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Software Engineering (303105254)

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DIGITAL LEARNING CONTENT

Unit-6

Software Testing and Quality assurance

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Contents- Software Testing

- Software Testing Concepts
- Psychology of testing
- Levels of testing
- Testing Process-
  - test plan, test case design, Execution
- Black-Box testing
  - Boundary value analysis
- Pair wise testing
- state based testing,
- White-Box testing
  - criteria and test case generation and tool support

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Contents- Quality Assurance

- Quality Control
- Assurance, Cost, Reviews
- Software Quality Assurance
- Approaches to SQA
- Reliability
- Quality Standards- ISO9000 And 9001

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Concepts

Testing is the **process of exercising a program with the specific intent of finding errors prior to delivery to the end user**.

Why?

To understand testing techniques that are geared to discover program faults

To introduce guidelines for interface testing

To understand specific approaches to object- oriented testing

To understand the principles of CASE tool support for testing

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Psychology of testing

- All tests should be **traceable** to customer requirements.
- Tests should be **planned** long before testing begins.
- The Pareto principle applies to software testing.
- Testing should begin "**in the small**" and progress toward testing "**in the large.**"
- **Exhaustive** testing is not possible.
- To be most effective, **testing should be conducted by an independent third party**.

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Software testing phases

- **Component testing**
  - **Individual** program components testing
  - Tests **are derived from the developer's experience**
- **Integration testing**
  - **Testing of groups of components** integrated to create a system or sub-system
  - Tests are **based on a system specification**

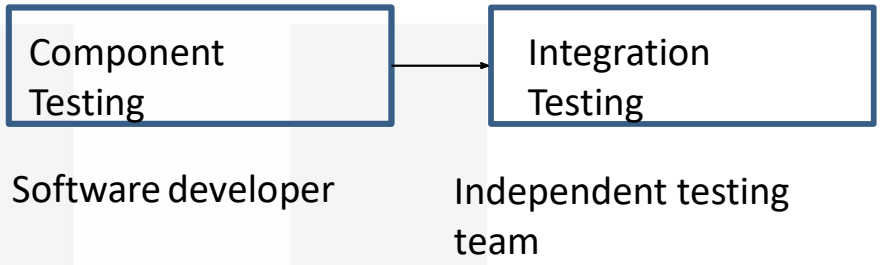

Figure 6.1 Software testing phase

Testing process

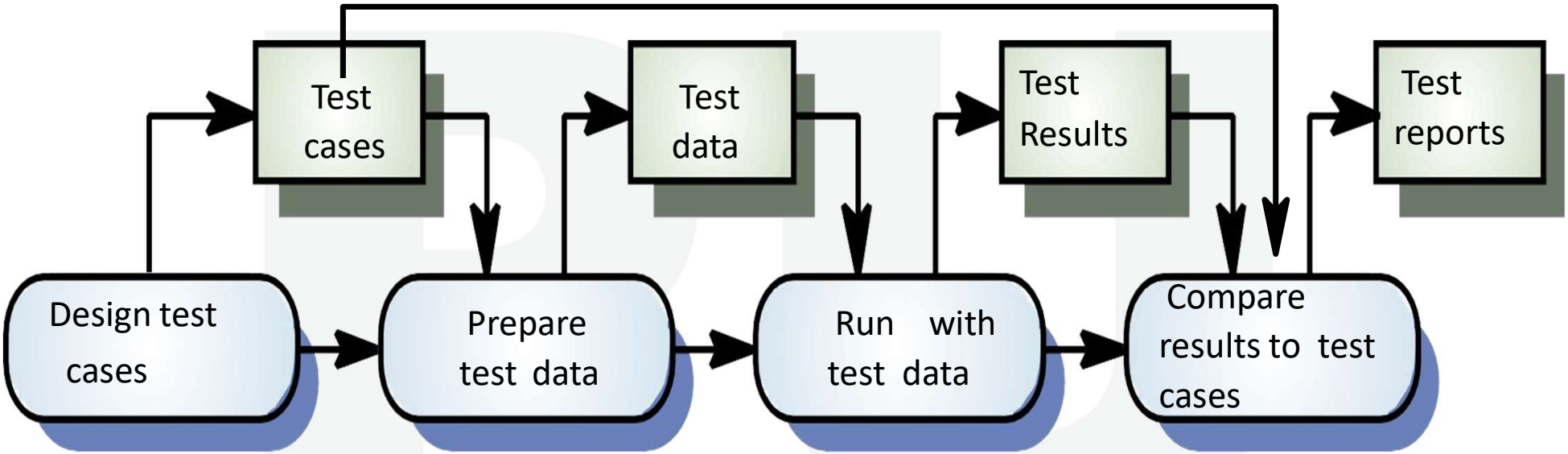

Figure 6.2 Software testing process

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Test plan

- Test planning, the **most important activity to ensure that there is initially a list of tasks** and milestones in a baseline plan to track the progress of the project.
- It also defines **the size of the test effort**.
- It is the **main document often called as master test plan or a project test plan and usually developed during the early phase of the project**.

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Test Planning Activities

- To determine the **scope and the risks that need to be tested and that are NOT to be tested**.
- **Documenting** Test Strategy.
- Deciding **Entry and Exit** criteria.
- **Evaluating** the test estimate.
- Planning **when and how to test** and deciding **how the test results will be evaluated, and defining test exit criterion**.
- Ensuring that the **test documentation generates repeatable test assets**.

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Test case design

- Test case design methods provide **a mechanism that can help to ensure the completeness of tests**
- Provide the **highest likelihood for uncovering errors** in software.

