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Software Engineering for Placement

Unit-1:Introduction

1. Introduction to Software Engineering

What is Software Engineering?

Software Engineering is the **discipline** and **systematic approach** to designing, developing, operating, and maintaining software. It applies **engineering principles** and **computer science concepts** to build software that meets quality standards like reliability, efficiency, and scalability.

Unlike simple programming, software engineering focuses on **the entire software lifecycle**, from initial requirements through design, implementation, testing, deployment, and maintenance.

Key Objectives of Software Engineering

- **Build Efficient Software**
  Software must use resources like memory, CPU, and storage optimally to deliver good performance.
- **Build Reliable Software**
  Software should function correctly under specified conditions and handle errors gracefully.
- **Build Scalable Software**
  The software should work well even when the number of users or data volume increases.
- **Reduce Complexity Using Engineering Principles**
  Techniques like modular design, abstraction, and design patterns help manage complexity and improve understandability.
- **Improve Productivity**
  Use of tools, frameworks, and well-defined processes increases the speed of development without sacrificing quality.
- **Enhance Quality and Maintainability**
  Writing clean, modular code with proper documentation makes it easier to maintain and extend software.
- **Minimize Cost and Development Time**
  Efficient project management and engineering practices reduce wasted effort, bugs, and delays, ultimately saving money and time.

Why is Software Engineering Important?

- Software systems today are highly complex, often involving millions of lines of code.

- They must meet stringent quality standards, security, and regulatory compliance.
- Poorly engineered software can lead to failures, costly downtime, and security breaches.
- A systematic engineering approach helps deliver reliable, maintainable software on time and within budget.

Example

Consider developing a **banking application**:

- Without software engineering, a developer might write code ad hoc, leading to bugs, poor performance, and difficulty in future updates.
- With software engineering:
    - The project starts with **planning**: gathering requirements like fund transfers, account balance checks, and loan processing.
    - **Design** involves creating system architecture, user interfaces, and database models.
    - **Coding** follows coding standards and modular principles.
    - **Testing** ensures the software is secure, handles edge cases, and performs well.
    - **Maintenance** handles future regulatory changes, new features, or bug fixes.

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2. Software Components

Software is typically composed of several **components or modules**, each responsible for a distinct part of the system's overall functionality. These components work together to provide the complete software solution.

Major Software Components:

- **User Interface (UI)**
  This is the front-facing part of the software where users interact with the system. It includes screens, forms, buttons, menus, and other elements that collect input from users and display output.
  Example: In a web app, the UI could be the product listing page where users browse items.
- **Business Logic**
  Also called the "application logic" or "domain logic," this component implements the core functional rules and calculations of the software. It processes user inputs, applies business rules, and determines outcomes.
  Example: In an e-commerce app, the business logic calculates the cart total after applying discounts and taxes.
- **Data Access Layer**
  This module handles communication between the business logic and data storage. It

abstracts the details of database queries or file operations to provide a clean interface for retrieving and storing data.
Example: Functions that fetch product details or update user information from the database.

- **Database**
  A database stores persistent data used by the software, such as user profiles, product inventories, transactions, etc. It ensures data is saved across sessions and can be queried efficiently.
  Example: Product tables, user accounts, and order history stored in a relational database.
- **Utilities/Helpers**
  These are supporting modules or libraries that provide common functionalities like logging, error handling, encryption, or date formatting. They help avoid code duplication and simplify main component code.

Example: E-commerce Application

Component	Example in E-commerce App
UI	Product listing page, checkout forms
Business Logic	Cart total calculation, order processing
Data Access Layer	Functions to read/write product data
Database	Tables for products, users, orders
Utilities/Helpers	Payment gateway integration, logging

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3. Software Characteristics

Software is distinct from hardware and traditional physical systems due to several unique traits:

Characteristic	Description
Intangible	Software cannot be physically touched or seen like hardware; it exists as code and data.
Developed, not manufactured	Software is created through design, coding, and testing rather than being assembled physically.
Flexible	Software is easier to modify and adapt compared to hardware, enabling quick updates or changes.
Easy to replicate	Software can be copied perfectly and at almost zero cost, unlike physical products.
No wear and tear	Software does not degrade physically over time, though it may become obsolete or incompatible.

Explanation of Characteristics:

- **Intangibility** makes software maintenance and management different since you cannot physically inspect it; instead, you rely on code reviews and testing.
- **Development process** involves creative and technical work: analyzing requirements, designing architecture, writing code, and rigorous testing.
- **Flexibility** means software can be updated to fix bugs, add features, or adapt to new hardware without physical changes.
- **Replication** allows easy distribution, enabling widespread use at low cost (e.g., software downloads).
- **No physical degradation** means software remains operational unless bugs or external changes (e.g., OS updates) cause failures.

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4. Software Crisis

What is Software Crisis?

The **Software Crisis** refers to the widespread problems and challenges faced in software development, especially prominent during the 1960s through the 1980s, but still relevant today in some cases. The term was coined to describe the **difficulty of producing reliable, efficient, and timely software** that meets user needs within budget and time constraints.

Causes of the Software Crisis:

- **Project overruns in cost and time**
  Many software projects ended up costing much more than planned and took much longer to complete. This happened due to poor planning, underestimated complexities, and frequent requirement changes.
- **Poor quality or buggy software**
  Software often shipped with many defects, causing frequent crashes, errors, or failures. This lowered user trust and increased maintenance costs.
- **Unclear or changing requirements**
  Often, requirements were vague, incomplete, or constantly changing, making it difficult for developers to deliver what users actually needed.
- **Inadequate testing**
  Due to tight schedules or lack of resources, proper testing was often skipped or rushed, allowing bugs to go unnoticed until deployment.
- **Lack of skilled developers**
  The field of software engineering was relatively new, and there was a shortage of trained professionals with the necessary skills and experience.

Impacts of the Software Crisis:

- **Delayed product releases**
  Many projects failed to meet deadlines, delaying the time to market and losing competitive advantages.
- **Failure to meet customer expectations**
  Delivered software often did not fulfill the promised features or performance, leading to dissatisfaction.
- **Increased security vulnerabilities**
  Poorly tested and rushed software introduced security risks that could be exploited.
- **High maintenance costs**
  Fixing defects post-release was costly and time-consuming.

Example:

- A notable example of the software crisis was a **government defense project** in the 1970s and 80s that was intended to develop a complex weapons system. Despite huge investments (billions of dollars), the project was **canceled** due to persistent software bugs, missed deadlines, and budget overruns. This highlighted the critical need for better software engineering practices.

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5. Software Engineering Processes

What is a Software Engineering Process?

A **software engineering process** is a structured set of activities and tasks that guide the development of a software system from conception to delivery and maintenance. It helps ensure the project is organized, manageable, and produces high-quality software.

Common Activities in Software Engineering Processes:

1. **Requirements Gathering**
   Collecting detailed user needs, business rules, and functional/non-functional requirements to understand what the software should do.
2. **System Design**
   Architecting the software's structure, including data flow, components, interfaces, and user interaction design.
3. **Implementation (Coding)**
   Writing the actual source code according to the design specifications.
4. **Testing**
   Verifying the software functions correctly through various testing methods (unit testing, integration testing, system testing).
5. **Deployment**
   Releasing the software to the user environment for actual use.

6. **Maintenance**
   Ongoing updates and fixes after deployment to handle bugs, add features, or adapt to changes.

Types of Software Engineering Processes:

- **Plan-driven (Waterfall Model)**
  This is a linear, sequential approach where each phase (requirements, design, implementation, etc.) is completed fully before moving to the next. Requirements are fixed upfront.
  Advantages: Clear milestones, easy to manage for small or well-understood projects.
  Disadvantages: Inflexible to changes; late discovery of problems.
- **Agile**
  Agile is an iterative and incremental approach. Software is developed in small cycles called sprints, allowing continuous feedback, adaptability, and improvement. Requirements can evolve over time.
  Advantages: Flexible, responsive to change, promotes collaboration.
  Disadvantages: Needs high team involvement and good communication.

Example:

Using **Agile methodology** to develop a messaging app might involve breaking the project into two-week sprints. In each sprint, a small set of features (e.g., user login, chat window) are planned, implemented, tested, and delivered for review. Feedback from users is incorporated into the next sprint, allowing rapid adaptation.

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6. Similarities and Differences from Conventional Engineering Processes

Aspect	Software Engineering	Conventional Engineering
Product	Intangible software	Physical structures or machines
Design Changes	Easier and cheaper to modify during development	Expensive and time-consuming to alter
Testing	Mostly simulated with software tools	Requires physical prototypes and tests
Failure Mode	Logic errors, bugs, runtime failures	Material fatigue, mechanical breakdowns
Replicability	Easy to duplicate perfect copies with no cost	Manufacturing required for each copy

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Explanation:

- Software engineering deals with intangible products like programs, which can be copied perfectly without wear and tear, unlike physical machines or structures.
- Changing a design in software is typically less costly and quicker compared to physical products, where redesign might mean retooling factories or rebuilding prototypes.
- Testing software can be automated and simulated, whereas conventional engineering often requires physical testing (e.g., crash tests for cars).
- Failures in software usually come from errors in logic or implementation, while in conventional engineering, failures stem from physical wear or material defects.

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7. Software Quality Attributes

What Are Software Quality Attributes?

Software quality attributes refer to **non-functional** characteristics that define the overall quality and user experience of software beyond just working features. They determine how well the software performs, how easy it is to use and maintain, and how it behaves under different conditions.

Key Quality Attributes:

- **Reliability**
  The software performs its intended functions correctly and consistently over time, even in unexpected situations. It should have minimal failures.
  Example: A banking app should reliably process transactions without errors.
- **Usability**
  How easy and intuitive the software is for users. This includes learnability, user interface design, and accessibility.
  Example: WhatsApp's interface is simple and easy to navigate for people of all ages.
- **Maintainability**
  The ease with which the software can be fixed, updated, or enhanced after release. Well-structured code and clear documentation improve maintainability.
  Example: Modular code allows developers to quickly fix bugs or add features.
- **Efficiency**
  How well the software uses system resources like CPU, memory, and network bandwidth. Efficient software runs smoothly without wasting resources.
  Example: Video streaming apps compress data efficiently to reduce buffering.
- **Portability**
  The ability to run on different hardware platforms or operating systems with minimal changes.
  Example: Software that runs on Windows, Mac, Linux, and mobile platforms.

- **Security**
  Protects software and data from unauthorized access, attacks, or data breaches. Includes encryption, authentication, and secure coding practices.
  Example: WhatsApp uses end-to-end encryption to keep messages private.
- **Scalability**
  The ability of software to handle increased workload or user base without performance degradation.
  Example: WhatsApp supports billions of users simultaneously without crashing.

Example:

WhatsApp exemplifies many quality attributes: it is **scalable** (supports millions of users), **secure** (end-to-end encrypted messages), and **usable** (intuitive interface and easy onboarding).

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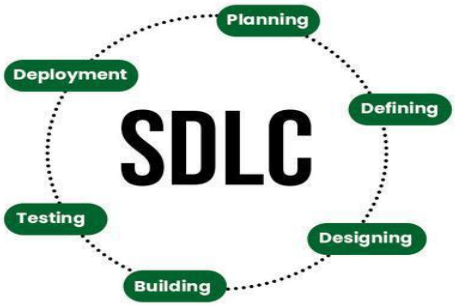
8. Software Development Life Cycle (SDLC)

What is SDLC?

SDLC is a **systematic and structured approach** for software development that ensures quality, correctness, and efficient delivery by defining clear phases from initial idea to maintenance.



Common SDLC Models:

1. **Waterfall Model**
   - Linear and sequential; each phase completes fully before moving on.
   - Easy to manage but inflexible to requirement changes once the project starts.
2. **V-Model**
   - An extension of Waterfall with a parallel testing phase corresponding to each development phase.
   - Emphasizes validation and verification.
3. **Incremental Model**

   - Develops software in small parts (increments) that add functionality step-by-step.
   - Allows partial delivery and early feedback.
4. **Iterative Model**
   - Builds software through repeated cycles (iterations), gradually refining the product.
   - Allows evolving requirements and continuous improvement.
5. **Agile Model**
   - Highly adaptive, iterative, and team-driven.
   - Focuses on rapid delivery in short cycles (sprints), continuous feedback, and collaboration.

