, etc.
Brainstorming	Group discussion to generate ideas and identify requirements.

6. QUALITIES OF GOOD REQUIREMENTS

- **Correct** – reflect the real needs.
- **Complete** – all necessary requirements are included.
- **Unambiguous** – clear and only one interpretation.
- **Consistent** – no conflicts among requirements.
- **Feasible** – achievable within constraints.
- **Verifiable** – can be checked and validated.
- **Necessary** – only essential requirements.
- **Prioritized** – ranked for importance and stability.
- **Modifiable** – easy to change if required.
- **Traceable** – linked to source and dependent requirements.

7. BENEFITS

- Better understanding of stakeholder needs.
- Helps in accurate planning and estimation.
- Reduces rework and development cost.
- Improves quality of product.
- Provides a baseline for design, development and testing.
- Improves communication among stakeholders.

8. USER REQUIREMENTS vs SYSTEM REQUIREMENTS

Basis	User Requirements	System Requirements
Definition	Describe what the user needs.	Describe what the system must do and constraints.
Written By	Users / Customers	Analysts / System Engineers
Level	High-level and general	Detailed and technical
Focus	Goals and tasks	Functions, performances and constraints
Language	Natural language	Formal and precise
Purpose	Understand user needs	Guide design, development and testing
Example	"System shall allow user to book railway ticket."	"System shall validate user login within 2 seconds."

9. IN SHORT

The Requirements Engineering Process ensures that the right requirements are gathered, analyzed, documented, validated and managed effectively so that the final software system meets user needs and business goals.

Key Takeaway

"Right requirements build the right system."

REQUIREMENTS ELICITATION

Requirements Elicitation is the process of **discovering, gathering** and **understanding** the needs, expectations and constraints of stakeholders for a software system.

1. DEFINITION

Requirements Elicitation is the first and most important activity in the requirements engineering process. It involves finding out what the stakeholders need from the system. The goal is to gather complete, accurate and relevant information.

2. OBJECTIVES

- Discover the real needs of stakeholders.
- Identify problems, opportunities and goals.
- Gather complete and relevant requirements.
- Understand the domain and business rules.
- Establish a good communication with stakeholders.
- Create a foundation for analysis and documentation.

3. STAKEHOLDERS

People who have interest in or will be affected by the system.

- Customers / End Users
- Managers
- Domain Experts
- Developers
- Testers
- Operations / Support Staff
- External Systems

4. ELICITATION TECHNIQUES (METHODS)

Technique	Description	How it Helps	Best Used When
Interviews	One-to-one or group conversation with stakeholders.	Helps to understand needs in depth, clarify doubts and gather detailed information.	Requirements are complex and need in-depth understanding.
Questionnaires (Surveys)	Set of written questions sent to many stakeholders.	Collects information from a large number of people quickly.	When many stakeholders are distributed or have less time.
Observation	Observing stakeholders while they perform their work.	Helps to understand actual activities, processes and hidden requirements.	When stakeholders find it difficult to explain their work.
Document Study	Studying existing documents like reports, manuals, policies, forms, etc.	Provides background information and existing constraints.	When relevant documents are available.
Brainstorming	Group discussion to generate ideas and requirements.	Encourages creativity and helps to identify more requirements.	When exploring new ideas or solving problems.
Prototyping	Creating a simple model or prototype to get feedback.	Helps stakeholders visualize the system and give better suggestions.	When requirements are unclear or likely to change.
JAD Sessions (Joint Application Design)	Structured meeting with key stakeholders and developers.	Quickly collects and validates requirements through active participation.	When time is limited and key stakeholders are available.
Interface Analysis	Studying interfaces with other systems, hardware or software.	Identifies data, control and communication requirements.	When the system interacts with other external entities.

5. ELICITATION PROCESS (STEPS)

1. **Identify Stakeholders**
   Find all internal and external stakeholders.
2. **Plan Elicitation Activities**
   Decide what information is needed and which techniques to use.
3. **Conduct Elicitation**
   Use appropriate techniques to gather information.
4. **Validate Information**
   Confirm the gathered information with stakeholders.
5. **Document Findings**
   Write down the elicited requirements clearly.
6. **Review and Refine**
   Review the information and refine it for completeness and accuracy.

6. GUIDELINES FOR EFFECTIVE ELICITATION

- Build trust and good communication with stakeholders.
- Listen actively and ask the right questions.
- Use a combination of techniques.
- Focus on goals, not solutions.
- Avoid assumptions and technical jargon.
- Be neutral and patient.
- Record everything clearly.
- Validate and confirm frequently.

7. CHALLENGES

- Stakeholders may not know exactly what they want.
- Different stakeholders may have conflicting needs.
- Stakeholders may be unavailable.
- Incomplete or vague information.
- Changing requirements.

8. IMPORTANCE

- Helps to build the right system.
- Reduces rework and cost.
- Improves customer satisfaction.
- Provides a clear direction for analysis, design and development.

IN SHORT

Requirements elicitation is about asking the right questions, listening carefully and understanding what stakeholders really need, so that the system can be built to solve the right problem.

REQUIREMENTS ANALYSIS

Requirements Analysis is the process of examining the elicited requirements in detail to understand, organize, model, prioritize, resolve conflicts and ensure feasibility and consistency.

1. DEFINITION

Requirements Analysis is the process of studying the gathered requirements in detail to understand what the system should do. It involves organizing, structuring, modeling and validating the requirements to ensure they are complete, consistent, feasible and testable before the design phase.

2. OBJECTIVES

- Understand requirements in depth.
- Identify and resolve conflicts.
- Ensure completeness and consistency.
- Prioritize requirements.
- Check feasibility and constraints.
- Convert requirements into models.
- Provide a clear foundation for design and development.

3. ACTIVITIES INVOLVED

- Requirements classification and organization
- Requirements modeling
- Requirements prioritization
- Requirements validation
- Requirements documentation
- Feasibility study
- Traceability establishment

4. ANALYSIS TECHNIQUES (METHODS)

Technique	Description	How it Helps	When to Use
Data Flow Diagrams (DFD)	Shows how data moves through the system.	Helps in understanding system functions and data handling.	When focusing on processes and data movement.
Use Case Modeling	Describes interactions between actors and the system.	Helps in identifying functional requirements from the user point of view.	When understanding system features and user goals.
Class Diagram	Shows classes, attributes and relationships.	Helps in identifying data structure and relationships.	When focusing on object-oriented systems.
ER Diagram	Represents entities and their relationships.	Helps in database design and data requirements.	When dealing with data intensive systems.
Decision Table	Shows conditions and corresponding actions.	Helps in representing complex business rules clearly.	When rules are complex and combinations are many.
Decision Tree	Shows possible conditions and outcomes.	Helps in understanding logic and decision making.	When decisions depend on multiple conditions.
State Diagram	Shows states and transitions of a system.	Helps in understanding system behavior over time.	When system behavior changes based on events.

5. QUALITIES OF GOOD REQUIREMENTS

- Correct – reflect real needs.
- Complete – all necessary requirements included.
- Unambiguous – clear and only one interpretation.
- Consistent – no conflicts among requirements.
- Feasible – achievable within given constraints.
- Verifiable – can be checked or tested.
- Necessary – essential for the system.
- Prioritized – ordered by importance.
- Modifiable – easy to change if required.
- Traceable – linked to source and used throughout the project.

6. ANALYSIS PROCESS (STEPS)

1. **Review Requirements**
   Study elicited requirements carefully.
2. **Classify and Organize**
   Group requirements into meaningful categories.
3. **Model Requirements**
   Create models (DFD, Use Case, ERD, etc.).
4. **Analyze and Refine**
   Check for conflicts, gaps and redundancies.
5. **Prioritize Requirements**
   Rank requirements based on importance.
6. **Validate Requirements**
   Ensure requirements are correct, complete and feasible.

7. BENEFITS

- Provides a clear understanding of requirements.
- Reduces misunderstandings and conflicts.
- Helps in accurate estimation of cost and time.
- Ensures the system meets user needs.
- Forms a strong base for design and development.
- Improves communication among stakeholders.
- Reduces rework and project risks.

8. KEY OUTPUTS

- Requirements specification (SRS)
- Use case diagram
- Data flow diagrams
- Class / ER diagrams
- Business rules
- Requirements traceability matrix
- Feasibility report
- Prioritized requirements list

IN SHORT

Requirements Analysis turns raw requirements into meaningful, well-structured and validated information so that the right system can be built in the right way.

REQUIREMENTS VALIDATION

Requirements Validation is the process of ensuring that the elicited requirements are **correct, complete, consistent, feasible, testable** and meet the **real needs of stakeholders** before proceeding to design.

1. DEFINITION

Requirements Validation checks whether the requirements specification truly reflects what the stakeholders need and whether it is of the right quality. It ensures we are building the **right** product.

2. OBJECTIVES

- Ensure requirements are correct and meet stakeholder needs.
- Ensure requirements are complete and no important requirement is missing.
- Ensure requirements are consistent and free from conflicts.
- Ensure requirements are feasible to implement.
- Ensure requirements are testable and measurable.
- Gain stakeholder agreement and sign-off.

3. ACTIVITIES INVOLVED

- Requirements reviews
- Prototyping
- Walkthroughs
- Test case derivation
- Consistency checks
- Feasibility analysis
- Stakeholder feedback and sign-off

4. VALIDATION TECHNIQUES (METHODS)

Technique	Description	How it Helps	When to Use
Requirements Reviews	Review the requirements document thoroughly.	Finds errors, missing requirements and improvements.	Always before finalizing the requirements.
Walkthroughs	Author explains requirements to stakeholders step by step.	Finds misunderstandings and ambiguities.	When requirements are complex.
Prototyping	Create a prototype (UI/Model) to validate requirements.	Helps stakeholders visualize and validate early.	When requirements are unclear or new.
Test Case Derivation	Derive test cases from requirements.	Checks if requirements are testable and measurable.	During validation and before testing phase.
Consistency Checks	Check for conflicts, duplicates and inconsistencies.	Ensures requirements do not contradict each other.	During and after requirements analysis.
Feasibility Analysis	Evaluate technical, economic and operational feasibility.	Ensures requirements are achievable within constraints.	Before final approval of requirements.
Stakeholder Feedback	Get feedback from all stakeholders.	Ensures requirements meet real needs and expectations.	Before sign-off and after major changes.

5. QUALITIES CHECKED DURING VALIDATION

- **Correct** – reflects real stakeholder needs.
- **Complete** – all required requirements are included.
- **Consistent** – no conflicts or contradictions.
- **Unambiguous** – clear and only one interpretation.
- **Feasible** – achievable within given constraints.
- **Testable** – can be verified through tests.
- **Traceable** – linked to source and design.
- **Necessary** – every requirement adds value.
- **Prioritized** – right priority given to each requirement.
- **Verifiable** – can be reviewed and validated.

6. VALIDATION PROCESS (STEPS)

1. **Prepare for Validation**
   Understand requirements and validation criteria.
2. **Select Validation Techniques**
   Choose appropriate techniques based on requirements type.
3. **Conduct Validation**
   Apply selected techniques and review requirements.
4. **Log Issues**
   Record defects, gaps and suggestions.
5. **Resolve Issues**
   Update requirements and resolve identified problems.
6. **Obtain Sign-off**
   Get stakeholder approval and sign-off.

7. BENEFITS

- Ensures we build the right product.
- Reduces rework and cost.
- Improves quality of requirements.
- Increases stakeholder satisfaction.
- Improves communication and understanding.
- Reduces risk of project failure.
- Provides a strong foundation for design, development and testing.

8. KEY OUTPUTS

- Validated requirements document (Requirements Specification)
- Defect/Issue list
- Updated requirements
- Test cases (derived)
- Stakeholder sign-off
- Traceability matrix updates
- Change requests (if any)

IN SHORT

Requirements Validation ensures that the requirements are of high quality and meet stakeholder needs before moving forward, so that we build the right system right from the start.

9. VALIDATION vs VERIFICATION

	Validation (Are we building the right product?)	Verification (Are we building the product right?)
Focus	Ensures we are building the right thing.	Ensures we are building the thing right.
Type	Checks requirements.	Checks outputs / deliverables.
Performed by	Stakeholders, users, business analysts.	Developers, testers, QA team.
When	During requirements phase.	During design, development and testing.
Example	Reviewing requirements with users.	Testing the implemented system.

Remember:
Validation says "Are we building the right product?"
Verification says "Are we building the product right?"

