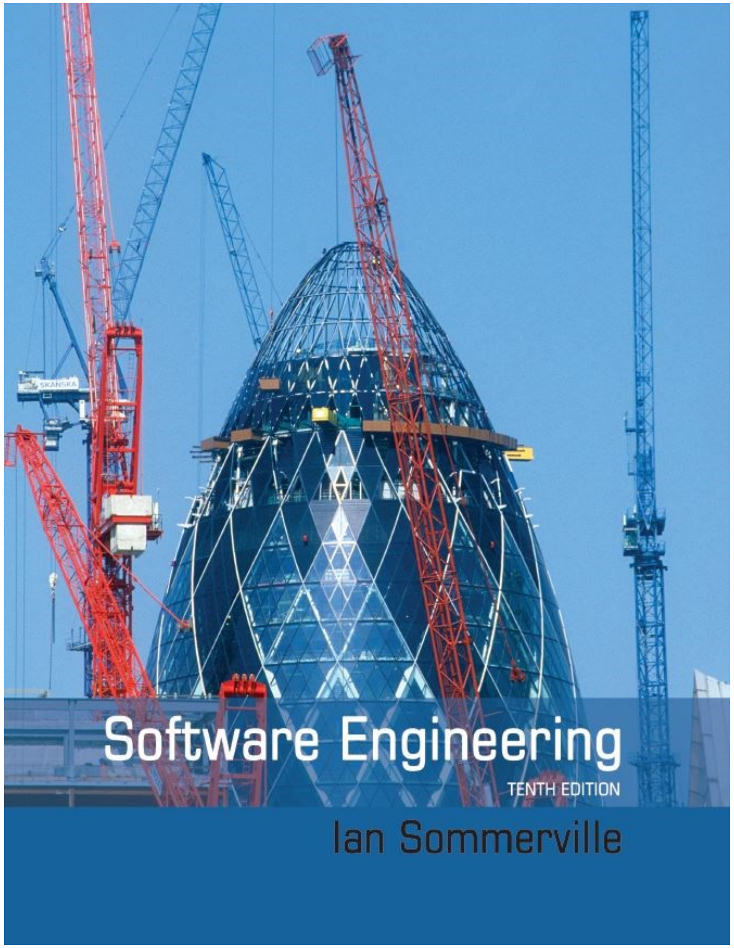
Software Engineering

Tenth Edition



Chapter 9

Software Evolution

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Learning Objectives

9.1 Evolution processes

9.2 Legacy systems

9.3 Software maintenance

Software Change

- Software change is inevitable
  - New requirements emerge when the software is used;
  - The business environment changes;
  - Errors must be repaired;
  - New computers and equipment is added to the system;
  - The performance or reliability of the system may have to be improved.
- A key problem for all organizations is implementing and managing change to their existing software systems.

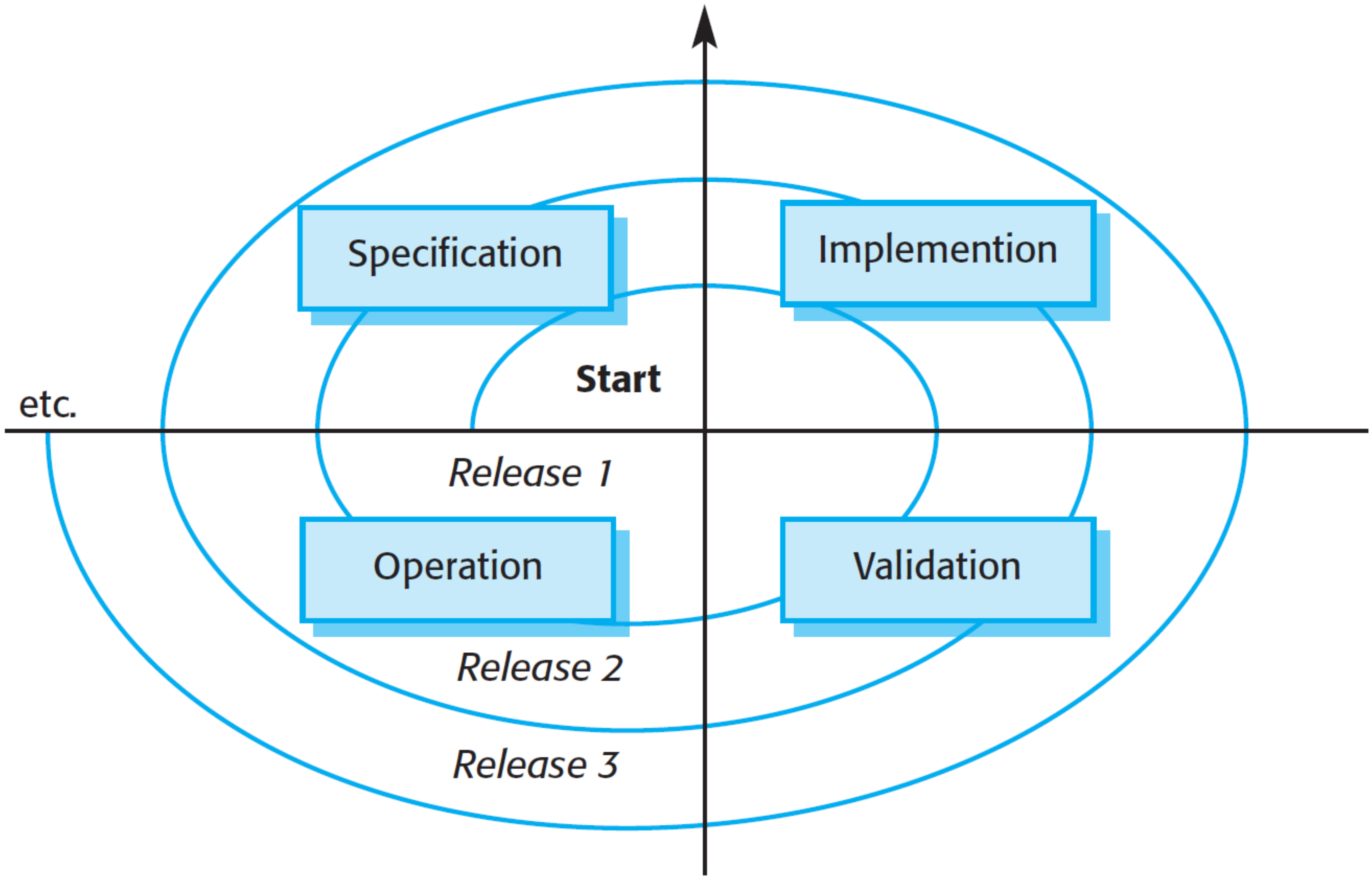
Importance of Evolution

- Organisations have huge investments in their software systems - they are critical business assets.
- To maintain the value of these assets to the business, they must be changed and updated.
- The majority of the software budget in large companies is devoted to changing and evolving existing software rather than developing new software.

