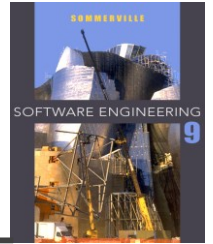


Chapter 24 - Quality Management

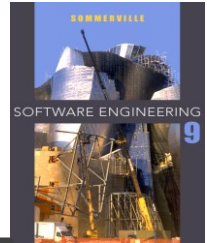
Lecture 1



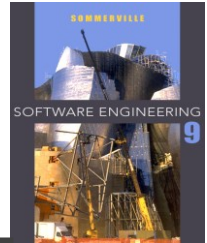
Topics covered

- ✧ Software quality
- ✧ Software standards
- ✧ Reviews and inspections
- ✧ Software measurement and metrics

Software quality management

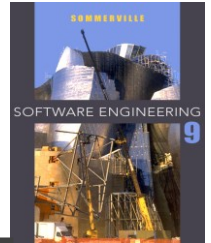


- ✧ Concerned with ensuring that the required level of quality is achieved in a software product.
- ✧ Three principal concerns:
 - **At the organizational level,**
 - quality management is concerned with **establishing a framework** of organizational processes **and standards** that will lead to high-quality software.
 - **At the project level,**
 - quality management involves the **application of specific quality processes** and **checking** that these planned processes **have been followed**.
 - **At the project level,**
 - quality management is **also concerned** with establishing a **quality plan for a project**. The quality plan should **set out the quality goals** for the project and **define what processes and standards are to be used**.



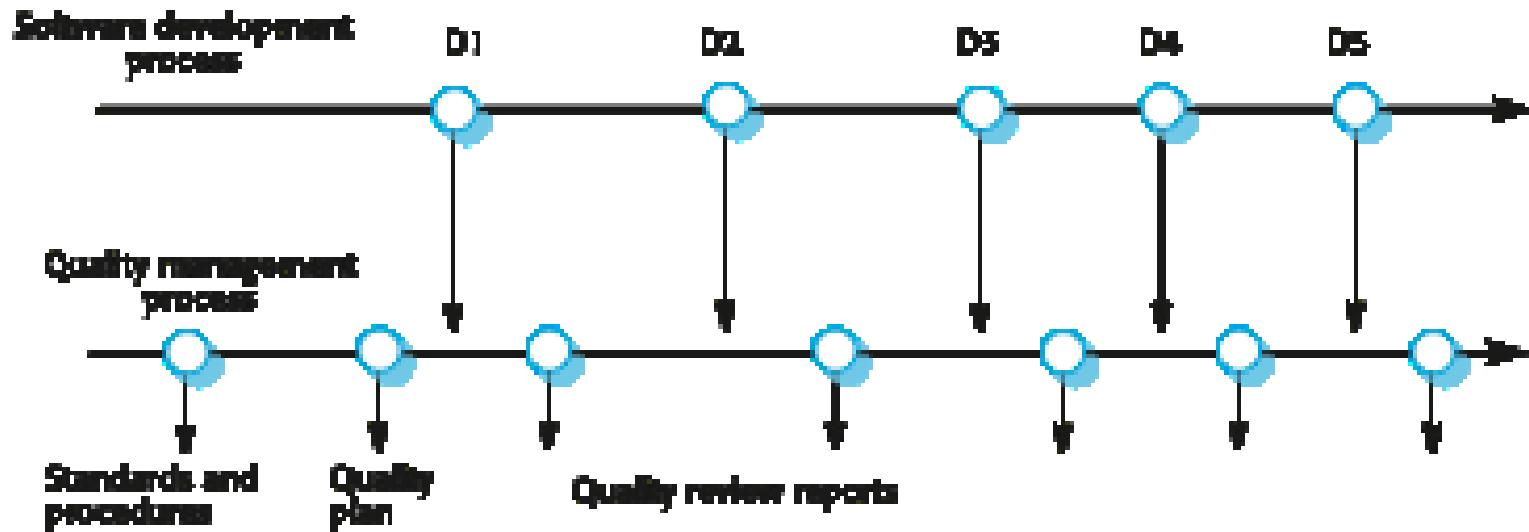
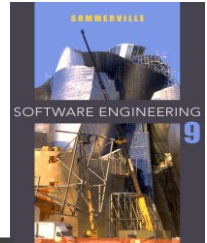
- ✧ In the software industry, different companies and industry sectors interpret **quality assurance and quality control** in different ways.
- ✧ Sometimes, **quality assurance** simply means the definition of **procedures, processes, and standards** that are aimed at ensuring that software quality is achieved.
- ✧ In other cases, quality assurance also **includes all configuration management, verification, and validation activities** that are applied after a product has been handed over by a development team.
- ✧ For us the term ‘**quality assurance**’ to **include verification and validation and the processes of checking that quality procedures have been properly applied.**
- ✧ The term ‘**quality control**’ will be **avoided** as this term is **not widely used** in the software industry.

Quality management activities

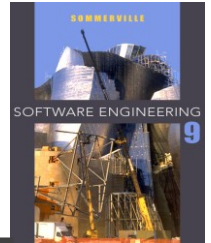


- ✧ Quality management **provides an independent check on the software development process.**
- ✧ The quality management process **checks the project deliverables** to ensure that they are **consistent with organizational standards and goals** (see figure below)
- ✧ The **quality team** should be **independent** from the development team so that they can take an **objective view** of the software.
- ✧ This allows them to report on software quality **without being influenced** by software development issues.

Quality management and software development

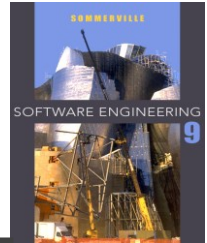


Quality planning



- ✧ A **quality plan** sets out
 - the desired **product qualities**
 - and **how these are assessed**
 - and defines the **most significant quality attributes**.
- ✧ The quality plan should **define the quality assessment process**.
- ✧ It should **set out which organisational standards should be applied** and, where necessary, **define new standards to be used**.

Quality plans



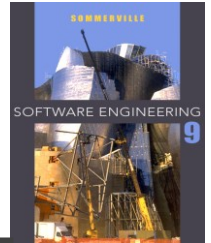
✧ Quality plan structure

- Product introduction;
 - A **description of the product**, its **intended market**, and the **quality expectations** for the product
- Product plans;
 - The **critical release dates** and **responsibilities for the product**, along **with plans for distribution and product servicing**.
- Process descriptions;
 - **The development and service processes and standards** that should be used for product development and management.
- Quality goals;
 - The quality goals and plans for the product, **including an identification and justification of critical product quality attributes**.
- Risks and risk management.
 - **The key risks that might affect product quality** and **the actions** to be taken to address these risks.

