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# **Software Engineering (COMP 401)**

## **Chapter 2- Software Processes**

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July 2022

# Topics covered

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- ◇ Software process models
- ◇ Process activities
- ◇ Coping with change
- ◇ Process improvement

# The software process

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- ◇ A structured set of activities required to develop a software system.
- ◇ Many different software processes but all involve:
  - Specification – defining what the system should do;
  - Design and implementation – defining the organization of the system and implementing the system;
  - Validation – checking that it does what the customer wants;
  - Evolution – changing the system in response to changing customer needs.
- ◇ A software process model is an abstract representation of a process. It presents a description of a process from some particular perspective.

# Software process descriptions

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- ◇ When we describe and discuss processes, we usually talk about the activities in these processes such as specifying a data model, designing a user interface, etc. and the ordering of these activities.
- ◇ Process descriptions may also include:
  - Products, which are the outcomes of a process activity;
  - Roles, which reflect the responsibilities of the people involved in the process;
  - Pre- and post-conditions, which are statements that are true before and after a process activity has been enacted or a product produced.

# Plan-driven and agile processes

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- ◇ Plan-driven processes are processes where all of the process activities are planned in advance and progress is measured against this plan.
- ◇ In agile processes, planning is incremental and it is easier to change the process to reflect changing customer requirements.
- ◇ In practice, most practical processes include elements of both plan-driven and agile approaches.
- ◇ There are no right or wrong software processes.

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# Software process models

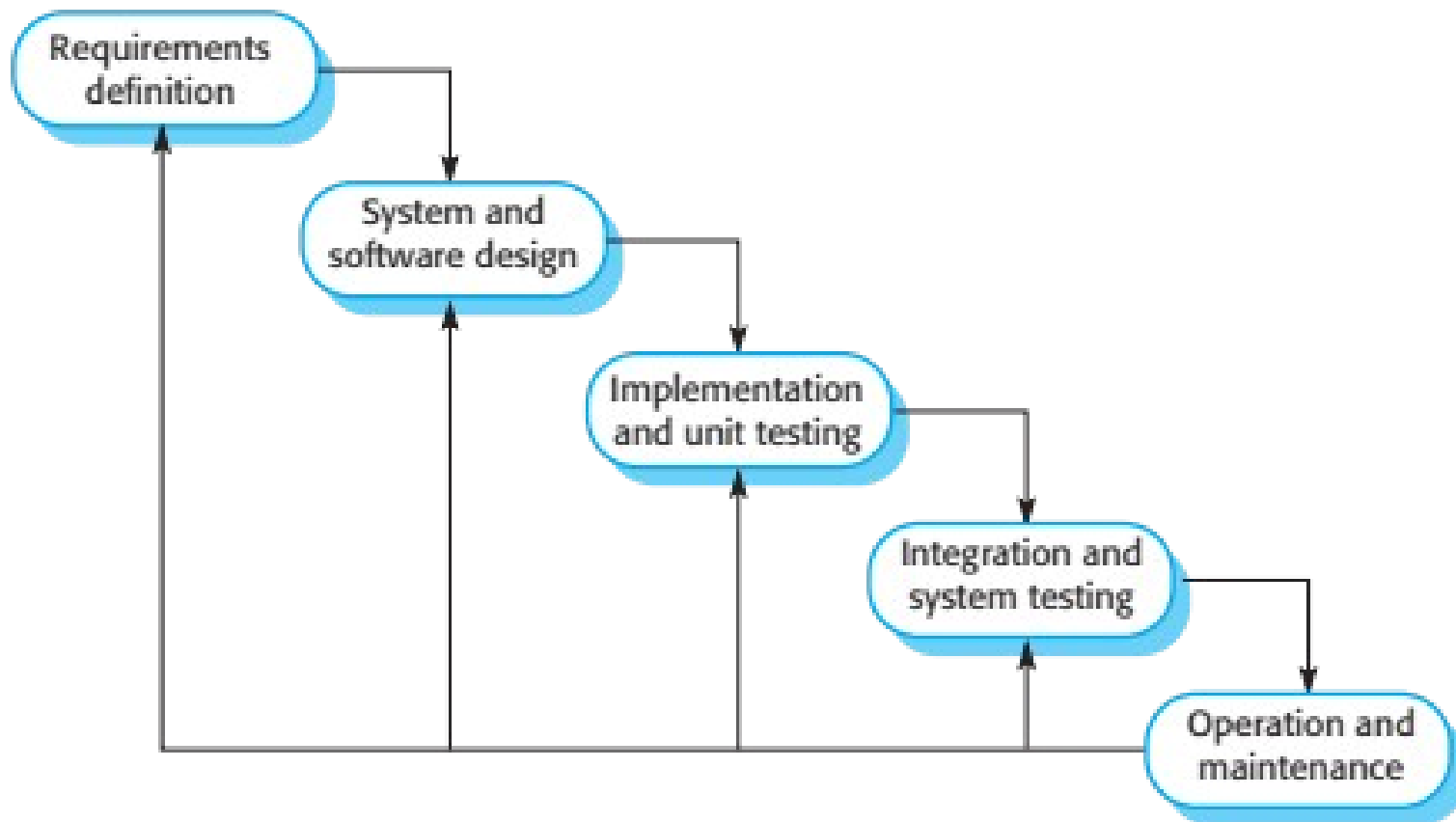
# Software process models

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- ◇ The waterfall model
  - Plan-driven model. Separate and distinct phases of specification and development.
- ◇ Incremental development
  - Specification, development and validation are interleaved. May be plan-driven or agile.
- ◇ Integration and configuration
  - The system is assembled from existing configurable components. May be plan-driven or agile.
- ◇ In practice, most large systems are developed using a process that incorporates elements from all of these models.

# The waterfall model

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# Waterfall model phases

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- ◇ There are separate identified phases in the waterfall model:
  - Requirements analysis and definition
  - System and software design
  - Implementation and unit testing
  - Integration and system testing
  - Operation and maintenance
- ◇ The main drawback of the waterfall model is the difficulty of accommodating change after the process is underway. In principle, a phase has to be complete before moving onto the next phase.