Importance of Evolution

- Software evolution is particularly expensive in enterprise systems when individual software systems are part of a broader “system of systems.”
- *Brownfield software development* describes situations in which software systems have to be developed and managed in an environment where they are dependent on other software systems.

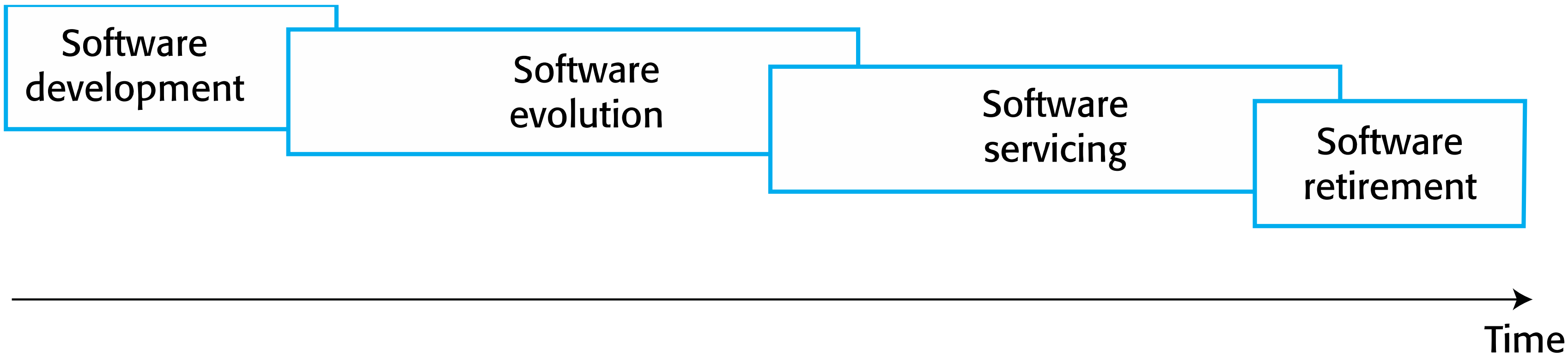
A Spiral Model of Development and Evolution



Importance of Evolution

- New releases of the systems that incorporate changes and updates are usually created at regular intervals.
- Software engineering is therefore a spiral process with requirements, design, implementation, and testing going on throughout the lifetime of the system
- In the last 10 years, the time between iterations of the spiral has reduced dramatically.
- The process of changing the software after delivery is called *software maintenance*. Maintenance involves extra process activities, such as program understanding, in addition to the normal activities of software development.

Evolution and Servicing



Evolution and Servicing

- Evolution
  - The stage in a software system's life cycle where it is in operational use and is evolving as new requirements are proposed and implemented in the system.
- Servicing
  - At this stage, the software remains useful but the only changes made are those required to keep it operational i.e. bug fixes and changes to reflect changes in the software's environment. No new functionality is added.
- Phase-out
  - The software may still be used but no further changes are made to it.