REQUIREMENTS MANAGEMENT

Requirements Management is the process of identifying, documenting, organizing, tracking, controlling and maintaining requirements and their changes throughout the software development life cycle.

1. DEFINITION

Requirements Management is the process of managing changes to requirements, maintaining their integrity and traceability, and ensuring that the requirements are consistent, up-to-date and aligned with business goals throughout the project.

2. OBJECTIVES

- Maintain agreement on requirements throughout the project.
- Manage changes to requirements effectively.
- Ensure requirements are traceable and consistent.
- Provide visibility of requirements status.
- Reduce rework and project risks.
- Ensure the delivered system meets business and user needs.

3. ACTIVITIES INVOLVED

- Requirements identification and documentation
- Requirements organization and structuring
- Requirements prioritization
- Requirements version control
- Requirements change management
- Requirements traceability
- Requirements status tracking
- Requirements audits and reviews
- Requirements baselining

4. KEY ACTIVITIES IN DETAIL

Activity	Description	How it Helps	Key Outputs
Identify & Document Requirements	Capture requirements from stakeholders and document them clearly.	Provides a clear understanding of what is needed.	Requirements Specification (SRS)
Organize & Structure Requirements	Group and structure requirements using models, hierarchies or templates.	Improves understandability and consistency.	Requirement Models, Use Case Diagrams, Backlog
Prioritize Requirements	Rank requirements based on business value, risk, cost and dependencies.	Helps focus on what is most important first.	Prioritized Requirement List
Control Changes (Change Management)	Evaluate, approve/reject and implement changes to requirements.	Prevents uncontrolled changes and scope creep.	Change Requests, Change Log
Maintain Traceability	Establish and maintain links between requirements and other artifacts (design, code, tests).	Ensures end-to-end visibility and impact analysis.	Traceability Matrix
Track Status	Monitor and track the status of requirements throughout the project.	Provides up-to-date visibility of progress.	Requirement Status Reports, Dashboards
Version Control & Baselines	Manage versions of requirements and create baselines at key milestones.	Preserves history and supports releases.	Baselines, Version History
Audit & Review	Review requirements for correctness, completeness, consistency and compliance.	Improves quality and reduces defects.	Review Reports, Audit Results

5. BENEFITS

- Better alignment with business goals and stakeholder needs.
- Reduced rework and change costs.
- Improved quality and consistency of requirements.
- Better visibility and control.
- Effective impact analysis.
- Supports decision making.
- Ensures regulatory compliance.

6. REQUIREMENTS MANAGEMENT PROCESS (STEPS)

1. **Plan Requirements Management**
   Define process, roles, tools and standards.
2. **Elicit & Document Requirements**
   Gather and document requirements.
3. **Organize & Prioritize Requirements**
   Structure and prioritize requirements.
4. **Control & Manage Changes**
   Handle change requests through a formal process.
5. **Track & Report Status**
   Monitor progress and communicate status.
6. **Review, Audit & Baseline**
   Review, audit and establish baselines.

7. CHANGE MANAGEMENT PROCESS

1. **Change Request Raised**
   Stakeholder raises a change request.
2. **Impact Analysis**
   Analyze impact on scope, time, cost, quality.
3. **Review & Decision**
   CCB (Change Control Board) reviews and decides.
4. **Update Requirements**
   Update documents, models and traceability.
5. **Communicate Changes**
   Inform all affected stakeholders.
6. **Track & Verify**
   Verify changes and update status.

Change Request → Impact Analysis → Decision → Update & Communicate → Verify & Close

8. TOOLS USED

- JIRA
- IBM DOORS
- Azure DevOps
- ReqView
- Caliber RM
- Codebeamer
- Helix RM
- Polarion

9. REQUIREMENTS MANAGEMENT PLAN (INCLUDES)

- Purpose and scope
- Roles and responsibilities
- Processes and procedures
- Tools and templates
- Change control process
- Traceability strategy
- Metrics and reporting
- Review and audit plan
- Configuration and version control
- Communication plan

10. IN SHORT

Requirements Management ensures that the right requirements are managed in the right way, at the right time, so that we build the right product.

KEY TAKEAWAY

Good requirements management leads to better control, better communication, and better quality — resulting in successful project delivery.

Unit - III


DATA STRUCTURES
ALGORITHMS
COMPUTER NETWORKS
DATABASE SYSTEMS


#include <iostream>
using namespace std;
int main()
{
cout << "Hello, World!";
return 0;
}

RISK MANAGEMENT: RISK STRATEGIES

Risk strategies are the planned approaches used to deal with identified risks. The goal is to reduce threats, take advantage of opportunities and achieve project objectives.

1. WHAT IS RISK STRATEGY?

- A risk strategy defines how risks will be handled to minimize negative impacts or maximize positive opportunities.
- It is decided after risk analysis and based on the risk's probability, impact, and priority.

2. OBJECTIVES

- Minimize the impact of threats.
- Maximize the benefits of opportunities.
- Use resources effectively.
- Improve decision making.
- Increase the chance of project success.

3. RISK CATEGORIES

Threats	Events that may cause negative impact.
Opportunities	Events that may cause positive impact.
Uncertainties	Events with both positive and negative impact.

4. MAJOR RISK STRATEGIES

STRATEGY	PURPOSE	DESCRIPTION	WHEN TO USE	EXAMPLE
1. AVOID	Eliminate the risk by removing the cause.	Change the plan to remove the risk completely.	When the risk has very high impact and alternatives are available.	Using a proven technology instead of a new, untested one.
2. MITIGATE	Reduce the probability or impact of the risk.	Take action to reduce the chance of occurrence or the severity.	When the risk is likely to happen but its effect can be reduced.	Adding more testing to reduce the risk of software defects.
3. TRANSFER	Shift the risk to a third party.	Pass the responsibility or ownership of the risk to someone else.	When another party is better able to manage the risk.	Purchasing insurance to transfer the financial risk.
4. ACCEPT	Acknowledge the risk and take no active action.	Accept the risk and prepare to deal with its consequences.	When the risk is low or the cost of action is more than the potential loss.	Accepting minor delays that do not significantly affect the project.
5. EXPLOIT	Maximize the benefit of an opportunity.	Take action to ensure the opportunity occurs and brings maximum value.	When the opportunity has high positive impact and is likely to occur.	Allocating resources to a feature that can give a competitive advantage.
6. ENHANCE	Increase the probability or impact of an opportunity.	Take action to improve the chances or results of the opportunity.	When the opportunity is possible but not certain.	Training the team to improve chances of early delivery.
7. SHARE	Share the opportunity with other parties.	Collaborate to benefit from the opportunity together.	When collaboration increases the chance of success.	Partnering with another company to co-develop a product.

5. FACTORS FOR CHOOSING A STRATEGY

- Probability of the risk/opportunity
- Impact on project objectives
- Cost of implementing the strategy
- Availability of alternatives
- Time and resource constraints
- Organizational policies and tolerance

6. EXAMPLE: THREAT RISK

Risk	Key developer may leave the project.
Analysis	Probability: High Impact: High
Chosen Strategy	Mitigate
Action	• Cross-train team members • Maintain updated documentation • Offer retention incentives

7. BEST PRACTICES

- Choose strategies based on careful analysis.
- Combine multiple strategies when needed.
- Review and update strategies regularly.
- Monitor effectiveness of strategies.
- Document all decisions and actions.

8. KEY TAKEAWAY

The right risk strategy at the right time helps to minimize threats, maximize opportunities and ensure successful project delivery.

SUMMARY TABLE

Avoid	Eliminate the risk	Exploit	Maximize opportunity
Mitigate	Reduce probability or impact	Enhance	Increase opportunity
Transfer	Shift to another party	Share	Collaborate for opportunity
Accept	Accept and prepare		

SOFTWARE RISKS

Software risks are potential problems or events that may occur during software development and affect project objectives such as cost, schedule, scope, quality and customer satisfaction.

1. DEFINITION

A software risk is an uncertain event or condition that, if it occurs, can negatively affect the software project objectives.

Risks are identified, analyzed and managed so that their negative impact is minimized.

2. CHARACTERISTICS

- Uncertain – may or may not occur.
- Has both probability and impact.
- Can be positive (opportunity) or negative (threat).
- Can be internal or external.
- Can be managed, not completely eliminated.

3. EXAMPLES OF SOFTWARE RISKS

- Requirement changes
- Technological uncertainties
- Resource unavailability
- Schedule delays
- Cost overrun
- Defects and quality issues
- User acceptance problems
- Security threats
- Third-party / vendor risks

4. COMMON SOFTWARE RISKS

Risk	Description	Type	Possible Impact	Possible Causes	Mitigation / Control
Requirement Changes	Requirements are unclear, incomplete or change frequently.	Threat	Rework, delays, cost overrun, scope creep	Poor communication, lack of user involvement, changing business needs	Elicit complete requirements, requirement reviews, change management process
Technological Risks	Use of new or unproven technology.	Threat	Technical failures, performance issues, project delays	Immature technology, lack of knowledge, integration difficulties	Evaluate technology early, prototypes, training, fallback alternatives
Resource Risks	Lack of skilled people or high turnover.	Threat	Schedule delay, low productivity, quality issues	Unrealistic planning, competition for resources, poor retention	Resource planning, cross-training, motivation, backup resources
Schedule Risks	Project tasks take longer than planned.	Threat	Delivery delay, penalties, customer dissatisfaction	Underestimation, dependencies, technical problems	Accurate estimation, monitoring, buffer time, regular review
Cost / Budget Risks	Project costs exceed the planned budget.	Threat	Financial loss, reduced scope	Poor estimation, scope creep, change requests	Cost estimation, change control, continuous tracking
Quality Risks (Defects)	Software contains defects or does not meet quality standards.	Threat	Rework, customer complaints, failure in production	Poor design, inadequate testing, time pressure	Reviews, testing, quality standards, automation, continuous integration
User Acceptance Risks	Users may not accept or be satisfied with the system.	Threat	Low usage, rejection of the product	Poor usability, lack of user involvement	User involvement, prototypes, usability testing, training
Security Risks	System may be vulnerable to security threats.	Threat	Data breach, loss of confidentiality, financial loss	Weak security practices, vulnerabilities, attacks	Security requirements, code reviews, encryption, penetration testing
Third-party / Vendor Risks	Dependence on external vendors or components.	Threat	Delays, integration issues, service unavailability	Vendor failure, poor quality, contract issues	Vendor evaluation, SLA, alternatives, regular monitoring

5. INTERNAL vs EXTERNAL RISKS

Internal Risks (Within Project Team)

- Requirement issues
- Design and coding problems
- Resource limitations
- Process and communication issues

External Risks (Outside Project Team)

- Changing technologies
- Market or business changes
- Third-party / vendor issues
- Natural disasters, legal changes

6. IMPACT ON PROJECT

- Affect cost (budget overrun)
- Affect schedule (delays)
- Affect scope (features reduced)
- Affect quality (defects)
- Affect customer satisfaction

7. HOW TO REDUCE SOFTWARE RISKS

- Identify risks early
- Analyze and prioritize risks
- Plan risk responses
- Monitor risks continuously
- Communicate risks
- Review and update risk plan

8. IN SHORT

Software risks cannot be eliminated completely, but by identifying, analyzing and managing them effectively, we can minimize negative impact and increase the chances of project success.

RISK IDENTIFICATION

Risk Identification is the process of finding, recognizing and describing potential risks that may affect the success of a project.

1. DEFINITION

Risk identification is the first and most important step in risk management. It helps to discover risks early so that they can be analyzed, planned for, and handled before they cause damage to the project.

2. OBJECTIVES

- Find as many potential risks as possible.
- Understand sources and causes of risks.
- Document risks for further analysis.
- Increase awareness of risks among project team.
- Provide a basis for risk analysis and prioritization.

3. BENEFITS

- Early awareness of potential problems
- Better planning and decision making
- Reduced surprises and uncertainty
- Improved risk response
- Saves time and project cost
- Improves chance of project success

4. SOURCES OF RISKS

Project Management	Technical	People	External	Organizational
• Unclear objectives	• New or unproven technology	• Lack of skills	• Market changes	• Policy changes
• Poor planning	• Complexity	• High turnover	• Legal / regulatory changes	• Budget constraints
• Scope changes	• Technical failures	• Poor teamwork	• Natural disasters	• Organizational restructuring
• Lack of resources	• Integration problems	• Conflict	• Vendor / supplier issues	• Competing priorities
• Poor communication	• Performance issues	• Low productivity		

5. COMMON RISK CATEGORIES

- Strategic Risks
- Operational Risks
- Financial Risks
- Technical Risks
- Compliance Risks
- Environmental Risks

6. RISK IDENTIFICATION TECHNIQUES

Technique	Description	How it Helps
Brainstorming	Team members openly share ideas about possible risks.	Generates many risks from different perspectives.
Interviews	Discuss with experts, team members, stakeholders.	Gets detailed information and expert insights.
Checklists	Use predefined risk checklists from past projects.	Ensures no common risks are missed.
SWOT Analysis	Analyze Strengths, Weaknesses, Opportunities, Threats.	Helps identify internal and external risks.
Assumptions Analysis	Identify assumptions and check what could go wrong.	Uncovers risks hidden in assumptions.
Historical Data / Lessons Learned	Review past projects and lessons learned.	Helps identify recurring and high impact risks.