Any product or system can be tested on two ways:

1. **Knowing the specified function that a product has been designed to perform**; (Black Box)
2. knowing the **internal workings of a product, tests can be conducted to ensure that "all gears mesh," that is, internal operations are performed according to specifications** (White box testing)

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Test Execution

- Test execution is the **process of executing the code and comparing the expected and actual results**.

Following factors are to be considered for a test execution process:

- Based on a risk, **select a subset of test suite to be executed for this cycle.**
- **Assign the test cases** in each test suite to testers for execution.
- **Execute tests, report bugs, and capture test status** continuously.
- **Resolve blocking issues** as they arise.
- **Report status, adjust assignments, and reconsider plans and priorities daily**.
- **Report test cycle findings and status**.

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Levels of testing

- There are different levels during the process of testing.
- Levels of testing **include different methodologies that can be used while conducting software testing**.

The main levels of software testing are –

- **Functional Testing**
- **Non-functional Testing**

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Functional Testing

- This is a type of **black-box** testing that is based on the specifications of the software that is to be tested.
- **Functional testing of a software is conducted on a complete, integrated system to evaluate the system's compliance with its specified requirements**.

There are five steps that are involved while testing an application for functionality.

1. The determination of **the functionality that the intended application is meant to perform.**
2. **The creation of test data based on the specifications** of the application.
3. **The output based on the test data** and the specifications of the application.
4. **The writing of test scenarios and the execution of test cases**.
5. **The comparison of actual and expected results** based on the executed test cases.

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Unit Testing

- This type of testing is **performed by developers before the setup is handed over to the testing team to formally execute the test cases**.
- Unit testing is **performed by the respective developers on the individual units of source code assigned areas**.
- The **developers use test data that is different from the test data of the quality assurance team**.
- The goal of unit testing is to **isolate each part of the program and show that individual parts are correct** in terms of requirements and functionality.

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Integration Testing

- Integration testing is defined as the **testing of combined parts of an application to determine if they function correctly**.
- Integration testing can be done in two ways: Bottom-up integration testing and Top-down integration testing.

1. **Bottom-up integration**

This testing begins with unit testing, followed by tests of progressively **higher-level combinations of units called modules or builds**.

2. **Top-down integration**

In this testing, the **highest-level modules are tested first and progressively, lower-level modules are tested thereafter**.

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System Testing

- System testing tests the system as a whole.
- This type of testing is performed by a specialized testing team.

System testing is important because of the following reasons –

- System testing is the first step in the Software Development Life Cycle, where the application is tested as a whole.
- The application is tested thoroughly to verify that it meets the functional and technical specifications.
- The application is tested in an environment that is very close to the production environment where the application will be deployed.
- System testing enables us to test, verify, and validate both the business requirements as well as the application architecture.

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Non-Functional Testing

- Non-functional testing involves testing a software from the requirements which are nonfunctional in nature but important such as performance, security, user interface, etc.

  Some of the important and commonly used non-functional testing types are discussed below.

  - Performance Testing
  - Load Testing
  - Stress Testing
  - Usability Testing
  - Security Testing
  - Portability Testing

Black-Box testing

- An approach to testing where the program is considered as a 'black-box'
- The program test cases are based on the system specification
- Test planning can begin early in the software process

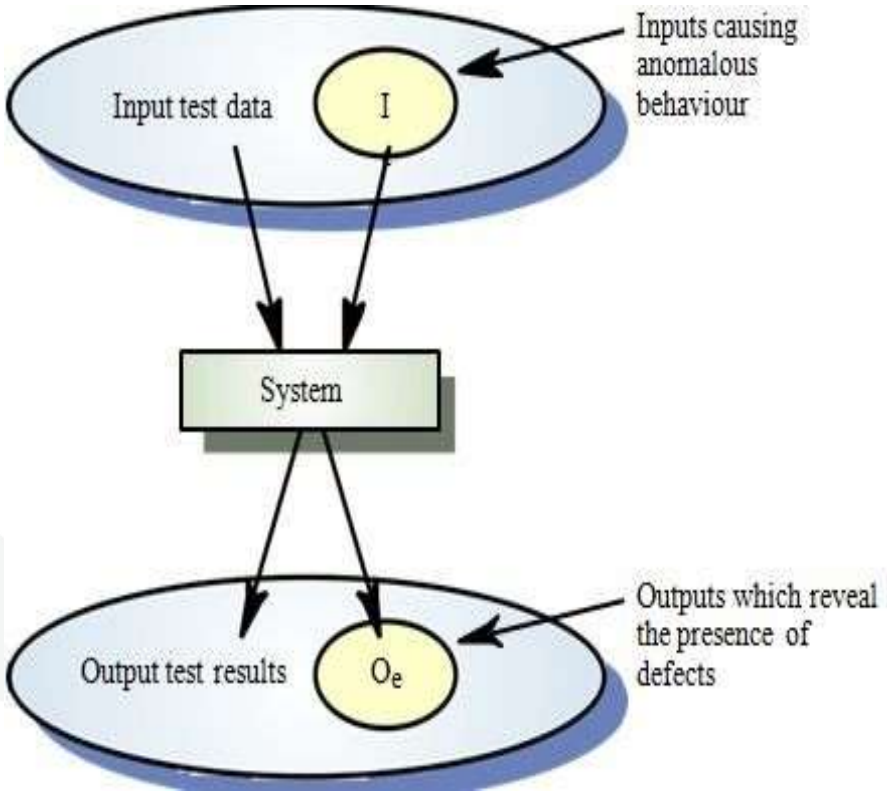

Figure 6.3 Black box testing

Continue…

- Also called *behavioral testing,* focuses on the functional requirements of the software.
- It enables the software engineer to derive sets of input conditions that will fully exercise all functional requirements for a program.
- Black-box testing is not an alternative to white-box techniques but it is complementary approach.
- **Black-box testing attempts to find errors in the following categories**:
  - Incorrect or missing functions,
  - Interface errors,
  - Errors in data structures or external data base access.
  - Behavior or performance errors,
  - Initialization and termination errors.