Evolution Processes

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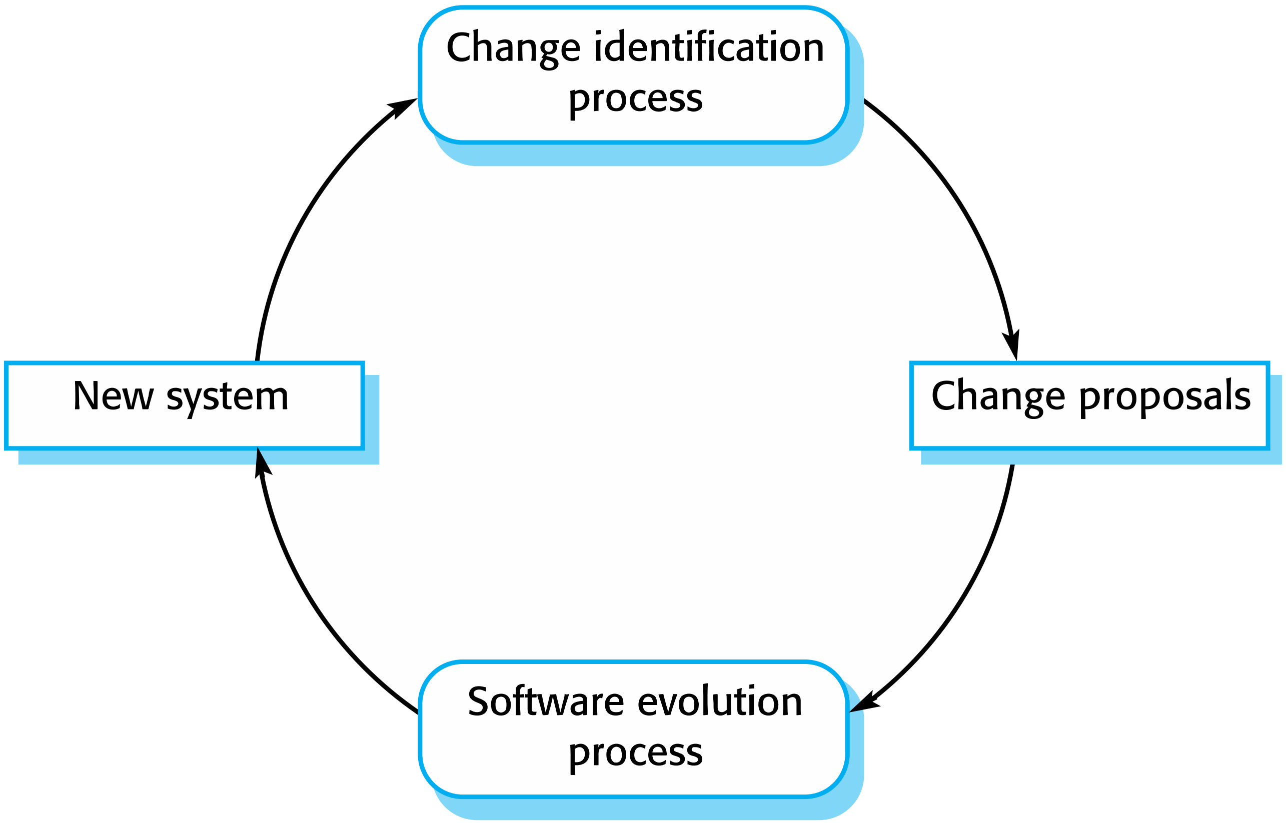
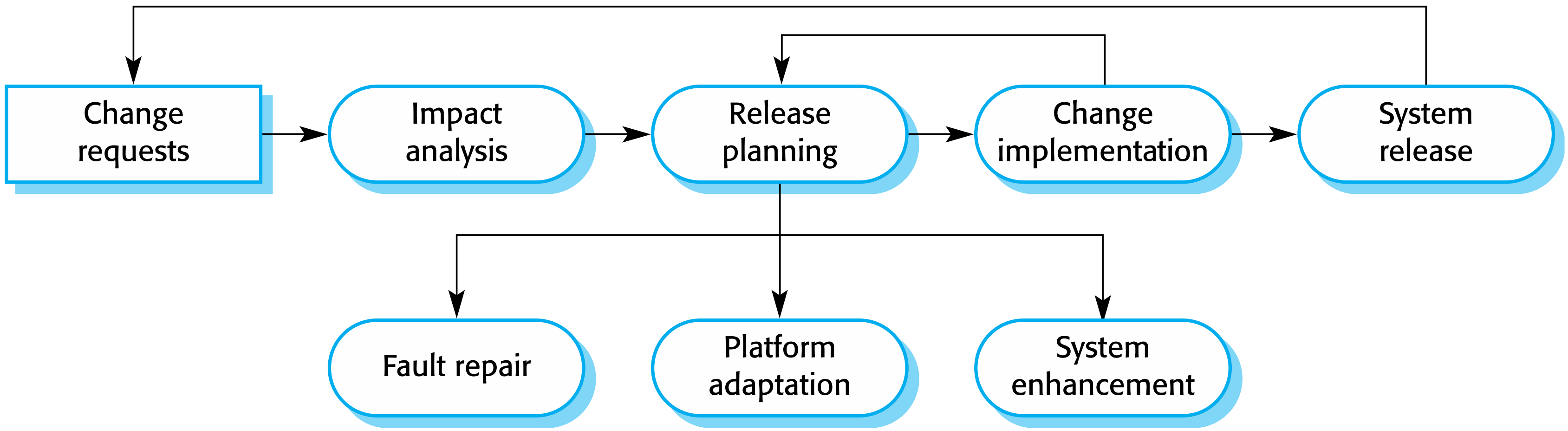
Evolution Processes

- Software evolution processes depend on
  - The type of software being maintained;
  - The development processes used;
  - The skills and experience of the people involved.
- Proposals for change are the driver for system evolution.
  - Should be linked with components that are affected by the change, thus allowing the cost and impact of the change to be estimated.
- Change identification and evolution continues throughout the system lifetime.

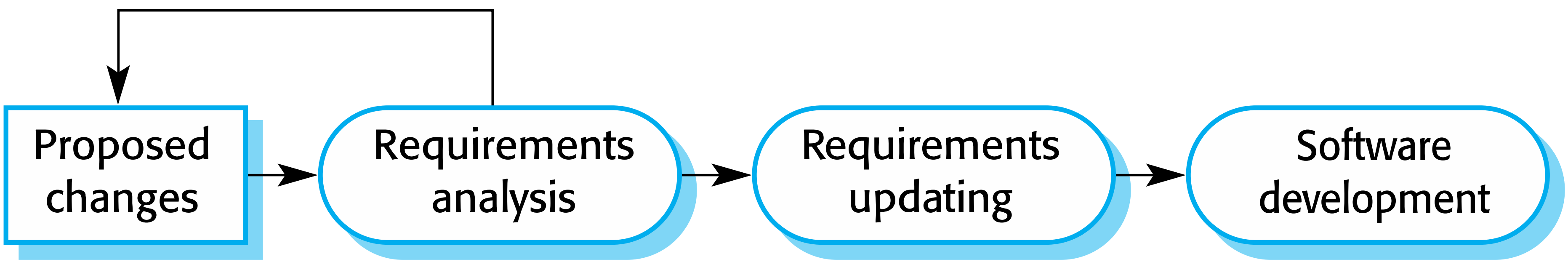
Change Identification and Evolution Processes



The Software Evolution Process



Change Implementation



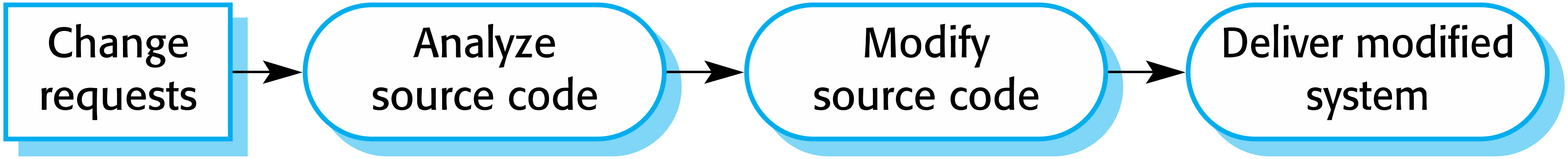
Change Implementation

- Iteration of the development process where the revisions to the system are designed, implemented and tested.
- A critical difference is that the first stage of change implementation may involve program understanding, especially if the original system developers are not responsible for the change implementation.
- If requirements specification and design documents are available, these should be updated during the evolution process to reflect the changes that are required.

Urgent Change Requests

- Urgent changes may have to be implemented without going through all stages of the software engineering process
  - If a serious system fault has to be repaired to allow normal operation to continue;
  - If changes to the system's environment (e.g. an OS upgrade) have unexpected effects;
  - If there are business changes that require a very rapid response (e.g. the release of a competing product).