7. RISK IDENTIFICATION OUTPUT

- List of identified risks
- Description of each risk
- Possible causes
- Potential impact areas
- Initial information for risk analysis

8. TIPS FOR EFFECTIVE RISK IDENTIFICATION

- Involve a diverse team.
- Look at the project from different perspectives.
- Be open and encourage all ideas.
- Use multiple techniques.
- Keep updating the risk list throughout the project.

9. RISK IDENTIFICATION PROCESS (STEPS)

1. **Understand Project** — Study project goals, scope, deliverables and environment.
2. **Gather Information** — Collect information from documents, stakeholders, and experts.
3. **Identify Risks** — Use techniques to find as many risks as possible.
4. **Document Risks** — Write down risks with description and causes.
5. **Review & Validate** — Review the risk list with team and stakeholders.
6. **Update Regularly** — Keep identifying new risks as project progresses.

IN SHORT: Risk identification helps us answer the question "What can go wrong?" so that we can be prepared and take the right actions to keep the project on track.

RMMM PLAN

(RISK MITIGATION, MONITORING AND MANAGEMENT PLAN)

An RMMM Plan defines how identified risks will be mitigated, monitored and managed throughout the project to reduce their impact and probability.

1. DEFINITION

An RMMM Plan is a living document that describes:

- Identified risks
- Mitigation strategies
- Monitoring activities
- Management / contingency actions
- Roles and responsibilities
- Triggers and escalation path

2. OBJECTIVES

- Reduce the probability and impact of risks.
- Ensure early detection of risks.
- Define actions to manage risks effectively.
- Assign ownership for risks.
- Provide visibility of risk status to stakeholders.
- Support informed decision making.

3. BENEFITS

- Proactive risk handling
- Minimizes negative impact on project
- Better planning and resource allocation
- Improved risk visibility and control
- Higher chance of project success

4. RMMM PLAN – KEY COMPONENTS

Component	Description	Key Questions Answered	Example
Risk Identification	List all identified risks with description, category and cause.	What are the risks? Why can they occur?	High staff turnover may lead to knowledge loss.
Risk Analysis	Assess probability and impact (qualitative / quantitative).	How likely is it? What is the potential impact?	Probability: High Impact: High
Risk Prioritization	Rank risks based on probability and impact.	Which risks need more attention first?	Risk Priority Number (RPN) = 20 (High)
Risk Mitigation Strategy	Define strategies to reduce probability or impact.	What can be done to reduce the risk?	Provide cross-training to reduce dependency on single person.
Risk Monitoring	Define how and when risks will be monitored.	How will we detect early signs? Who will monitor? How often?	Review risk status in weekly meetings. Owner: Project Lead.
Risk Management / Contingency Plan	Define actions if the risk occurs (contingency plan).	What actions if the risk happens? Who will take action?	Reassign tasks, extend schedule by 2 weeks.
Roles & Responsibilities	Assign risk owner and team members.	Who is responsible? Who supports?	Risk Owner: Module Lead Support: QA Lead
Triggers	Define early warning indicators that a risk may occur.	What are the signals? When to escalate?	If 2 or more team members leave in a month.
Escalation Path	Define escalation levels and communication path.	To whom will we escalate? At what level?	Team Lead → Project Manager → Steering Committee
Review & Update	Review the plan periodically and update.	When will we review? What triggers update?	Review every month or when major change happens.

5. RISK MITIGATION STRATEGIES (EXAMPLES)

- Avoid – Change plan to eliminate risk.
- Mitigate – Reduce probability or impact.
- Transfer – Shift risk to a third party.
- Accept – Accept the risk with active plan.
- Exploit – Take advantage of positive risks.

6. RISK MONITORING ACTIVITIES

- Regular risk review meetings
- Track risk indicators
- Update risk status
- Measure effectiveness of mitigation
- Report risk status to stakeholders

7. RISK STATUS INDICATORS

Low	Risk is under control. No immediate action.
Medium	Risk is being monitored. Mitigation in progress.
High	Risk needs attention. Mitigation not effective enough.
Critical	Risk is likely / has occurred. Take immediate action.

8. SAMPLE RMMM PLAN (EXTRACT)

Risk ID	Risk Description	Category	Prob.	Impact	Priority	Mitigation Strategy	Owner	Monitoring	Contingency Plan	Status
R1	Key developer may leave	People	High	High	High	Cross-training, Knowledge sharing	Tech Lead	Weekly 1:1, HR reports	Hire replacement, Reallocate tasks	High
R2	Requirements changes frequently	Technical	Medium	High	High	Better requirement gathering, Change control process	BA Lead	Change log, Review meetings	Re-plan, Adjust schedule	High
R3	Delay in third-party service	External	Medium	Medium	Medium	Early vendor engagement, Regular follow-up	Admin Lead	Vendor updates (Bi-weekly)	Use alternate vendor / Extend timeline	Medium
R4	Critical defect in production	Technical	Low	High	Medium	Code review, Testing, Quality standards	QA Lead	Defect trends, Test reports	Hotfix, Rollback plan	Low

9. RMMM PLAN REVIEW

- Review at planned intervals
- Review after major changes
- Ensure action items are closed
- Update mitigation and contingency plans
- Communicate updated risks to stakeholders

10. IN SHORT

An RMMM Plan ensures that risks are identified early, actions are planned in advance, and the project stays on track even when uncertainities arise.

11. KEY TAKEAWAY

Plan for risks today,
Monitor them regularly,
Manage them affectively,
Deliver project successfully.

DESIGN ENGINEERING: DESIGN PROCESS

The Design Process is a **systematic approach** to transform requirements into a quality software solution.

1. DEFINITION

Design Engineering is the process of designing a software solution that meets the functional and non-functional requirements of the system. It acts as a bridge between requirements and implementation.

2. OBJECTIVES

- Convert requirements into a blueprint for implementation.
- Achieve high quality, reliable and efficient software.
- Optimize performance, cost and resources.
- Ensure scalability, maintainability and usability.
- Reduce risks and rework.

3. CHARACTERISTICS

- Goal oriented
- Iterative and incremental
- Creative and analytical
- Evaluation based
- Considers technical and business aspects
- Results in software architecture and detailed design

4. DESIGN PROCESS – PHASES

1. **REQUIREMENTS ANALYSIS** – Understand and analyze all functional and non-functional requirements.
2. **DESIGN INPUT (DATA GATHERING)** – Collect necessary data, standards, constraints and resources.
3. **CONCEPTUAL DESIGN** – Develop multiple concepts / solutions to satisfy the requirements.
4. **DESIGN EVALUATION** – Evaluate alternatives based on feasibility, cost, risk, quality and constraints.
5. **DETAILED DESIGN** – Create detailed design of the selected solution (components, modules, interfaces, DB, etc.).
6. **DESIGN VERIFICATION** – Verify the design meets all requirements and quality attributes.
7. **DESIGN VALIDATION** – Validate the design with user needs and business objectives.
8. **DESIGN DOCUMENTATION** – Prepare and review design documents for implementation and maintenance.

5. DETAILS OF DESIGN PHASES

Phase	Key Activities
1 Requirements Analysis	Study SRS, identify goals, constraints, assumptions and interfaces.
2 Design Input (Data Gathering)	Gather data about technologies, tools, platforms, standards and existing systems.
3 Conceptual Design	Create high-level models, system architecture options, and select best approach.
4 Design Evaluation	Compare alternatives using metrics like cost, performance, reliability, scalability, maintainability.
5 Detailed Design	Design modules, algorithms, database schema, UI, APIs, data structures, class diagrams, sequence diagrams, etc.
6 Design Verification	Review, walkthroughs, inspections, and checklists to ensure correctnecs and completeness.
7 Design Validation	Ensure the design satisfies user needs and business rules through reviews, prototypes, simulations.
8 Design Documentation	Prepare design documents, diagrams, interface specs, test plans and user documentation.

6. DESIGN PRINCIPLES (GOOD DESIGN)

- Correctness – Meets all requirements.
- Simplicity – Easy to understand.
- Modularity – Divided into manageable modules.
- Efficiency – Optimal use of resources.
- Reliability – Consistent and dependable.
- Scalability – Easy to grow and adapt.
- Maintainability – Easy to maintain and modify.
- Reusability – Components can be reused.
- Usability – Easy for users to use.
- Security – Protects data and assets.
- Cost Effective – Achieves goals within budget.

7. DESIGN MODELS / APPROACHES

- Structured Design
- Object-Oriented Design (OOD)
- Modular Design
- Data-Centered Design
- Component-Based Design
- Service-Oriented Design (SOA)
- Agile Design (Iterative)

8. DESIGN DELIVERABLES

- System Architecture / Design Diagram
- Module Design / Class Diagram
- Database Design
- Interface Design
- Algorithm / Logic Design
- Data Flow & Control Flow Diagrams
- Design Specification Document (DSD)

9. EXAMPLE: DESIGN PROCESS IN ACTION (ONLINE LIBRARY SYSTEM)

Phase	Example Activity	Example Output
1 Requirements Analysis	Identify features: login, search books, issue/return, fine, reports	Requirement list, Use cases
2 Design Input	Technologies: Java, MySQL, Web; Standards: IEEE, Security policies	Input data, constraints
3 Conceptual Design	Consider 2–3 architectures (3-tier, microservices, etc.)	High-level architecture options
4 Design Evaluation	Compare based on cost, performance, security, scalability	Selected architecture (e.g., 3-tier)
5 Detailed Design	Design classes (User, Book, Issue, Return), DB schema, UI screens	Class diagrams, ER diagram, UI mockups
6 Design Verification	Review diagrams, check completeness, consistency	Review report, corrections
7 Design Validation	Get feedback from librarian and users via prototype	Validation report, approved design
8 Design Documentation	Prepare DSD, architecture document, interface specs	Design document ready for coding

10. IN SHORT

The Design Process ensures that the right solution is built in the right way by transforming ideas and requirements into a well-structured and implementable software design.

KEY TAKEAWAY

A good design leads to high quality software that is reliable, efficient, easy to maintain and meets user needs.

DESIGN QUALITY

Design Quality is the degree to which a software design meets the requirements and satisfies the needs of users while adhering to good design principles.

1. DEFINITION

Design Quality refers to how well a software design meets the functional and non-functional requirements, follows design principles and results in a system that is reliable, efficient, maintainable, usable and scalable.

2. OBJECTIVES

- Deliver a design that meets all requirements.
- Ensure high performance and reliability.
- Make the system easy to maintain and evolve.
- Optimize use of resources and reduce cost.
- Improve user satisfaction.

3. IMPORTANCE

- Good design reduces development and maintenance cost.
- It improves product quality and user satisfaction.
- Helps in handling changes and future growth.
- Reduces risk of defects and failures.
- Increases reusability of components.

4. QUALITY ATTRIBUTES OF GOOD DESIGN

Attribute	Description	Benefits	Example
Correctness	The design must correctly implement all functional requirements.	Meets user needs and works as expected.	All calculations in a billing system are accurate.
Efficiency	The design should use resources (time, memory, CPU, network) efficiently.	Better performance and lower operational cost.	Efficient database queries reduce response time.
Simplicity	The design should be as simple as possible.	Easy to understand, develop and maintain.	Simple module structure with fewer interfaces.
Modularity	The design is divided into small, independent modules.	Easy maintenance, testing and reuse.	Separate modules for login, payment and report.
Reliability	The design should work without failure for a long time.	High availability and user trust.	System continues to work even during heavy load.
Scalability	The design should handle growth in users, data and functionality.	Supports future expansion without major redesign.	System can handle 10,000 users today and 1,00,000 users tomorrow.
Maintainability	The design should be easy to modify and fix.	Lower maintenance cost and effort.	Bug fixes can be done in one module without affecting others.
Usability	The design should be easy to use and understand.	Higher user satisfaction.	User-friendly interface and clear navigation.
Security	The design should protect data and resist unauthorized access.	Ensures data privacy and system safety.	Use of encryption, authentication and role-based access.
Testability	The design should be easy to test and validate.	Early defect detection and better quality.	Modules have clear inputs and outputs for unit testing.