Continue…

- Black-box testing purposely ignored control structure, attention is focused on the information domain.
- Tests are designed to answer the following questions:
  - How is functional validity tested?
  - How is system behavior and performance tested?
  - What classes of input will make good test cases?
- By applying black-box techniques, we derive a set of test cases that satisfy the following criteria
  - Test cases that reduce the number of additional test cases that must be designed to achieve reasonable testing (i.e minimize effort and time)
  - Test cases that tell us something about the presence or absence of classes of errors

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Boundary value analysis

- Boundary value analysis is a test case design technique that complements equivalence partitioning.
- Rather than selecting any element of an equivalence class, BVA leads to the selection of test cases at the "edges" of the class.
- In other word, Rather than focusing solely on input conditions, BVA derives test cases from the output domain as well.

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Guidelines for BVA

- If an input condition specifies a range bounded by values *a* and *b,* test cases should be designed with values *a* and *b* and just above and just below *a* and *b*.
- If an input condition specifies a number of values, test cases should be developed that exercise the minimum and maximum numbers. Values just above and below minimum and maximum are also tested.
- Apply guidelines 1 and 2 to output conditions.
- If internal program data structures have prescribed boundaries be certain to design a test case to exercise the data structure at its boundary

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Pair wise testing

- **Pairwise Testing** is a type of software testing in which **permutation and combination method is used to test the software**.
- used to test **all the possible discrete combinations** of the parameters involved.
- It is a **P&C based method**, in which to test a system or an application, for each pair of input parameters of a system, all possible discrete combinations of the parameters are tested.
- By **using the conventional or exhaustive testing approach it may be hard to test the system** but by using **the permutation and combination method it can be easily done**.

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Advantages of Pairwise Testing

The advantages of pairwise testing are:

- Pairwise **testing reduces the number of execution** of test cases.
- Pairwise testing **increases the test coverage almost up to hundred percentage**.
- Pairwise testing **increases the defect detection** ratio.
- Pairwise testing **takes less time to complete the execution** of the test suite.
- Pairwise testing **reduces the overall testing budget** for a project.

Disadvantages of Pairwise Testing

The disadvantages of pairwise testing are:

- Pairwise testing **is not beneficial if the values of the variables are inappropriate.**
- In pairwise testing it **is possible to miss the highly probable combination** while selecting the test data.
- In pairwise testing, **defect yield ratio may be reduced if a combination is missed.**
- Pairwise testing **is not useful if combinations of variables are not understood correctly.**

State based testing

- To **understand the objects that are modeled in software and the relationships that connect these objects**.
- Next step is to **define a series of tests that verify "all objects have the expected relationship to one another.**
- Stated in other way:
  - **Create a graph of important objects and their relationships**
  - **Develop a series of tests that will cover the graph,**

  So that each object and relationship is exercised and errors are uncovered.

Begin by creating graph –

- a collection of **nodes** that represent objects
- **links** that represent the relationships between objects
- **node weights** that describe the properties of a node
- **link weights** that describe some characteristic of a link.