✧ Quality plans should be **short, succinct documents**

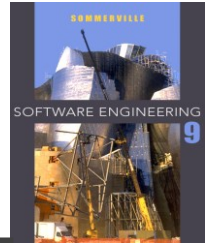
- If they are too long, no-one will read them.

Scope of quality management



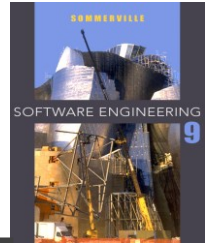
- ✧ Quality management is **particularly important for large, complex systems.**
- ✧ The **quality documentation**
 - is **a record of what has been done** by each subgroup in the project.
 - It helps people check that **important tasks have not been forgotten**
 - or that **one group has not made incorrect assumptions about what other groups have done.**
 - is a **record of progress**
 - and **supports continuity** of development as the development team changes.

For smaller systems



- ✧ quality management **needs less documentation** and should **focus on establishing a quality culture** and ensuring that all team members have a positive approach to software quality.
- ✧ **Not as much paperwork is needed** because a small development team can **communicate informally**.
- ✧ Standards and processes are important
- ✧ but quality **managers should also aim to develop a ‘quality culture’** where **everyone responsible for software development is committed to achieving a high level of product quality**.
- ✧ They should encourage teams to **take responsibility for the quality of their work** and to **develop new approaches to quality improvement**.
- ✧ **Intangible aspects e.g. readability and elegance**

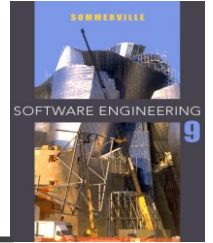
Software quality



- ✧ **Quality**, simplistically, means that a product should **meet its specification**
- ✧ it may be impossible to come to an objective conclusion about **whether or not a soft-ware system meets its specification** for the following reasons:
 1. **it is difficult to write complete and unambiguous software specifications (see chap4).**
 - ➔ Software developers and customers **may interpret the requirements in different ways** and it may be impossible to reach agreement on whether or not software conforms to its specification.

2. Specifications usually integrate requirements from **several classes of stakeholders**. These requirements are **inevitably a compromise** and **may not include** the requirements of **all stakeholder groups**.
 - **The excluded stakeholders** may therefore perceive the system as a **poor quality system**, even though it implements the agreed requirements.
3. It is **impossible to measure certain quality characteristics** (e.g., maintainability) directly and so they **cannot be specified in an unambiguous way**. I discuss the difficulties of measurement in Section 24.4.

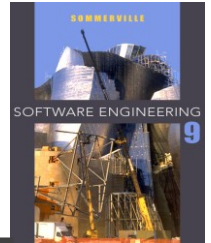
- ✧ In short checking that a software system conforms to its specifications is **problematical**
- ✧ There is a **tension between customer quality requirements** (efficiency, reliability, etc.) and **developer quality requirements** (maintainability, reusability, etc.);
 - Some quality requirements are **difficult to specify in an unambiguous way (e.g. Maintainability cannot be measured)**;
 - Software specifications are **usually incomplete and often inconsistent**.
- ✧ The focus may be **‘fitness for purpose’** rather than specification conformance.



Software fitness for purpose

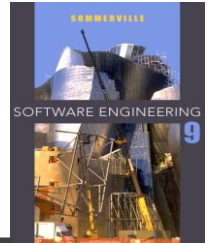
- ✧ Have programming and documentation **standards been followed** in the development process?
- ✧ Has the software been **properly tested**?
- ✧ Is the software sufficiently **dependable** to be put into use?
- ✧ Is **the performance** of the software **acceptable for normal use**?
- ✧ Is the **software usable**?
- ✧ Is the software **well-structured and understandable**?

Software quality attributes

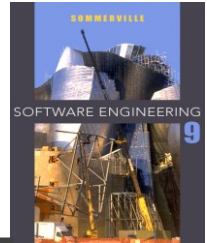


Safety	Understandability	Portability
Security	Testability	Usability
Reliability	Adaptability	Reusability
Resilience	Modularity	Efficiency
Robustness	Complexity	Learnability

Quality conflicts



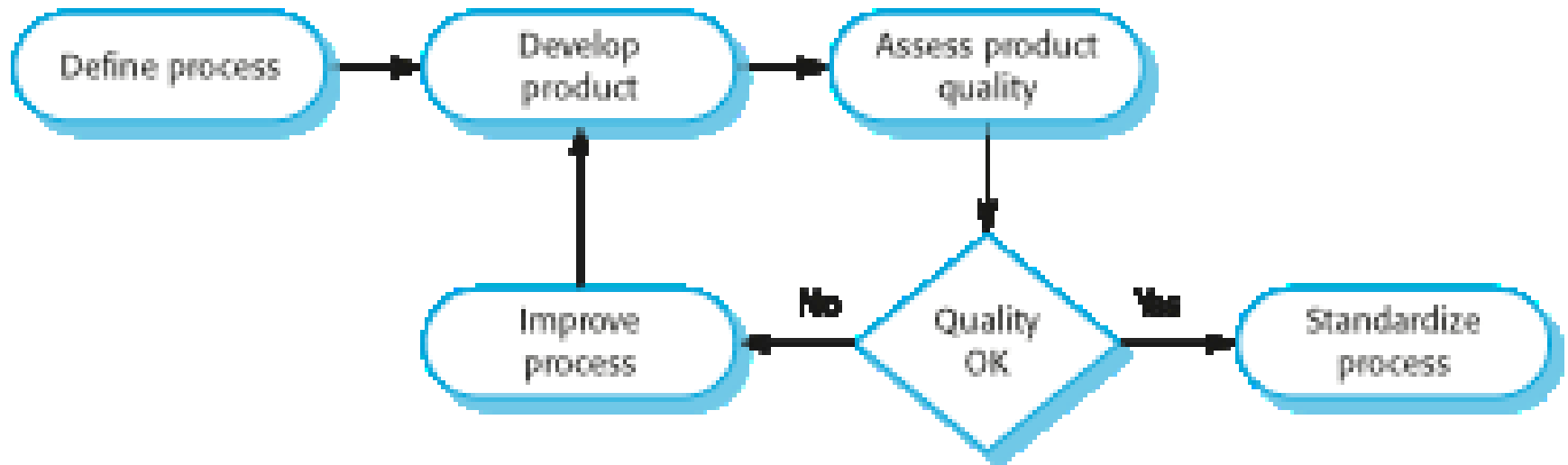
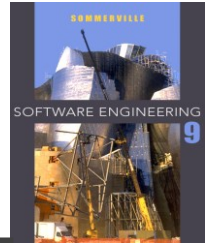
- ✧ It is **not possible for any system to be optimized for all of these attributes** –
 - for example, **improving robustness may lead to loss of performance.**
- ✧ The **quality plan should therefore define the most important quality attributes** for the software that is being developed.
- ✧ **The plan should also include**
 - a **definition of the quality assessment process**, an agreed way of assessing whether some quality, such as maintainability or robustness, is present in the product.