5. PRINCIPLES OF GOOD DESIGN

- "Keep It Simple" (KISS)
- Abstraction – Focus on essential details
- Encapsulation – Hide internal details
- Low Coupling – Minimize dependencies
- High Cohesion – Keep related things together
- Information Hiding – Hide unnecessary details
- Separation of Concerns – Divide and manage independent aspects

6. FACTORS AFFECTING DESIGN QUALITY

- Clear and complete requirements
- Experience and skills of the designer
- Use of proper design methods and tools
- Adherence to design standards
- Time and budget constraints
- Complexity of the problem
- Technology and platform used
- Team communication and reviews

7. DESIGN QUALITY CHECKLIST

- ☑ Does the design meet all requirements?
- ☑ Is the design simple and easy to understand?
- ☑ Are the modules highly cohesive and loosely coupled?
- ☑ Is the design reusable?
- ☑ Is the design efficient in terms of resources?
- ☑ Is the design secure?
- ☑ Is the design easy to test and maintain?

8. MEASURING DESIGN QUALITY (METRICS)

Metric	Measures	Indicates
Cyclomatic Complexity	Number of independent paths	Complexity of design
Coupling	Interdependence between modules	Lower is better
Cohesion	Relatedness within a module	Higher is better
Maintainability Index	Ease of maintenance	Higher is better
Code Reusability	Percentage of reusable parts	Higher is better
Defect Density	Defects per KLOC	Lower is better
Response Time	Time to respond to a request	Lower is better

9. GOOD DESIGN vs POOR DESIGN

Good Design	Poor Design
Simple and easy to understand	Complex and hard to understand
Flexible and easy to change	Rigid and difficult to change
High performance and efficiency	Poor performance
Easy to test and maintain	Hard to test and maintain
Reusable components	Low reusability
Lower cost in long term	Higher cost in long term
User friendly	Difficult for users

10. IN SHORT

Design Quality ensures that the software is correct, efficient, reliable, maintainable, secure and user-friendly.

KEY TAKEAWAY

A high Quality design is the foundation of a successful software. Good design today leads to low cost, high performance and high quality software tomorrow.

INTRODUCTION TO SOFTWARE ARCHITECTURE

Software Architecture is the **fundamental organization** of a software system, embodied in its components, their relationships and the principles and guidelines governing its design and evolution.

1. DEFINITION

Software Architecture is the high-level structure of a software system. It defines the major components, their interfaces, their interactions and the constraints governing how they work together to satisfy functional and non-functional requirements.

2. OBJECTIVES

- To understand the overall structure of the system.
- To satisfy functional and non-functional requirements.
- To guide the design and implementation.
- To improve quality attributes like performance, security, reliability, maintainability.
- To manage complexity and support future changes.

3. IMPORTANCE

- Acts as a blueprint for the system.
- Helps in better planning and decision making.
- Improves communication among stakeholders.
- Facilitates reuse and scalability.
- Reduces risk and development cost.
- A good architecture leads to a high quality system.

4. WHAT DOES ARCHITECTURE DEFINE?

Components	Major building blocks of the system (modules, services, layers, etc.)
Connectors	Mechanisms of communication between components.
Interfaces	Points where components or external entities interact.
Constraints	Rules and limitations on how components can interact.
Properties	Quality attributes such as performance, security, reliability, availability, etc.

5. VIEWS OF SOFTWARE ARCHITECTURE (4+1 VIEW MODEL)

Logical View
Shows the system functionality from the end-user perspective.

Development View
Shows organization of the system in terms of software modules.

Use Case View
Describes the system functionality as seen by external actors.

Process View
Shows the system's concurrency and synchronization.

Physical View
Shows the mapping of software onto hardware infrastructure.

6. KEY ARCHITECTURAL CONCERNS

- Functionality – What the system does.
- Performance – How fast it responds.
- Reliability – How it works without failure.
- Availability – How often it is available.
- Security – Protection from threats.
- Maintainability – Ease of modification.
- Scalability – Ability to handle growth.
- Usability – Ease for users.
- Cost – Development and operational cost.

7. PRINCIPLES OF GOOD SOFTWARE ARCHITECTURE

- Modularity – Divide system into well-defined modules.
- Abstraction – Focus on essentials, hide unnecessary details.
- Information Hiding – Hide internal data and decisions.
- Separation of Concerns – Divide different responsibilities.
- High Cohesion – Related functions within a module.
- Low Coupling – Minimize dependencies between modules.
- Simplicity – Keep architecture simple and understandable.
- Reusability – Design for reuse of components.
- Flexibility – Easy to adapt to changes.

8. ARCHITECTURAL STYLES (EXAMPLES)

- Layered (n-tier)
- Client–Server
- Pipe and Filter
- Model–View–Controller (MVC)
- Event–Driven
- Microservices
- Service-Oriented Architecture (SOA)
- Broker

9. EXAMPLES OF ARCHITECTURAL STYLES

Style	Description	Best Used For	Advantages	Disadvantages
Layered (n-tier)	System is divided into layers, each layer provides services to the layer above.	Large systems, enterprise applications	Easy maintenance, scalability, separation of concerns	Performance overhead between layers
Client–Server	Clients request services, servers provide services.	Network applications, distributed systems	Centralized management, resource sharing	Server failure affects all clients, network dependency
Pipe and Filter	Data flows through a series of filters (transformations).	Compilers, data processing systems	Easy to understand, reusable filters, parallel processing	Not suitable for interactive systems
Model–View–Controller	Separates data (Model), UI (View) and control logic (Controller).	Web applications, GUI applications	Supports multiple views, maintainable, testable	More components, higher complexity initially
Microservices	System is a collection of small, independently deployable services.	Large, scalable cloud applications	Independent deployment, scalability, technology diversity	Complex management, network latency, data consistency

10. ARCHITECTURE vs DESIGN

Architecture	Design
High-level	Low-level
Overall structure	Detailed components
Focus on quality attributes	Focus on implementation details
Rarely changes	Changes frequently
Example: Layered, MVC	Example: Class design, algorithms

11. BENEFITS OF GOOD ARCHITECTURE

- Meets business and user needs.
- Improves quality attributes.
- Reduces development time and cost.
- Facilitates testing, deployment and maintenance.
- Supports future growth and change.
- Better risk management.

12. IN SHORT

Software Architecture is the foundation of a successful software system. It defines the structure and behavior of the system at a high level and guides design, implementation and evolution to meet current needs and future challenges.

KEY TAKEAWAY

A well-designed architecture ensures the system is reliable, scalable, secure, maintainable and delivers value to users and the business.

DATA DESIGN

Data Design is the process of planning, structuring and organizing data to meet the requirements of a system in an efficient, accurate, consistent and secure way.

1. DEFINITION

Data Design is the process of creating a logical and physical plan for data storage, organization, relationships and access to meet business requirements and ensure data integrity, security and performance.

2. OBJECTIVES

- To design data structures that support business needs.
- To ensure data accuracy, consistency and integrity.
- To reduce data redundancy.
- To improve data accessibility and performance.
- To ensure data security and privacy.
- To support future growth and changes.

3. IMPORTANCE

- Provides a clear understanding of data requirements.
- Helps in building efficient databases.
- Reduces development time and cost.
- Improves data quality and decision making.
- Ensures data integrity and consistency.
- Supports scalability and flexibility.

4. DATA DESIGN PROCESS

Requirements Analysis
Study business needs and data requirements.

Conceptual Design
Identify entities, attributes and relationships. Create ER diagram.

Logical Design
Map ER diagram to relational schema (normalization).

Physical Design
Design tables, indexes, storage, partitions and access paths.

Implementation
Create database objects and load data.

Testing & Maintenance
Test data, tune performance and maintain database.

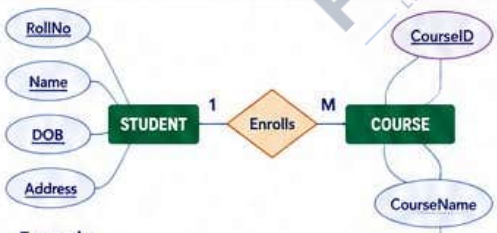
5. LEVELS OF DATA DESIGN

Level	Description	Output
Conceptual (High Level)	Focuses on what data the organization needs without considering implementation details.	ER Diagram, Data Dictionary (Entities, Attributes, Relationships)
Logical (Medium Level)	Focuses on how data is organized logically in the system.	Relational Schema, Normalized Tables, Keys, Constraints
Physical (Low Level)	Focuses on how data is stored physically in the database.	Table structures, Indexes, Storage allocation, File organization

6. COMPONENTS OF DATA DESIGN

Entities	Attributes	Relationships	Keys	Constraints
Real-world objects about which data is stored.	Properties or characteristics of an entity.	Association between two or more entities.	Uniquely identify records (primary key, foreign key).	Rules applied on data to ensure accuracy and integrity.

7. DATA MODELING (ER MODEL)



Example:
A STUDENT enrolls in many COURSES.
A COURSE can have many STUDENTS.

8. DATA NORMALIZATION (WHY?)

Normalization is the process of organizing data to minimize redundancy and dependency.

Normal Form	Goal
1NF	Eliminate repeating groups, make attributes atomic.
2NF	Remove partial dependency on composite key.
3NF	Remove transitive dependency.
BCNF	Stronger version of 3NF for better integrity.

9. DATA DICTIONARY

A data dictionary stores metadata about data used in the system.

It includes:

- Data element name
- Description
- Data type
- Size / Format
- Constraints
- Default value
- Source and usage

10. EXAMPLE – STUDENT MANAGEMENT SYSTEM (DATA DESIGN)

(a) ENTITIES

Entity	Description
STUDENT	Stores student details
COURSE	Stores course details
ENROLLMENT	Stores enrollment details

(b) RELATIONSHIPS

Relationship	Between	Cardinality
Enrolls	STUDENT – ENROLLMENT	1 : M
Has	COURSE – ENROLLMENT	1 : M

(c) RELATIONAL SCHEMA (LOGICAL DESIGN)

Table Name	Attributes
STUDENT	RollNo (PK), Name, DOB, Address, Phone
COURSE	CourseID (PK), CourseName, Credits
ENROLLMENT	EnrollID (PK), RollNo (FK), CourseID (FX), EnrollDate, Grade

11. PHYSICAL DESIGN CONSIDERATIONS

- Choose appropriate data types and sizes.
- Create indexes for faster access.
- Use partitions for large tables.
- Decide storage structure and file organization.
- Plan backup and recovery strategy.

12. GOOD DATA DESIGN RESULTS IN

- High data quality and accuracy
- Minimum redundancy
- Faster data access and retrieval
- Easy maintenance and modification
- Better security and consistency

13. IN SHORT

Good data design is the foundation of any successful information system. It ensures that data is organized efficiently to support current needs and adapt to future changes.

KEY TAKEAWAY

Data design ensures that the right data is collected, structured and stored in the right way to support business processes and decision making effectively.

ARCHITECTURAL PATTERN

Architectural Pattern is a general, reusable solution to a commonly occurring software design problem within a given context.

1. INTRODUCTION

Architectural patterns provide proven solutions for designing the overall structure of a software system. They are not finished designs, but templates that can be adapted as per requirements.

2. IMPORTANCE

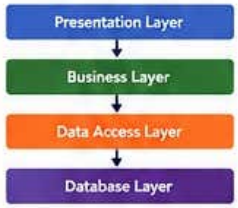
- Provide proven solutions to recurring problems.
- Improve reusability and maintainability.
- Help in better communication among stakeholders.
- Reduce design time and development cost.
- Improve system quality attributes like performance, scalability, reliability, security.

3. CHARACTERISTICS

- Proven solution to a common problem.
- Describes the structure at a high level.
- Independent of specific technologies.
- Provide a vocabulary for architects.
- Can be customized to fit requirements.

4. COMMON ARCHITECTURAL PATTERNS

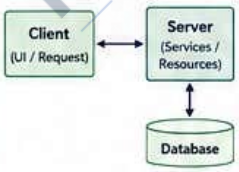
1. LAYERED PATTERN



Organizes the system into horizontal layers. Each layer has a specific responsibility.

Use: Traditional enterprise applications.