Continue…

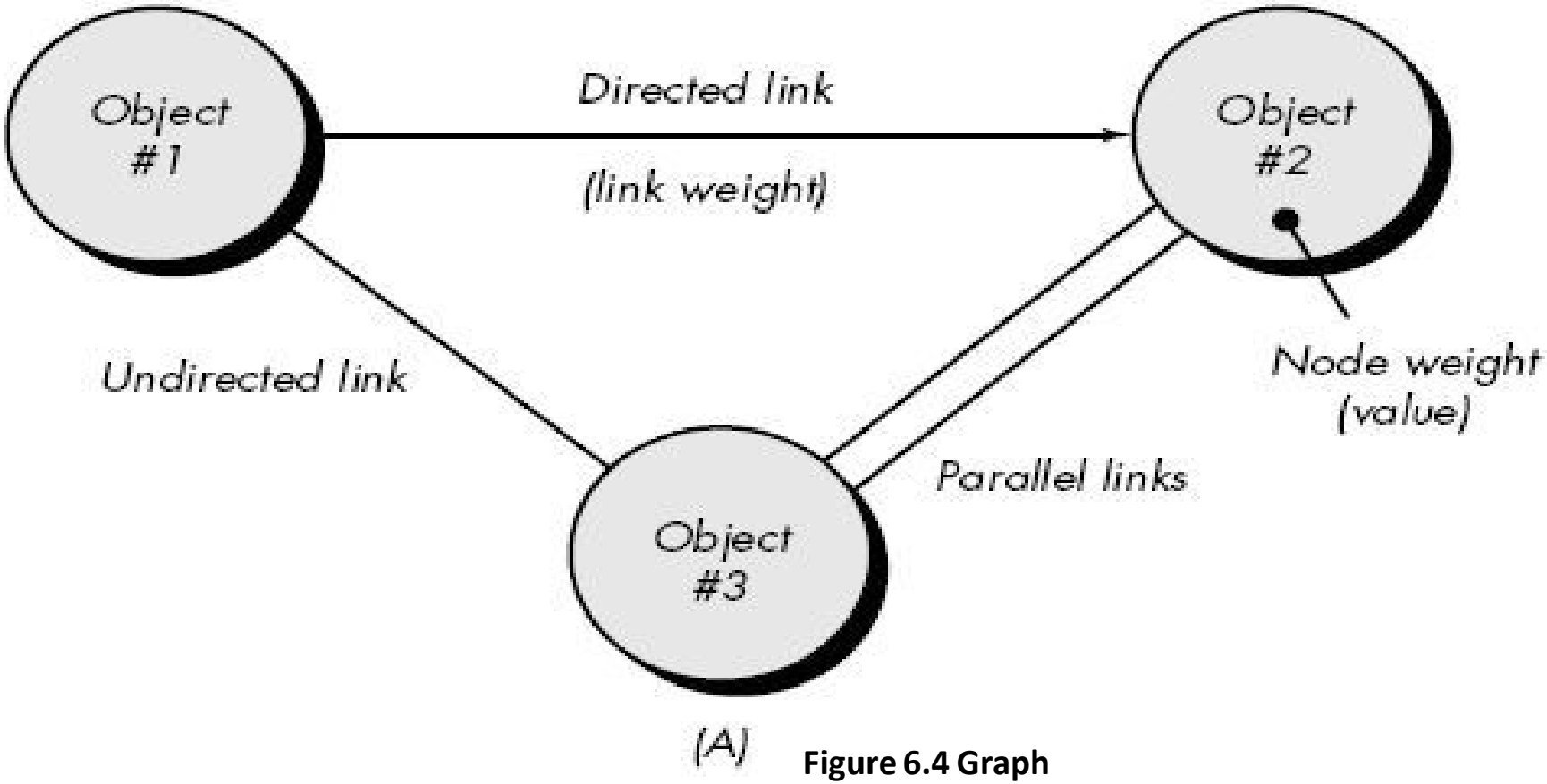

Figure 6.4 Graph notation

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Continue…

- Nodes are represented as circles connected by links that take a number of different forms.
- A **directed link** (represented by an arrow) indicates that a relationship moves in only one direction.
- A **bidirectional link**, also called a symmetric link, implies that the relationship applies in both directions.
- **Parallel links** are used when a number of different relationships are established between graph nodes.

Continue…

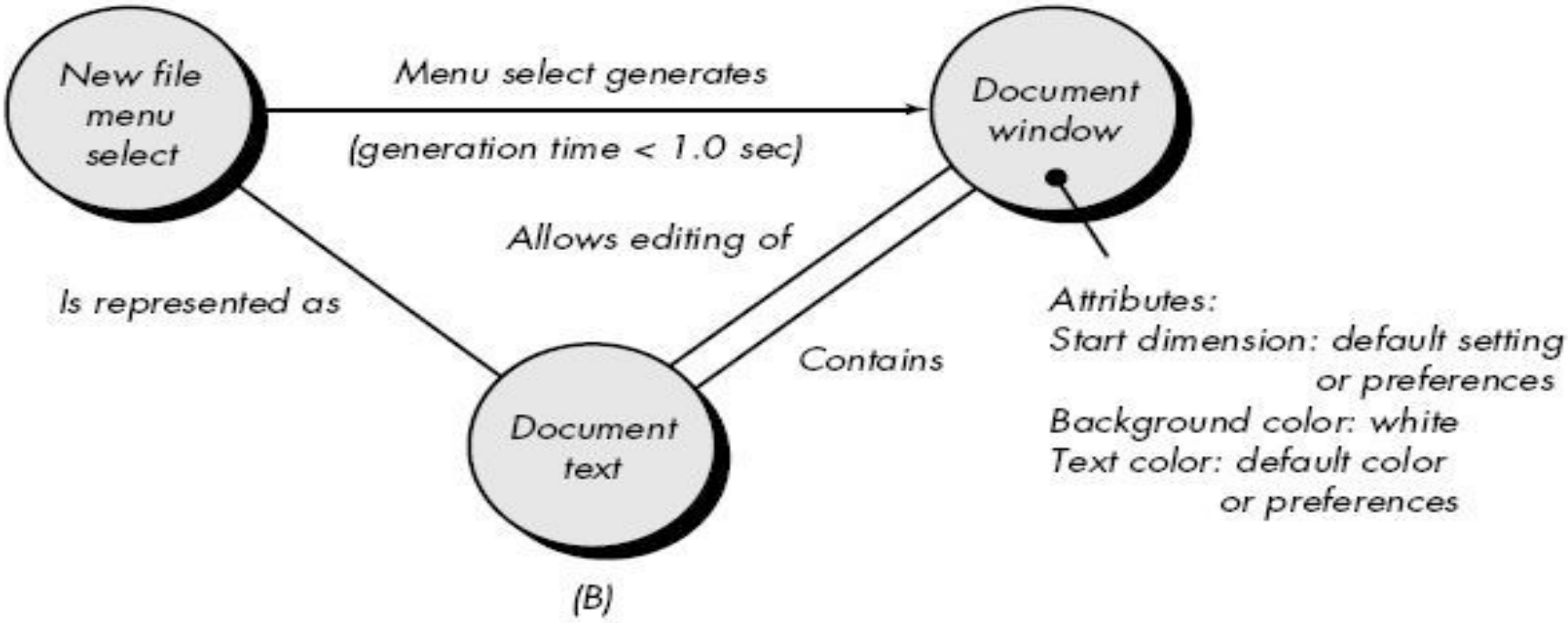

Figure 6.5 Simple example

Continue…

- Object #1 = **new file menu select**
- Object #2 = **document window**
- Object #3 = **document text**

Referring to example figure, a menu select on **new file** generates a **document window.**

- The link weight indicates that the window must be generated in less than 1.0 second.
- The node weight of **document window** provides a list of the window attributes that are to be expected when the window is generated.
- An undirected link establishes a symmetric relationship between the **new file menu select** and **document text,**
- parallel links indicate relationships between **document window** and **document text**

Continue…

- Number of behavioral testing methods that can make use of graphs:

Transaction flow modeling.