Typical Phases of SDLC:

1. **Requirement Analysis**
   Understanding and documenting what users and stakeholders need from the software.
2. **Design**
   Planning the system architecture, data models, and user interfaces.
3. **Implementation (Coding)**
   Writing the software code according to design.
4. **Testing**
   Checking the software for defects and verifying it meets requirements.
5. **Deployment**
   Releasing the software for use in the real environment.
6. **Maintenance**
   Ongoing updates, bug fixes, and improvements after deployment.

Example:

In an **Agile SDLC**, a ride-sharing app could release features iteratively:

- First iteration: Implement basic **booking** functionality.
- Next iteration: Add **driver tracking**.
- Then: Add **payments** and other features.

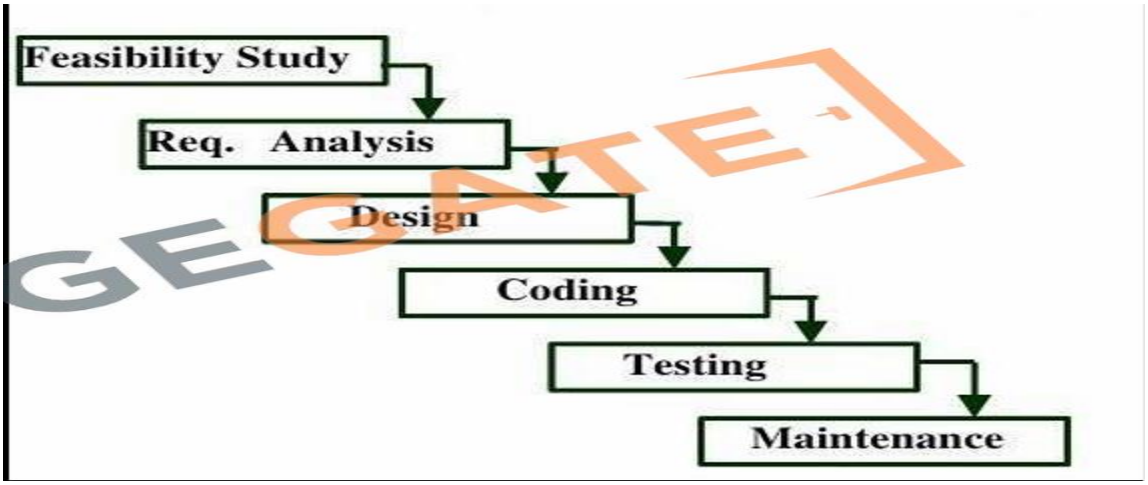
Each iteration allows feedback from users to improve the next set of features.

Model:

1. Waterfall Model

Definition:

The Waterfall Model is a traditional, linear software development process where the project is divided into sequential phases. Each phase must be fully completed before the next begins, like a waterfall flowing down.



Process & Phases:

1. **Requirement Analysis**: Gather and document all software requirements clearly.
2. **System Design**: Design the system architecture and detailed specifications.
3. **Implementation (Coding)**: Developers write code according to the design.
4. **Integration and Testing**: Test the software to find and fix bugs.
5. **Deployment**: Deliver the software to the user or production environment.
6. **Maintenance**: Perform ongoing support and update software as needed.

Characteristics:

- Strictly linear and sequential.
- No phase overlap or going back once a phase is completed.
- Documentation-intensive.

Advantages:

- Easy to understand, plan, and manage.
- Clear milestones and deliverables.
- Best for projects with well-defined, fixed requirements.

Disadvantages:

- Inflexible to changes; any change requires going back through phases.
- Testing happens late, which can lead to late discovery of defects.
- Not suitable for projects where requirements evolve or are unclear.

Use Case Example:

Large government or aerospace projects where requirements are rigid and unlikely to change.

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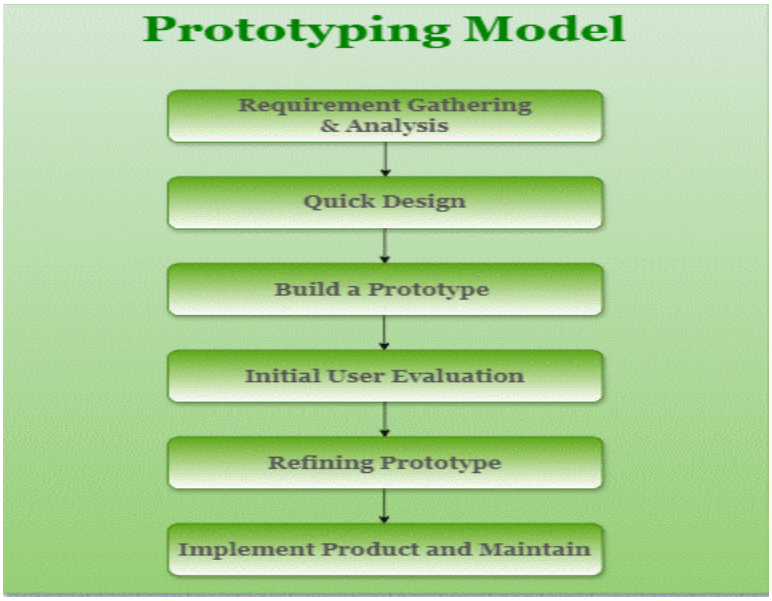
2. Prototype Model

Definition:

The Prototype Model focuses on building a quick, functional prototype of the software early in the process to help understand user requirements better through early feedback.



Process & Phases:

1. **Requirement Gathering**: Collect initial requirements.
2. **Quick Design**: Create a rough design focusing on major features.
3. **Build Prototype**: Develop a working but incomplete model.
4. **User Evaluation**: Gather user feedback on the prototype.
5. **Refinement**: Modify the prototype based on feedback.
6. **Final Development**: Develop the actual product once requirements are finalized.

Characteristics:

- User involvement is high throughout.

- Helps clarify ambiguous or poorly understood requirements.
- Iterative refining of prototype until approval.

Advantages:

- Reduces misunderstandings and clarifies requirements.
- User feedback ensures the product aligns with expectations.
- Early detection of design flaws.

Disadvantages:

- Can lead to scope creep as users keep asking for changes.
- Users might think the prototype is the finished product, causing confusion.
- Not suitable for very complex systems with many components.

Use Case Example:

UI/UX-heavy apps like mobile apps or websites where look and feel need validation early.

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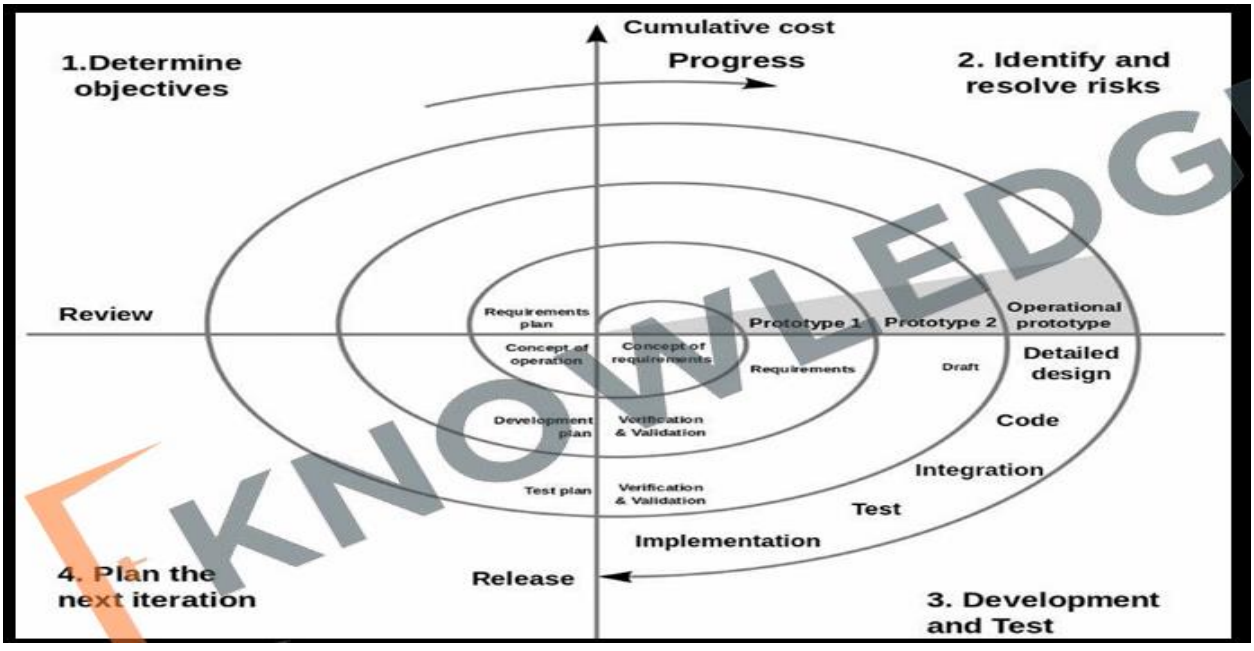
3. Spiral Model

Definition:

The Spiral Model blends iterative development (like prototyping) with systematic aspects of the Waterfall model, adding strong risk assessment and mitigation.



Process & Phases (each spiral):

1. **Determine Objectives**: Define goals for the current cycle.
2. **Identify and Resolve Risks**: Analyze risks and plan solutions.
3. **Develop and Test**: Build and test the software incrementally.
4. **Plan the Next Iteration**: Prepare for the next spiral cycle.

Each spiral produces a more complete system incrementally.

Characteristics:

- Emphasizes risk analysis at every cycle.
- Iterative and incremental development with formal review points.
- Suitable for large, complex, and high-risk projects.

Advantages:

- Early identification and management of risks.
- Flexible to requirement changes as the product evolves.
- Supports iterative refinement.

Disadvantages:

- Complex and expensive to implement.
- Requires risk assessment expertise.
- Not ideal for small or simple projects.

Use Case Example:

Banking systems or aerospace software where risk and complexity are high.

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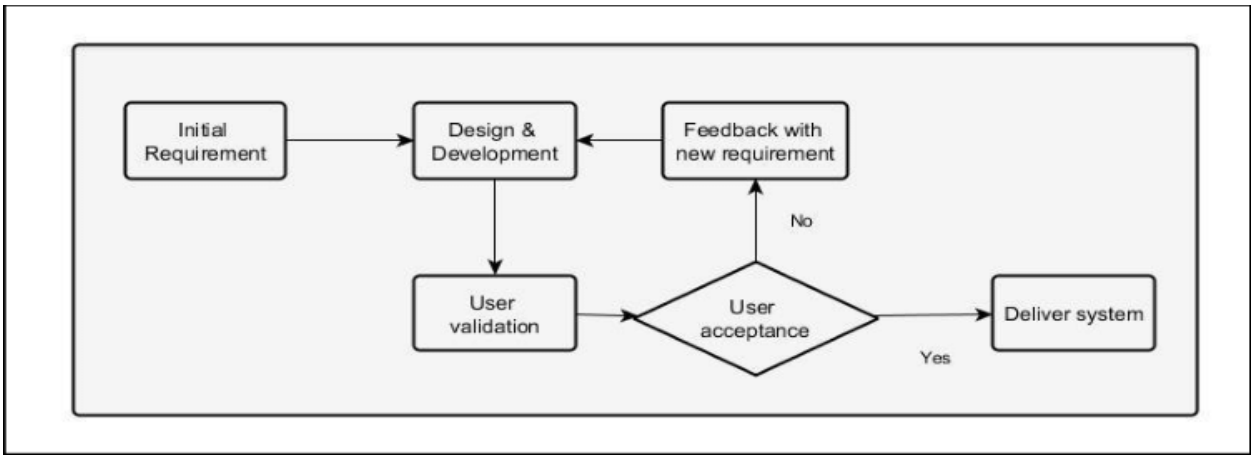
4. Evolutionary Development Models

Definition:

These models emphasize developing a basic version of the software first and then evolving it through repeated feedback and enhancements until the final system emerges.