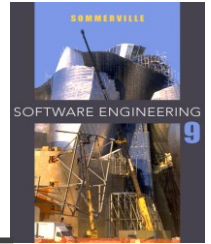


Process and product quality

- ✧ The quality of a developed product is **influenced by the quality of the production process.**
- ✧ This is **important** in software development as some product **quality attributes are hard to assess.**
- ✧ However, **there is a very complex and poorly understood relationship between software processes and product quality.**
 - The **application of individual skills and experience** is particularly important in software development;
 - **External factors** such as the **novelty of an application** or the need for an **accelerated development schedule** may **impair product quality.**

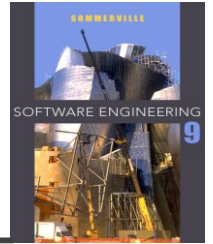
Process-based quality





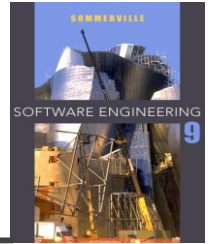
Software standards

- ✧ Standards **define the required attributes of a product or process**. They play an important role in quality management.
- ✧ Standards **may be international, national, organizational or project standards**.
- ✧ Product standards
 - **define characteristics that all software components should exhibit e.g. a common programming style.**
- ✧ Process standards
 - **define how the software process should be enacted.**



Importance of standards

- ✧ **Encapsulation of best practice- avoids repetition of past mistakes (Standards capture wisdom that is of value to the organization).**
- ✧ They are a **framework for defining what quality means** in a particular setting
 - ➔ i.e. **that organization's view of quality.**
- ✧ **They provide continuity - new staff** can understand the organisation by understanding the standards that are used.
 - ➔ Consequently, **the learning effort** required when starting new work **is reduced.**



Two related types of Standards

1. Product standards These apply to the software product being developed.

They include

document standards, such as the structure of requirements documents,

documentation standards, such as a standard comment header for an object class definition,

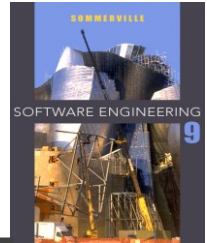
and **coding standards**, which define how a programming language should be used.

2. Process standards

- These define the processes that should be followed during software development.
- should include the definition of processes **that check that product standards** have been followed
- They should **encapsulate good development practice.**
- Process standards **may include**
 - **definitions of specification,**
 - **design and validation processes,**
 - **process support tools,**
 - **and a description of the documents** that should be written during these processes

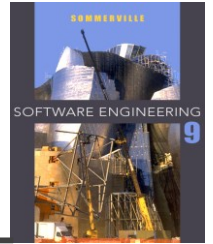
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- ✧ National and international bodies such as the U.S. DoD, ANSI, BSI, NATO, and the IEEE support the production of standards.
 - ✧ These are general standards that can be applied across a range of projects.
 - ✧ **Bodies such as NATO** and other defense organizations may require that **their own standards be used in the development contracts** that they place with software companies.

-
- ✧ **Quality management teams** that are developing **standards for a company** should normally base these company standards on **national and international** standards.
 - ✧ Using **international standards as a starting point**, the quality assurance team should draw up a **standards ‘handbook’**. This should define the standards that are needed by their organization.
 - ✧ **Examples of standards** that could be included in such a handbook are shown in **Figure below**.



Product and process standards

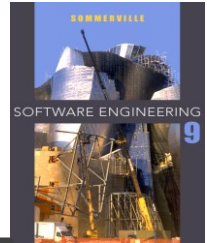
Product standards	Process standards
Design review form	Design review conduct
Requirements document structure	Submission of new code for system building
Method header format	Version release process
Java programming style	Project plan approval process
Project plan format	Change control process
Change request form	Test recording process



Problems with standards

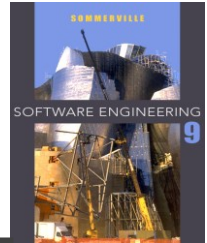
- ✧ They may not be seen as relevant and up-to-date by software engineers.
- ✧ They often involve too much bureaucratic form filling.
- ✧ If they are unsupported by software tools,
 - ➔ **tedious form filling work** is often involved to maintain the documentation associated with the standards.

Standards development



✧ **To minimize dissatisfaction** and to encourage buy-in to standards, **quality managers** who set the standards **should therefore take the following steps**

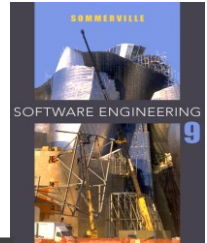
- **Involve practitioners** in development. **Engineers should understand the rationale** underlying a standard.
- **Review standards** and their usage **regularly**. Standards can quickly become outdated and this reduces their credibility amongst practitioners.
- Provide tools to support standards:
 - Excessive clerical work is the most significant complaint against standards.
 - Web-based forms are not good enough.
 - For example, **document standards** can be implemented using word **processor styles**.



ISO 9001 standards framework

- ✧ An international set of standards that can be used as a basis for developing quality management systems.
- ✧ **ISO 9001**, the most general of these standards, **applies to organizations that design, develop and maintain products**, including software.
- ✧ The ISO 9001 standard **is not itself a standard for software development** but is a **framework for developing software standards**.
 - It sets out **general quality principles**,
 - **describes quality processes in general**
 - and **lays out the organizational standards and procedures** that should be defined. These should be documented in an **organizational quality manual**.

ISO 9001 core processes



- ✧ The **major revision of the ISO 9001** standard in **2000** reoriented the standard around nine core processes (**Figure below**).
- ✧ If an organization is to be **ISO 9001 conformant**,
 - it must **document how its processes relate** to these core processes.
 - It must also **define and maintain records that demonstrate** that the defined organizational processes have been followed.
 - The company **quality manual should describe** the relevant **processes** and **the process data** that has to be collected and maintained.