The Emergency Repair Process



Agile Methods and Evolution

- Agile methods are based on incremental development so the transition from development to evolution is a seamless one.
  - Evolution is simply a continuation of the development process based on frequent system releases.
- Automated regression testing is particularly valuable when changes are made to a system.
- Changes may be expressed as additional user stories.
- Agile methods need to be modified to be used for maintenance and evolution.

Handover Problems

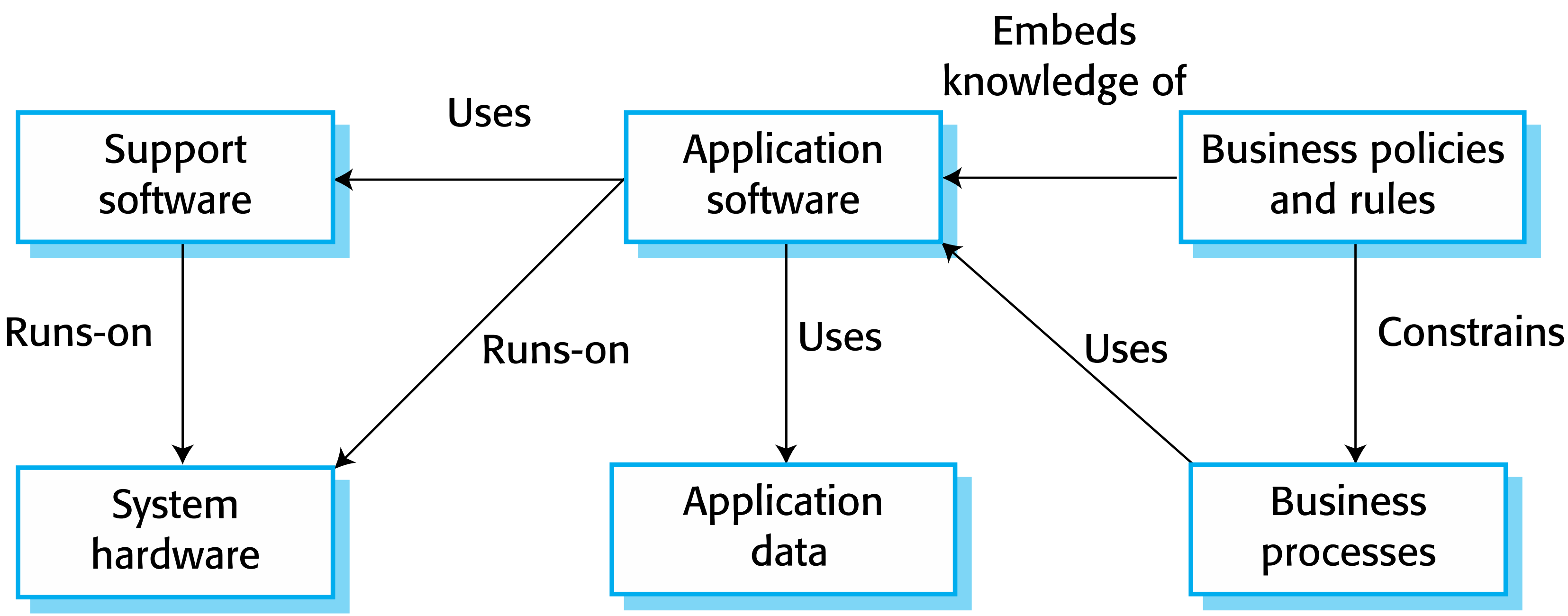
- Where the development team have used an agile approach but the evolution team is unfamiliar with agile methods and prefer a plan-based approach.
  - The evolution team may expect detailed documentation to support evolution and this is not produced in agile processes.
- Where a plan-based approach has been used for development but the evolution team prefer to use agile methods.
  - The evolution team may have to start from scratch developing automated tests and the code in the system may not have been refactored and simplified as is expected in agile development.

Legacy Systems

Legacy Systems

- Legacy systems are older systems that rely on languages and technology that are no longer used for new systems development.
- Legacy software may be dependent on older hardware, such as mainframe computers and may have associated legacy processes and procedures.
- Legacy systems are not just software systems but are broader socio-technical systems that include hardware, software, libraries and other supporting software and business processes.

The Elements of a Legacy System



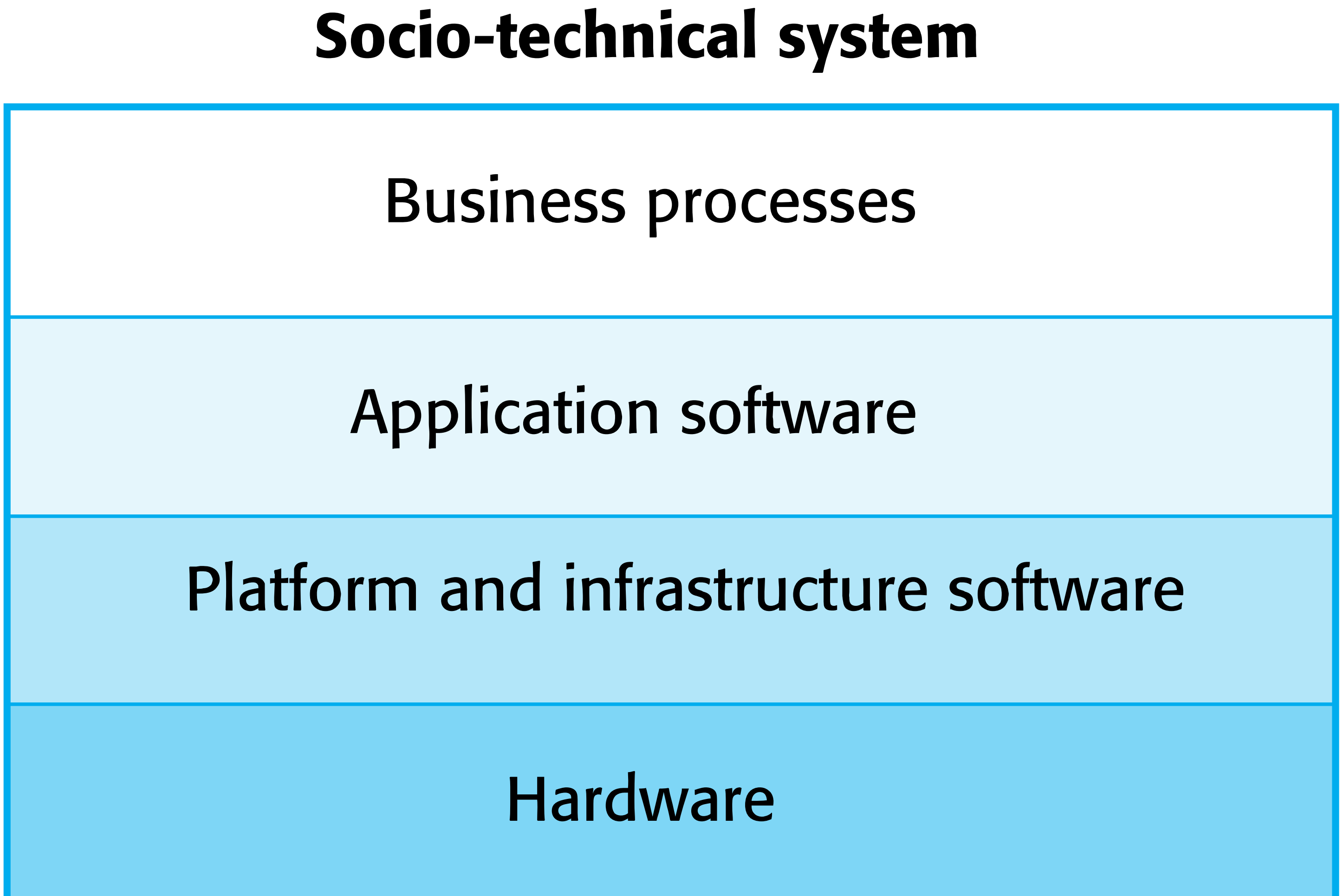
Legacy System Components (1 of 2)