Key Concepts:

- Continuous delivery and user feedback.
- Incremental addition of features.
- Flexibility to evolving requirements.

Types:

- **Incremental Model**: Build the software in small increments, each delivering part of the functionality.
- **Exploratory Development**: Focuses on evolving the software based on experimentation and user feedback.
- **Throwaway Prototyping**: Develop prototypes to understand requirements, then discard them before final development.

Advantages:

- Early delivery of partial, working software.
- User involvement improves quality and satisfaction.
- Adapts well to changing requirements.

Disadvantages:

- Risk of weak architecture if not managed carefully.
- May increase cost and time due to repeated changes.
- Continuous integration efforts needed.

Use Case Example:

Startups or innovative apps where requirements evolve based on market feedback.

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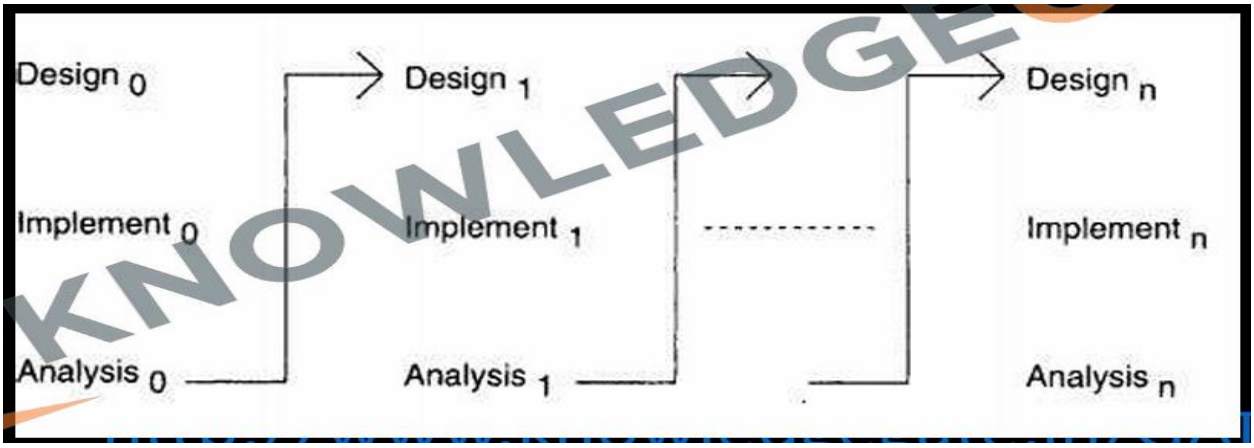
5. Iterative Enhancement Model

Definition:

The Iterative Model develops software in small portions or cycles, each cycle improving and adding more features to the previous version.

Process:

1. Begin with a simple, working system.
2. Enhance features or add new ones with each iteration.
3. Refactor and test in every cycle to maintain quality.



Characteristics:

- Each iteration is a mini-waterfall: design, code, test.
- Encourages continuous refinement and improvement.
- Involves customer feedback after each iteration.

Advantages:

- Early availability of functional parts of the system.
- Easier risk management due to smaller cycles.
- Continuous improvement increases product quality.

Disadvantages:

- Requires thorough planning and strong project management.
- Increased testing efforts due to repeated cycles.
- Potentially longer time if iterations are poorly planned.

Use Case Example:

Educational apps or software where new features are regularly introduced.

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6. Agile Model

Definition:

Agile is a flexible, iterative development methodology emphasizing collaboration, customer feedback, and fast delivery of small, usable features.

Principles:

- Individuals and interactions over processes and tools.
- Working software over comprehensive documentation.
- Customer collaboration over contract negotiation.
- Responding to change over following a fixed plan.

Process:

- Work is divided into short cycles called **sprints** (typically 2-4 weeks).
- Each sprint delivers a working product increment.
- Regular meetings (daily stand-ups, sprint reviews) to foster communication and adaptation.
- Continuous integration and testing.

Characteristics:

- Highly adaptive to change.
- Encourages face-to-face communication and teamwork.
- Focuses on delivering customer value quickly and regularly.

Advantages:

- Fast response to changing requirements.
- Improves product quality through continuous testing.
- Higher customer satisfaction via involvement throughout development.

Disadvantages:

- Less predictability in scope and timelines.
- Requires experienced and self-organizing teams.
- Documentation may be insufficient for some regulatory environments.

Use Case Example:

Modern web and mobile app development, startups, products requiring rapid innovation (e.g., Spotify, Airbnb).

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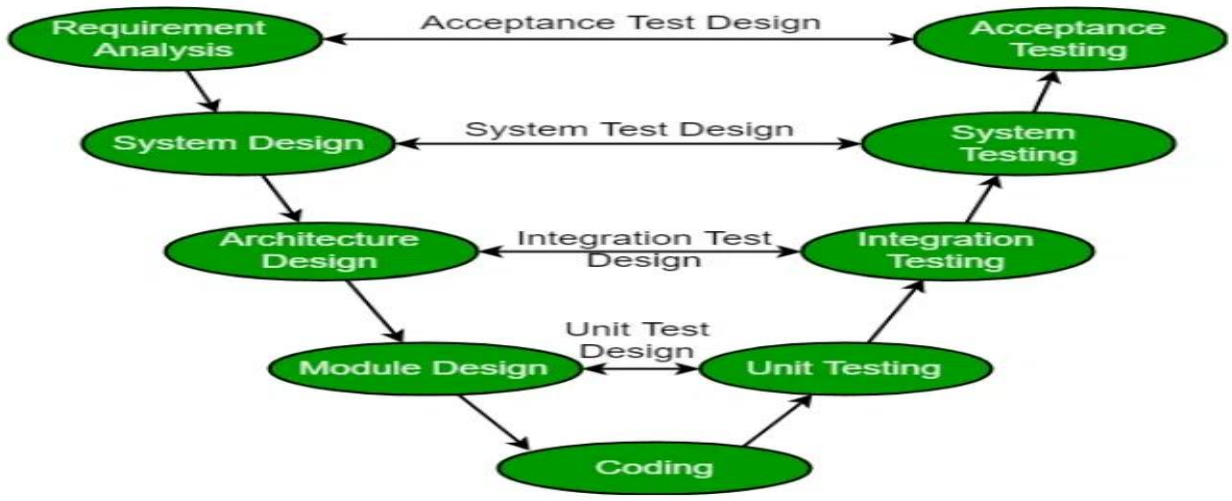
7. V-Model (Verification and Validation Model)

Definition:

The V-Model is an extension of the Waterfall Model where each development phase has a corresponding testing phase. The process looks like a "V" with development on one side and testing on the other.



Process:

- Left side: Requirements → Design → Implementation.

- Right side: Unit Testing → Integration Testing → System Testing → Acceptance Testing.

Characteristics:

- Emphasizes early test planning alongside development.
- Each development activity corresponds directly to a testing activity.

Advantages:

- Early defect detection through parallel testing.
- Clear, disciplined structure.
- Suitable for projects with well-defined requirements.

Disadvantages:

- Inflexible to changes after project starts.
- Like Waterfall, poor for projects with evolving requirements.

Use Case Example:

Safety-critical systems, medical devices, where validation and verification are crucial.

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8. DevOps Model

Definition:

DevOps integrates development (Dev) and operations (Ops) teams to enable continuous integration, continuous delivery (CI/CD), and automation to speed up software release cycles.

Characteristics:

- Automation of building, testing, and deployment processes.
- Continuous monitoring of software performance and security.
- Emphasizes collaboration between developers, QA, and operations.

Advantages:

- Faster time to market through automation.
- Improves reliability with continuous testing and monitoring.
- Better collaboration and reduced silos.

Disadvantages:

- Requires cultural shift and tooling investment.
- Can be complex to implement in traditional organizations.

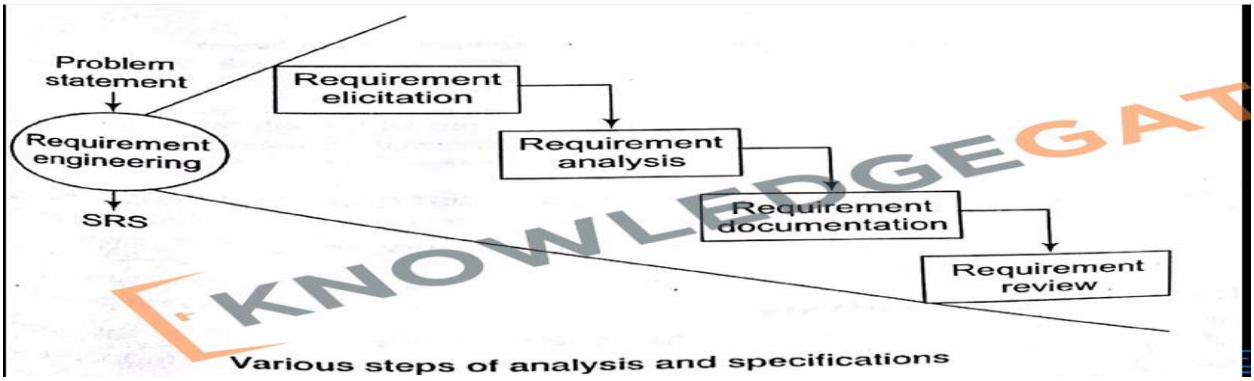
Use Case Example:

Cloud-native applications, microservices, and large-scale web services.

Unit-2:Software Requirement Specifications (SRS)

□ Requirement Engineering Process

Requirement Engineering is the process of defining, documenting, and maintaining software requirements. It ensures that the software system meets the user's expectations and business needs.



Various steps of analysis and specifications

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1. Requirement Elicitation

➢ What It Is:

The process of **gathering requirements** from stakeholders (users, customers, developers, etc.).

➢ Techniques:

- **Interviews** (structured/unstructured)

- **Questionnaires**
- **Workshops**
- **Observation**
- **Brainstorming**
- **Use Cases and Scenarios**

➢ **Goal:**

Understand **what the user really needs**, not just what they say they want.

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2. Requirement Analysis

➢ **What It Is:**

The process of **refining and organizing** requirements into a structured format.

➢ **Tasks:**

- Remove ambiguities, contradictions, and incompleteness.
- Identify dependencies and constraints.
- Categorize into functional, non-functional, and domain requirements.

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3. Requirement Documentation

➢ **What It Is:**

Recording requirements in a clear, understandable, and structured format.

➢ **Tool:**

Software Requirements Specification (SRS) document.

➢ **Benefits:**

- Acts as a reference for design, development, and testing.
- Enables traceability.

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4. Review and Management of User Needs

➢ **What It Is:**

Ensuring that gathered requirements are correct, complete, and agreed upon.

➢ **Activities:**

- Requirement reviews
- Stakeholder validation
- Change management and version control

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5. Feasibility Study

➢ **What It Is:**

Analyzing whether the project is **technically, economically, and operationally feasible**.

➢ **Types:**

- **Technical Feasibility** – Is the technology available?
- **Economic Feasibility** – Is it cost-effective?
- **Legal Feasibility** – Are there legal constraints?
- **Operational Feasibility** – Can the system be implemented and operated?

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6. Information Modeling

➢ **What It Is:**

Describing and structuring the data and processes of the system using models.