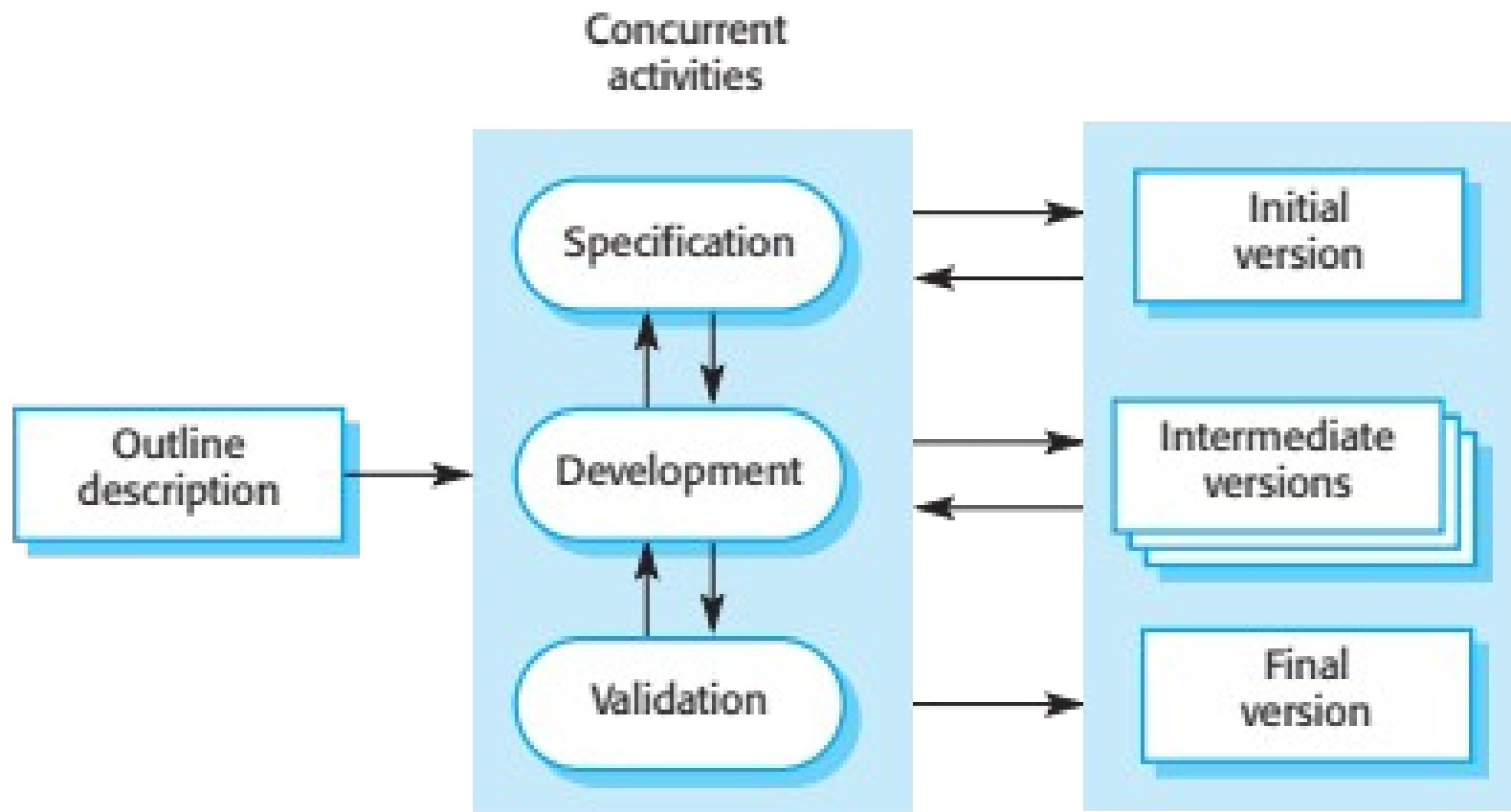
# Waterfall model problems

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- ◇ Inflexible partitioning of the project into distinct stages makes it difficult to respond to changing customer requirements.
  - Therefore, this model is only appropriate when the requirements are well-understood and changes will be fairly limited during the design process.
  - Few business systems have stable requirements.
- ◇ The waterfall model is mostly used for large systems engineering projects where a system is developed at several sites.
  - In those circumstances, the plan-driven nature of the waterfall model helps coordinate the work.

# Incremental development

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# Incremental development benefits

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- ◇ The cost of accommodating changing customer requirements is reduced.
  - The amount of analysis and documentation that has to be redone is much less than is required with the waterfall model.
- ◇ It is easier to get customer feedback on the development work that has been done.
  - Customers can comment on demonstrations of the software and see how much has been implemented.
- ◇ More rapid delivery and deployment of useful software to the customer is possible.
  - Customers are able to use and gain value from the software earlier than is possible with a waterfall process.

# Incremental development problems

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- ◇ The process is not visible.
  - Managers need regular deliverables to measure progress. If systems are developed quickly, it is not cost-effective to produce documents that reflect every version of the system.
- ◇ System structure tends to degrade as new increments are added.
  - Unless time and money is spent on refactoring to improve the software, regular change tends to corrupt its structure. Incorporating further software changes becomes increasingly difficult and costly.

# Integration and configuration

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- ◇ Based on software reuse where systems are integrated from existing components or application systems (sometimes called COTS -Commercial-off-the-shelf) systems).
- ◇ Reused elements may be configured to adapt their behaviour and functionality to a user's requirements
- ◇ Reuse is now the standard approach for building many types of business system
  - Reuse covered in more depth in Chapter 15.