- *System hardware* Legacy systems may have been written for hardware that is no longer available.
- *Support software* The legacy system may rely on a range of support software, which may be obsolete or unsupported.
- *Application software* The application system that provides the business services is usually made up of a number of application programs.
- *Application data* These are data that are processed by the application system. They may be inconsistent, duplicated or held in different databases.

Legacy System Components (2 of 2)

- *Business processes* These are processes that are used in the business to achieve some business objective. Business processes may be designed around a legacy system and constrained by the functionality that it provides.
- *Business policies and rules* These are definitions of how the business should be carried out and constraints on the business. Use of the legacy application system may be embedded in these policies and rules.

Legacy System Layers



Changes in Legacy System

- Changing one layer in the system may introduce new facilities, and higher layers in the system may then be changed to take advantage of these facilities.
- Changing the software may slow the system down so that new hardware is needed to improve the system performance.
- It is often impossible to maintain hardware interfaces, especially if new hardware is introduced.

Legacy System Problems

- Skill shortages
  - There are more than 200 billion lines of COBOL code in current business systems.
- Security vulnerabilities
- The original software tool supplier may be out of business or may no longer maintain the support tools used to develop the system.
- The system hardware may be obsolete and so increasingly expensive to maintain.

Legacy System Replacement

- Legacy system replacement is risky and expensive so businesses continue to use these systems
- System replacement is risky for a number of reasons
  - Lack of complete system specification
  - Tight integration of system and business processes
  - Undocumented business rules embedded in the legacy system
  - New software development may be late and/or over budget

Legacy System Change

- Legacy systems are expensive to change for a number of reasons:
  - No consistent programming style
  - Use of obsolete programming languages with few people available with these language skills
  - Inadequate system documentation
  - System structure degradation
  - Program optimizations may make them hard to understand
  - Data errors, duplication and inconsistency