➢ **Examples:**

- **Data Flow Diagrams (DFD)**
- **Entity-Relationship Diagrams (ERD)**

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7. Data Flow Diagrams (DFD)

➢ **What It Is:**

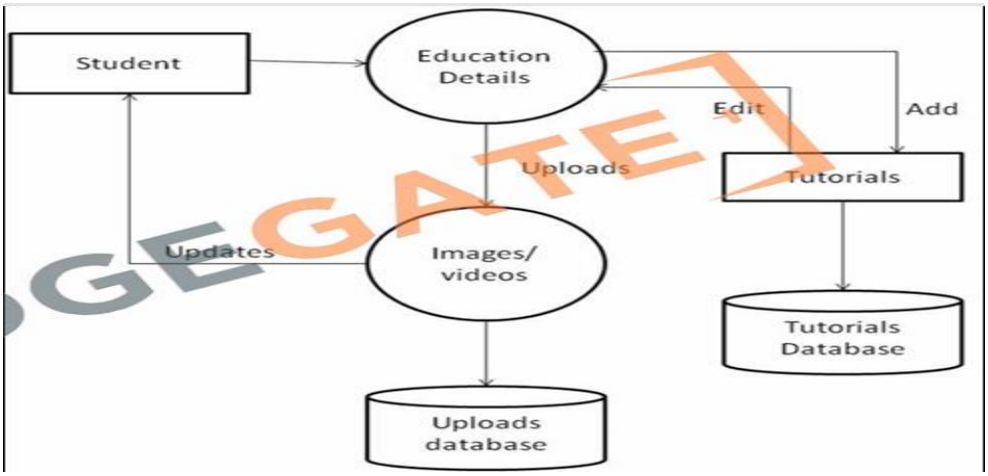
A graphical representation of the **flow of data** in a system.

➢ **Levels:**

- **Level 0 (Context Diagram)** – Overall system as a single process.
- **Level 1** – Breaks down the main process into subprocesses.

➢ **Symbols:**

- Circle (process)
- Arrow (data flow)
- Rectangle (external entity)
- Open rectangle (data store)



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8. Entity-Relationship Diagrams (ERD)

➢ **What It Is:**

A diagram that shows **entities (objects)** and their **relationships**.

➢ **Components:**

- Entities (e.g., Customer, Product)
- Attributes (e.g., name, ID)
- Relationships (e.g., "buys", "owns")

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9. Decision Tables

➢ **What It Is:**

A tabular method for representing **complex business logic** with multiple conditions and actions.

➢ **Structure:**

- Conditions
- Actions
- Rules (combinations of conditions with corresponding actions)

Aspect	Decision Table	Decision Tree
Structure	Tabular format that lists **conditions**, **actions**, and **rules**.	Tree-like diagram that represents **decision paths** with **branches**.
Decision Making	Based on various **combinations of conditions** leading to specific **actions**.	Based on **sequential decisions**, leading to final **outcomes**.
Ease of Use	Simple for **logical representation**, but can become **cumbersome** with many variables.	More **intuitive** and **visual**, but can be **complex** with many branches.
Application	Preferred when you need a **clear view of all possible combinations** of inputs and outputs.	Preferred when visualizing **step-by-step decision-making** is important.
Best Use Case	Rule-based systems like loan eligibility, insurance claim approvals.	Classification problems, diagnostics, customer decision analysis.
Complexity Handling	Handles **multiple rules** effectively in a compact form.	Can visually **explode** with increasing conditions.
Visual Appeal	Less visual, more structured.	Highly visual, easy to explain to non-technical users.

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10. SRS Document (Software Requirements Specification)

➢ **What It Is:**

A **formal document** that captures all software requirements.

➢ **Sections:**

- Introduction
- Overall Description
- Functional Requirements
- Non-functional Requirements
- External Interfaces

- System Features

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11. IEEE Standards for SRS

➢ **Standard:**

IEEE 830 (now replaced by IEEE 29148-2018)

➢ **Purpose:**

Provides a **standard structure** and **guidelines** for preparing an SRS.

➢ **Benefits:**

- Improved clarity and consistency
- Easier to maintain and update
- Ensures completeness and correctness

Software Quality Assurance (SQA)

 Definition

SQA is a **systematic process** that ensures software products and processes comply with **defined quality standards and customer requirements**.

 Objective

- **Prevent defects** before they occur.
- **Improve the overall quality** of the software product.
- **Ensure customer satisfaction** by delivering a reliable product.

 Process

SQA activities span the entire **software development lifecycle (SDLC)**:

- Planning quality assurance activities.
- Implementing **quality control** mechanisms.

- Reviewing and improving processes continuously.

 Techniques

SQA employs several techniques to assess and maintain software quality:

- **Code Reviews**
- **Inspections**
- **Audits**
- **Testing** (unit, integration, system, and acceptance)

 Standards

SQA adheres to international **quality standards**, including:

- **ISO 9001** – Quality management systems.
- **IEEE 730** – Software Quality Assurance Plan standards.
- **CMMI** – Capability Maturity Model Integration.

 Quality Attributes

Focuses on evaluating the software based on key attributes:

- **Reliability** – Performs consistently under expected conditions.
- **Maintainability** – Easy to modify and update.
- **Usability** – User-friendly interface and interaction.
- **Efficiency** – Uses resources optimally.
- **Functionality** – Meets specified requirements.

 Continuous Improvement

- Tracks **defects**, **failures**, and **customer feedback**.
- Uses this data to **enhance processes and tools** over time.

 Metrics

Quantitative measurements help evaluate and monitor software quality:

- □ **Defect Density** – Number of defects per unit of code.
- □ **Code Coverage** – Percentage of code executed during testing.

□ **Training**

- Regular **training and workshops** for developers and testers.
- Ensures awareness of best practices, tools, and evolving standards.

□ **Documentation**

- Maintains complete documentation for:
  - □ **Requirements**
  - □ **Design decisions**
  - □ **Test cases and results**
  - □ **Traceability** and **audits**

Verification vs. Validation

Aspect	Verification (White Box Testing)	Validation (Black Box Testing)
Definition	Ensures software is developed according to specified **requirements and standards**	Ensures software meets **end-user needs** and is fit for **intended use**
Key Question	"Are we building the product **right**?"	"Are we building the **right** product?"
Focus Area	Design phase, internal logic, and flow of the program	Final product behavior and output
Techniques Used	- Code Reviews - Static Analysis Tools - Design/Code Inspections	- Functional Testing - User Acceptance Testing - System Testing
Approach Type	**Static** (examines code without execution)	**Dynamic** (executed to observe output)
Examples	Peer reviews of design, checking code syntax and structure	Checking whether a login page works as expected or not

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Software Quality Factors

□ Definition

- Software quality factors are attributes that influence a product's **functionality**, **performance**, and **maintainability**.
- These are classified as:
  - **Directly measurable**: e.g., number of bugs.
  - **Indirectly measurable**: e.g., usability or maintainability.

□ McCall's Quality Model (1977)

McCall suggested **11 software quality factors**, grouped into **three categories**:

---

1. Product Operation Factors – Relate to how the software behaves during operation

Factor	Description
Correctness	Does the software perform required functions correctly?
Reliability	Can the software perform under specific conditions for a time period?
Efficiency	Does it use system resources optimally (CPU, memory, etc.)?
Integrity	Is the software secure and protected from unauthorized access?
Usability	Is it easy to learn and use for end-users?

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2. Product Revision Factors – Focus on how easily the software can be modified

Factor	Description
Maintainability	How easily can the software be corrected or improved?
Flexibility	Can it be easily adapted to changes in requirements?
Testability	How easily can the software be tested to identify bugs or issues?

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3. Product Transition Factors – Concerned with software adaptability to new environments

Factor	Description
Portability	Can the software run in different environments (OS/platform)?
Reusability	Can parts of the software be reused in other applications?
Interoperability	Can the software interact with other systems effectively?

ISO 9000 in Software Engineering

 Overview

- ISO 9000 is a **set of international standards** for **quality management** and **assurance**.
- In software engineering, it ensures the development of **high-quality software** through well-defined processes.

 Key Components of ISO 9000

1. **Quality Management System (QMS)**
   - Defines quality **policies** and **objectives**.
   - Requires **documentation** of processes and procedures.
   - Involves **monitoring**, **analysis**, and **corrective actions**.
2. **Management Responsibility**
   - Commitment from top management.
   - Establishment of a **quality policy**.
   - Regular **review** of QMS performance.
3. **Resource Management**
   - Provision of **human resources**, infrastructure, and work environment.
   - Personnel **training** and **competency development**.
4. **Product Realization**
   - Covers requirements, **design**, development, **testing**, and delivery.
   - Also includes **post-delivery support**.
5. **Measurement, Analysis, and Improvement**
   - **Monitoring** and **auditing** of processes.
   - **Corrective and preventive actions**.
   - Focus on **continual improvement**.

 ISO 9000 Principles

1. **Customer Focus**
2. **Leadership**
3. **Process Approach**
4. **Continual Improvement**

 Important ISO Standards

Standard	Description
ISO 9001:2015	Framework for QMS, applicable across all industries. Focus on customer satisfaction and continuous improvement.
ISO/IEC/IEEE 90003:2018	Tailors ISO 9001:2015 for software engineering. Covers development, maintenance, and delivery.

 Benefits of ISO 9000 in Software Engineering

- Enhanced **customer satisfaction**
- Improved **process efficiency**
- Reduced risk of **software defects**
- Increased **market competitiveness**

 ISO 9000 Implementation Steps

1. Get **top management commitment**
2. Establish **QMS**
3. **Train** employees
4. **Document** policies and processes
5. Monitor and **analyze** processes
6. Implement **improvements**
7. Conduct **internal audits**
8. Seek **ISO 9001 certification**

Capability Maturity Model (CMM)

 Definition

CMM is a structured model for improving software processes, ensuring **predictability, efficiency, and quality** in software development.

 CMM Levels of Maturity

Level	Name	Description
1	Initial	Ad hoc, chaotic process; no structured management or planning. Heavily depends on individual effort.
2	Repeatable	Basic project management practices in place. Success depends on past

Level	Name	Description
		experiences.
3	Defined	Organization-wide standardization of software processes. Includes documentation and training.
4	Managed	Quantitative process measurement. Time and cost are predictable and tracked.
5	Optimized	Focus on **continuous improvement**. Root cause analysis and defect prevention strategies implemented.

 Purpose of CMM

- Evaluate the **maturity** of software processes in an organization.
- Identify **key practices** to move up the maturity levels.
- Improve **software quality** through **structured process refinement**.

 Advantages of CMM

- Enhances **process control** and **project predictability**
- Improves **software quality**
- Facilitates **continuous improvement**
- Increases **customer confidence**

Unit-3:Software Design

1. Basic Concepts of Software Design

 What is Software Design?

Software design is the process of **converting software requirements into a logical and technical plan**, which serves as a **blueprint** for developing the system.

 Think of it like:

Designing a house – the architect draws the floor plan before construction begins.
Similarly, in software, a design plan is created **before writing the code**.

 Key Aspects:

- It defines **how** the system will do what it is supposed to do (based on the requirements).
- It helps in **structuring the software components**, their interfaces, and their interactions.
- It is done **after requirement analysis** and **before actual coding** begins.

 Goals of Software Design

The main goals are to ensure that the final software system is of **high quality**, **meets all requirements**, and is easy to maintain and extend.

1. Satisfy Functional Requirements

- The design must include all the features and behavior that the client needs.
- Example: If a system needs login functionality, the design must define how that login module will work.

2. Improve Software Quality

Software quality includes several aspects:

- **Maintainability**: Easy to modify in future (e.g., adding a new feature).
- **Scalability**: Able to handle increased users or data.
- **Performance**: Responds quickly and uses system resources efficiently.

A good design ensures that these qualities are **built-in from the beginning**.

3. Reduce Complexity

- Breaking a big system into **small manageable parts (modules)**.
- This makes understanding, testing, and updating the system easier.

4. Promote Reuse

- Design components in a **generalized way** so that they can be reused in other projects or modules.
- Example: A reusable "Payment Gateway" module can be used across different e-commerce platforms.

 Design Activities

Design is not a single step—it's a set of **staged activities** moving from general to specific:

---

1. Architectural Design (High-Level Design)

Also called **System Design**, this is the **first level of design**.

It focuses on:

- The **overall structure** of the software system.
- Breaking the system into **major components or subsystems**.
- Describing **how these components interact**.

 Example:

In a banking system:

- Major components: Login Module, Account Management, Transaction Module
- Architecture: Client-Server, Layered Architecture, or Microservices

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2. Detailed Design (Low-Level Design)

Also called **Module Design**, this is the **next level**.