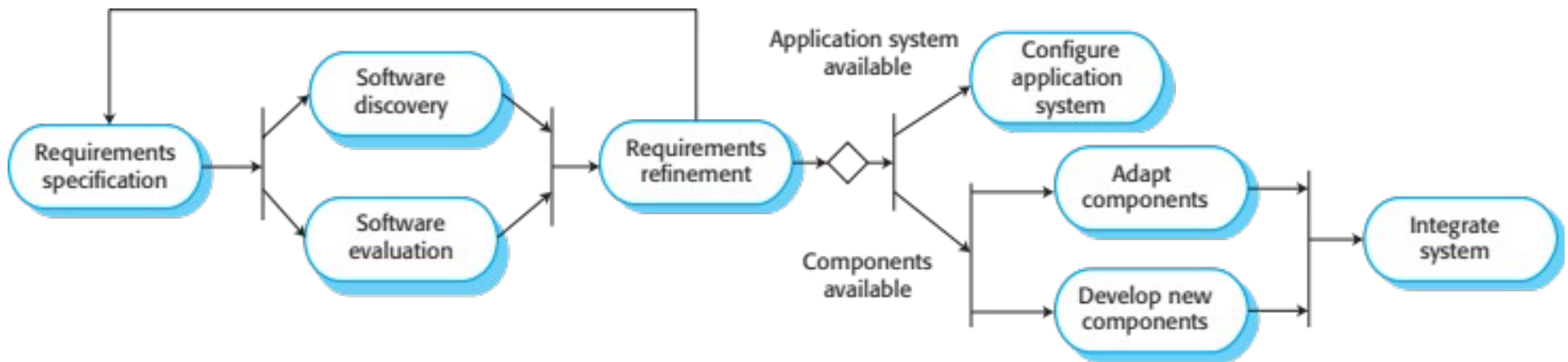
# Types of reusable software

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- ◇ Stand-alone application systems (sometimes called COTS) that are configured for use in a particular environment.
- ◇ Collections of objects that are developed as a package to be integrated with a component framework such as .NET or J2EE.
- ◇ Web services that are developed according to service standards and which are available for remote invocation.

# Reuse-oriented software engineering

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# Key process stages

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- ◇ Requirements specification
- ◇ Software discovery and evaluation
- ◇ Requirements refinement
- ◇ Application system configuration
- ◇ Component adaptation and integration

# Advantages and disadvantages

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- ◇ Reduced costs and risks as less software is developed from scratch
- ◇ Faster delivery and deployment of system
- ◇ But requirements compromises are inevitable so system may not meet real needs of users
- ◇ Loss of control over evolution of reused system elements

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## Process activities

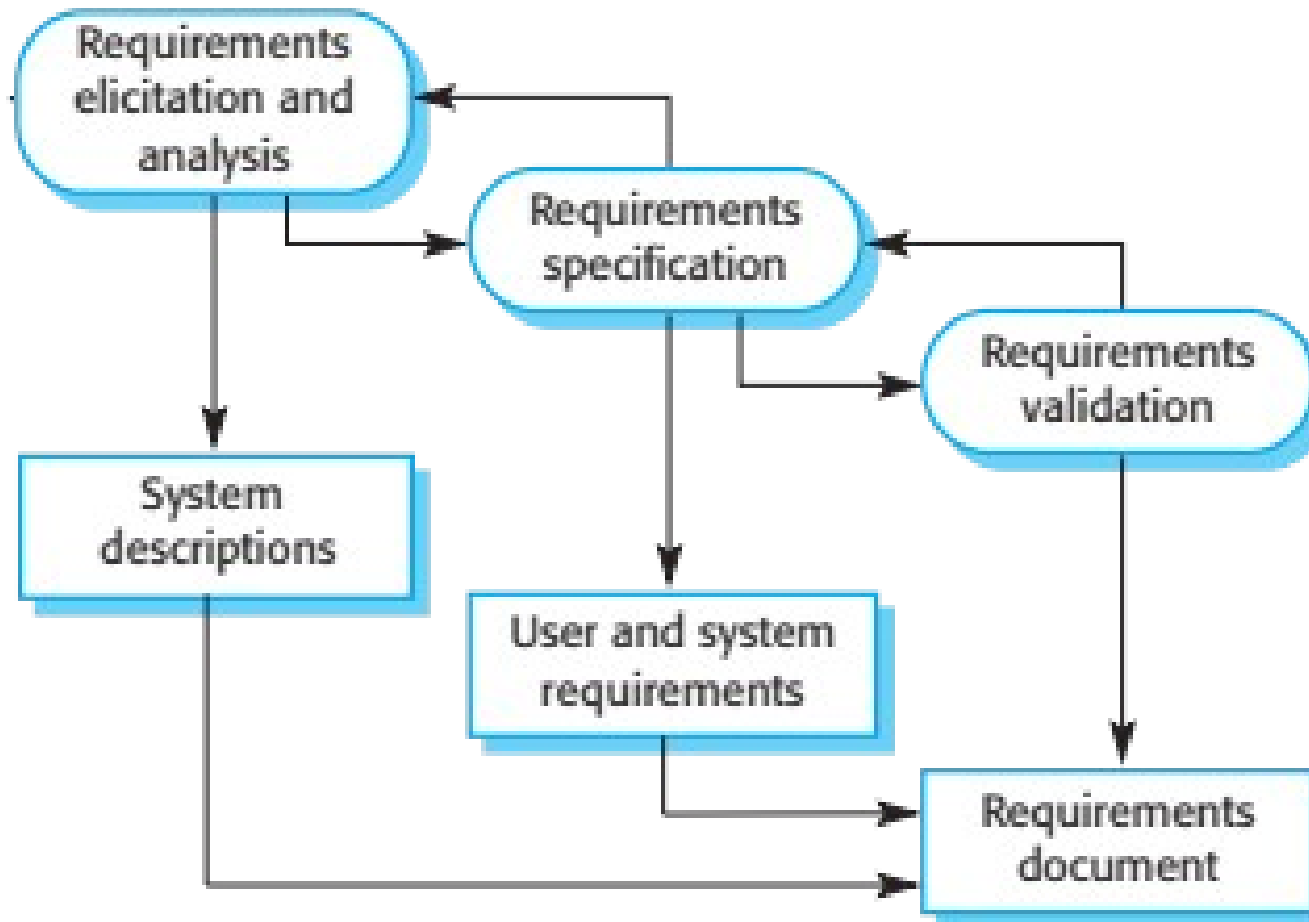
## Process activities

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- ◇ Real software processes are inter-leaved sequences of technical, collaborative and managerial activities with the overall goal of specifying, designing, implementing and testing a software system.
- ◇ The four basic process activities of specification, development, validation and evolution are organized differently in different development processes.
- ◇ For example, in the waterfall model, they are organized in sequence, whereas in incremental development they are interleaved.