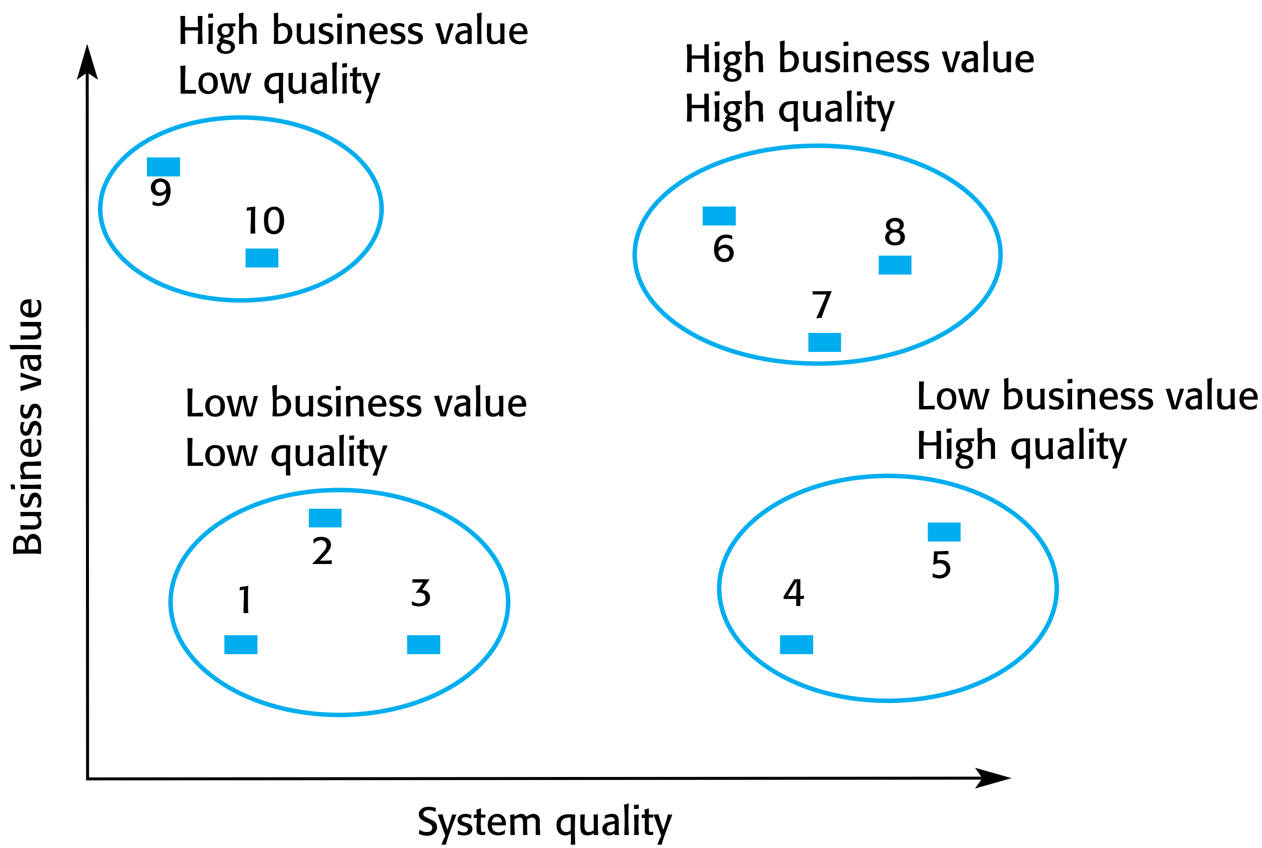
Legacy System Management

- Organisations that rely on legacy systems must choose a strategy for evolving these systems
  - Scrap the system completely and modify business processes so that it is no longer required;
  - Continue maintaining the system;
  - Transform the system by re-engineering to improve its maintainability;
  - Replace the system with a new system.
- The strategy chosen should depend on the system quality and its business value.

Legacy System Assessment

- When you are assessing a legacy system, you have to look at it from both a business perspective and a technical perspective.
  - From a business perspective, you have to decide whether or not the business really needs the system.
  - From a technical perspective, you have to assess the quality of the application software and the system's support software and hardware.
- You then use a combination of the business value and the system quality to inform your decision on what to do with the legacy system.

Figure 9.13 an Example of a Legacy System Assessment



Legacy System Categories

- Low quality, low business value
  - These systems should be scrapped.
- Low-quality, high-business value
  - These make an important business contribution but are expensive to maintain. Should be re-engineered or replaced if a suitable system is available.
- High-quality, low-business value
  - Replace with COTS, scrap completely or maintain.
- High-quality, high business value
  - Continue in operation using normal system maintenance.

Business Value Assessment

- Assessment should take different viewpoints into account
  - System end-users;
  - Business customers;
  - Line managers;
  - IT managers;
  - Senior managers.
- Interview different stakeholders and collate results.

Issues in Business Value Assessment

- The use of the system
  - If systems are only used occasionally or by a small number of people, they may have a low business value.
- The business processes that are supported
  - A system may have a low business value if it forces the use of inefficient business processes.
- System dependability
  - If a system is not dependable and the problems directly affect business customers, the system has a low business value.
- The system outputs
  - If the business depends on system outputs, then the system has a high business value.

System Quality Assessment

- Business process assessment
  - How well does the business process support the current goals of the business?
- Environment assessment
  - How effective is the system’s environment and how expensive is it to maintain?
- Application assessment
  - What is the quality of the application software system?

Business Process Assessment

- Use a viewpoint-oriented approach and seek answers from system stakeholders
  - Is there a defined process model and is it followed?
  - Do different parts of the organisation use different processes for the same function?
  - How has the process been adapted?
  - What are the relationships with other business processes and are these necessary?
  - Is the process effectively supported by the legacy application software?

Factors Used in Environment Assessment

Factor	Questions
Supplier stability	Is the supplier still in existence? Is the supplier financially stable and likely to continue in existence? If the supplier is no longer in business, does someone else maintain the systems?
Failure rate	Does the hardware have a high rate of reported failures? Does the support software crash and force system restarts?
Age	How old is the hardware and software? The older the hardware and support software, the more obsolete it will be. It may still function correctly but there could be significant economic and business benefits to moving to a more modern system.
Performance	Is the performance of the system adequate? Do performance problems have a significant effect on system users?

Factors Used in Environment Assessment

Factor	Questions
Support requirements	What local support is required by the hardware and software? If there are high costs associated with this support, it may be worth considering system replacement.
Maintenance costs	What are the costs of hardware maintenance and support software licences? Older hardware may have higher maintenance costs than modern systems. Support software may have high annual licensing costs.
Interoperability	Are there problems interfacing the system to other systems? Can compilers, for example, be used with current versions of the operating system? Is hardware emulation required?

Factors Used in Application Assessment

Factor	Questions
Understandability	How difficult is it to understand the source code of the current system? How complex are the control structures that are used? Do variables have meaningful names that reflect their function?
Documentation	What system documentation is available? Is the documentation complete, consistent, and current?
Data	Is there an explicit data model for the system? To what extent is data duplicated across files? Is the data used by the system up to date and consistent?
Performance	Is the performance of the application adequate? Do performance problems have a significant effect on system users?

Factors Used in Application Assessment

Factor	Questions
Programming language	Are modern compilers available for the programming language used to develop the system? Is the programming language still used for new system development?
Configuration management	Are all versions of all parts of the system managed by a configuration management system? Is there an explicit description of the versions of components that are used in the current system?
Test data	Does test data for the system exist? Is there a record of regression tests carried out when new features have been added to the system?
Personnel skills	Are there people available who have the skills to maintain the application? Are there people available who have experience with the system?

System Measurement

- You may also collect quantitative data to make an assessment of the quality of the application system
  - *The number of system change requests*; The higher this accumulated value, the lower the quality of the system.
  - *The number of different user interfaces used by the system*; The more interfaces, the more likely it is that there will be inconsistencies and redundancies in these interfaces.
  - *The volume of data used by the system*. As the volume of data (number of files, size of database, etc.) processed by the system increases, so too do the inconsistencies and errors in that data. Cleaning up old data is a very expensive and time-consuming process