ISO 9001 core processes

Product delivery processes

Business acquisition

Design and development

Test

Production and delivery

Service and support

Supporting processes

Business management

Supplier management

Inventory management

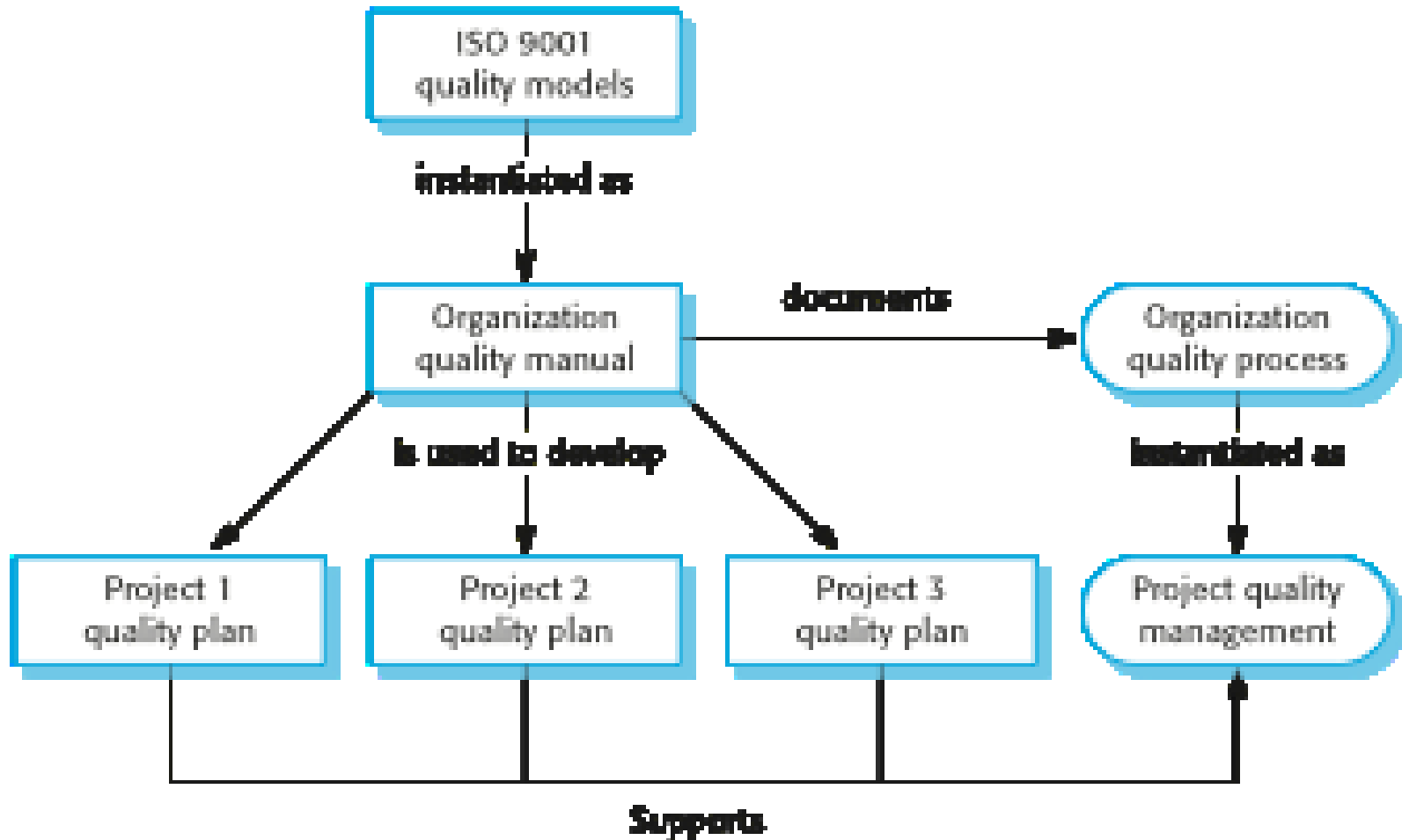
Configuration management

✧ **The relationships between**

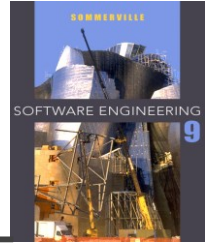
- **ISO 9001,**
- **organizational quality manuals,**
- **and individual project quality plans**
- **are shown in the Figure below.**

✧ This diagram has been derived from a model given by Ince (1994), who explains how the general ISO 9001 standard can be used as a basis for software quality management processes.

ISO 9001 and quality management



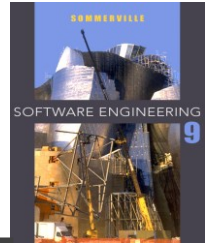
ISO 9001 certification



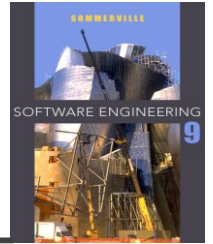
- ✧ Quality standards and procedures should be documented in an organisational quality manual.
- ✧ An **external body may certify** that an organisation's quality manual conforms to ISO 9000 standards.
- ✧ **Some customers require suppliers** to be ISO 9000 certified although the need for flexibility here is increasingly recognised.

- ✧ **Some people think** that ISO 9001 certification means that the quality of the software produced by certified companies **will be better than that from uncertified companies.**
- ✧ **This is not necessarily true.**
- ✧ The ISO 9001 standard **focuses on ensuring that the organization has quality management procedures** in place and it **follows these procedures.**
- ✧ There is **no guarantee** that ISO 9001 certified companies **use the best software development practices** or that their processes lead to high-quality software.

Key points

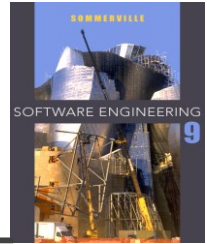


- ✧ Software quality management is **concerned with ensuring that software has a low number of defects** and that it **reaches the required standards of maintainability, reliability, portability and so on.**
- ✧ SQM includes
 - **defining standards for processes and products** and
 - **establishing processes to check that these standards have been followed.**
- ✧ Software standards are important for quality assurance as they represent an identification of 'best practice'.
- ✧ Quality management procedures may be documented in an **organizational quality manual**, based on the generic model for a quality manual suggested in the ISO 9001 standard.