- The **nodes represent steps in some transaction and the links represent the logical connection between steps**

Finite state modeling.

- The **nodes represent different user observable states** of the software and the **links represent the transitions** that occur to move from state to state. (Starting point and ending point)

Data flow modeling.

- The **nodes are data objects** and the **links are the transformations that occur to translate one data object into another**.

Timing modeling.

- The **nodes are program objects and the links are the sequential connections between those objects**.

White-Box testing

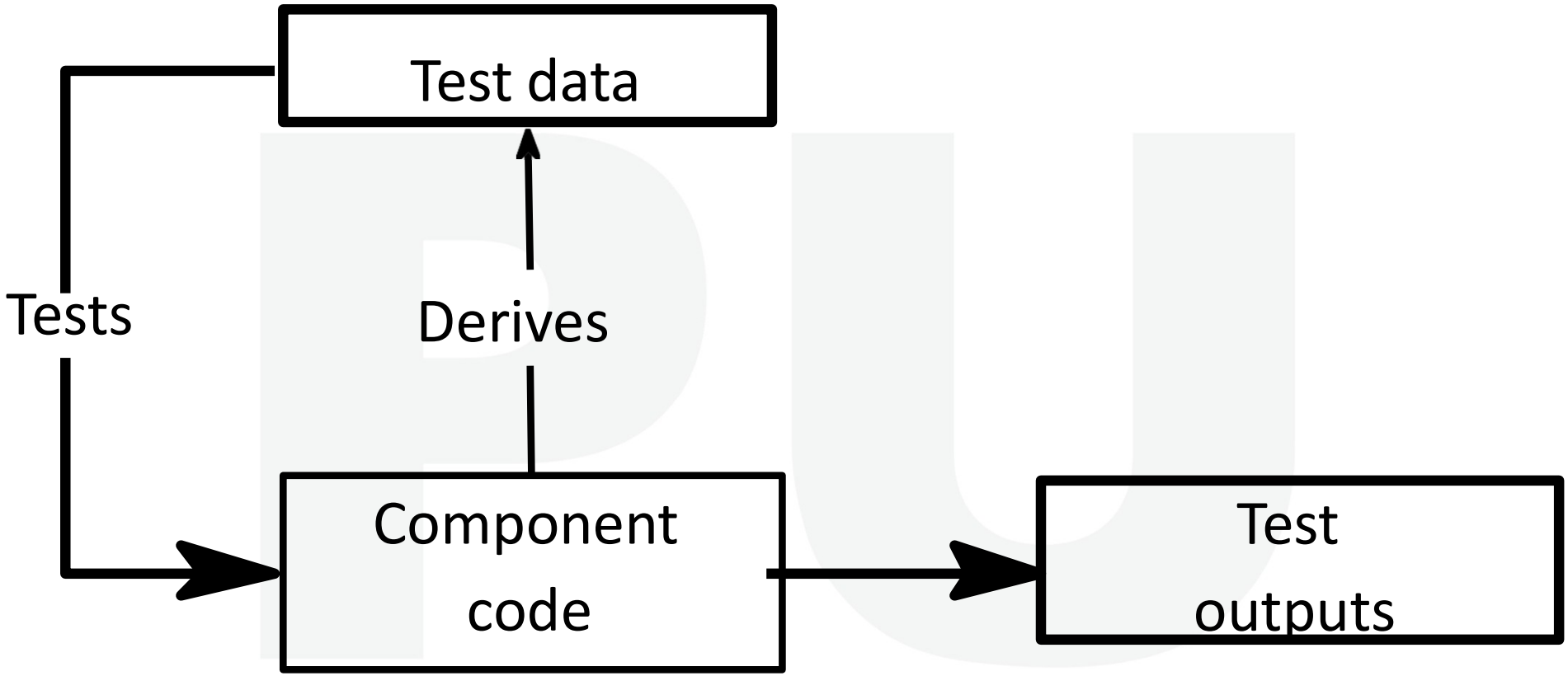

Figure 6.6 Architecture of White –Box testing

Continue…

- White-box testing is a **test case design** method
- Uses the **control structure of the procedural design to derive test cases**
- Using white-box testing methods, **the software engineer can derive test cases that**
- Guarantee that **all independent paths within a module have been exercised at least once**
- Exercise **all logical decisions** on their true and false sides
- Execute **all loops at their boundaries** and within their operational bounds
- Exercise **internal data structures to ensure their validity**.

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Basis path testing

Basis path testing is a white-box testing technique

- To derive a logical complexity measure of a procedural design.
- Test **cases derived to exercise the basis set are guaranteed to execute every statement in the program at least one time**.

Methods:

2. Flow graph notation
3. Independent program paths or Cyclamatic complexity
4. Deriving test cases
5. Graph Matrices

Flow Graph Notation

- Start with simple notation for the representation of control flow (called flow graph). It represent logical control flow.