Software Maintenance

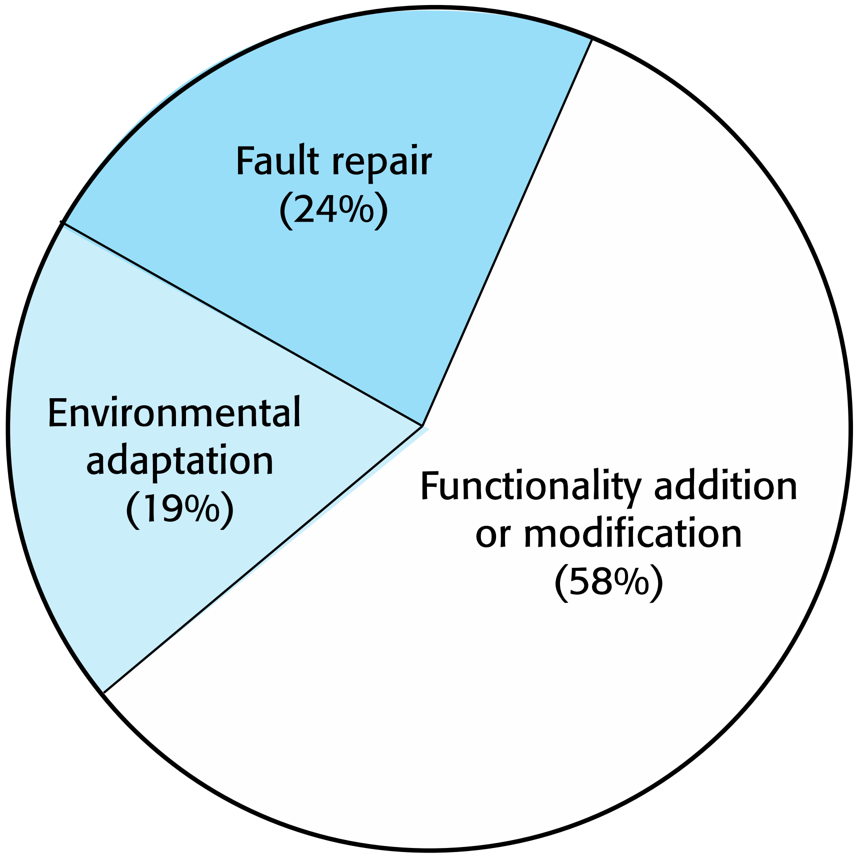
Software Maintenance

- Modifying a program after it has been put into use.
- The term is mostly used for changing custom software. Generic software products are said to evolve to create new versions.
- Maintenance does not normally involve major changes to the system’s architecture.
- Changes are implemented by modifying existing components and adding new components to the system.

Types of Maintenance

- Fault repairs
  - Changing a system to fix bugs/vulnerabilities and correct deficiencies in the way meets its requirements.
- Environmental adaptation
  - Maintenance to adapt software to a different operating environment
  - Changing a system so that it operates in a different environment (computer, OS, etc.) from its initial implementation.
- Functionality addition and modification
  - Modifying the system to satisfy new requirements.

Maintenance Effort Distribution



Maintenance Costs

- Usually greater than development costs (2* to 100* depending on the application).
- Affected by both technical and non-technical factors.
- Increases as software is maintained. Maintenance corrupts the software structure so makes further maintenance more difficult.
- Ageing software can have high support costs (e.g. old languages, compilers etc.).

Maintenance Costs

- It is usually more expensive to add new features to a system during maintenance than it is to add the same features during development
  - A new team has to understand the programs being maintained
  - Separating maintenance and development means there is no incentive for the development team to write maintainable software
  - Program maintenance work is unpopular
    - Maintenance staff are often inexperienced and have limited domain knowledge.
  - As programs age, their structure degrades and they become harder to change

Maintenance Costs

- In principle, it is almost always cost-effective to invest effort in designing and implementing a system to reduce the costs of future changes.
- Good software engineering techniques such as precise specification, test-first development, the use of object-oriented development, and configuration management all help reduce maintenance cost.
- These principled arguments for lifetime cost savings by investing in making systems more maintainable are, unfortunately, impossible to substantiate with real data.