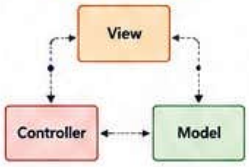
2. CLIENT-SERVER PATTERN



Clients request services from the server which provides resources or processes.

Use: Web applications, distributed systems.

3. MODEL-VIEW-CONTROLLER (MVC) PATTERN



Separates an application into Model (data), View (UI) and Controller (logic).

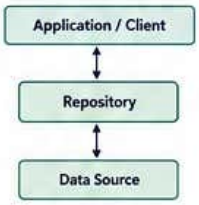
Use: Web apps, GUI applications.

4. PIPE AND FILTER PATTERN

Data is processed through a series of filters (processing components) connected as a pipeline.

Use: Compilers, data processing, ETL systems.

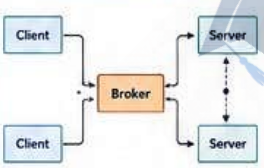
5. REPOSITORY PATTERN



An intermediary (repository) manages data access logic and hides data sources from clients.

Use: Data access layer in enterprise applications.

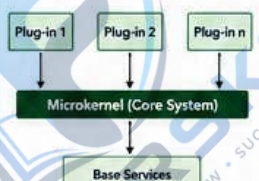
6. BROKER PATTERN



Broker acts as an intermediary that handles communication between clients and servers.

Use: Distributional systems, messaging systems.

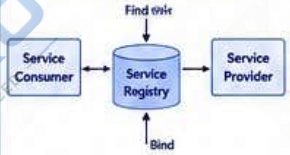
7. MICROKERNEL PATTERN



A small core system provides basic services; additional features are added as plug-ins.

Use: IDEs, OS, extensible systems.

8. SERVICE-ORIENTED ARCHITECTURE (SOA)

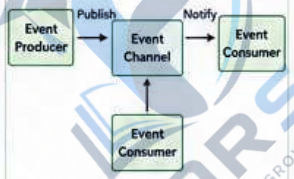


Loose coupling between services that communicate over a network.

Services are discoverable and reusable.

Use: Enterprise integration systems.

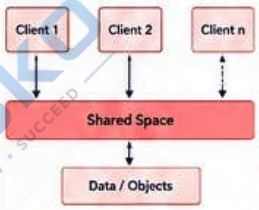
9. EVENT-DRIVEN PATTERN



Components communicate by producing and consuming events.

Use: Real-time systems, messaging, IoT applications.

10. SPACE-BASED PATTERN



A shared data space is used for communication between components.

Use: Real-time, distributed and collaborative systems.

5. COMPARISON OF COMMON ARCHITECTURAL PATTERNS

Pattern	Structure	Coupling	Scalability	Best Used For	Advantages	Limitations
Layered	Hierarchical layers	Medium	Medium	Enterprise applications	Simple, reusable	Performance overhead between layers
Client-Server	Client & Server	Low	High	Distributed applications	Easy to deploy, scalable	Server can become bottleneck
MVC	Model-View-Controller	Low	High	Web, GUI applications	Separation of concerns	Complex for small applications
Pipe and Filter	Pipeline of filters	Low	High	Data processing, compilers	Reusability, easy to parallelize	Not suitable for interactive apps
Repository	Client–Repository–Data source	Low	Medium	Data intensive applications	Centralized data logic	Single point of failure (repository)
Broker	Broker between client & server	Low	High	Distributed, messaging systems	Scalable, flexible	Broker can be complex
Microkernel	Core + Plug-ins	Low	High	Extensible systems	Easy to extend	Designing plugins can be hard
SOA	Services & registry	Low	High	Enterprise integration	Reusability, interoperability	Complexity in management
Event-Driven	Producers & consumers	Low	High	Real-time systems, IoT	Decoupled, scalable	Harder to debug
Space-Based	Shared space	Medium	Medium	Real-time, collaborative	Simple communication	Concurrency issues

6. BENEFITS OF USING ARCHITECTURAL PATTERNS

- Provides tested and proven solutions.
- Improves maintainability and flexibility.
- Enhances communication with stakeholders.
- Reduces risks and cost.
- Supports scalability and performance.

7. HOW TO CHOOSE THE RIGHT PATTERN?

- Understand the problem and requirements.
- Identify quality attributes (performance, security, etc.).
- Evaluate patterns that fit the context.
- Consider trade-offs and constraints.
- Customize the pattern as needed.

8. IN SHORT

Architectural patterns are high-level design solutions that help build robust, maintainable, scalable and reusable software systems.

The right pattern at the right time makes development more efficient and successful.

KEY TAKEAWAY

Architectural patterns provide a blueprint for structuring software systems, enabling better design, communication and evolution of applications.

USER INTERFACE DESIGN

User Interface Design is the process of designing the look, feel and interaction of software applications to provide a positive user experience while achieving user goals.

1. INTRODUCTION

User Interface (UI) is the point of interaction between the user and the system. A well-designed UI makes the system easy to use, efficient, attractive and satisfying.

2. OBJECTIVES

- To create interfaces that are easy to learn and use.
- To improve user productivity and efficiency.
- To reduce user errors.
- To enhance user satisfaction.
- To provide a consistent look and feel.
- To support accessibility and inclusivity.

3. IMPORTANCE

- First impression of the system is through UI.
- Good UI increases adoption and usage.
- Reduces training and support cost.
- Improves user satisfaction and retention.
- Enhances overall quality of the software.

4. GOLDEN RULES OF UI DESIGN

1. Place the user in control.
2. Reduce the user's memory load.
3. Make the interface consistent.
4. Design for simplicity.
5. Provide feedback.
6. Prevent errors and help users recover.

5. STEPS IN UI DESIGN PROCESS

1. Understand Users	2. Analyze Requirements	3. Design Concepts	4. Prototype	5. Evaluate	6. Implement & Refine
Identify users, their needs, goals and behaviors.	Study functional and non-functional requirements.	Create ideas, sketches, wireframes.	Build interactive prototypes for early feedback.	Test with users, identify issues, improve.	Implement the UI and continually refine it.

6. PRINCIPLES OF GOOD UI DESIGN

Principle	Description
Clarity	Information and options should be clear and easy to understand.
Consistency	Use consistent layouts, colors, fonts, and terminology.
Simplicity	Keep the interface simple and focused on user goals.
Visibility	Make important elements visible and easy to find.
Feedback	Provide immediate and meaningful feedback for user actions.
Flexibility	Allow users to customize and use shortcuts.
Forgiveness	Prevent errors and provide easy recovery from mistakes.

7. KEY ELEMENTS OF UI DESIGN

- **Layout** – Arrangement of elements on the screen.
- **Colors** – Use colors that are consistent, harmonious and accessible.
- **Typography** – Choose readable fonts and proper text hierarchy.
- **Icons & Images** – Use meaningful and simple icons and images.
- **Buttons** – Clearly indicate actions and make them easy to click.
- **Forms** – Collect data using well-designed input fields and controls.
- **Navigation** – Help users move around the system easily.
- **Feedback** – Show messages, alerts, progress and confirmations.

8. TYPES OF UI DESIGN

- **Command Line Interface (CLI)** – Uses text commands.
- **Menu Driven Interface** – Uses menus and options.
- **Graphical User Interface (GUI)** – Uses windows, icons, buttons, etc.
- **Touchscreen Interface** – Designed for touch interaction.
- **Voice User Interface (VUI)** – Uses voice commands.
- **Augmented / Virtual Reality Interface** – Immersive UI.

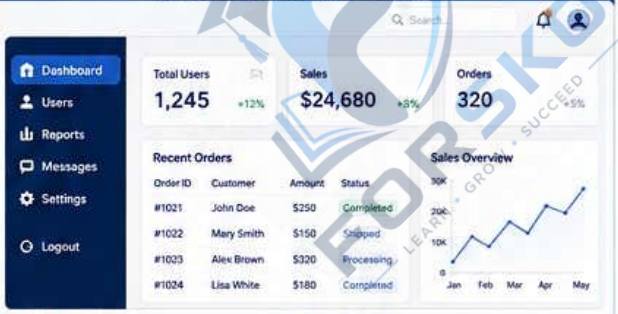
9. UI DESIGN GUIDELINES

- Use meaningful labels and text.
- Follow platform standards and conventions.
- Ensure readability (font size, contrast).
- Design responsive for different screen sizes.
- Keep important actions within easy reach.
- Avoid clutter and unnecessary elements.
- Ensure accessibility (color contrast, keyboard navigation, screen readers).

10. COMMON UI DESIGN PATTERNS

- **Dashboard** – Overview of key information.
- **Wizard** – Step-by-step guidance.
- **Tabs** – Organize content in sections.
- **Accordion** – Expand/collapse content.
- **Search** – Quickly find information.
- **Modal Dialog** – Show important messages or forms.

11. EXAMPLE OF A GOOD UI



- Clear layout
- Consistent colors
- Easy navigation
- Readable text
- Useful feedback
- Good information hierarchy

12. DO'S AND DON'TS

DO'S

- Do understand your users.
- Do keep it simple and consistent.
- Do provide clear feedback.
- Do test with real users.
- Do follow accessibility guidelines.

DON'TS

- Don't overload the screen.
- Don't use inconsistent elements.
- Don't hide important information.
- Don't ignore error messages.
- Don't make users think too much.

13. CHARACTERISTICS OF GOOD UI

- **Usable** – Easy to learn and use.
- **Efficient** – Helps users achieve goals quickly.
- **Effective** – Allows users to complete tasks accurately.
- **Engaging** – Pleasant and satisfying experience.
- **Accessible** – Usable by people with diverse abilities and disabilities.

KEY TAKEAWAY

A well-designed user interface improves user satisfaction, increases productivity and makes the system successful.

GOLDEN RULES OF USER INTERFACE DESIGN

These rules help create interfaces that are **usable**, **effective**, **attractive**, **efficient** and **satisfying** for users.

1 PLACE THE USER IN CONTROL

Users should feel that they are in control of the interface. Provide freedom, easy navigation and undo/redo options.

2 REDUCE THE USER'S MEMORY LOAD

Do not force users to remember information from one part of the interface to another. Keep information visible and easy to access.

3 MAKE THE INTERFACE CONSISTENT

Use consistent layout, colors, fonts, buttons and terminology throughout the application. Consistency helps users learn faster and makes interaction predictable.

4 DESIGN FOR SIMPLICITY

Keep the interface simple and focused. Remove unnecessary elements and provide only what is essential.

5 PROVIDE FEEDBACK

Give users clear and timely feedback about their actions. Let them know what is happening on the system.

6 PREVENT ERRORS AND HELP USERS RECOVER

Design the interface to prevent errors as much as possible. When errors occur, show clear messages and provide easy ways to fix them.

7 MAINTAIN VISIBILITY OF SYSTEM STATUS

Always keep users informed about what is going on through appropriate messages, indicators, progress bars, etc.

8 BE CONSISTENT WITH REAL WORLD

Use language, concepts and arrangements that are familiar to users from the real world.

9 DESIGN FOR ACCESSIBILITY

Make the interface usable by people with diverse abilities. Follow accessibility standards (colors, contrast, keyboard navigation, screen readers, etc.).

10 DESIGN FOR FLEXIBILITY AND EFFICIENCY

Provide shortcuts and customizable options for experienced users while keeping the interface easy for beginners.

KEY TAKEAWAY

Following these golden rules helps create user interfaces that are easy to use, efficient, error-free and satisfying, leading to a better user experience.

USER INTERFACE DESIGN STEPS

A step-by-step process to design effective, usable and engaging user interfaces.

1 UNDERSTAND USERS

Understand who the users are, their goals, needs, behaviors and pain points.

Key Activities
- User research (interviews, surveys)
- Create personas
- Empathy mapping

2 ANALYZE REQUIREMENTS

Define the goals of the product and the functional & non-functional requirements.

Key Activities
- Gather requirements
- Define scope
- Create user stories / use cases

3 DESIGN CONCEPTS

Ideate and create design concepts that solve user problems and meet goals.

Key Activities
- Brainstorm ideas
- Create information architecture
- Sketch ideas / flow

4 CREATE WIREFRAMES

Create low-fidelity layout (wireframes) to structure the interface and content.

Key Activities
- Low-fidelity wireframes
- Define layout & navigation
- Review and refine

5 DESIGN VISUAL UI

Design the look and feel of the interface (colors, typography, icons, components).

Key Activities
- Choose color palette & typography
- Design UI components
- Create high-fidelity mockups

6 BUILD PROTOTYPE

Create interactive prototype to simulate user flow and interactions.