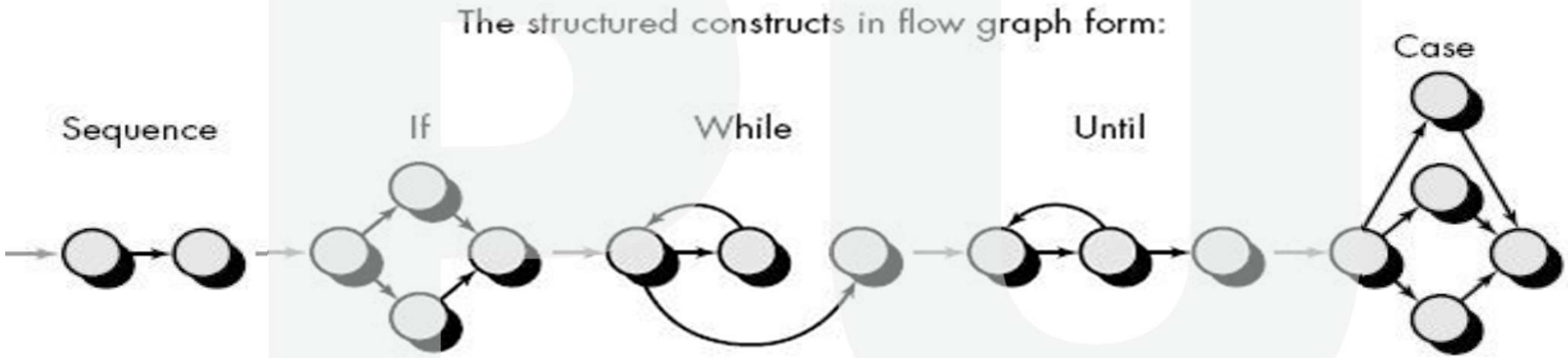

Figure 6.7 Flow graph notation

Continue…

- A sequence of process boxes and decision diamond can map into a single node.
- The **arrows on the flow graph, called edges or links**, represent flow of control and are parallel to flowchart arrows.
- An edge must terminate at a node, even if the node does not represent any procedural statement.
- Areas bounded by edges and nodes are called **regions**.
- When compound condition are encountered in procedural design, flow graph becomes slightly more complicated.

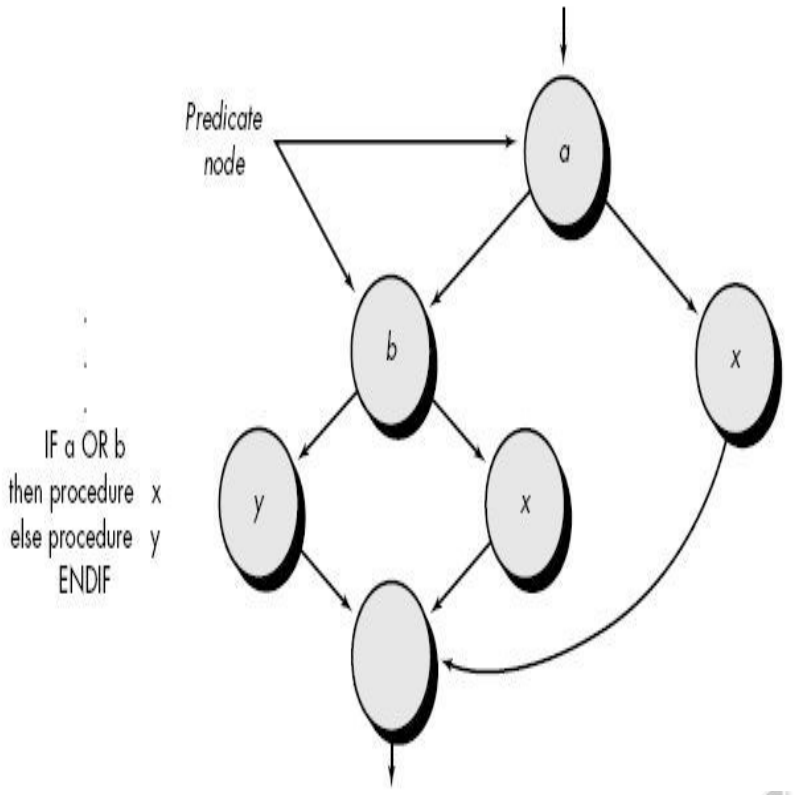

Figure 6.8 Compound logic

Continue…

- When **we translating segment into flow graph, separate node is created for each condition**.

- Each **node that contains a condition** is called **predicate node** and is characterized by two or more edges comes from it.

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Independent program paths or Cyclomatic complexity

- An independent path is any path through the program that introduces at **least one new set of processing statement or new condition**.
  For example, a set of independent paths for flow graph:
  Path 1: 1-11
  Path 2: 1-2-3-4-5-10-1-11
  Path 3: 1-2-3-6-8-9-1-11
  Path 4: 1-2-3-6-7-9-1-11
- Note that each new path introduces a new edge.
  - The **path 1-2-3-4-5-10-1-2-3-6-8-9-1-11 is not considered to an independent path because it is simply a combination of already specified paths and does not traverse any new edges**.
  - Test cases should be designed to force execution of these paths (basis set).

Continue…

- **Cyclomatic complexity** is a software metrics that provides a quantitative measure of the logical complexity of a program.

It defines no. of independent paths in the basis set and also provides number of test that must be conducted.

One of three ways to compute cyclomatic complexity:

1. The *no. of regions* corresponds to the cyclomatic complexity.
2. **Cyclomatic complexity, V(G), for a flow graph, G, is defined as V(G) = E - N + 2**
   where E is the number of flow graph edges, N is the number of flow graph nodes.
3. **Cyclomatic complexity, V(G), for a flow graph, G, is also defined as V(G) = P + 1**
   where P is the number of predicate nodes edges

So the value of V(G) provides us with upper bound of test cases.