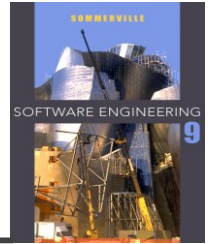
Chapter 24 - Quality Management

Lecture 2



Reviews and inspections

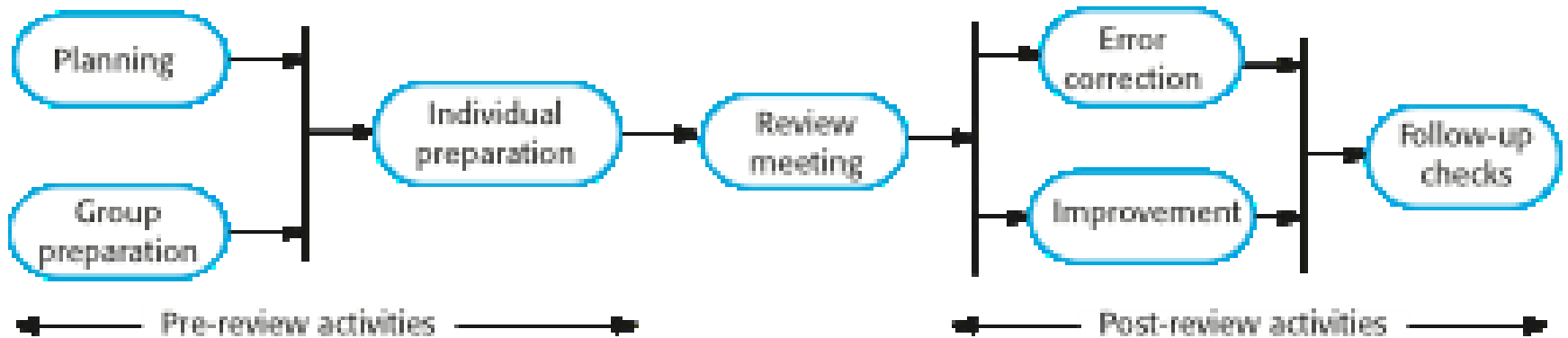
- ✧ A **group examines** part or all of a process or system and its documentation **to find potential problems.**
- ✧ Software or documents may be '**signed off**' at a review which **signifies that progress to the next development stage** has been approved by management.
- ✧ There are **different types** of review with **different objectives**
 - Inspections **for defect removal** (product);
 - Reviews **for progress assessment** (product and process);
 - **Quality reviews** (product and standards).

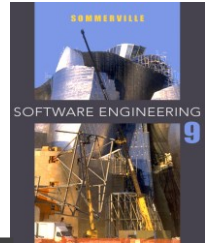


Quality reviews

- ✧ A group of people carefully **examine part or all of a software system and its associated documentation.**
- ✧ **Code, designs, specifications, test plans, standards, etc.** can all be reviewed.
- ✧ Software or documents may be **'signed off'** at a review which **signifies that progress to the next development stage has been approved by management.**

The software review process



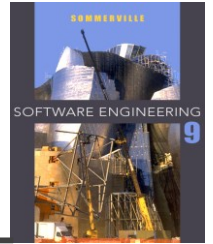


Reviews and agile methods

- ✧ The review process in agile software development is **usually informal**.
 - In Scrum, for example, **there is a review meeting after each iteration** of the software has been completed (a sprint review), where quality issues and problems may be discussed.
- ✧ In extreme programming, **pair programming ensures that code is constantly being examined and reviewed** by another team member.
- ✧ XP **relies on individuals taking the initiative to improve and refactor code**.
- ✧ Agile approaches are **not usually standards-driven**, so **issues of standards compliance are not usually considered**.

Program inspections

- ✧ **These are peer reviews** where engineers examine the source of a system with **the aim of discovering anomalies and defects.**
- ✧ Inspections **do not require execution of a system** so may be **used before implementation.**
- ✧ They **may be applied to any representation of the system** (requirements, design, configuration data, test data, etc.).
- ✧ They have been shown to be an **effective technique for discovering program errors.**



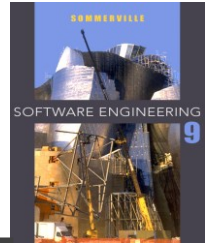
Inspection checklists

- ✧ **Checklist of common errors** should be used to drive the inspection.
- ✧ Error checklists are **programming language dependent** and reflect the characteristic errors that are likely to arise in the language.
- ✧ In general, the 'weaker' **the type checking**, the larger the checklist.
- ✧ **Examples:** Initialisation, Constant naming, loop termination, array bounds, etc.

An inspection checklist (a)

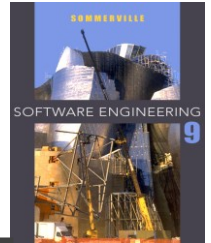
Fault class	Inspection check
Data faults	<ul style="list-style-type: none"> • Are all program variables initialized before their values are used? • Have all constants been named? • Should the upper bound of arrays be equal to the size of the array or Size -1? • If character strings are used, is a delimiter explicitly assigned? • Is there any possibility of buffer overflow?
Control faults	<ul style="list-style-type: none"> • For each conditional statement, is the condition correct? • Is each loop certain to terminate? • Are compound statements correctly bracketed? • In case statements, are all possible cases accounted for? • If a break is required after each case in case statements, has it been included?
Input/output faults	<ul style="list-style-type: none"> • Are all input variables used? • Are all output variables assigned a value before they are output? • Can unexpected inputs cause corruption?

An inspection checklist (b)



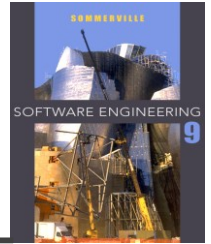
Fault class	Inspection check
Interface faults	<ul style="list-style-type: none">• Do all function and method calls have the correct number of parameters?• Do formal and actual parameter types match?• Are the parameters in the right order?• If components access shared memory, do they have the same model of the shared memory structure?
Storage management faults	<ul style="list-style-type: none">• If a linked structure is modified, have all links been correctly reassigned?• If dynamic storage is used, has space been allocated correctly?• Is space explicitly deallocated after it is no longer required?
Exception management faults	<ul style="list-style-type: none">• Have all possible error conditions been taken into account?