Key Activities
- Add interactions & transitions
- Link screens
- Build clickable prototype

7 TEST WITH USERS

Test the design with real users to identify issues and collect feedback.

Key Activities
- Usability testing
- Observe & collect feedback
- Identify pain points

8 ITERATE & IMPROVE

Improve the design based on feedback and repeat until it meets user needs.

Key Activities
- Refine UI & interactions
- Fix issues
- Validate improvements

9 IMPLEMENT DESIGN

Handoff the final design to developers for development.

Key Activities
- Prepare style guide & assets
- Provide specifications
- Collaborate with developers

10 LAUNCH & EVALUATE

Launch the product and continue to evaluate and improve.

Key Activities
- Monitor user behavior
- Collect analytics & feedback
- Plan future improvements

KEY TAKEAWAY

Good interface design is an iterative process focused on users, balancing functionality, usability and aesthetics.

Unit - IV


DATA STRUCTURES
ALGORITHMS
COMPUTER NETWORKS
DATABASE SYSTEMS


#include <iostream>
using namespace std;
int main()
{
cout << "Hello, World!";
return 0;
}

OVERVIEW OF SYSTEM MODELS

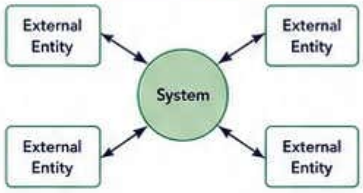
System models are simplified representations of a system used to understand, analyze, design and communicate its structure and behavior.

WHY SYSTEM MODELS?

- Help in understanding complex systems
- Improve communication among stakeholders
- Aid in analysis and design
- Save time and reduce cost
- Help in identifying issues and risks early

TYPES OF SYSTEM MODELS

1. CONTEXT MODEL (LEVEL 0 MODEL)

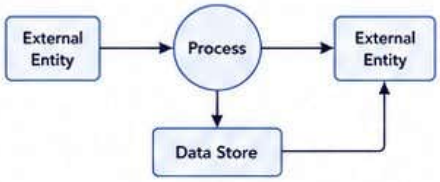


Shows the system as a whole and its interaction with external entities.

Used For:

- ✔ Define system boundary
- ✔ Identify external entities
- ✔ High-level understanding

2. DATA FLOW MODEL (DFD)

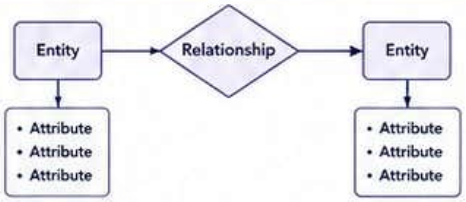


Shows how data flows through the system, the processes performed and where data is stored.

Used For:

- ✔ Analyze data flow
- ✔ Understand processes
- ✔ Identify data stores
- ✔ Create logical design

3. ENTITY RELATIONSHIP MODEL (ER MODEL)

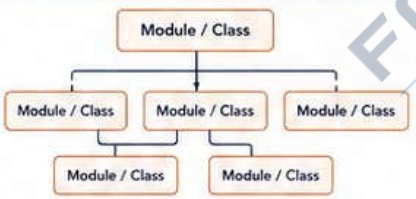


Represents data, entities and relationships among them in a database.

Used For:

- ✔ Database design
- ✔ Define entities
- ✔ Define relationships
- ✔ Normalize data

4. STRUCTURAL MODEL

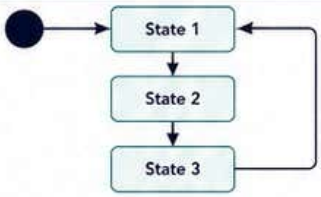


Shows the system structure in terms of modules, classes and their relationships.

Used For:

- ✔ Design program structure
- ✔ Define modules/classes
- ✔ Show calling relationships
- ✔ Support maintainability

5. BEHAVIORAL MODEL

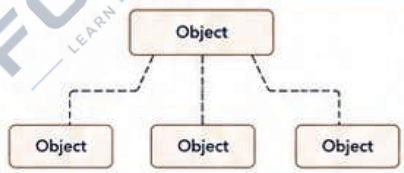


Represents the dynamic behavior of the system using states, transitions and events.

Used For:

- ✔ Model system behavior
- ✔ Handle events
- ✔ Define state transitions
- ✔ Useful for real-time systems

6. OBJECT MODEL



Shows objects in the system and their relationships at a particular point in time.

Used For:

- ✔ Analyze real-world objects
- ✔ Show object relationships
- ✔ Useful in OOP systems
- ✔ Snapshot of the system

COMPARISON OF SYSTEM MODELS

Model	Focus	Represents	Level	Main Purpose	Example
Context Model	External View	System & External Entities	Very High	Define system boundary	Banking system with Customers, Bank, ATM
Data Flow Model	Data Flow	Processes, Data Flow, Data Stores	High	Analyze how data moves	Order processing system
ER Model	Data Structure	Entities, Attributes, Relationships	Medium	Design database	Student – Course enrollment system
Structural Model	Structure	Modules, Classes, Components	Medium	Design system structure	Library management system modules
Behavioral Model	Behavior	States, Events, Transitions	Medium	Model dynamic behavior	Traffic light control system
Object Model	Objects	Objects, Links, Relationships	Low (Snapshot)	Show objects at a point in time	Online shopping cart objects

KEY TAKEAWAY

System models help us understand a system from different perspectives.

Using the right model at the right time leads to better analysis, design and successful development of software systems.

UML DIAGRAMS

UML (**Unified Modeling Language**) is a standard visual modeling language used to specify, visualize, construct and document the artifacts of a software system.

WHAT IS UML?

- A standard modeling language.
- Provides a way to visualize the design of a system.
- Helps in communication among stakeholders.
- Independent of any programming language.
- Supports all phases of Software Development Life Cycle.

BENEFITS

- Improves visualization of the system.
- Better communication.
- Early detection of issues.
- Documentation of system.
- Reusability and maintainability.
- Supports forward and reverse engineering.

CATEGORIES OF UML DIAGRAMS

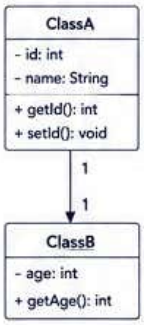
Structural Diagrams
Describe the static structure of the system.

Behavioral Diagrams
Describe the dynamic behavior of the system.

STRUCTURAL DIAGRAMS (Describe the static structure of the system)

1. CLASS DIAGRAM

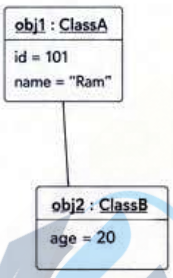
Shows classes, their attributes, methods and relationships.



Used for: Domain Model, Detailed Design

2. OBJECT DIAGRAM

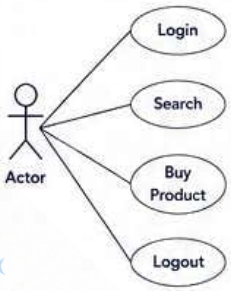
Shows objects and the relationships between them at a particular time.



Used for: Example instances of classes

3. USE CASE DIAGRAM

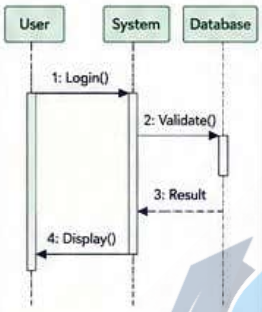
Shows the interaction between actors and the system's use cases.



Used for: Requirement gathering, System scope

4. SEQUENCE DIAGRAM

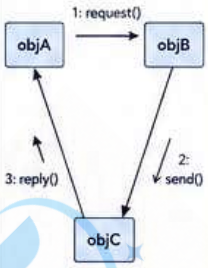
Shows interaction between objects in a time sequence.



Used for: Interaction scenarios, Dynamic behavior

5. COLLABORATION DIAGRAM

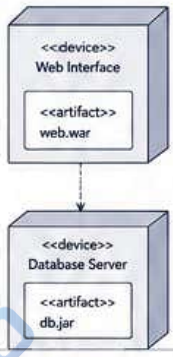
Shows interaction among objects emphasizing links.



Used for: Interaction with focus on object links

7. DEPLOYMENT DIAGRAM

Shows the hardware nodes and the deployment of artifacts on them.

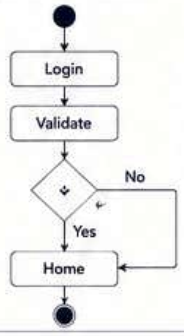


Used for: Deployment topology

BEHAVIORAL DIAGRAMS (Describe the dynamic behavior of the system)

1. ACTIVITY DIAGRAM

Shows the flow of activities or actions in a process.



Used for: Workflow, Business process

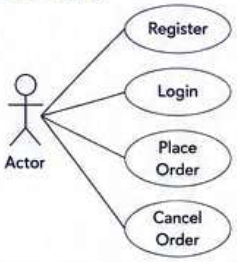
2. STATE MACHINE DIAGRAM

Shows the states of an object and the transitions between those states.

Used for: Object life cycle, State transitions

3. USE CASE DIAGRAM (Behavioral)

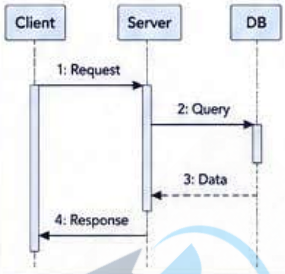
Also considered a behavioral diagram as it captures the system behavior from actor perspective.



Used for: Functional requirements

4. SEQUENCE DIAGRAM (Behavioral)

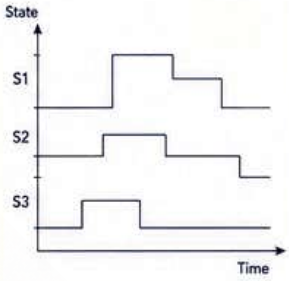
Shows time-ordered interaction among objects.



Used for: Dynamic behavior, Time sequence

5. TIMING DIAGRAM

Shows changes of state over a period of time.



Used for: Real-time systems, Timing constraints

COMMON RELATIONSHIPS (Used in Structural Diagrams)

Relationship	Symbol	Description	Example
Association	——	General connection between classes.	A → B
Aggregation	◇——	Whole–part relationship (weak).	Whole ◇→ Part
Composition	◆——	Whole–part relationship (strong).	Whole ◆→ Part
Generalization	——▷	Inheritance relationship.	Parent / Child
Dependency	- - - -→	One class depends on another.	A - - -→ B

WHEN TO USE WHICH DIAGRAM?

- **Use Case Diagram** – For requirements and system scope.
- **Class Diagram** – For system structure and design.
- **Sequence Diagram** – For interaction flow over time.
- **Activity Diagram** – For business processes & workflows.
- **State Machine Diagram** – For object life cycle.
- **Component Diagram** – For software component view.
- **Deployment Diagram** – For deployment architecture.
- **Collaboration Diagram** – For object collaboration view.

KEY TAKEAWAY

- UML provides visual blueprint of the system.
- Helps in analysis, design, implementation and maintenance.
- Structural diagrams show WHAT the system is.
- Behavioral diagrams show HOW the system behaves.
- Using UML improves quality and reduces development risks.

Top-Down Rule: Start with **Use Case Diagram** to capture requirements, then move to **Class Diagram**, and then to other diagrams.

A picture is worth a thousand words, UML makes those words meaningful!

TESTING STRATEGIES

A strategic approach to software testing ensures quality, reduces risks and delivers a reliable product.

WHAT IS TESTING?

Testing is the process of evaluating a software system to find defects and ensure that it meets the specified requirements.

WHY TESTING STRATEGY?

- Provides a roadmap for testing activities
- Helps in early defect detection
- Optimizes time, cost and resources
- Improves product quality and customer satisfaction

A STRATEGIC APPROACH TO SOFTWARE TESTING

1. **Test Planning** — Defing objectives, scope, resources, schedule and risks.
2. **Test Analysis** — Analyze requirements, identify test conditions and data.
3. **Test Design** — Design test cases, test data, test scenarios.
4. **Test Execution** — Run test cases, log defects and collect results.
5. **Evaluate Exit Criteria** — Check if exit criteria are met for test completion.
6. **Test Closure** — Prepare test report, lessons learned and closure activities.

TYPES OF TESTING

Functional Testing

Verifies that the system functions as per requirements.

Examples: Unit, Integration, System, Acceptance.

Non-Functional Testing

Evaluates non-functional aspects like performance, usability, security, etc.

Examples: Performance, Load, Stress, Usability, Security.