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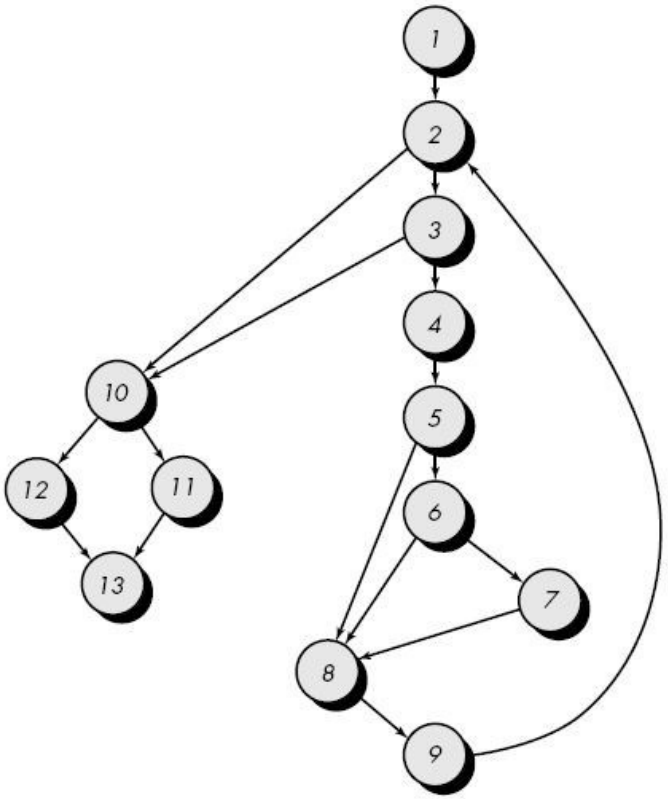
Deriving Test Cases

- It is a series of steps method.
- The procedure average depicted in PDL.
- Average, an extremely simple algorithm, contains compound conditions and loops.

To derive basis set, follow the steps.

1. **Using the design or code as a foundation, draw a corresponding flow graph.**
   - A flow graph is created by numbering those PDL statements that will be mapped into corresponding flow graph nodes.

Deriving Test Cases



Flow graph for the procedure average

Continue…

2. **Determine the cyclomatic complexity of the resultant flow graph.**
   - *V*(*G*) can be determined without developing a flow graph by counting all conditional statements in the PDL (for the procedure *average,* compound conditions count as two) and adding 1
   - *V*(*G*) = 6 regions
   - *V*(*G*) = 17 edges - 13 nodes + 2 = 6
   - *V*(*G*) = 5 predicate nodes + 1 = 6
3. **Determine a basis set of linearly independent paths**
   - The value of *V*(*G*) provides the number of linearly independent paths through the program control structure.
   - path 1: 1-2-10-11-13
   - path 2: 1-2-10-12-13
   - path 3: 1-2-3-10-11-13
   - path 4: 1-2-3-4-5-8-9-2-. . .
   - path 5: 1-2-3-4-5-6-8-9-2-. . .
   - path 6: 1-2-3-4-5-6-7-8-9-2-. . .
   - The ellipsis (. . .) following paths 4, 5, and 6 indicates that any path through the remainder of the control structure is acceptable.

Continue…

4. **Prepare test cases that will force execution of each path in the basis set.**
   - Data should be chosen so that conditions at the predicate nodes are appropriately set as each path is tested.
   - Each test case is executed and compared to expected results.
   - **Once all test cases have been completed, the tester can be sure that all statements in the program have been executed at least once.**

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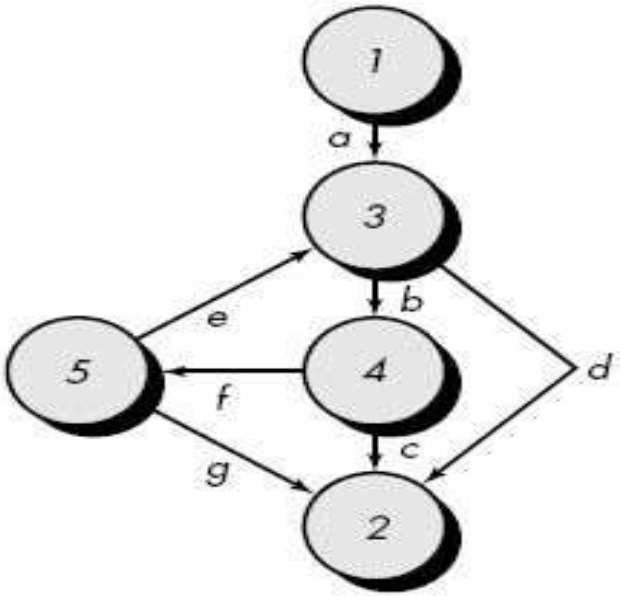
Graph Matrices

- A graph matrix is a **square matrix whose size (i.e., number of rows and columns) is equal to the number of nodes on the flow graph**.
- Each **row and column corresponds to an identified node, and matrix entries correspond to connections (an edge) between nodes**.
- Each node **on the flow graph is identify by numbers, while each edge is identify by letters**.
- The graph matrix is **nothing more than a tabular representation of a flow graph.**
- By adding a **link weight to each matrix entry, the graph matrix can become a powerful tool for evaluating program control structure during testing**.
- The link weight provides additional information about control flow. In its simplest form, **the link weight is 1 (a connection exists) or 0 (a connection does not exist).**

Continue…



Flow graph

Node \ Connected to node	1	2	3	4	5
1			a		
2					
3		d		b	
4		c			f
5		g	e		

Graph matrix

Connection matrix

Node \ Connected to node	1	2	3	4	5
1			1		
2					
3		1		1	
4		1			1
5		1	1		

Graph matrix

Figure 6.9 Connection matrix

Connection matrix

- Each letter has been replaced with a 1, indicating that a connection exists **(this graph matrix is called a *connection matrix).***
- In fig.(connection matrix) each row with two or more entries represents a predicate node.
- We can directly measure cyclomatic complexity value by performing arithmetic operations

Connections = Each row Total no. of entries – 1.