It focuses on:

- The **internal design of each module** or component defined in the architectural design.
- Creating **algorithms, data structures, flowcharts**, and **pseudo-code**.

 Example:

If the architectural design includes a "Transaction Module":

- The detailed design will describe how "fund transfer", "withdrawal", "deposit" will work internally.
- It might use pseudo code to explain the fund transfer logic.

---

2. Architectural Design

 What is Architectural Design?

Architectural Design is the **high-level blueprint** of a software system. It focuses on the **overall structure** of the system and **how its main components fit together and interact**.

- It defines **major software components or modules**.
- It specifies the **interfaces** between those components.
- It explains the **relationships** and **interactions** between components.
- It sets the **foundation** for detailed design and implementation.

Key Elements of Architectural Design:

Element	Description
Software Components/Modules	The main building blocks or subsystems of the software, e.g., Authentication module, Database module.
Interfaces	The ways in which components communicate or interact (APIs, protocols).
Relationships	How components connect, depend on, or communicate with each other (data flow, control flow).

Common Architectural Styles:

Style	Description	Example / Use Case
Layered Architecture	Organizes software into layers with specific roles (e.g., presentation, business logic, data access).	OSI model in networking, MVC in web apps
Client-Server Architecture	Separates system into clients (requesters) and servers (responders).	Web applications, email servers
Microservices Architecture	System is divided into small independent services communicating via APIs.	Large-scale web apps like Netflix, Amazon
Pipe-and-Filter Architecture	Data passes through a series of processing components (filters) connected by pipes.	Data processing systems, compilers

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 Example: Layered Architecture

- Layer 1: User Interface (UI)
- Layer 2: Business Logic
- Layer 3: Data Access Layer
- Layer 4: Database

Each layer communicates only with the layer directly below or above it, which helps in isolation and easy maintenance.

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3. Low-Level Design (Detailed Design)

 Modularization

- The process of **dividing the system into smaller, independent modules**.
- Each module has a **specific responsibility or function**.
- Benefits:
  - **Improves readability**: Easier to understand small modules than a huge codebase.
  - **Enhances reusability**: Modules can be reused in other projects or parts of the system.
  - **Simplifies testing**: Individual modules can be tested independently.

 Design Structure Charts (DSC)

- A **hierarchical diagram** showing modules and their relationships.
- Represents:
  - **Control flow**: Which module calls which.
  - **Data flow**: Data passed between modules.
- Useful for visualizing the structure and dependencies in the system.

 Pseudo Code

- A simplified, **English-like representation** of the program logic.
- Helps designers and developers understand the algorithm without worrying about syntax.
- Used to:
  - Plan logic before coding.
  - Communicate design to team members.

□ Flow Charts

- A **graphical representation of an algorithm or workflow** using standardized symbols.
- Helps visualize the **control flow** (decisions, loops, start/end points).
- Symbols include:
  - Oval: Start/End
  - Rectangle: Process or operation
  - Diamond: Decision or condition
  - Arrow: Flow direction

---

4. Coupling and Cohesion Measures

□ Cohesion

Definition:
Cohesion measures **how closely the elements (functions, variables) inside a single module are related to each other**. It tells us how focused a module is on performing a single task or closely related tasks.

Why is Cohesion important?

- **High cohesion** means a module has a well-defined purpose and all its parts contribute directly to that purpose.
- **Good design** aims for **high cohesion**, which leads to easier maintenance, better understandability, and reusability.
- **Low cohesion** means a module is trying to do many unrelated things, making it complex and hard to maintain.

Types of Cohesion (From Best to Worst):

Type	Description	Example
Functional Cohesion	All elements contribute to a single well-defined task.	A module that calculates taxes only.
Sequential Cohesion	Output of one part is input to	A module reading data, processing,

Type	Description	Example
	another within the module.	and then formatting it.
Communicational Cohesion	Elements operate on the same data or resources.	A module that processes customer data: updates and reports.
Temporal Cohesion	Elements executed together in the same phase/time.	Initialization routines at system startup.
Logical Cohesion	Elements perform similar functions but choose based on conditions.	A module handling all input/output operations but for different devices.
Coincidental Cohesion	Elements have no meaningful relationship; random grouping.	A module with unrelated functions like printing, calculations, and logging.

Coupling

Definition:
Coupling measures the **degree of interdependence between different modules** in a system.

Why is Coupling important?

- **Low coupling** means modules interact with each other as little as possible.
- **Good design** aims for **low coupling**, which increases modularity, reduces impact of changes, and makes the system easier to maintain and test.
- **High coupling** means modules depend heavily on each other, making changes risky and complex.

Types of Coupling (From Best to Worst):

Type	Description	Example
Data	Modules share data only through	Passing variables explicitly between

Type	Description	Example
Coupling	parameters.	modules.
Stamp Coupling	Modules share a composite data structure, but only part is used.	Passing a whole record or object but only some fields are used.
Control Coupling	One module controls the behavior of another by passing control flags.	Passing a flag variable to control module flow.
External Coupling	Modules depend on externally imposed data formats or protocols.	Modules sharing data through external files or devices.
Common Coupling	Modules share global data.	Multiple modules accessing global variables.
Content Coupling	One module directly uses or modifies internal data of another module. (Worst)	A module accessing internal variables of another module directly.

Intuitive Example:

Imagine a software system with:

- **High Cohesion:** A "User Authentication" module that only handles login, logout, and user verification.
- **Low Coupling:** The "User Authentication" module communicates with the "Database" module only via well-defined APIs passing user data, rather than directly accessing database internals.

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5. Design Strategies

□ Function-Oriented Design (FOD)

- **Concept:**
  In Function-Oriented Design, the system is broken down into a set of **functions** or **procedures**. Each function performs a specific task or operation.

- **Focus:**
  Focuses on **what** the system does — the processes and transformations applied to the data.
- **Tools:**
  Uses **Data Flow Diagrams (DFDs)** to represent the flow of data between functions/modules.
- **Characteristics:**
  - Emphasizes functions over data.
  - Good for systems where the primary concern is processing data step-by-step.
  - Easier to implement sequential and procedural programs.
- **Example:**
  An order processing system might have functions like validateOrder(), calculatePrice(), generateInvoice(), and shipOrder().

Object-Oriented Design (OOD)

- **Concept:**
  The system is decomposed into **objects**, which combine **data** and **behavior** (methods). Objects represent real-world entities or concepts.
- **Focus:**
  Focuses on **both data and behavior**, encapsulating them within objects.
- **Key Features:**
  - **Classes and Inheritance:** Objects are instances of classes, which can inherit properties from other classes.
  - **Encapsulation:** Hides internal details and exposes only necessary interfaces.
  - **Polymorphism:** Objects can take many forms, allowing for flexible and reusable code.
  - **Reuse:** Encourages reuse through inheritance and composition.
- **Tools:**
  Uses **Unified Modeling Language (UML)** diagrams such as class diagrams, sequence diagrams, and use case diagrams to model the system.
- **Example:**
  In a banking system, classes like Account, Customer, and Transaction encapsulate both data (account number, balance) and behavior (deposit, withdraw).

Top-Down Design

- **Concept:**
  Starts from the **highest level** of the system — the main function or overall system architecture — and breaks it down step-by-step into smaller, more detailed parts.
- **Approach:**
  - Begin with the big picture.

    - Decompose into submodules or sub-functions.
    - Continue breaking down until modules are simple enough to implement.
- **Benefits:**
    - Provides a clear overview and structure of the system.
    - Helps in understanding complex systems by focusing on broad tasks first.
    - Easy to manage and track progress.
- **Use Case:**
  When designing a new system where the requirements are understood at a high level but need detailed specification.

 Bottom-Up Design

- **Concept:**
  Starts from the **lowest-level modules** or components, which are well understood or reusable, and combines them to build higher-level systems.
- **Approach:**
    - Identify existing modules or design small, reusable modules.
    - Integrate these modules into larger components.
    - Build up to the complete system.
- **Benefits:**
    - Effective when reusable components or libraries are available.
    - Encourages reuse and reduces redundancy.
    - Useful in incremental development and prototyping.
- **Use Case:**
  When working with existing codebases or libraries and assembling a new system using these modules.

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6. Software Measurement and Metrics

 Purpose of Software Metrics

Software metrics are quantitative measures used to assess different attributes of software and the software development process. Their main purposes include:

- **Measuring software size:** How large or complex the software is.
- **Measuring complexity:** How difficult the software is to understand, develop, or maintain.
- **Estimating effort:** How much work/time/resources are needed to develop or maintain the software.

- **Evaluating quality:** Assessing attributes like reliability, maintainability, and performance.

Why Use Metrics?

- To **estimate project costs and timelines** more accurately.
- To **monitor progress** during software development.
- To **control quality** and detect issues early.
- To **improve processes** by identifying bottlenecks or areas of risk.
- To **benchmark** performance across projects or teams.

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7. Size-Oriented Measures

 Halstead's Software Science

Halstead's metrics are based on the **count of operators and operands** in the software's source code. It treats a program as a sequence of tokens (operators and operands) and derives quantitative measures to estimate complexity and effort.

Key Terms:

Symbol	Meaning
n_1	Number of **unique operators**
n_2	Number of **unique operands**
N_1	Total number of operators
N_2	Total number of operands

Halstead's Formulas:

1. **Program Length (N)**
   $N = N_1 + N_2$
   Total number of operators and operands.
2. **Program Vocabulary (n)**
   $n = n_1 + n_2$
   Number of unique operators and operands.
3. **Volume (V)**
   $V = N \times \log_2(n)$
   Represents the size of the implementation in terms of information content.
4. **Difficulty (D)**
   $D = \frac{n_1}{2} \times \frac{N_2}{n_2}$
   How difficult the program is to write or understand.
5. **Effort (E)**
   $E = V \times D$
   Estimated effort required to develop or maintain the software.

Interpretation:

- **Higher Volume (V):** Indicates more code or higher complexity.
- **Higher Difficulty (D):** Indicates that the program is more complex or hard to understand.
- **Higher Effort (E):** More time and resources likely needed.

Function Point (FP) Based Measures

Function Point Analysis is a **user-oriented metric** that measures software size by quantifying the **functionality delivered to the user**, rather than code size.

Components Measured:

Component	Description
External Inputs (EI)	User inputs that the system processes
External Outputs (EO)	Outputs sent to the user
External Inquiries (EQ)	Interactive inputs that require a response (queries)

Component	Description
Internal Logical Files (ILF)	Data files maintained within the system
External Interface Files (EIF)	Files used by the system but maintained externally

---

How Function Points Are Calculated:

1. Count the number of each component type (EI, EO, EQ, ILF, EIF).
2. Assign a **complexity weight** (Low, Average, High) to each component based on criteria like number of data elements or file types.
3. Calculate weighted totals for each component.
4. Sum the weighted values to get the **Unadjusted Function Point (UFP)** count.
5. Apply a **Value Adjustment Factor (VAF)** based on general system characteristics like performance, usability, and complexity.
6. Final Function Point (FP) = UFP × VAF

Why Use Function Points?

- Measures software size **independent of programming language**.
- Focuses on **user requirements** and delivered functionality.
- Useful for early estimation and project management.
- Helps in benchmarking productivity.

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8. Cyclomatic Complexity Measures

□ What is Cyclomatic Complexity?

Cyclomatic Complexity (CC) is a **software metric** introduced by Thomas McCabe in 1976. It measures the **complexity of a program's control flow** by counting the number of **linearly independent paths** through the program.

- **Purpose:**
  To estimate how complex the decision structure of a program is.
- **Why important?**
  A higher cyclomatic complexity indicates more branches and decision points in the code, which means the program is more complex and potentially harder to understand, maintain, and test.

□ Control Flow Graph (CFG)

Before calculating Cyclomatic Complexity, you need to understand the **Control Flow Graph** of a program:

- A **CFG** is a directed graph representing the flow of control in a program.
- **Nodes (N):** Represent blocks of code or instructions.
- **Edges (E):** Represent the flow or transitions between these blocks (like jumps after decisions).
- **Connected Components (P):** Usually 1 for a single program, it represents the number of independent subgraphs.