Structural Testing

Tests the internal structure and logic of the code.

Examples: White-box testing techniques.

Change-related Testing

Ensures that changes or new code do not affect existing functionality.

Examples: Regression, Confirmation, Smoke.

Maintenance Testing

Testing done on modified software to ensure new changes work correctly.

Examples: Retest, Regression.

BLACK-BOX TESTING

- Tests the functionality without knowing the internal code.
- Focus on inputs and expected outputs.
- Based on requirements and specifications.
- Test from the user's point of view.

Techniques:

- Equivalence Partitioning
- Boundary Value Analysis
- Decision Table Testing
- State Transition Testing

VS

WHITE-BOX TESTING

- Tests the internal code, structure and logic.
- Focus on code coverage.
- Based on program design and code.
- Test from the developer's point of view.

Techniques:

- Statement Coverage
- Branch Coverage
- Path Coverage
- Condition Coverage

LEVELS OF TESTING

1. Unit Testing

Tests individual units (functions/classes). Done by developers.

Objective: Validate each unit of code.

2. Integration Testing

Tests the interaction between integrated units. Done after unit testing.

Objective: Check interfaces and data flow.

3. System Testing

Tests the complete, integrated system. Done by QA team.

Objective: Validate system against requirements.

4. Acceptance Testing

Validates the system with customer/business. Done by users.

Objective: Check business readiness.

5. Maintenance Testing

Testing after deployment to ensure changes/work in the production.

Objective: Ensure stability after changes.

BEST PRACTICES

- Start testing activities early in the SDLC.
- Involve skilled resources and use the right tools.
- Automate repetitive and time-consuming tests.
- Maintain traceability between requirements and test cases.
- Regularly review and update test cases.
- Focus on risk-based testing.
- Defect management and reporting should be effective.

TEST STRATEGY CONSIDERATIONS

Scope	What will be tested and what will not.
Test Approach	Levels, types and techniques to be used.
Resources	People, skills, tools and environment.
Test Environment	Hardware, software and data needs.
Schedule	When each testing activity will happen.
Risks & Mitigation	Identify risks and plan mitigation.
Exit Criteria	Conditions to declare testing complete.

KEY TAKEAWAY

A well-planned testing strategy ensures comprehensive test coverage, early defect detection and delivery of high-quality software that meets user expectations.

A STRATEGIC APPROACH TO SOFTWARE TESTING

A planned and systematic approach to ensure high quality software that meets requirements and satisfies the customer.

OBJECTIVES

Ensure Quality
Deliver a defect-free or low-defect software product.

Meet Requirements
Verify that the software meets functional and non-functional requirements.

Reduce Risks
Identify and mitigate risks early in the development cycle.

Optimize Cost
Find defects early to reduce rework and overall cost.

Increase Confidence
Build confidence among stakeholders in the quality of the software.

KEY COMPONENTS OF TEST STRATEGY

1. **Scope**
   Define what to test and what not to test.
2. **Test Objectives**
   Define the testing goals aligned with business and project objectives.
3. **Resources**
   Identify skilled people, tools, environment and budget.
4. **Schedule**
   Plan testing activities, milestones and deliverables.
5. **Test Approach**
   Define levels of testing, types, techniques and methodologies.
6. **Risks and Contingencies**
   Identify risks and plan mitigation and contingency actions.
7. **Metrics and Reporting**
   Define metrics to measure progress and test effectiveness.
8. **Entry and Exit Criteria**
   Define the conditions to start and end each testing level.

TESTING LEVELS

- **Acceptance Testing** — By end users to validate business requirements (UAT, Alpha, Beta)
- **System Testing** — Testing the complete integrated system.
- **Integration Testing** — Testing interactions between integrated modules.
- **Unit / Component Testing** — Testing individual units/components in isolation.

Defects are cheaper to fix at lower levels.
Start testing early and test throughout the SDLC.

TESTING TYPES (APPROACH)

1. **Black Box Testing**
   Focuses on functionality without knowing internal code.
2. **White Box Testing**
   Focuses on internal code, logic and structure.
3. **Gray Box Testing**
   Combination of black box and white box testing.
4. **Manual Testing**
   Testing done manually by human testers.
5. **Automation Testing**
   Testing using tools and scripts to automate test execution.

STRATEGIC TESTING PROCESS (WORKFLOW)

1. **Requirement Analysis**
   Understand requirements, identify testable requirements.
2. **Test Strategy Planning**
   Define scope, objectives, approach, resources, schedule and risks.
3. **Test Planning**
   Create test plan, estimates, entry/exit criteria and environment needs.
4. **Test Design**
   Design test scenarios, test cases, test data and scripts.
5. **Test Execution**
   Execute test scases, log defects and track results.
6. **Test Closure**
   Evaluate exit criteria, report results and lessons learned.

Continuous Feedback

TEST STRATEGY PRINCIPLES

- Start testing early and involve testers early.
- Focus on risk areas and business-critical features.
- Pesticide paradox – Review and improve tests regularly.
- Defect clustering – Find most defects in fewer modules.
- Context driven – No one-size-fits-all approach.
- Traceability – Link requirements, tests and defects.
- Balance quality, time and cost.

> "Good strategy leads to effective testing and quality software."

RISK-BASED TESTING APPROACH

1. **Identify Risks**
   Identify product, project and business risks.
2. **Analyze & Prioritize**
   Evaluate impact and likelihood. Prioritize risks.
3. **Plan Tests**
   Design tests to address high priority risks.
4. **Execute & Evaluate**
   Execute tests and evaluate risk reduction.
5. **Monitor**
   Continuously monitor and re-assess risks.

KEY METRICS TO TRACK

- **Test Case Pass %** — Percentage of test cases passed.
- **Defect Density** — Defects per KLOC (thousand lines of code).
- **Defect Leakage** — Defects found after release.
- **Test Coverage** — Code or requirement coverage by tests.
- **Requirements Coverage** — Percentage of requirements covered by tests.
- **Execution Progress** — Percentage of test execution completed.

KEY TAKEAWAY

A strategic approach to testing ensures that the right testing is done in the right way at the right time to deliver high quality software, reduce risks and maximize customer satisfaction.

TEST STRATEGIES FOR CONVENTIONAL SOFTWARE

A planned set of testing activities and techniques used to verify and validate conventional (non-real-time, non-embedded) software applications.

OBJECTIVES

- Ensure software quality and reliability
- Meet functional and non-functional requirements
- Find defects early and reduce risks
- Optimize cost and time
- Increase customer satisfaction

WHAT IS CONVENTIONAL SOFTWARE?

Software applications that run on general-purpose systems (desktops, web, mobile, servers) and are not constrained by real-time or embedded system limitations.

Examples: Business applications, Web applications, Desktop applications, Database systems, E-commerce systems.

KEY PRINCIPLE

> "Test the right things, the right way, at the right time to deliver quality software efficiently."

STRATEGY CATEGORIES

1. BUSINESS-BASED STRATEGY

- Focus on business goals and user needs.
- Prioritize features based on business impact and risk.

2. RISK-BASED STRATEGY

- Identify and analyze risks.
- Focus testing on high-risk areas first.
- Reduce the probability and impact of failures.

3. LEVEL-BASED STRATEGY

- Plan testing activities across all testing levels.
- Start from lower levels (Unit) and move to higher levels.

4. PROCESS-BASED STRATEGY

- Define test process, standards and workflows.
- Ensure consistency, repeatability and continuous improvement.

5. METRICS-BASED STRATEGY

- Define metrics to measure test progress and effectiveness.
- Use metrics for decision making and improvement.

TESTING LEVELS (CONVENTIONAL SOFTWARE)

Unit / Component Testing	Test individual units or components in isolation by developers.
Integration Testing	Test interfaces and interactions between integrated modules.
System Testing	Test the complete and integrated system against requirements.
Acceptance Testing	Validate the system with business requirements (UAT, Alpha, Beta).
Maintenance Testing	Testing after changes, fixes or in enhancements.

TESTING TECHNIQUES

Black Box Techniques

- Equivalence Partitioning
- Boundary Value Analysis
- Decision Table Testing
- State Transition Testing
- Use Case Testing
- Pairwise Testing

White Box Techniques

- Statement Coverage
- Branch Coverage
- Condition Coverage
- Path Coverage
- Loop Testing
- Data Flow Testing

TEST DESIGN APPROACHES

Requirement-Based Testing
Tests are derived from functional and non-functional requirements.

Scenario-Based Testing
Tests are designed around real-world usage scenarios.

Use Case-Based Testing
Tests are derived from use cases and user workflows.

Data-Based Testing
Use different types of data to verify system behavior.

Risk-Based Testing
Focus on high-risk modules and critical functionalities.

TEST STRATEGY PROCESS (WORKFLOW)

1 Test Planning

- Understand scope
- Identify objectives
- Define resources
- Identify risks

2 Test Analysis

- Study requirements
- Identify testable items
- Prioritize based on risk and business value

3 Test Design

- Select techniques
- Create test cases
- Prepare test data

4 Test Execution

- Execute test cases
- Log results and defects
- Retest fixes

5 Test Evaluation

- Analyze results
- Measure metrics
- Assess quality

6 Test Closure

- Sign-off and reporting
- Lessons learned
- Improve for next cycle

KEY TEST PRACTICES

- Start testing early in the SDLC.
- Involve testers in requirement analysis.
- Review and prioritize tests regularly.
- Maintain traceability (Req → Test → Defect).
- Use automation for regression testing.
- Continuously monitor and improve.

TYPES OF TESTING (COMMON IN CONVENTIONAL SOFTWARE)

- Functional Testing
- Non-Functional Testing
- Regression Testing
- Smoke Testing
- Sanity Testing
- Compatibility Testing
- Usability Testing
- Performance Testing
- Security Testing
- Installation Testing
- Recovery Testing
- Configuration Testing
- Data Migration Testing

KEY METRICS

- Test Case Pass % = (Passed / Executed) × 100
- Defect Density = Defects / KLOC
- Test Coverage = (Covered Items / Total Items) × 100
- Test Execution Progress = (Executed / Planned) × 100
- Requirements Coverage = (Req. Covered / Total Req.) × 100

KEY TAKEAWAY

An effective test strategy for conventional software ensures that testing efforts are aligned with business goals, risks, and quality objectives to deliver reliable and valuable software.

BLACK-BOX AND WHITE-BOX TESTING

BLACK-BOX

WHITE-BOX

Two fundamental approaches to software testing used to find defects and ensure software quality, but they differ in terms of knowledge of internal code and the way tests are designed.

BLACK-BOX TESTING

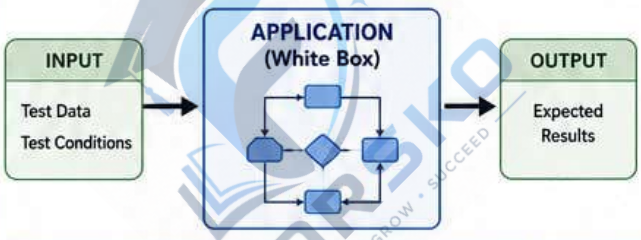
Testing the functionality of a software application without knowing its internal code/structure.

Tester's View

- No knowledge of internal code
- Focus on what the system does
- Validates requirements and functionality

WHITE-BOX TESTING

Testing the internal code, logic and structure of a software application with full knowledge of its implementation.



Tester's View

- Full knowledge of internal code
- Focus on how the system works
- Validates code structure, logic and paths

KEY COMPARISON

Aspect	Black-Box Testing	White-Box Testing
Knowledge of Code	No knowledge of internal code	Full knowledge of internal code
Focus	Functionality, usability, requirements	Logic, structure, paths, conditions
Test Design	Based on requirements and specifications	Based on code structure and logic
Test Data	Chosen to validate features and scenarios	Chosen to execute paths and conditions
Performed By	Testers, QA Engineers	Developers, Testers
Level of Testing	System Testing, Acceptance Testing	Unit Testing, Integration Testing
Purpose	To find defects from user's perspective	To find defects in code and logic
Examples	Input validation, UI testing, Functional testing	Path testing, Branch testing, Statement coverage
Defects Found	Missing/incorrect functionality, UI issues, Data issues, Interface errors	Logic errors, Dead code, Loop issues, Incorrect conditions
Test Coverage	Lower (depends on test cases)	Higher (covers code structure)

BLACK-BOX TESTING TECHNIQUES

Equivalence Partitioning
Divide input data into valid and invalid partitions and test one value from each.

Boundary Value Analysis
3 1 3
Test boundary values of input ranges.