V(G)= Sum of all connections + 1

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Quality Control - Quality

- **Quality as "a characteristic or attribute of something."**
- Two kinds of quality may be encountered:
  - Quality of design of a product increases, if the product is **manufactured according to specifications**.
  - Quality of conformance is the **degree to which the design specifications are followed during manufacturing**.

- **In software development**
  - Quality of **design encompasses requirements, specifications, and the design of the system**.
  - Quality of conformance is an issue **focused primarily on implementation**.
- **User satisfaction = compliant product + good quality + delivery within budget and schedule**

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Quality control

- Quality control involves **the series of inspections, reviews, and tests used throughout the software process**.
- Quality control includes a **feedback** loop to the process.
- A key concept of quality control is that **all work products have defined, measurable specifications to which we may compare the output of each process.**
- The feedback loop is **essential to minimize the defects** produced.

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Quality Assurance

- Quality assurance consists of the **auditing and reporting functions of management.**
- If the data provided through quality assurance identify problem it is management's responsibility to address the problems and apply the **necessary resources to resolve quality issues**.

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Cost of Quality

- The cost of quality includes **all costs incurred in the pursuit of quality or in performing quality-related activities**.

- Quality costs may be divided 3 mode of cost:
  - **Prevention**
  - **Appraisal**
  - **Failure**.

Continue…

- **Prevention costs include:**
  - Quality planning
  - Formal technical reviews
  - Test equipment
  - Training

- **Appraisal costs include activities to gain insight into product**
  - In-process and Inter-process inspection
  - Equipment calibration and maintenance
  - Testing

Continue…

- **Failure costs**
  - Internal Failure Cost
    - rework
    - repair
    - failure mode analysis
- **External Failure Cost**
  - complaint resolution
  - product return and replacement
  - help line support
  - warranty work

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Software Quality Assurance

Definition:

Conformance to explicitly stated functional and performance requirements, **explicitly documented development standards, and implicit characteristics that are expected of all professionally developed software**.

- **Definition serves to emphasize three important points:**
  - **Software requirements** are the foundation from which quality is measured.
  - If **specified standards criteria are not followed**, lack of quality will almost surely result.
  - A set of **implicit requirements** often goes unmentioned.

SQA group Activity

- SQA group made up of software engineers, project managers, customers, sales people, and the individuals members.
- SQA group that has responsibility for quality assurance planning, oversight, record keeping, analysis and reporting.
- Software engineers address quality activities by applying technical methods and measures, conducting formal technical reviews, and performing well-planned software testing.
- SQA group is to assist the software team in achieving a high quality end product.

Role of an SQA group

1. Prepares an SQA plan for a project.

The plan is developed during project planning and is reviewed by all stakeholders.

- **The plan identifies**
  - Evaluations to be performed
  - Audits and reviews to be performed
  - Standards that are applicable to the project
  - Procedures for error reporting and tracking
  - Documents to be produced by the SQA group
  - Amount of feedback provided to the software project team

Continue…

2. Participates in the development of the project's software process description.
3. Reviews software engineering activities to verify compliance with the defined software process.
4. Audits designated software work products to verify compliance with those defined as part of the software process.
5. The SQA group reviews selected work products;

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Software Reliability

- Software reliability is defined in statistical terms as "**the probability of failure-free operation of a computer program in a specified environment for a specified time**".
- What is meant by the term failure?
  - Failure is nonconformance to software requirements.
  - Correction of one failure may in fact result in the introduction of other errors that ultimately result in other failures.

Software reliability can be measured directed and estimated using historical and developmental data.

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Measures of Reliability and Availability

- A simple measure of reliability is mean-time- between-failure (MTBF), where

  MTBF = MTTF + MTTR

- The acronyms MTTF and MTTR are mean-time-to-failure and mean-time-to-repair, respectively.
- MTBF is a far more useful measure than defects/KLOC or defects/FP.
- Stated simply, an end-user is concerned with failures, not with the total error count.
- a reliability measure, we must develop a measure of availability

Continue…

- **Software availability :** It is the probability that a program is operating according to requirements at a given point in time and is defined as

  Availability = [MTTF/(MTTF + MTTR)] 100%

- The MTBF reliability measure is equally sensitive to MTTF and MTTR.
- The availability measure is somewhat more sensitive to MTTR, an indirect measure of the maintainability of software

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Quality Standards- ISO9000 And 9001

SQA Standards

•Software quality assurance standards can be classified into two main classes –

1. Software quality assurance management standards, including **certification and assessment methodologies** (quality management standards)
2. Software **project development process standards** (project process standards)

Quality Management Standards

- These focus on the **organization's SQA system, infrastructure and requirements**, while leaving the choice of methods and tools to the organization.
- With quality management standards, **organizations can steadily assure that their software products achieve an acceptable level of quality.**

  Example – ISO 9000-3 and the Capability Maturity Model (CMM)

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ISO 9001 Certification

- ISO (the International Organization for Standardization) is a **worldwide federation of national standards** bodies.
- ISO technical committees **prepare the International Standards**.
- ISO collaborates closely with the **International Electro-technical Commission (IEC) on all matters of electro-technical standardization**.
- International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.
- Draft of the **International Standards adopted by the technical committees is circulated to the member bodies for voting**.
- ISO 9001 was **prepared by Technical Committee ISO/TC 176, Quality management and quality assurance, Subcommittee SC 2, Quality systems.**

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