Example of a simple CFG:

(Start) → [Block 1] → [Decision] → [Block 2 or Block 3] → (End)

□ Cyclomatic Complexity Formula

The cyclomatic complexity (M) can be calculated by the formula:

$$M=E-N+2P$$

Where:

Symbol	Meaning
E	Number of edges in the CFG
N	Number of nodes in the CFG
P	Number of connected components (usually 1)

□ Example Calculation:

Suppose a program has:

- **Nodes (N) = 10**
- **Edges (E) = 12**
- **Connected Components (P) = 1**

Using the formula:

$$M=12-10+2\times1=4$$

So, the **Cyclomatic Complexity = 4**.

 Interpretation:

- **M = 1:** Program has no control flow statements (no decisions), only one path.
- **M = 2:** Program has one decision (if-else) → two paths.
- **Higher M (>10):** Program is very complex → difficult to test and maintain.

 Why is Cyclomatic Complexity Useful?

- **Testing:** Minimum number of test cases needed = Cyclomatic Complexity (to cover all paths).
- **Maintainability:** High complexity indicates code might be hard to understand or modify.
- **Risk Assessment:** Helps identify risky parts of the code.

Unit-4:Software Testing

1. Testing Objectives

Software Testing is the process of executing a program or system with the intent of identifying bugs (errors or defects) and verifying that the software behaves as expected.

 Key Objectives of Software Testing:

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1. Detect Defects Before Deployment

- **Main Goal** of testing is to find and fix **errors and bugs** in the early stages.
- Catching bugs **before deployment** saves cost, time, and avoids reputation damage.
- Example: Detecting a login bug before a product goes live.

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2. Ensure Software Meets Functional and Non-Functional Requirements

- **Functional Requirements**: What the system **should do** (e.g., "User should be able to register").
- **Non-Functional Requirements**: How the system **should behave** (e.g., speed, reliability).
- Testing ensures that both types are met properly.

---

3. Ensure Reliability, Security, and Performance

- The system should work **reliably** over time without crashing.
- It must be **secure** against unauthorized access or data leaks.
- It should perform well under **different loads and stress levels**.

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4. Increase Customer Confidence

- A thoroughly tested system boosts the **confidence of clients and users**.
- They are more likely to trust a product that works consistently and predictably.

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5. Ensure Software Works Correctly in All Expected Scenarios

- The system should behave correctly for:
  - **Normal inputs**
  - **Edge cases**
  - **Invalid inputs**
- Ensures robustness and avoids failure in unexpected situations.

---

2. Types of Testing

 Unit Testing

- **Definition**: Testing **individual functions or modules** in isolation.
- **Objective**: Verify each module performs as expected.
- **Who Does It?** Usually done by **developers** during the coding phase.
- **Scope**: Smallest testable parts like a function or method.

 Tools:

- Java: JUnit
- Python: PyTest
- C++: Google Test

Example: Testing a calculateTotal() function separately before integrating with the shopping cart.

 Integration Testing

- **Definition**: Testing how **different modules or services interact** with each other.
- **Objective**: Detect **interface mismatches, data exchange problems**, or communication issues.
- **When?** After unit testing and before full system testing.

 Types:

- **Top-Down**: Start testing from the top-level modules and integrate downward.
- **Bottom-Up**: Start testing from the lower modules and build up.

Example: Testing login module interaction with the user database module.

Acceptance Testing

- **Definition**: Final stage of testing done by **end users or clients**.
- **Objective**: Confirm if the system meets **business needs and expectations**.
- **Done When?** Before software is released to production.

 Types:

- **Alpha Testing**:
  - Done **in-house** by internal staff.
  - Controlled environment.
- **Beta Testing**:
  - Done by a **limited number of real users** in a real environment.
  - Provides real-world feedback and reveals unseen bugs.

Example: A bank tests their online portal with real users before full launch.

 Regression Testing

- **Definition**: Testing previously tested components **after code changes** (like bug fixes or feature updates).
- **Objective**: Ensure that new changes do **not break** existing functionality.
- **Automated Tools** like Selenium, JUnit, etc., are often used.

Example: After fixing a login issue, you re-test registration and dashboard functionalities.

 Testing for Functionality (Functional Testing)

- **Definition**: Verifies the system behaves **as per functional specifications**.
- Answers: **"Does the system do what it's supposed to?"**
- Focuses on **inputs, outputs, and behavior**.

Example: Checking if the 'Add to Cart' button adds items correctly.

Testing for Performance

- **Definition**: Tests how the system performs under **stress, load, and varying conditions**.
- **Key Focus Areas**:
  - **Response time**
  - **Throughput**
  - **Scalability**
  - **Stability**

 Types:

- **Load Testing**: Test under expected user loads.
- **Stress Testing**: Test under extreme or beyond-limit conditions.
- **Soak Testing**: Run the system for a long duration to detect memory leaks.

Example: Measuring how a web app performs with 1000 simultaneous users.

Top-Down Testing

 Definition:

Testing begins from the **topmost module (main controller)** and moves **downward**, progressively integrating and testing sub-modules.

 How it works:

- The **top-level modules** (those that call other modules) are tested first.
- **Lower-level modules** (which are not yet developed or tested) are replaced with **stubs**.
- As lower modules are implemented, the stubs are gradually replaced.

 What are Stubs?

- Stubs are **dummy modules** that mimic the behavior of lower-level modules.
- They provide **simplified responses** to the higher modules for testing purposes.

 Example: If Module A calls Module B and B is not ready, a **stub** for B is used to simulate its expected output.

Advantages:

- **Early validation** of high-level logic or architecture.
- Allows **early user interface prototyping**.
- Major design flaws in **main control flow** can be caught early.

Disadvantages:

- Lower-level modules are tested late.
- Requires **many stubs**, which can be time-consuming to write.
- Some important functionalities are **tested late**, increasing risk.

 Use Case Example:

A banking application's dashboard module (top-level) is tested first using stubs for account management, transaction history, and payment modules (lower-level modules).

Bottom-Up Testing

 Definition:

Testing begins with the **lowest-level (leaf) modules**, and gradually progresses **upward**, integrating into the main system.

 How it works:

- **Lowest-level modules** are tested first.
- Higher-level modules that are not yet ready are simulated using **drivers**.

- These drivers call the lower modules to test them in isolation.

 What are Drivers?

- Drivers are **test harnesses** or temporary modules that **simulate higher-level modules**.
- They call the low-level modules with test data and observe the output.

 Example: If Module Z is a utility function used by Module Y (which is not ready), a **driver** is used to directly call Z and test it.

Advantages:

- **Core functionalities** (often in low-level modules) are tested first.
- Useful when **low-level modules** are completed before the higher ones.
- Reduces the need to wait for top modules to be ready.

Disadvantages:

- Main control logic is tested late.
- Requires **many drivers**, increasing initial effort.
- User interface or end-to-end flow cannot be tested early.

 Use Case Example:

In an e-commerce app, modules for calculating discounts and taxes (low-level logic) are tested first using drivers that simulate user checkout actions.

---

4. Testing Strategies

Testing strategies are **structured approaches** to ensure that software behaves correctly, is reliable, and meets all requirements. These strategies include how to test (white-box or black-box), who tests (internal or external), and how test data is prepared.

Test Drivers and Test Stubs

These are **temporary code components** used in integration testing.

 Drivers:

- **Used in Bottom-Up Testing**
- Mimic higher-level modules.
- Call the lower-level module being tested.

 Think of a driver as a mock "main()" that invokes lower-level functions directly.

 Stubs:

- **Used in Top-Down Testing**
- Mimic lower-level modules that are **not yet available**.
- Called by the higher-level module to simulate responses.

 Stubs return hard-coded values or simple outputs in place of actual sub-modules.

Structural Testing (White Box Testing)

Also known as **Glass Box Testing**, this method focuses on the **internal workings of the code**.

 Tester must:

- Know the code structure.
- Understand logic, conditions, and loops.

 Techniques:

Technique	Description
Statement Coverage	Ensures every statement in the code is executed at least once.
Branch Coverage	Ensures each possible **if-else** or decision branch is tested.
Path Coverage	All possible execution **paths** through the code are tested.
Condition Coverage	All **boolean sub-expressions** are tested to be both true and false.

 Example: If there is an if (a > 10 && b < 5) condition, both parts (a > 10 and b < 5) are tested for true and false.

Functional Testing (Black Box Testing)

This tests the software **from the user's perspective**.

 Tester:

- Does **not need** to know the internal code.
- Uses only the **requirements/specifications** to design test cases.

 Techniques:

Technique	Description
Boundary Value Analysis	Tests values **at the edge** of valid input ranges (e.g., 0, 1, max-1, max).
Equivalence Partitioning	Divides input data into **valid and invalid partitions**, tests one value from each partition.

 Example: For an age input field accepting 18–60, test 17 (invalid), 18 (valid boundary), 60 (valid boundary), and 61 (invalid).

Test Data Suite Preparation

 Purpose:

To ensure test cases are effective, a **comprehensive set of test data** must be prepared.

 It should include:

- **Valid inputs** → expected outputs.
- **Invalid inputs** → graceful error handling.
- **Edge cases** → maximum, minimum, and boundary values.
- **Realistic scenarios** → simulate real-world usage.

 Example: For a login system:

- Valid: Correct username & password.
- Invalid: Wrong credentials, empty fields.
- Edge: Long strings, special characters.

 Alpha and Beta Testing

These are **acceptance-level testing** methods performed **before software release**.

 Alpha Testing:

- Conducted **in-house** by developers or QA team.
- Done **before** releasing to actual users.
- Simulates a real environment.
- Helps detect bugs before public access.

 Example: A new feature in a mobile app is tested by the internal QA team in a staging environment.

 Beta Testing:

- Conducted by a **limited group of real users**.
- Happens in a **real environment**.
- Helps gather feedback and catch **unexpected issues**.

 Example: Google releases a beta version of Android to developers for feedback before the final release.

---

5. Static Testing Strategies

Unlike **dynamic testing** (which involves running the software), **static testing** is done **without executing the code**. It focuses on identifying defects **early** in the software development lifecycle, especially in design documents, code, and specifications.

 Key Goals of Static Testing:

- Find **errors** before code execution.
- Improve **code quality**, **maintainability**, and **readability**.
- Ensure **compliance** with design/coding standards.
- Reduce the cost and time of fixing bugs later.

---

1. Formal Technical Reviews (Peer Reviews)

Definition:

A structured process where **a team of developers or peers** formally reviews a document or code to identify problems.

Features:

- Conducted early (e.g., during design or coding).
- Involves **moderator, author, reviewer, and recorder** roles.
- Discusses **logic, design quality, standard compliance**, and **potential errors**.
- May include **checklists** for review criteria.

Benefits:

- Detects issues **before execution**.
- Enhances **team collaboration and knowledge sharing**.
- Increases software **reliability and maintainability**.

---

2. Walkthrough

Definition:

An **informal** review where the **author presents the code or document** to team members for feedback.

Features:

- Typically done during early stages of development.
- No formal preparation needed.
- The developer **explains the logic** and flow while others ask questions or provide suggestions.
- Aims at **gaining understanding** and **identifying potential issues**.

Benefits:

- Encourages **team understanding** of the code/design.
- Helps new team members get familiar with the project.
- Effective in spotting misunderstandings or logical flaws early.

---

3. Code Inspection

Definition:

A **highly structured** static testing technique where the code is carefully **examined line by line** by a group.

Features:

- Led by a **moderator**.
- Follow a **checklist** (e.g., variable naming, error handling, proper loops).
- Participants include: **Author, Reviewer, Moderator, and Scribe**.
- Detects **logic errors, violations of coding standards, and performance issues**.

Benefits:

- One of the most **effective methods** of finding hidden defects.
- Helps maintain **coding discipline**.
- Results in **high-quality and clean code**.

---

4. Compliance with Design and Coding Standards

 Definition:

Ensuring that all design artifacts and code **adhere to predefined standards** or guidelines.