Decision Table Testing
Use a table to represent combinations of inputs and expected outputs.

State Transition Testing
Test behavior based on state changes.

Use Case Testing
Test based on user scenarios and workflows.

WHITE-BOX TESTING TECHNIQUES

Statement Coverage
Execute every statement in the code at least once.

Branch Coverage
Execute every branch (True/False path) at least once.

Condition Coverage
All conditions in decision statements evaluate to both True and False.

Path Coverage
Execute all possible paths in the code.

Loop Testing
Test loops with zero, one, many and boundary iterations.

BLACK-BOX TESTING

Advantages

- No need for programming knowledge
- Focuses on functionality and user needs
- Can be done early in SDLC
- Useful for large systems

Limitations

- Limited code coverage
- Cannot find hidden logic errors
- Redundant test cases possible

WHITE-BOX TESTING

Advantages

- High code coverage
- Finds hidden defects
- Improve code quality
- Effective in unit testing

Limitations

- Requires programming knowledge
- More time and effort
- Not suitable early in SDLC

KEY TAKEAWAY

Black-box testing validates *what* the software does;
White-box testing validates *how* the software works.
Both are complementary and essential for quality software.

VALIDATION TESTING

Building the Right Product

"Are we building the right product?"

DEFINITION

Validation testing is a process of evaluating a software product during or at the end of the development process to determine whether it satisfies the specified requirements and fulfills the intended use.

OBJECTIVES

- Ensure the software meets business needs and user expectations.
- Verify that we are building the right product.
- Identify missing or incorrect requirements early.
- Provide confidence to stakeholders.

KEY CHARACTERISTICS

- Focus on the external behavior of the system.
- Performed from the user's point of view.
- Validates requirements, functionality and usability.
- Usually performed by independent testers or end users.

WHEN IS IT PERFORMED?

Validation testing is performed at the end of the development phase, before releasing the product to the users.

It answers:
"Are we building the right product for the users?"

VALIDATION VS VERIFICATION

	Verification (We are building the product right)	Validation (We are building the right product)
Focus	Focus on process and documents	Focus on product and user needs
When	Done during development	Done at the end of development
By	By Developers/ Testers	By Testers/Users/ Customers
Examples	Techniques like walkthroughs, reviews, inspections	Functional testing, Usability testing, UAT, Beta testing
Purpose	Checks if we built the product correctly	Checks if we built the correct product

TYPES OF VALIDATION TESTING

Alpha Testing
Performed at developer's site by internal team before release.

Beta Testing
Performed at user's site by real users in a real or simulated environment.

User Acceptance Testing (UAT)
Performed by end users to validate the system against business requirements.

Operational Acceptance Testing (OAT)
Ensures the system is ready for operation in the real environment.

VALIDATION TESTING PROCESS

1. **Requirement Review**
   - Understand business requirements and user expectations.
   - Ensure testable requirements.
2. **Test Planning**
   - Define test scope, objectives and criteria.
   - Identify resources and environment.
3. **Test Design**
   - Design test cases based on user scenarios.
   - Prepare test data.
4. **Test Execution**
   - Execute test cases in the target environment.
   - Log defects.
5. **Result Evaluation**
   - Compare actual results with expected results.
   - Evaluate against acceptance criteria.
6. **Acceptance Decision**
   - If criteria met → Accept.
   - If not → Fix issues and retest.
7. **Reporting**
   - Report results to stakeholders.
   - Provide sign-off for release.

TECHNIQUES USED

- **Functional Testing** — Verifies features against requirements.
- **Usability Testing** — Checks ease of use and user experience.
- **Compatibility Testing** — Ensures product works in different environments.
- **Performance Testing** — Validates performance under expected load.
- **Security Testing** — Ensures the system is secure and reliable.

ACCEPTANCE CRITERIA (EXAMPLES)

- All critical and major defects are closed.
- System functions as per business requirements.
- Performance meets the defined benchmarks.
- Usability is satisfactory for target users.
- System is stable in the target environment.
- Data accuracy and integrity are maintained.
- Business stakeholders sign-off.

Acceptance criteria act as a checklist to decide whether the product is ready for release.

BENEFITS

- Ensures the right product is delivered to users.
- Increases customer satisfaction.
- Finds requirement gaps early.
- Reduces business risk.
- Improves product quality and reliability.

KEY TAKEAWAY

Validation testing ensures that the software meets user needs and business goals. It focuses on the product from the user's perspective and confirms that we are building the right product before it is released.

SYSTEM TESTING

Testing the complete and integrated system as a whole to evaluate it against the specified requirements.

DEFINITION

System testing is a level of testing in which the entire integrated software system is tested as a whole in a real-like environment to verify that it meets the specified functional and non-functional requirements.

It validates the system's behavior from the end-user perspective.

OBJECTIVES

- To evaluate the complete, integrated system.
- To verify that the system meets the functional requirements.
- To validate non-functional requirements (Performance, Security, Usability, etc.).
- To ensure the system works in an environment similar to production.
- To identify defects that exist in the interactions between integrated components.

KEY CHARACTERISTICS

- Tests the complete and integrated system.
- Performed by an independent QA/Test team.
- Focus on end-to-end functionality.
- Executed in a real-like environment.
- Based on business requirements and user scenarios.

WHERE DOES SYSTEM TESTING FIT?

Unit Testing → Tests individual units/ components in isolation.

Integration Testing → Tests interaction between integrated modules.

System Testing → Tests the complete integrated system as a whole.

Acceptance Testing → Validates the system with business needs (Users).

Maintenance Testing → Tests after deployment to find defects.

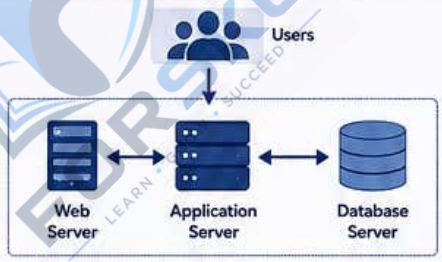
TYPES OF SYSTEM TESTING

- **Functional Testing** — Verifies all functional requirements of the system.
- **Performance Testing** — Evaluates performance, scalability, load, stress, and stability.
- **Security Testing** — Checks the system for vulnerabilities and data protection.
- **Usability Testing** — Ensures the system is easy to use and user-friendly.
- **Compatibility Testing** — Verifies the system across different browsers, OS, devices, and platforms.
- **Recovery Testing** — Checks the system's ability to recover from failures.
- **Installation Testing** — Verifies installation, upgrade, uninstall processes.

SYSTEM TESTING PROCESS

1. **Test Planning** — Define scope, objectives, resources, schedule, and environment.
2. **Test Case Design** — Design test cases based on SRS/BRD and user scenarios.
3. **Test Environment Setup** — Set up hardware, software, data, and tools.
4. **Test Execution** — Execute test cases and log results, defects and observations.
5. **Result Evaluation** — Compare actual results with expected results and analyze defects.
6. **Test Closure** — Re-test defects, generate test report and sign-off.

TEST ENVIRONMENT



Environment should be as close as possible to the production environment.

ENTRY CRITERIA

- All modules are integrated.
- Integration testing is completed.
- All critical and major defects are fixed.
- Test environment is ready.
- Test data is available.

EXIT CRITERIA

- All test cases executed.
- All critical and major defects are closed.
- System meets functional and non-functional requirements.
- Test report is reviewed and accepted.

DELIVERABLES

- Test Plan
- Test Cases
- Test Data
- Test Logs
- Defect Report
- Test Summary Report
- System Test Report
- Sign-off Report

BENEFITS

- Ensures the complete system works as expected.
- Early detection of integration and system-level defects.
- Validation of functional and non-functional requirements.
- Improves quality, reliability and user satisfaction.
- Reduces business risk.

EXAMPLE

In an Online Banking System, system testing would validate end-to-end scenarios like:

- User registration → Login → Fund transfer
- Account statement generation
- Bill payment → Transaction history
- Logout

It ensures the entire system works correctly together.

KEY TAKEAWAY

System testing validates the complete, integrated system in a real-like environment from the end-user perspective to ensure it meets all requirements and is ready for use.

THE ART OF DEBUGGING

Debugging is the systematic process of finding, analyzing and removing defects (bugs) from software to make it work as expected.

WHAT IS DEBUGGING?

Debugging is the process of identifying the cause of a failure (bug), locating it in the code and fixing it.

OBJECTIVES

- Find the root cause of defects.
- Fix the defect and prevent it from occurring again.
- Improve software quality and reliability.
- Reduce maintenance time and cost.
- Learn from mistakes and improve coding skills.

GOOD DEBUGGER'S MINDSET

- Be patient and calm.
- Understand the problem, don't guess.
- Think logically and systematically.
- Question every assumption.
- Learn from every bug.

PRINCIPLES OF EFFECTIVE DEBUGGING

1. **Reproduce the Problem**
   Make the bug occur consistently.
2. **Understand the Problem**
   Collect information, read error messages, and analyze.
3. **Make a Plan**
   Plan the approach before jumping into code.
4. **Divide and Conquer**
   Break the problem into smaller parts.
5. **Change One Thing at a Time**
   Make small changes and test.
6. **Track and Analyze**
   Use logs, debuggers, and tools to find clues.
7. **Fix the Root Cause**
   Don't just fix the symptom, fix the cause.
8. **Verify and Test**
   Ensure the bug is fixed and doesn't return.

TYPES OF BUGS

- **Syntax Errors**
  Violations of language rules; caught by compiler/interpreter.
- **Logical Errors**
  Incorrect logic; program runs but gives wrong output.
- **Runtime Errors**
  Occur during execution (e.g., divide by zero).
- **Semantic Errors**
  Code is syntactically correct but does not do what is intended.
- **Performance Bugs**
  Slow response, memory leaks, high CPU usage, etc.
- **Concurrency Bugs**
  Issues in multi-threaded or parallel execution.

COMMON SYMPTOMS

- Program crashes or hangs
- Unexpected output
- Wrong calculations
- Data corruption
- Memory overflow / leaks
- Slow performance
- UI not responding
- Compilation / runtime errors

REMEMBER

A good programmer writes code.
A great programmer writes code that can be debugged easily.

DEBUGGING PROCESS (STEP-BY-STEP)

1. **Detect the Bug**
   Identify that something is wrong (from errors, logs, users, tests).
2. **Gather Information**
   Collect error messages, logs, inputs, outputs, and environment details.
3. **Reproduce the Bug**
   Make the bug occur consistently using the same steps and data.
4. **Localize the Bug**
   Narrow down the area of code where the bug is likely to be.
5. **Identify Root Cause**
   Analyze the logic, data flow and find the exact reason.
6. **Fix the Bug**
   Make the necessary changes in the code to fix the cause.
7. **Verify the Fix**
   Test thoroughly to ensure the bug is fixed and gone.
8. **Prevent Future Bugs**
   Refactor, add tests, review code and follow best practices.

DEBUGGING TECHNIQUES

- **Print Debugging**
  Use print/log statements to trace values.
- **Rubber Duck Debugging**
  Explain your code line by line to an inanimate object.
- **Binary Search**
  Check the middle of the code, then narrow down the problem area.
- **Backtracking**
  Go backward from the point of failure to find the cause.
- **Logging**
  Use logs at important points to track flow and data.

USEFUL DEBUGGING TOOLS

Debugger	Step through code, set breakpoints, inspect variables.
Breakpoints	Pause execution at specific points.
Watch Window	Monitor the value of variables.
Call Stack	See the sequence of function calls.
Log/Console	View runtime information and errors.
Assertions	Check assumptions in code.

BEST PRACTICES

- Write clean, simple and well-structured code.
- Follow coding standards and naming conventions.
- Comment complex logic.
- Validate inputs and handle exceptions.
- Use meaningful variable names.
- Write unit tests – they find bugs early.
- Review code (peer/code review).
- Refactor regularly.

COMMON MISTAKES

- Guessing the solution without understanding.
- Ignoring error messages.
- Changing too many things at once.
- Not able to reproduce the bug.
- Fixing the symptom, not the root cause.
- Not testing after the fix.

TIPS FOR EFFECTIVE DEBUGGING

- Take breaks – a fresh mind finds bugs faster.
- Use small test cases.
- Stay organized and keep notes.
- Don't panic! Every bug is a learning opportunity.
- The more you debug, the better you become.

KEY TAKEAWAY

Debugging is not just about finding bugs, it is about thinking, analyzing and understanding your code deeply.

Good debugging skills = Better code + Better developer.

> "Programs must be written for people to read, and only incidentally for machines to execute."
> – Harold Abelson