Agile methods and inspections



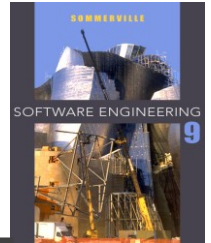
- ✧ Agile processes **rarely use formal inspection or peer review processes.**
- ✧ Rather, they **rely on team members cooperating to check each other's code**, and **informal guidelines**, such as '**check before check-in**', which suggest that programmers should check their own code.
- ✧ Extreme programming practitioners argue that **pair programming is an effective substitute** for inspection as this is, in effect, a continual inspection process.
- ✧ **Two people** look at every line of code and check it before it is accepted.

Software measurement and metrics



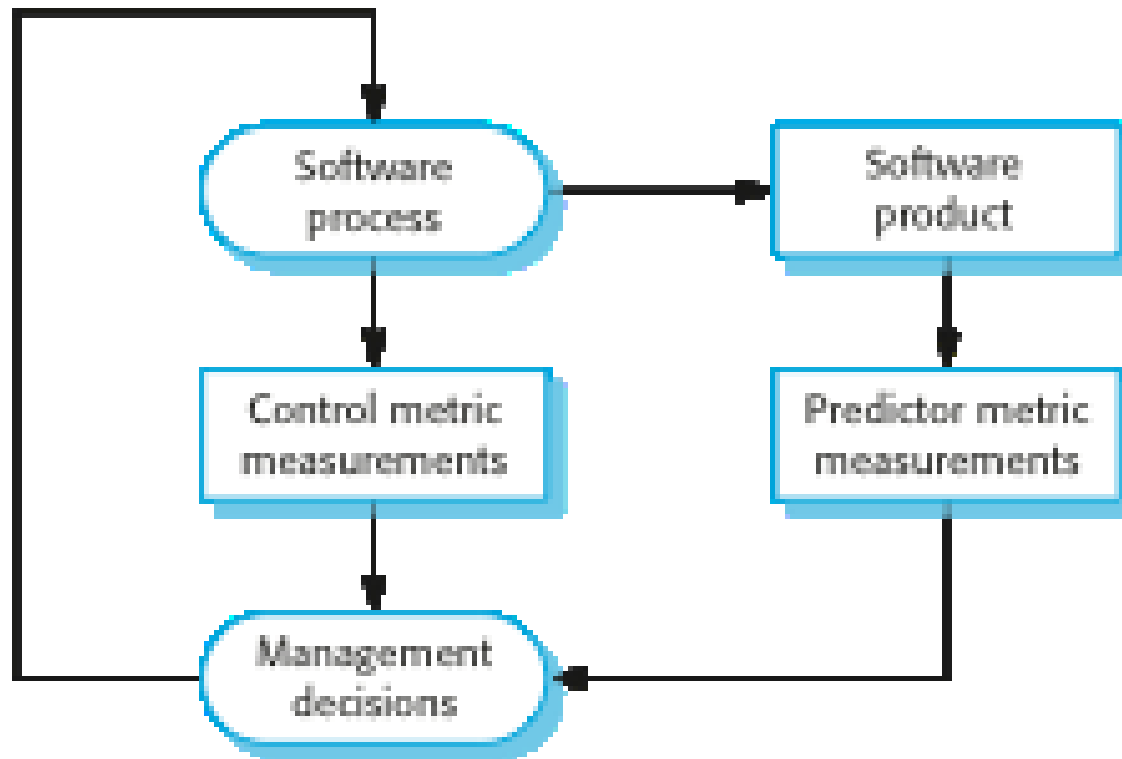
- ✧ Software measurement is **concerned with deriving a numeric value for an attribute** of a software product or process.
- ✧ This **allows for objective comparisons** between techniques and processes.
- ✧ Although some companies have introduced measurement programmes, **most organisations still don't make systematic use** of software measurement.
- ✧ There are **few established standards** in this area.

Software metric

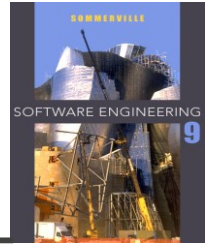


- ✧ **Any type of measurement which relates to a software system, process or related documentation**
 - Lines of code in a program,
 - the Fog index,
 - number of **person-days** required to develop a component.
- ✧ Allow the software and the software process to be **quantified**.
- ✧ May be **used to predict product attributes** or to control the software process.
- ✧ Product metrics can be **used for** general predictions or **to identify anomalous components**.

Predictor and control measurements



Use of measurements

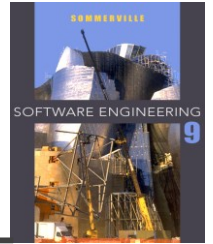


✧ To assign a value to system quality attributes

- By measuring the characteristics of system components, such as their **cyclomatic complexity**, and then aggregating these measurements, **you can assess system quality attributes, such as maintainability.**

✧ To identify the system components whose quality is sub-standard

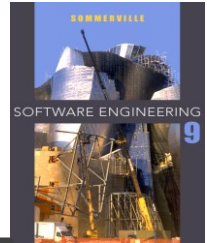
- Measurements can **identify individual components** with characteristics **that deviate from the norm.**
- **For example**, you can measure components to discover those with the **highest complexity.**
- These are **most likely to contain bugs** because the complexity makes them harder to understand.