 Examples of standards:

- **Naming conventions**: e.g., camelCase for variables, PascalCase for classes.
- **Indentation**: Consistent spacing for readability.
- **Commenting**: Proper documentation of logic and functions.
- **Error handling**: Using standardized exception blocks.
- **Modularization**: Proper function and class breakdown.

Benefits:

- Enhances **code readability and maintainability**.
- Makes it easier for teams to **collaborate and onboard** new developers.

- Avoids **technical debt** and inconsistent development styles.

Why Static Testing Is Important:

- **Saves time and cost**: Catching bugs early is cheaper than fixing them after testing or release.
- **Boosts quality**: Ensures clean, efficient, and standard-compliant code.
- **Improves collaboration**: Encourages knowledge sharing across the team.
- **Reduces rework**: Avoids repeated bugs and errors in later stages.

Unit-5:Software Maintenance

1. Software as an Evolutionary Entity

 What does it mean?

- **Software is not a one-time product**. Once it is developed and deployed, it **does not remain static**.
- Instead, it behaves like a **living system** that must **evolve over time** to remain relevant, functional, and efficient.

 Why does software need to evolve?

Software evolves because of the following **real-world factors**:

1. Changing User Needs

- Users continuously demand new features, better user experience, improved performance, etc.
- Example: Users might want dark mode, biometric login, or easier navigation.

2. Advancements in Technology

- New hardware, programming languages, and platforms emerge.
- Software must adapt to work with newer technologies (e.g., moving from desktop to mobile, or supporting cloud infrastructure).

3. Regulatory and Compliance Changes

- Governments and industry bodies often introduce **new rules** or **compliance standards**.
- Software must be updated to remain **legally compliant**.
- Example: GDPR in Europe required major changes to how data is handled in software.

4. Bug Fixes and Performance Improvements

- No software is perfect at launch. Bugs will appear post-deployment.
- Continuous evolution ensures stability, security, and performance.

 How does software evolve?

Software evolution typically involves:

- **Adding new features** (enhancements)
- **Fixing defects** (maintenance)
- **Optimizing code** for better performance
- **Refactoring** to make the code easier to understand and maintain
- **Adapting** to new platforms (mobile, web, cloud, etc.)

 Part of Software Life Cycle

- Software evolution is a major phase in the **Software Development Life Cycle (SDLC)**.
- It follows initial development and deployment.
- Without proper evolution and maintenance, even the best software becomes **obsolete** over time.

Real-Life Example

 Banking Application

- Initially supports debit/credit card transactions only.
- Over time, it must evolve to:
    - Support **UPI payments**
    - Include **QR code scanning**
    - Add **AI-based fraud detection**
    - Comply with **new RBI guidelines**
- Without these updates, the application will **lose users** and **fail in audits**.

---

2. Need for Maintenance

 What is Software Maintenance?

Software maintenance is the process of modifying a software application **after its deployment** to:

- Correct faults (bugs),
- Improve performance or other attributes,
- Adapt it to a changed environment,
- Or enhance its features based on user needs.

 Maintenance is an ongoing and essential phase in the Software Development Life Cycle (SDLC).

 Why is Software Maintenance Needed?

Software, like any real-world system, must keep up with changing conditions. Below are the main reasons:

 Key Reasons for Maintenance

1. Changing User Needs

- Over time, users may request:
  - New features
  - Enhanced user interface (UI)
  - Customizations to meet evolving business processes
- Example: An e-commerce site may need to add a wishlist feature or new payment options.

2. Changing Environments

- Software must adapt to:
  - New operating systems (e.g., Windows 12, Android 14)
  - Updated browsers or devices
  - New hardware (e.g., newer processors, higher resolution screens)
- Example: A desktop software might need updates to support touchscreen monitors or cloud connectivity.

3. Bug Fixes / Correcting Errors

- Some bugs are not detected during testing and only surface in the real world.
- Maintenance ensures:
  - Fixing logic errors
  - Resolving security vulnerabilities

    - Preventing system crashes
- Example: A banking app might crash when processing a large number of transactions — this needs immediate maintenance.

4. Performance Improvement

- To enhance:
    - Speed
    - Scalability
    - Resource efficiency (CPU, memory)
- Often involves refactoring or optimizing algorithms.
- Example: Reducing the load time of a web app to improve user experience.

5. Legal and Regulatory Compliance

- New regulations may demand changes in data storage, security, or transparency.
- Example: Implementing **GDPR compliance** for European users.

 Impact of Ignoring Maintenance

Risk	**Impact**
Ignored bugs	System crashes, user dissatisfaction
Outdated technology	Incompatibility with devices, obsolescence
Ignored performance issues	Slow response times, poor UX
Non-compliance with laws	Legal penalties, data breach risks

 Real-Life Example

Online Banking System:

- Initially designed for desktop users.
- Later needs to:
    - Support mobile platforms (Android/iOS)
    - Add UPI and QR payments
    - Comply with updated **RBI** and **KYC** guidelines
    - Optimize performance for rural areas with slow internet
- All of this requires **continuous maintenance**.

---

3. Categories of Maintenance

Software maintenance is **not just about fixing bugs**. It includes a range of activities to ensure the software continues to function correctly, efficiently, and securely as its environment and user needs evolve.

Maintenance is broadly classified into **four main categories**:

□ A. Corrective Maintenance

Purpose:
To **fix defects** or **bugs** discovered after the software has been deployed.

Key Characteristics:

- Performed **after a failure or error** is reported.
- Usually reactive (responds to problems).
- Can involve fixing logic errors, coding mistakes, or runtime issues.

Example:
Fixing a **null pointer exception** that causes a mobile app to crash when a user clicks on a button.

Goal:
Restore the software to its correct functioning state.

B. Adaptive Maintenance

Purpose:
To **adapt the software to changes** in the environment.

Key Characteristics:

- Environment may include hardware, operating systems, software dependencies, or regulatory requirements.
- Software is modified **without changing its core functionality**.

Example:

- Porting an existing web application to support **Android 14**.
- Updating to a new **database management system (DBMS)**.

- Ensuring software runs on a **new browser version**.

Goal:
Ensure continued usability of the software in a changing technological or regulatory environment.

C. Perfective Maintenance

Purpose:
To **improve or enhance** the software based on user feedback or performance analysis.

Key Characteristics:

- Involves **performance tuning**, **UI/UX improvements**, or **code optimization**.
- May include adding new features or refining existing ones.
- Focus is on **efficiency, maintainability**, and **usability**.

Example:

- Refactoring unoptimized code to **reduce execution time**.
- Redesigning the UI to improve **user experience**.
- Modularizing code for easier updates.

Goal:
Enhance the **overall quality and performance** of the system without altering its core purpose.

D. Preventive Maintenance

Purpose:
To make changes that **prevent future problems**.

Key Characteristics:

- Proactive maintenance — done **before any problem occurs**.
- Aimed at **improving long-term stability**, **reliability**, and **security**.
- Often involves **updating libraries**, **fixing latent bugs**, or improving **documentation**.

Example:

- Upgrading third-party libraries to fix known **security vulnerabilities**.
- Replacing deprecated APIs with newer, more robust alternatives.

Goal:
Reduce the **likelihood of future defects** and extend the software's life.

---

4. Cost of Maintenance

Software maintenance is a **critical and ongoing phase** of the software development life cycle (SDLC). While initial development might get more attention, **maintenance often consumes the majority of the total cost** over the product's lifetime.

 Key Facts

- **Maintenance costs typically account for 50% to 70%** of the **total cost** of a software product's lifecycle.
- Maintenance continues **long after** the software has been deployed.
- If not properly managed, maintenance can **exceed the cost** of initial development.

 Why Is Maintenance So Costly?

Here are the **main reasons** for the high cost of maintenance:

---

1. Poor Documentation

- When documentation (like design documents, user manuals, or code comments) is **incomplete or outdated**, understanding the software becomes hard.
- New developers or maintenance teams **waste time** trying to understand the software logic and structure.

Solution:
Maintain up-to-date and clear documentation.

---

2. Complex and Unstructured Code

- If the original code is **not modular**, not well-structured, or written with poor coding practices, it becomes **difficult to understand and change**.
- Spaghetti code increases the risk of introducing new bugs during updates.

Solution:
Follow best practices in design, structure, and coding.

---

3. Continuous Changes in Requirements

- Over time, businesses change strategies, regulations evolve, or user expectations grow.
- These changes often demand **frequent and significant alterations** to the software.

Example:
Adding support for UPI payments, new languages, or accessibility features.

---

4. Lack of Testing Infrastructure

- Inadequate or non-automated testing during maintenance leads to **undetected bugs**, which cause **rework** and increased costs.

Solution:
Use automated regression testing tools to reduce the cost and effort of testing.

---

5. Personnel Turnover

- New team members take time to **understand legacy code** and project context.
- Lack of knowledge transfer increases ramp-up time and errors.

□ Tip for Reducing Maintenance Costs

Best Practice	How It Helps
□ Good Design	Makes the system modular and easier to modify.
□ Proper Documentation	Speeds up understanding and onboarding.
□ Coding Standards	Ensures code consistency and readability.
□ Regular Refactoring	Prevents code rot and improves maintainability.

Best Practice	How It Helps
□ Automated Testing	Reduces the cost and effort of manual testing.

□ **Insight**

"The cost of fixing a bug found **after deployment** is **10x more** than fixing it during the design phase."

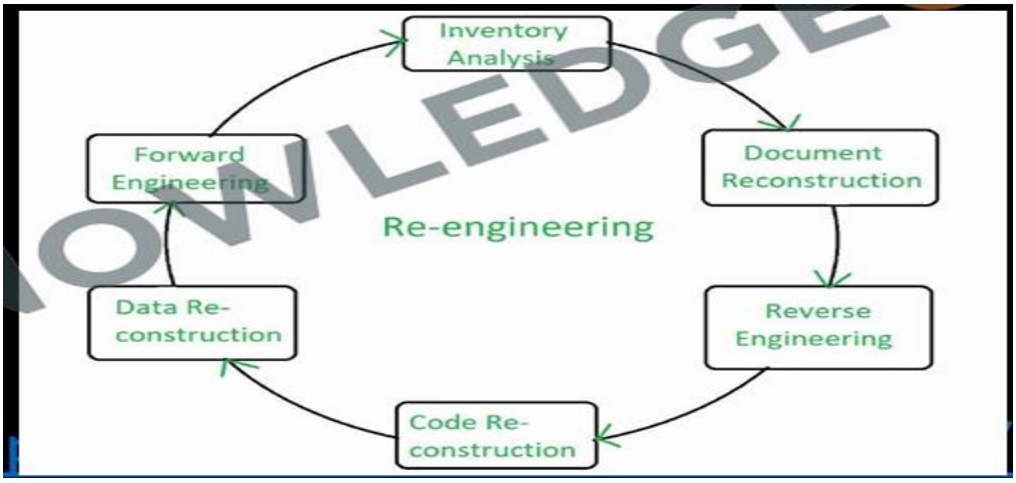
---

5. Software Re-Engineering

Software re-engineering is an important maintenance activity focused on **revamping existing software** to improve its overall quality, maintainability, and performance **without altering its fundamental functionalities**.

□ **What is Software Re-Engineering?**

- It is the process of **analyzing**, **modifying**, and **transforming** legacy or existing software systems.
- The goal is to **enhance software quality, extend its useful life, and reduce maintenance costs**.
- Unlike rewriting software from scratch, re-engineering **preserves core business logic and functionality** while improving the internal structure.



Key Activities in Software Re-Engineering:

1. **Code Restructuring**
   - Improving the internal structure of the source code without changing its external behavior.
   - Examples: Refactoring to remove duplicate code, improving modularity, renaming variables for clarity.
2. **Data Restructuring**
   - Modifying or reorganizing data formats, databases, or data models to improve performance or adapt to new platforms.
   - Example: Migrating from flat files to relational databases, or redesigning data schemas.
3. **Documentation Updating**
   - Ensuring that all design documents, user manuals, and code comments accurately reflect the current state of the software.
   - This aids future maintenance and onboarding.