# The requirements engineering process

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# Software specification

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- ◇ The process of establishing what services are required and the constraints on the system's operation and development.
- ◇ Requirements engineering process
  - Requirements elicitation and analysis
    - What do the system stakeholders require or expect from the system?
  - Requirements specification
    - Defining the requirements in detail
  - Requirements validation
    - Checking the validity of the requirements

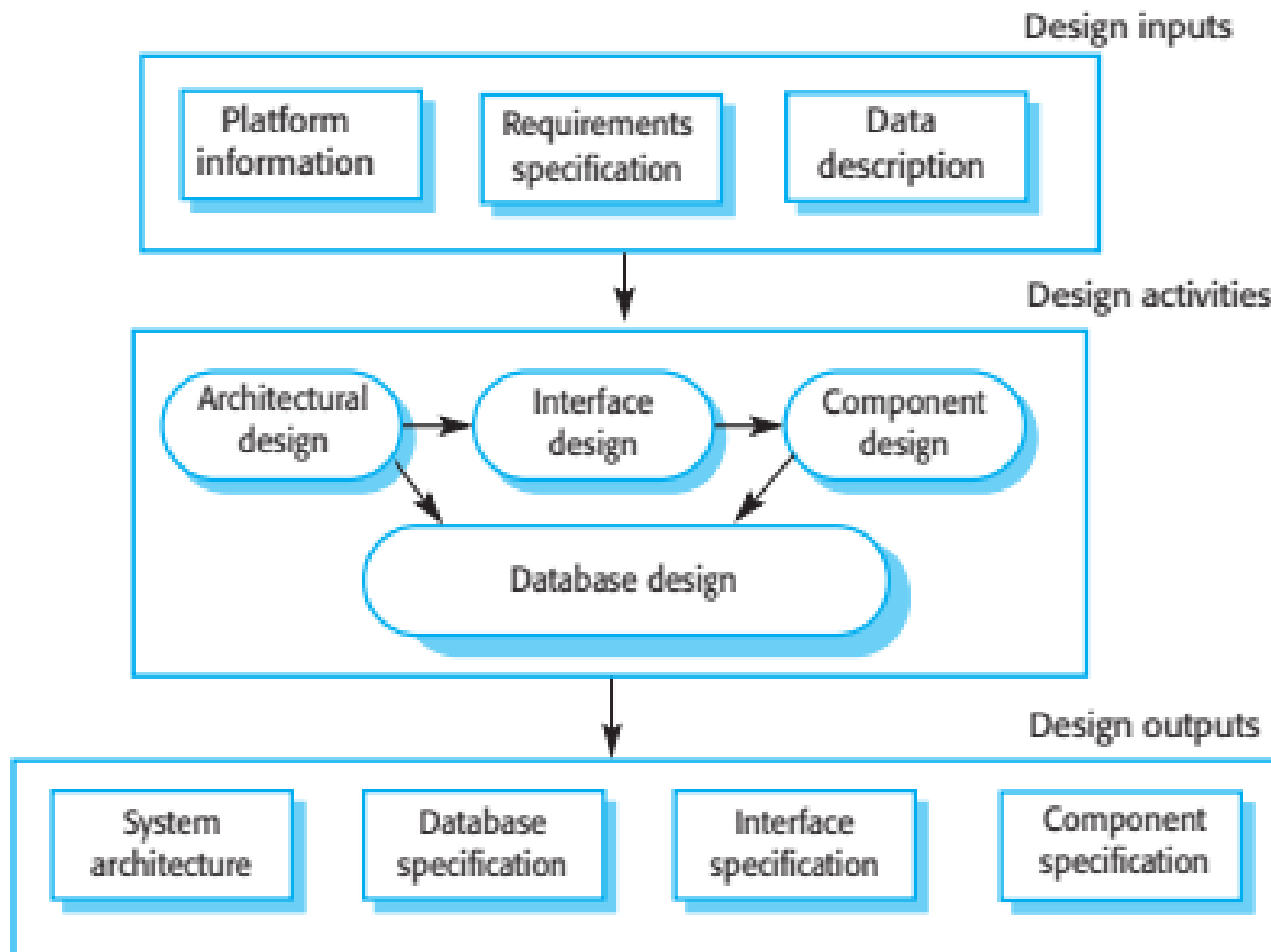
# Software design and implementation

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- ◇ The process of converting the system specification into an executable system.
- ◇ Software design
  - Design a software structure that realises the specification;
- ◇ Implementation
  - Translate this structure into an executable program;
- ◇ The activities of design and implementation are closely related and may be inter-leaved.

# A general model of the design process

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# Design activities

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- ◇ *Architectural design*, where you identify the overall structure of the system, the principal components (subsystems or modules), their relationships and how they are distributed.
- ◇ *Database design*, where you design the system data structures and how these are to be represented in a database.
- ◇ *Interface design*, where you define the interfaces between system components.
- ◇ *Component selection and design*, where you search for reusable components. If unavailable, you design how it will operate.

# System implementation

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- ◇ The software is implemented either by developing a program or programs or by configuring an application system.
- ◇ Design and implementation are interleaved activities for most types of software system.
- ◇ Programming is an individual activity with no standard process.
- ◇ Debugging is the activity of finding program faults and correcting these faults.

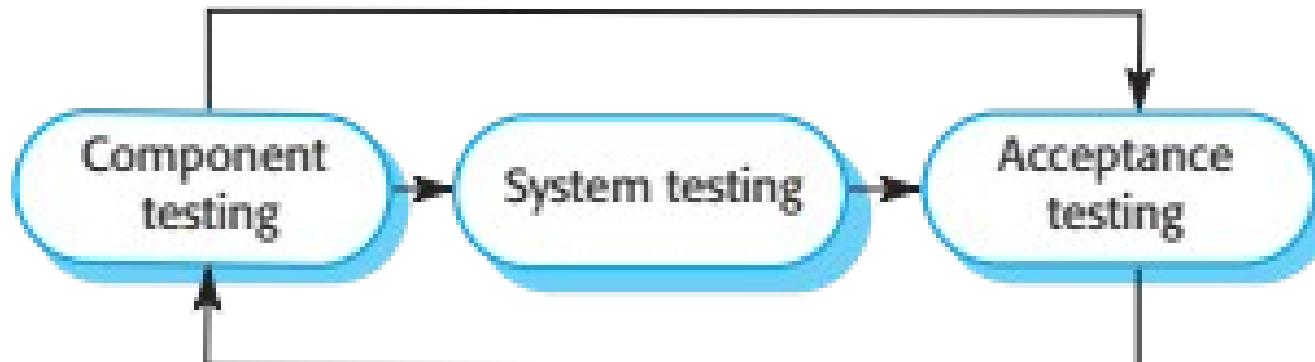
# Software validation

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- ◇ Verification and validation (V & V) is intended to show that a system conforms to its specification and meets the requirements of the system customer.
- ◇ Involves checking and review processes and system testing.
- ◇ System testing involves executing the system with test cases that are derived from the specification of the real data to be processed by the system.
- ◇ Testing is the most commonly used V & V activity.