Metrics assumptions

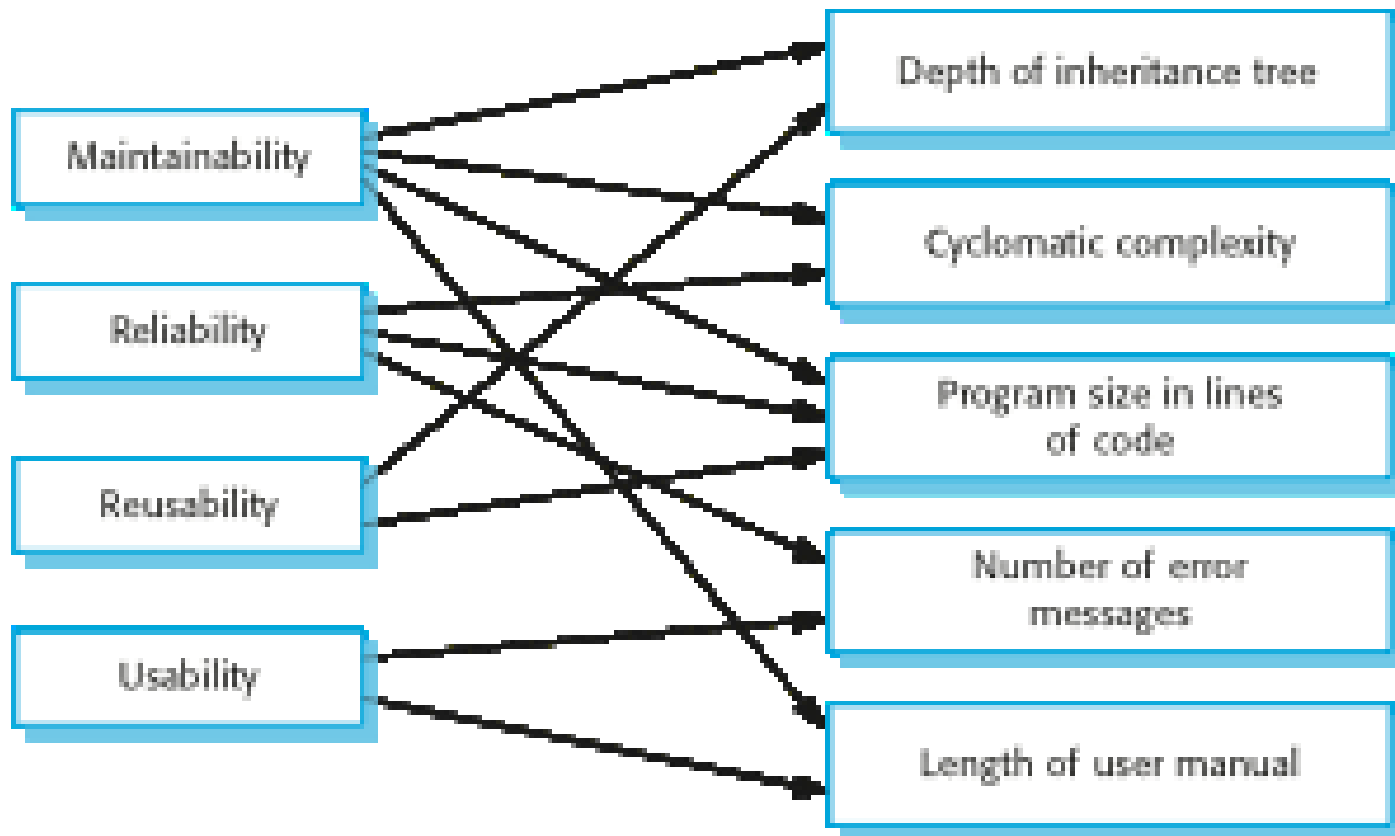
- ✧ **A software property can be measured.**
- ✧ **The relationship exists between what we can measure and what we want to know.**
- ✧ **We can only measure internal attributes but are often more interested in external software attributes.**
- ✧ **This relationship has been formalised and validated.**
- ✧ **It may be difficult to relate what can be measured to desirable external quality attributes.**

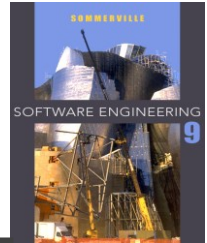
Relationships between internal and external software



External quality attributes

Internal attributes

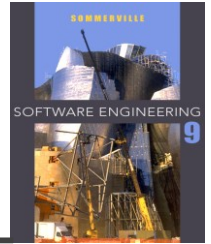




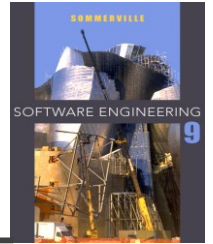
Problems with measurement in industry

- ✧ **It is impossible to quantify the return** on investment of introducing an organizational metrics program.
- ✧ There are **no standards for software metrics** or standardized processes for measurement and analysis.
- ✧ In many companies, **software processes are not standardized and are poorly defined and controlled.**
- ✧ **Most work** on software measurement has **focused on code-based metrics and plan-driven development** processes. However, more and more software is now developed by configuring ERP systems or COTS.
- ✧ Introducing measurement adds **additional overhead** to processes.

Product metrics



- ✧ A quality metric **should be a predictor of product quality.**
- ✧ Classes of product metric
 - **Dynamic metrics** which are collected by measurements made of a **program in execution**;
 - **Static metrics** which are collected by measurements made of the system representations;
 - **Dynamic metrics help** assess **efficiency and reliability**
 - **Static metrics help** assess **complexity, understandability and maintainability.**

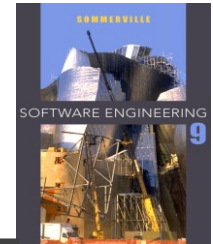


Dynamic and static metrics

- ✧ Dynamic metrics are **closely related to software quality attributes**
 - It is relatively **easy to measure the response time** of a system (performance attribute) or the number of failures (reliability attribute).
- ✧ Static metrics **have an indirect relationship with quality attributes**
 - You need to **try and derive a relationship** between these metrics and properties such as complexity, understandability and maintainability.

Static software product metrics

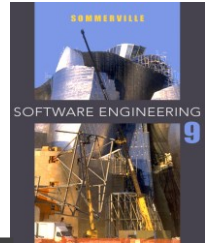
Software metric	Description
Fan-in/Fan-out	<p>Fan-in is a measure of the number of functions or methods that call another function or method (say X). Fan-out is the number of functions that are called by function X. A high value for fan-in means that X is tightly coupled to the rest of the design and changes to X will have extensive knock-on effects. A high value for fan-out suggests that the overall complexity of X may be high because of the complexity of the control logic needed to coordinate the called components.</p>
Length of code	<p>This is a measure of the size of a program. Generally, the larger the size of the code of a component, the more complex and error-prone that component is likely to be. Length of code has been shown to be one of the most reliable metrics for predicting error-proneness in components.</p>



Static software product metrics

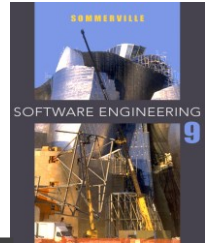
Software metric	Description
Cyclomatic complexity	This is a measure of the control complexity of a program. This control complexity may be related to program understandability. I discuss cyclomatic complexity in Chapter 8.
Length of identifiers	This is a measure of the average length of identifiers (names for variables, classes, methods, etc.) in a program. The longer the identifiers , the more likely they are to be meaningful and hence the more understandable the program .
Depth of conditional nesting	This is a measure of the depth of nesting of if-statements in a program. Deeply nested if-statements are hard to understand and potentially error-prone.
Fog index	This is a measure of the average length of words and sentences in documents . The higher the value of a document's Fog index, the more difficult the document is to understand.