Purpose of Software Re-Engineering

- **Extend the software's operational life** by making it easier and cheaper to maintain.
- **Improve software quality** such as maintainability, readability, and performance.
- Adapt the software to new hardware or software platforms without full redevelopment.
- Prepare the software for future enhancements.

Example

- A banking system originally written in **C++** is migrated to **Java** to take advantage of Java's portability, better memory management, and integration with web technologies.
- The **business logic remains the same**, but the internal implementation is modernized for maintainability and extensibility.

Benefits of Software Re-Engineering

Benefit	Explanation
Cost Efficiency	Cheaper than complete redevelopment.
Risk Reduction	Preserves proven business logic.
Improved Maintainability	Cleaner code and updated documentation.
Platform Migration	Enables running on new technologies or OS.

Benefit	Explanation
Extended Software Life	Keeps software relevant over longer periods.

 Challenges

- Requires detailed understanding of existing code.
- May be time-consuming and needs skilled resources.
- Risk of introducing errors if not carefully managed.

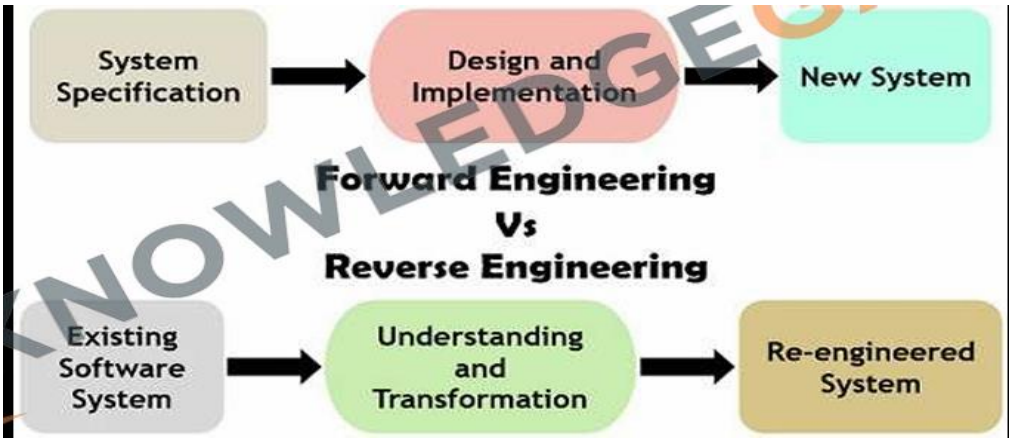
---

6. Reverse Engineering

Reverse engineering is the process of **analyzing an existing software product to understand its components, design, and functionality**, especially when original design documents or source code explanations are missing or incomplete.

 What is Reverse Engineering?

- It involves **examining a finished software system or binary executable** to extract knowledge about its internal workings.
- The goal is to **recover design and implementation details** to aid maintenance, troubleshooting, or further development.
- Reverse engineering is usually a **preliminary step before re-engineering**, where you need to understand the system deeply before making modifications.



 Key Aspects of Reverse Engineering:

- **Code Analysis:** Understanding source code or binaries to deduce logic, control flow, and data structures.
- **Structure Recovery:** Identifying module boundaries, interfaces, and dependencies.
- **Behavior Analysis:** Studying how software behaves in different scenarios to infer its functionality.
- **Documentation Creation:** Generating design documents, flowcharts, or UML diagrams from the analyzed system.

 Purpose of Reverse Engineering

- To **recover lost or outdated documentation**.
- To **understand legacy software** when original developers are no longer available.
- To **conduct software audits** for security or compliance.
- To support **software re-engineering** by providing insight into system internals.

 Use Cases

Use Case	Description
Software Audits	Analyzing software to verify compliance or security.
Recovering Lost Source Structure	Reconstructing design from code or binaries when documentation is missing.
Documentation Creation	Producing design diagrams and user manuals for legacy systems.
Security Analysis	Finding vulnerabilities in proprietary software.
Interoperability	Understanding a system to integrate with other systems.

 Benefits

- Enables maintenance of poorly documented or legacy systems.
- Helps new developers quickly understand complex systems.
- Facilitates migration or modernization projects.
- Supports discovery of hidden or undocumented features.

 Challenges

- Reverse engineering can be **time-consuming and complex**.
- Legal and ethical issues can arise if used to duplicate proprietary software.

- May require specialized tools for decompilation and analysis.

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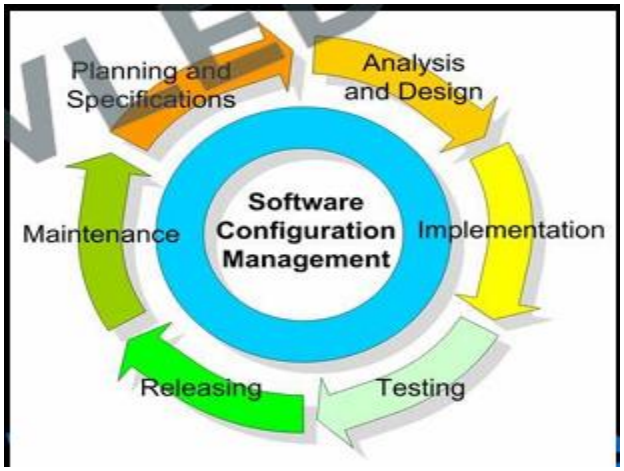
7. Software Configuration Management (SCM) Activities

What is SCM?

Software Configuration Management (SCM) is the discipline of **tracking and controlling changes in software products** to ensure consistency, quality, and traceability throughout the software lifecycle.



Why is SCM Important?

- Prevents **version conflicts** when multiple developers work on the same codebase.
- Helps maintain **integrity and traceability** of software artifacts (code, documents, configurations).
- Facilitates **reproducibility**, meaning you can recreate any previous version of the software reliably.
- Ensures controlled and documented changes, avoiding accidental disruptions.

Key SCM Activities:

Activity	Description
Version Control	Managing different versions of software components and tracking changes over time. Tools like Git, SVN are used.
Change Management	Handling requests for changes systematically to ensure that modifications are properly reviewed, approved, and implemented.

Activity	Description
Configuration Identification	Defining and identifying configuration items (source code, documents, modules) uniquely for tracking.
Configuration Audits	Verifying that the configurations comply with requirements and standards, ensuring no unauthorized changes.
Baseline Management	Establishing and maintaining baselines (stable versions) of software artifacts to serve as reference points.

Summary of SCM Purpose:

- **Maintain integrity and traceability:** Every change is recorded and can be traced back.
- **Ensure reproducibility:** You can recreate any version of the software.
- **Prevent version confusion:** Team members know exactly which version is current, avoiding conflicts.

---

8. Change Control Process

What is Change Control?

Change control is a **formal process to manage changes in software**, ensuring that only well-analyzed and approved changes are implemented, reducing risks and unintended side effects.

Steps Involved in Change Control:

Step	Description
1. Change Request Submitted	A formal request is made by a stakeholder or team member to modify the software.
2. Impact Analysis	Assess the potential impact of the change on cost, schedule, risk, and overall system.
3. Review Board Approval	A Change Control Board (CCB) or similar authority reviews and approves or rejects the change.
4. Implementation	If approved, the development team makes the necessary modifications to the software.
5. Testing	The changed module is tested to ensure correctness and that no new issues are introduced.
6. Documentation Update	All relevant documents, such as design specs, user manuals, and test cases, are updated.

Objective of Change Control:

- To **ensure that only beneficial and safe changes** are made to the software.
- To **minimize risks and disruptions** caused by uncontrolled or poorly managed changes.
- To maintain **software stability and reliability** throughout its lifecycle.

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9. Software Version Control

What is Version Control?

Version Control Systems (VCS) are tools that help developers **manage changes to source code over time**. They keep track of every modification, enabling developers to revert to previous versions if needed and collaborate without overwriting each other's work.

Types of Version Control Systems:

Type	Description	Examples
Local VCS	All versions are stored locally on a single machine, often in a database or file system. Simple but lacks collaboration features.	RCS (Revision Control System)
Centralized VCS (CVCS)	Uses a central server to store all versions. Developers check out files, make changes, and commit back to the server. Good for teams but single point of failure risk.	SVN (Subversion), CVS
Distributed VCS (DVCS)	Every user has a full copy of the repository including history, allowing offline work and faster operations. Changes are pushed/pulled between repositories.	Git, Mercurial

---

Benefits of Version Control:

- **Track history of code changes:** Know who changed what and when.
- **Restore older versions:** Roll back to a previous stable version if bugs arise.
- **Enable team collaboration:** Multiple developers work simultaneously without conflicts.
- **Identify and resolve conflicts:** Automatically or manually merge changes when concurrent edits happen.

Common Tools:

- **Git:** The most popular distributed VCS; used by GitHub, GitLab, Bitbucket.

- **SVN:** A centralized VCS, simpler but less flexible than Git.
- **Mercurial:** Another distributed VCS with similar features to Git.

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10. Resource Allocation Models

What is Resource Allocation in Maintenance?

Resource allocation refers to the planning and assigning of the right amount of **resources** (time, personnel, hardware, software tools) to effectively carry out software maintenance tasks.

What Do Resource Allocation Models Consider?

- **Effort Estimation:** How much work (in person-hours or days) is needed for changes.
- **Impact Analysis:** Understanding how changes affect the system, complexity, and resources required.
- **Cost-Benefit Ratio:** Balancing the cost of maintenance against the expected benefit or value.
- **Availability of Skilled Developers:** Ensuring that qualified personnel are assigned to appropriate tasks.

Example Model: COCOMO (Constructive Cost Model)

- COCOMO is a well-known model for estimating software development and maintenance costs based on software size (e.g., lines of code) and complexity.
- It helps predict the **effort, time, and resources** required for maintenance.
- Example: Larger, more complex software systems require more maintenance resources.

11. Software Risk Analysis and Management

What is Software Risk Management?

Software Risk Management is the **systematic process** of identifying, analyzing, prioritizing, and controlling risks that could negatively affect a software project or its maintenance. The goal is to reduce the likelihood and impact of risks to ensure the project's success and software quality.

Types of Software Risks

1. **Technical Risks**
    - Arise from technology choices or software design.
    - Examples:
        - Poor system architecture causing scalability issues.
        - Bugs or defects causing failures.
        - Use of outdated or incompatible technologies.
        - Integration problems with third-party tools.
2. **Project Risks**
    - Related to project management and execution.
    - Examples:
        - Schedule delays due to underestimated tasks.
        - Scope creep — uncontrolled changes expanding the project beyond original plans.
        - Resource unavailability (key developers leaving).
        - Budget overruns.
3. **Business Risks**
    - Concern alignment with business goals and external factors.
    - Examples:
        - Software failing to meet customer needs.
        - Regulatory or compliance changes impacting project.
        - Market competition reducing software relevance.
        - Poor user adoption or negative feedback.

Software Risk Management Process

1. **Risk Identification**
    - Detect and list all possible risks that might affect the software project or maintenance.
    - Techniques: Brainstorming, checklists, expert judgment.
2. **Risk Analysis**
    - Assess each risk for:
        - **Likelihood (Probability):** How likely is the risk to occur?
        - **Impact (Severity):** What effect will it have if it occurs?
    - This analysis helps understand risk seriousness.
3. **Risk Prioritization**
    - Rank risks based on their likelihood and impact.
    - Prioritize those with high probability and high impact to focus mitigation efforts.
4. **Risk Mitigation Planning**
    - Develop strategies to:
        - **Avoid:** Change plans to eliminate risk.
        - **Reduce:** Minimize the impact or likelihood.
        - **Transfer:** Outsource or insure the risk.
        - **Accept:** Acknowledge the risk and prepare contingency plans.
5. **Monitoring**

- Continuously track risks and mitigation effectiveness.
- Update risk status and plans as the project evolves.

Example of Risk and Mitigation

- **Risk:** The software must run on a new operating system version (e.g., Windows 12 or Android 14), which may not support some existing app features.
- **Mitigation:**
  - Begin testing the application on beta versions of the OS early.
  - Plan and allocate resources for migration or fixes.
  - Maintain communication with OS vendors for updates.
  - Prepare rollback plans or temporary workarounds.