# Stages of testing

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# Testing stages

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## ◇ Component testing

- Individual components are tested independently;
- Components may be functions or objects or coherent groupings of these entities.

## ◇ System testing

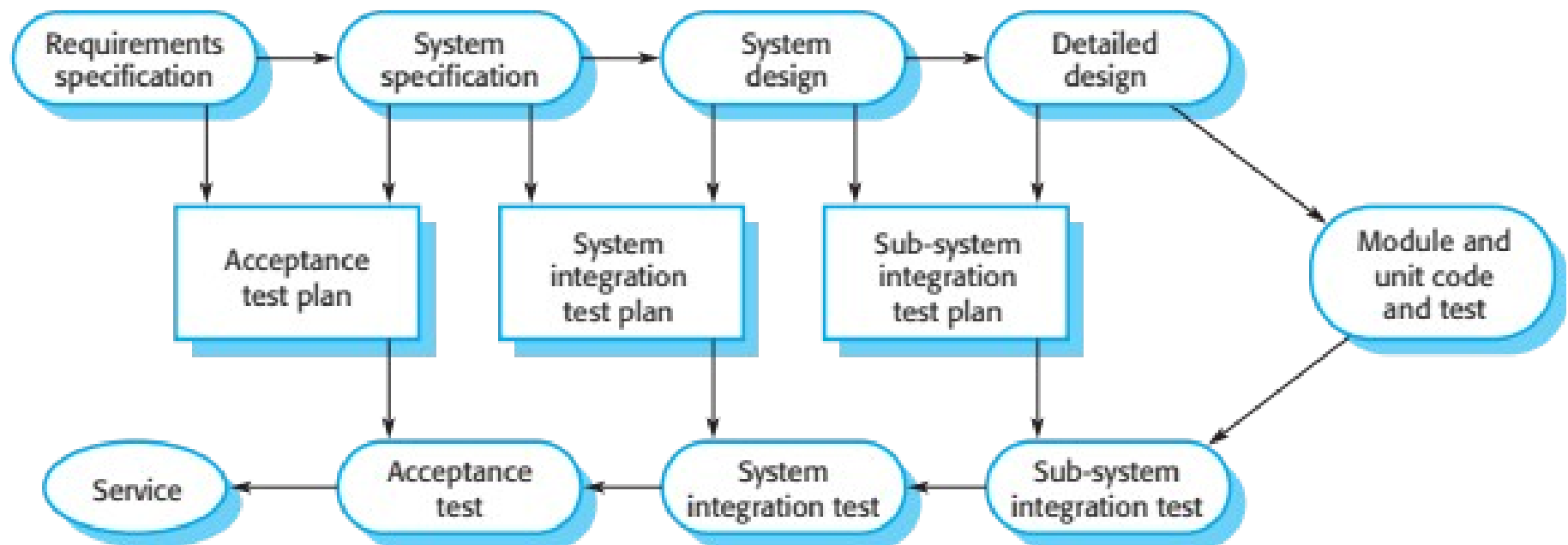
- Testing of the system as a whole. Testing of emergent properties is particularly important.

## ◇ Customer testing

- Testing with customer data to check that the system meets the customer's needs.

# Testing phases in a plan-driven software process (V-model)

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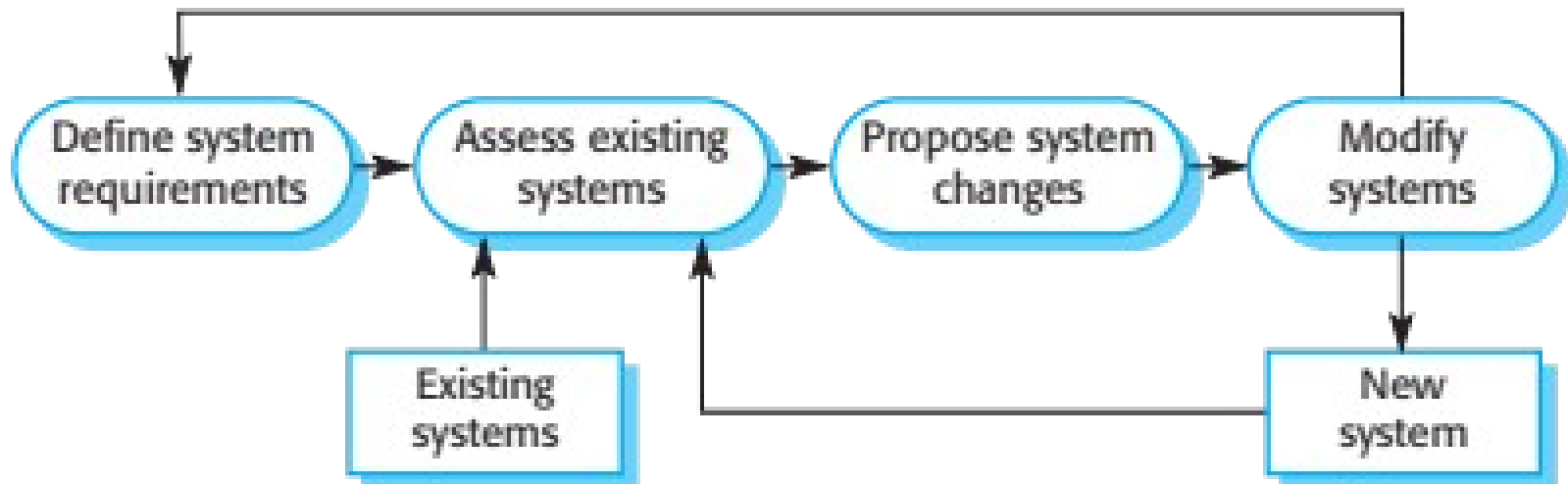
# Software evolution

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- ◇ Software is inherently flexible and can change.
- ◇ As requirements change through changing business circumstances, the software that supports the business must also evolve and change.
- ◇ Although there has been a demarcation between development and evolution (maintenance) this is increasingly irrelevant as fewer and fewer systems are completely new.