The CK object-oriented metrics suite

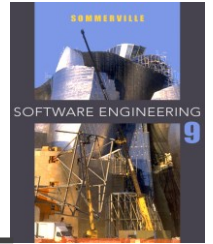


Object-oriented metric	Description
Weighted methods per class (WMC)	This is the number of methods in each class, weighted by the complexity of each method. Therefore, a simple method may have a complexity of 1, and a large and complex method a much higher value. The larger the value for this metric, the more complex the object class. Complex objects are more likely to be difficult to understand. They may not be logically cohesive, so cannot be reused effectively as superclasses in an inheritance tree.
Depth of inheritance tree (DIT)	This represents the number of discrete levels in the inheritance tree where subclasses inherit attributes and operations (methods) from superclasses. The deeper the inheritance tree, the more complex the design. Many object classes may have to be understood to understand the object classes at the leaves of the tree.
Number of children (NOC)	This is a measure of the number of immediate subclasses in a class. It measures the breadth of a class hierarchy, whereas DIT measures its depth. A high value for NOC may indicate greater reuse. It may mean that more effort should be made in validating base classes because of the number of subclasses that depend on them.

The CK object-oriented metrics suite



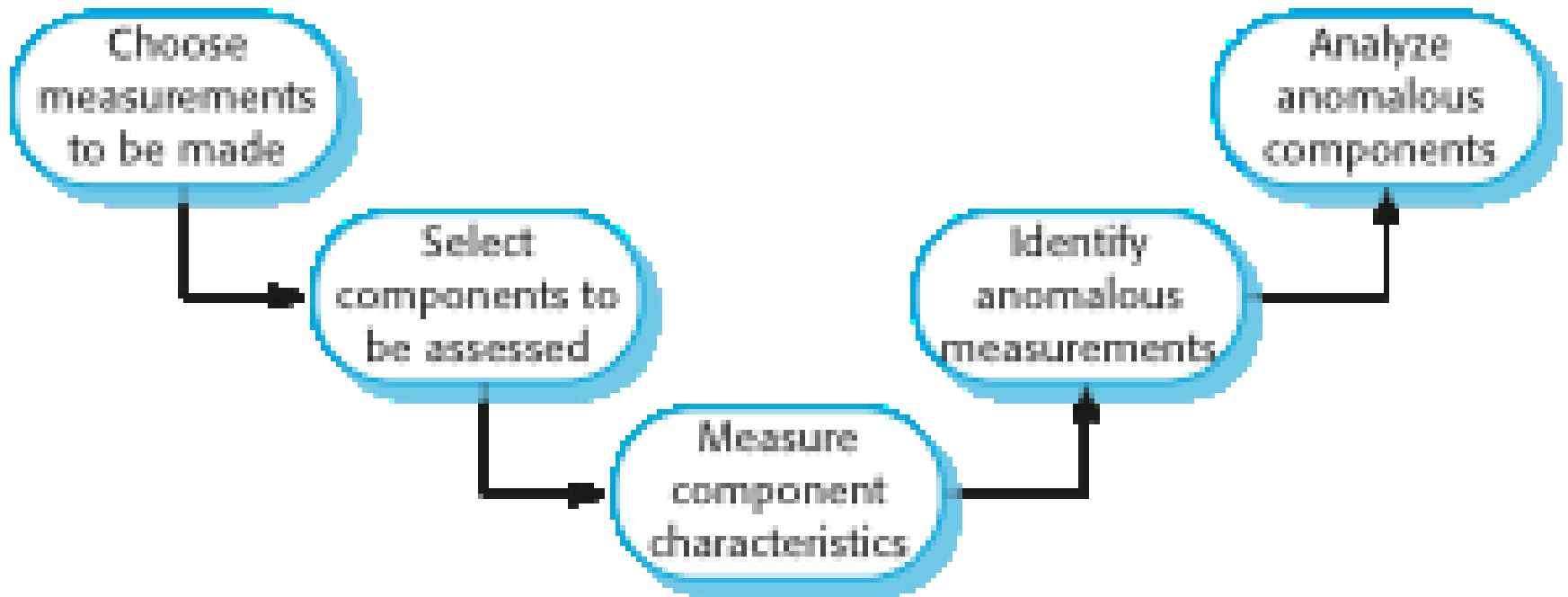
Object-oriented metric	Description
Coupling between object classes (CBO)	Classes are coupled when methods in one class use methods or instance variables defined in a different class . CBO is a measure of how much coupling exists. A high value for CBO means that classes are highly dependent , and therefore it is more likely that changing one class will affect other classes in the program.
Response for a class (RFC)	RFC is a measure of the number of methods that could potentially be executed in response to a message received by an object of that class. Again, RFC is related to complexity . The higher the value for RFC, the more complex a class and hence the more likely it is that it will include errors.
Lack of cohesion in methods (LCOM)	LCOM is calculated by considering pairs of methods in a class . LCOM is the difference between the number of method pairs without shared attributes and the number of method pairs with shared attributes . The value of this metric has been widely debated and it exists in several variations. It is not clear if it really adds any additional , useful information over and above that provided by other metrics.



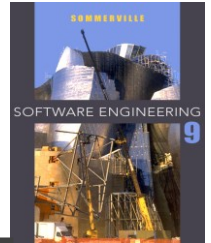
Software component analysis

- ✧ System component **can be analyzed separately using a range of metrics.**
- ✧ The values of these metrics **may then compared for different components** and, perhaps, with **historical measurement** data collected on previous projects.
- ✧ Anomalous measurements, which **deviate significantly from the norm**, may imply that there are **problems with the quality of these components.**

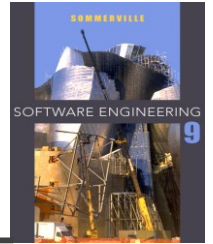
The process of product measurement



Measurement surprises



- ✧ **Reducing the number of faults in a program leads to an increased number of help desk calls**
 - The program is now thought of as more reliable and so has a wider more diverse market. The percentage of users who call the help desk may have decreased but the total may increase;
 - A more reliable system is used in a different way from a system where users work around the faults. This leads to more help desk calls.



Key points

- ✧ Reviews of the software process deliverables involve a team of people who check that quality standards are being followed.
- ✧ In a program inspection or peer review, a small team systematically checks the code. They read the code in detail and look for possible errors and omissions
- ✧ Software measurement can be used to gather data about software and software processes.
- ✧ Product quality metrics are particularly useful for highlighting anomalous components that may have quality problems.