# System evolution

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## **Coping with change**

# Coping with change

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- ◇ Change is inevitable in all large software projects.
  - Business changes lead to new and changed system requirements
  - New technologies open up new possibilities for improving implementations
  - Changing platforms require application changes
- ◇ Change leads to rework so the costs of change include both rework (e.g. re-analysing requirements) as well as the costs of implementing new functionality

# Reducing the costs of rework

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- ◇ Change anticipation, where the software process includes activities that can anticipate possible changes before significant rework is required.
  - For example, a prototype system may be developed to show some key features of the system to customers.
- ◇ Change tolerance, where the process is designed so that changes can be accommodated at relatively low cost.
  - This normally involves some form of incremental development. Proposed changes may be implemented in increments that have not yet been developed. If this is impossible, then only a single increment (a small part of the system) may have be altered to incorporate the change.

## Coping with changing requirements

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- ◇ System prototyping, where a version of the system or part of the system is developed quickly to check the customer's requirements and the feasibility of design decisions. This approach supports change anticipation.
- ◇ Incremental delivery, where system increments are delivered to the customer for comment and experimentation. This supports both change avoidance and change tolerance.

# Software prototyping

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- ◇ A prototype is an initial version of a system used to demonstrate concepts and try out design options.
- ◇ A prototype can be used in:
  - The requirements engineering process to help with requirements elicitation and validation;
  - In design processes to explore options and develop a UI design;
  - In the testing process to run back-to-back tests.

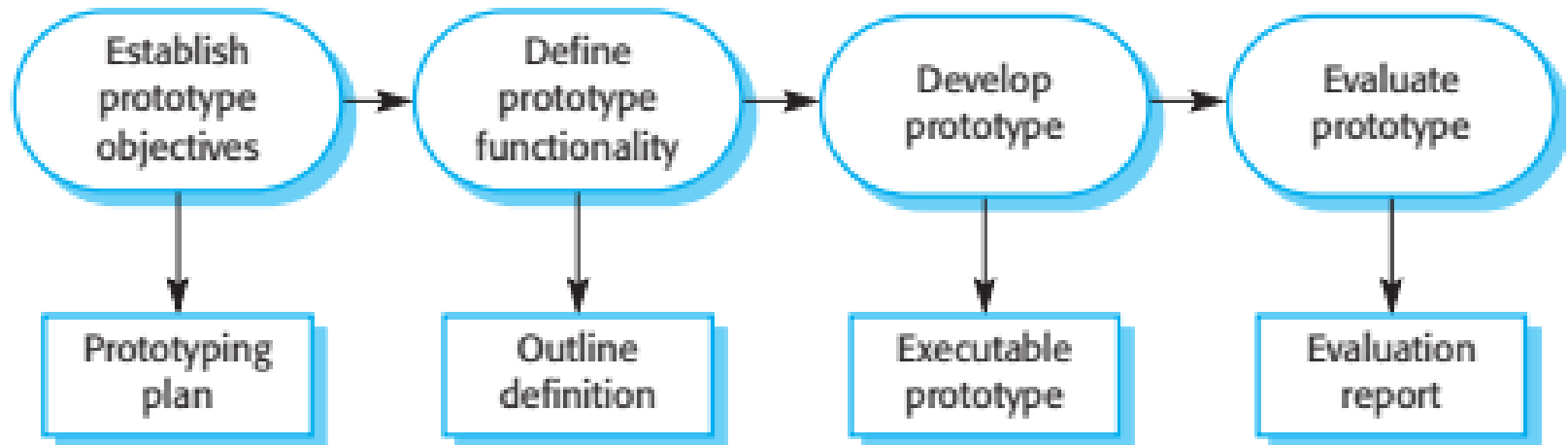
# Benefits of prototyping

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- ◇ Improved system usability.
- ◇ A closer match to users' real needs.
- ◇ Improved design quality.
- ◇ Improved maintainability.
- ◇ Reduced development effort.

# The process of prototype development

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# Prototype development

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- ◇ May be based on rapid prototyping languages or tools
- ◇ May involve leaving out functionality
  - Prototype should focus on areas of the product that are not well-understood;
  - Error checking and recovery may not be included in the prototype;
  - Focus on functional rather than non-functional requirements such as reliability and security



# Throw-away prototypes

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- ◇ Prototypes should be discarded after development as they are not a good basis for a production system:
  - It may be impossible to tune the system to meet non-functional requirements;
  - Prototypes are normally undocumented;
  - The prototype structure is usually degraded through rapid change;
  - The prototype probably will not meet normal organisational quality standards.

# Incremental delivery

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- ◇ Rather than deliver the system as a single delivery, the development and delivery is broken down into increments with each increment delivering part of the required functionality.
- ◇ User requirements are prioritised and the highest priority requirements are included in early increments.
- ◇ Once the development of an increment is started, the requirements are frozen though requirements for later increments can continue to evolve.

# Incremental development and delivery

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## ◇ Incremental development

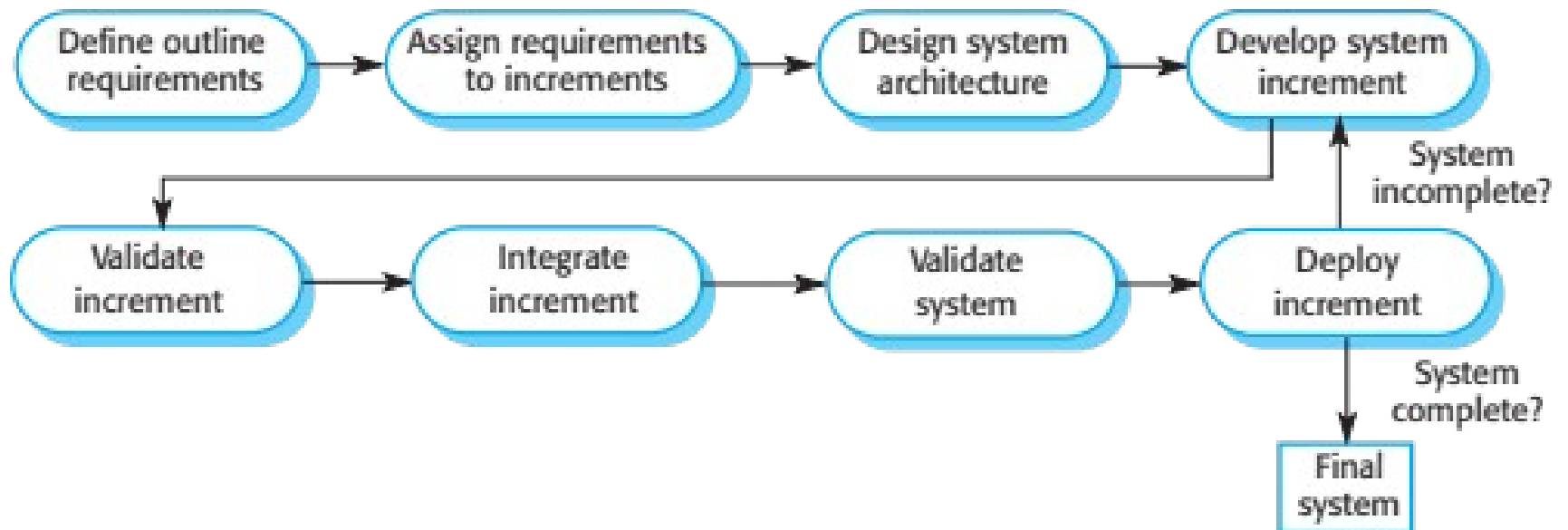
- Develop the system in increments and evaluate each increment before proceeding to the development of the next increment;
- Normal approach used in agile methods;
- Evaluation done by user/customer proxy.

## ◇ Incremental delivery

- Deploy an increment for use by end-users;
- More realistic evaluation about practical use of software;
- Difficult to implement for replacement systems as increments have less functionality than the system being replaced.

# Incremental delivery

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# Incremental delivery advantages

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- ◇ Customer value can be delivered with each increment so system functionality is available earlier.
- ◇ Early increments act as a prototype to help elicit requirements for later increments.
- ◇ Lower risk of overall project failure.
- ◇ The highest priority system services tend to receive the most testing.

# Incremental delivery problems

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- ◇ Most systems require a set of basic facilities that are used by different parts of the system.
  - As requirements are not defined in detail until an increment is to be implemented, it can be hard to identify common facilities that are needed by all increments.
- ◇ The essence of iterative processes is that the specification is developed in conjunction with the software.
  - However, this conflicts with the procurement model of many organizations, where the complete system specification is part of the system development contract.

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# Process improvement

# Process improvement

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- ◇ Many software companies have turned to software process improvement as a way of enhancing the quality of their software, reducing costs or accelerating their development processes.
- ◇ Process improvement means understanding existing processes and changing these processes to increase product quality and/or reduce costs and development time.



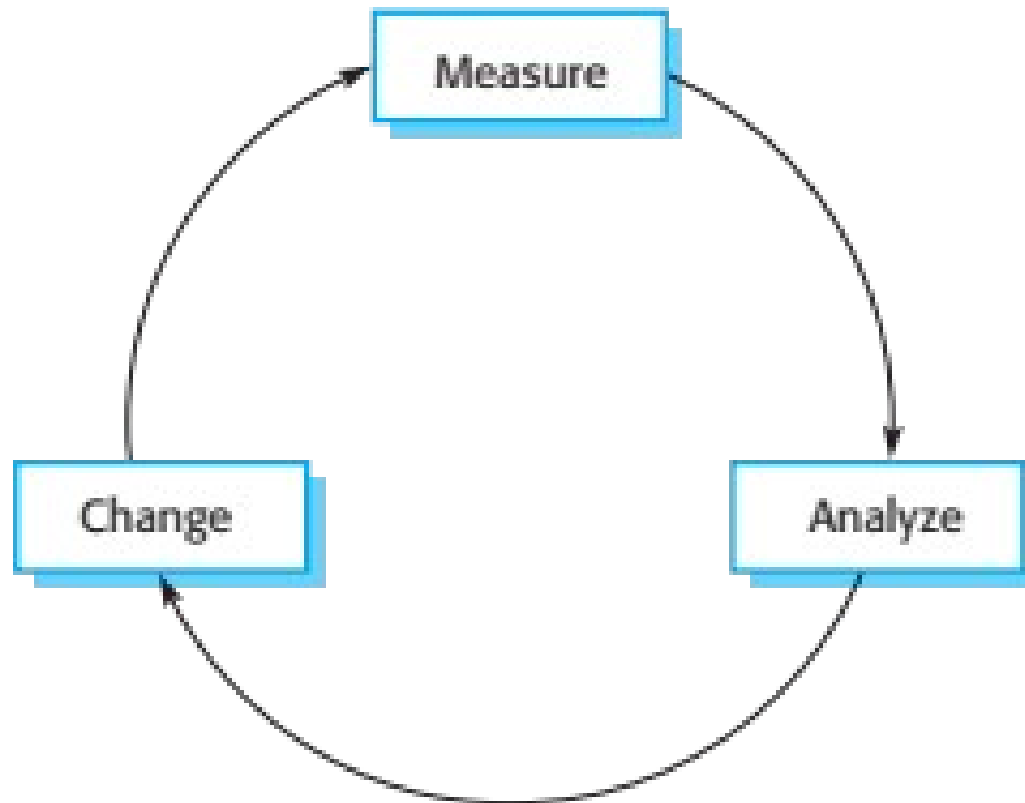
# Approaches to improvement

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- ◇ The process maturity approach, which focuses on improving process and project management and introducing good software engineering practice.
  - The level of process maturity reflects the extent to which good technical and management practice has been adopted in organizational software development processes.
- ◇ The agile approach, which focuses on iterative development and the reduction of overheads in the software process.
  - The primary characteristics of agile methods are rapid delivery of functionality and responsiveness to changing customer requirements.

# The process improvement cycle

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# Process improvement activities

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## ◇ *Process measurement*

- You measure one or more attributes of the software process or product. These measurements forms a baseline that helps you decide if process improvements have been effective.

## ◇ *Process analysis*

- The current process is assessed, and process weaknesses and bottlenecks are identified. Process models (sometimes called process maps) that describe the process may be developed.

## ◇ *Process change*

- Process changes are proposed to address some of the identified process weaknesses. These are introduced and the cycle resumes to collect data about the effectiveness of the changes.

# Process measurement

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- ◇ Wherever possible, quantitative process data should be collected
  - However, where organisations do not have clearly defined process standards this is very difficult as you don't know what to measure. A process may have to be defined before any measurement is possible.
- ◇ Process measurements should be used to assess process improvements
  - But this does not mean that measurements should drive the improvements. The improvement driver should be the organizational objectives.

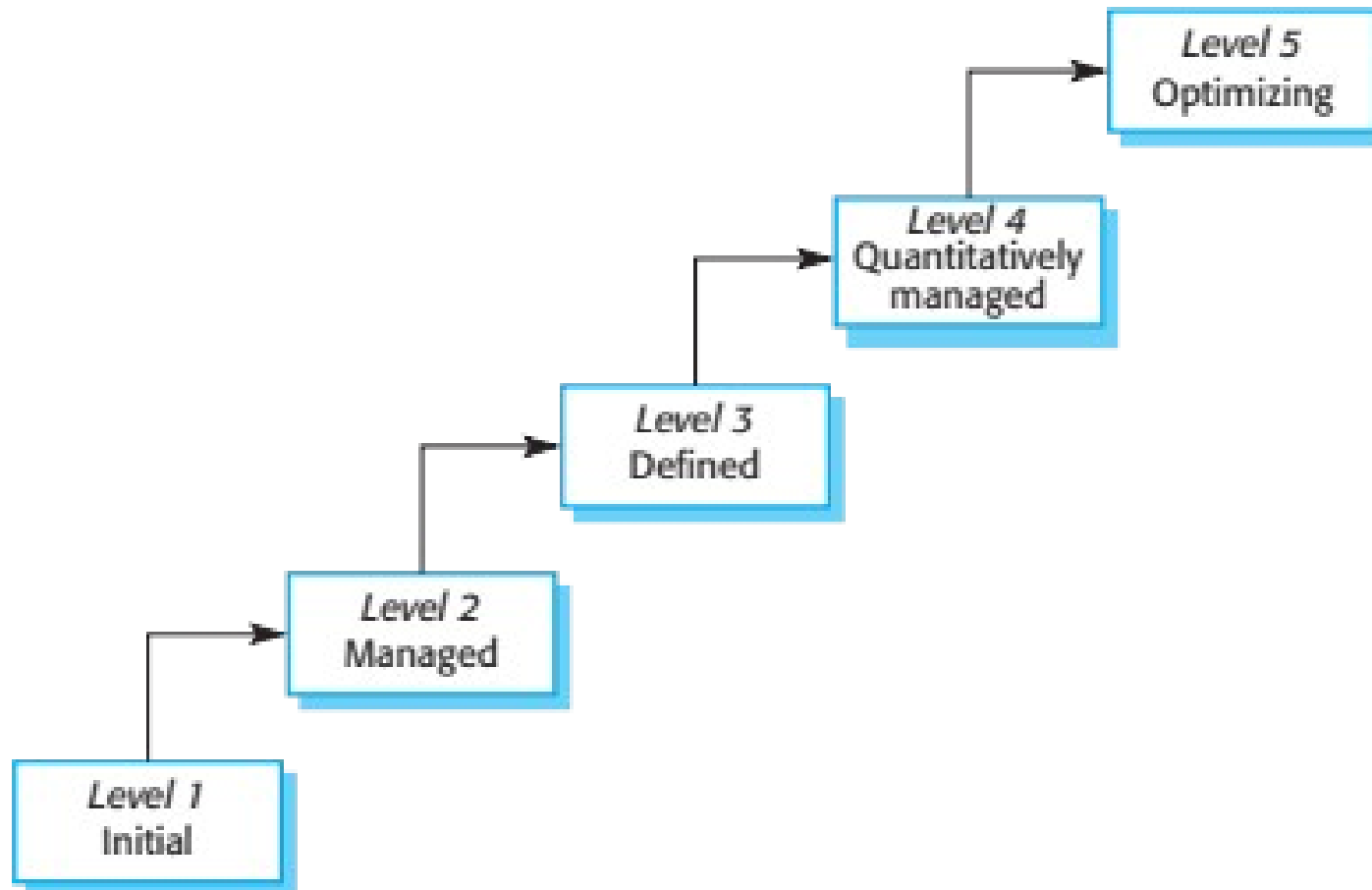
# Process metrics

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- ◇ Time taken for process activities to be completed
  - E.g. Calendar time or effort to complete an activity or process.
- ◇ Resources required for processes or activities
  - E.g. Total effort in person-days.
- ◇ Number of occurrences of a particular event
  - E.g. Number of defects discovered.

# Capability maturity levels

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# The SEI capability maturity model

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- ◇ Initial
  - Essentially uncontrolled
- ◇ Repeatable
  - Product management procedures defined and used
- ◇ Defined
  - Process management procedures and strategies defined and used
- ◇ Managed
  - Quality management strategies defined and used
- ◇ Optimising
  - Process improvement strategies defined and used

## Key points

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- ◇ Software processes are the activities involved in producing a software system. Software process models are abstract representations of these processes.
- ◇ General process models describe the organization of software processes.
  - Examples of these general models include the 'waterfall' model, incremental development, and reuse-oriented development.
- ◇ Requirements engineering is the process of developing a software specification.



## Key points

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- ◇ Design and implementation processes are concerned with transforming a requirements specification into an executable software system.
- ◇ Software validation is the process of checking that the system conforms to its specification and that it meets the real needs of the users of the system.
- ◇ Software evolution takes place when you change existing software systems to meet new requirements. The software must evolve to remain useful.
- ◇ Processes should include activities such as prototyping and incremental delivery to cope with change.

## Key points

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- ◇ Processes may be structured for iterative development and delivery so that changes may be made without disrupting the system as a whole.
- ◇ The principal approaches to process improvement are agile approaches, geared to reducing process overheads, and maturity-based approaches based on better process management and the use of good software engineering practice.
- ◇ The SEI process maturity framework identifies maturity levels that essentially correspond to the use of good software engineering practice.