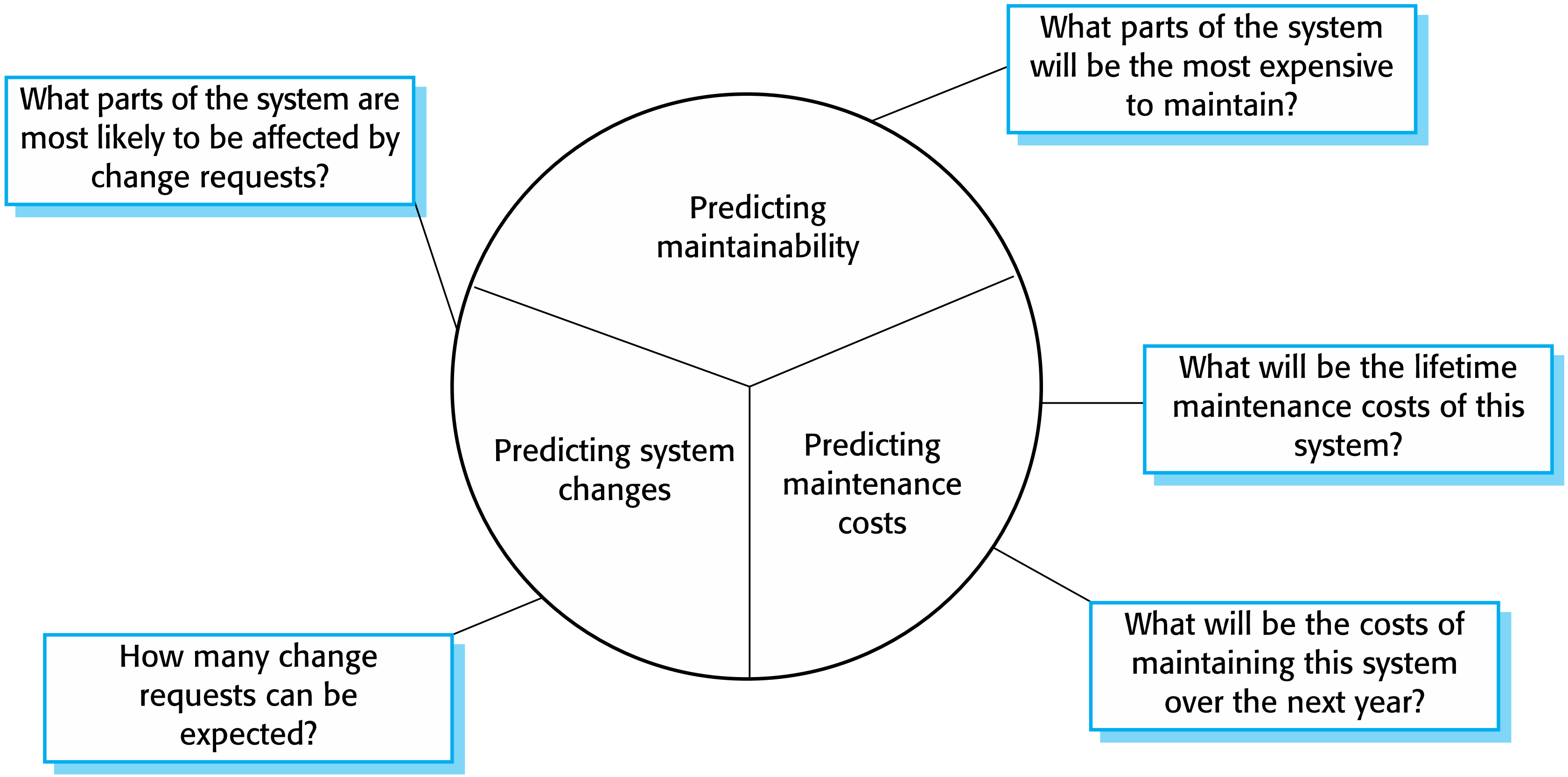
Maintenance Costs

- In reality, most businesses are reluctant to spend more on software development to reduce longer-term maintenance costs. There are two main reasons for their reluctance:
  - Investing in maintainability leads to short-term cost increases, which are measurable. However, the long-term gains can’t be measured at the same time.
  - Developers are not usually responsible for maintaining the system they have developed.

Maintenance Prediction

- Maintenance prediction is concerned with assessing which parts of the system may cause problems and have high maintenance costs
  - Change acceptance depends on the maintainability of the components affected by the change;
  - Implementing changes degrades the system and reduces its maintainability;
  - Maintenance costs depend on the number of changes and costs of change depend on maintainability.

Maintenance Prediction



Change Prediction

- Predicting the number of changes requires and understanding of the relationships between a system and its environment.
- Tightly coupled systems require changes whenever the environment is changed.
- Factors influencing this relationship are
  - Number and complexity of system interfaces;
  - Number of inherently volatile system requirements;
  - The business processes where the system is used.

Complexity Metrics

- Predictions of maintainability can be made by assessing the complexity of system components.
- Studies have shown that most maintenance effort is spent on a relatively small number of system components.
- Complexity depends on
  – Complexity of control structures;
  – Complexity of data structures;
  – Object, method (procedure) and module size.

Process Metrics

- Process metrics may be used to assess maintainability
  - Number of requests for corrective maintenance;
  - Average time required for impact analysis;
  - Average time taken to implement a change request;
  - Number of outstanding change requests.
- If any or all of these is increasing, this may indicate a decline in maintainability.

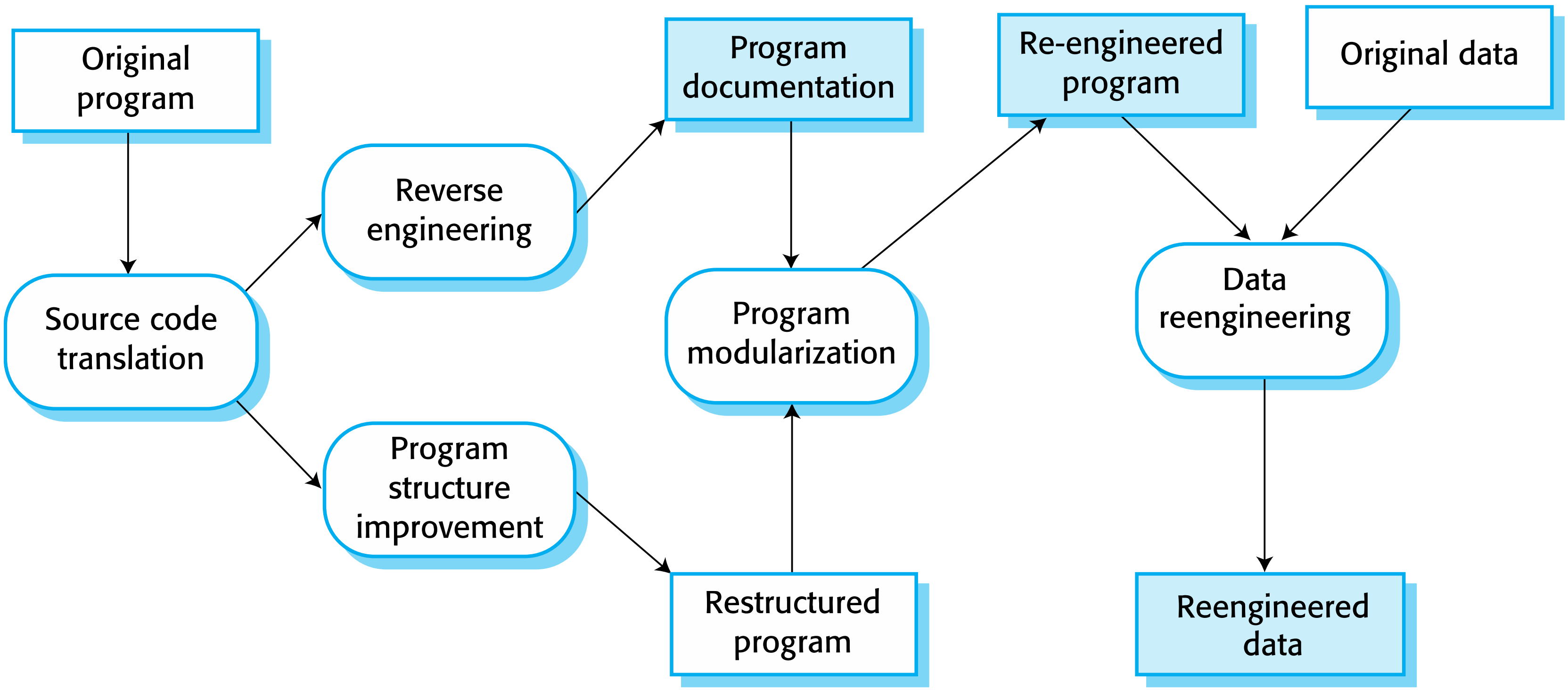
Software Reengineering

- To make legacy software systems easier to maintain, you can reengineer these systems to improve their structure and understandability.
- Reengineering may involve
  - redocumenting the system
  - refactoring the system architecture
  - translating programs to a modern programming language
  - modifying and updating the structure and values of the system's data

Advantages of Reengineering

- Reduced risk
  - There is a high risk in new software development. There may be development problems, staffing problems and specification problems.
- Reduced cost
  - The cost of re-engineering is often significantly less than the costs of developing new software.

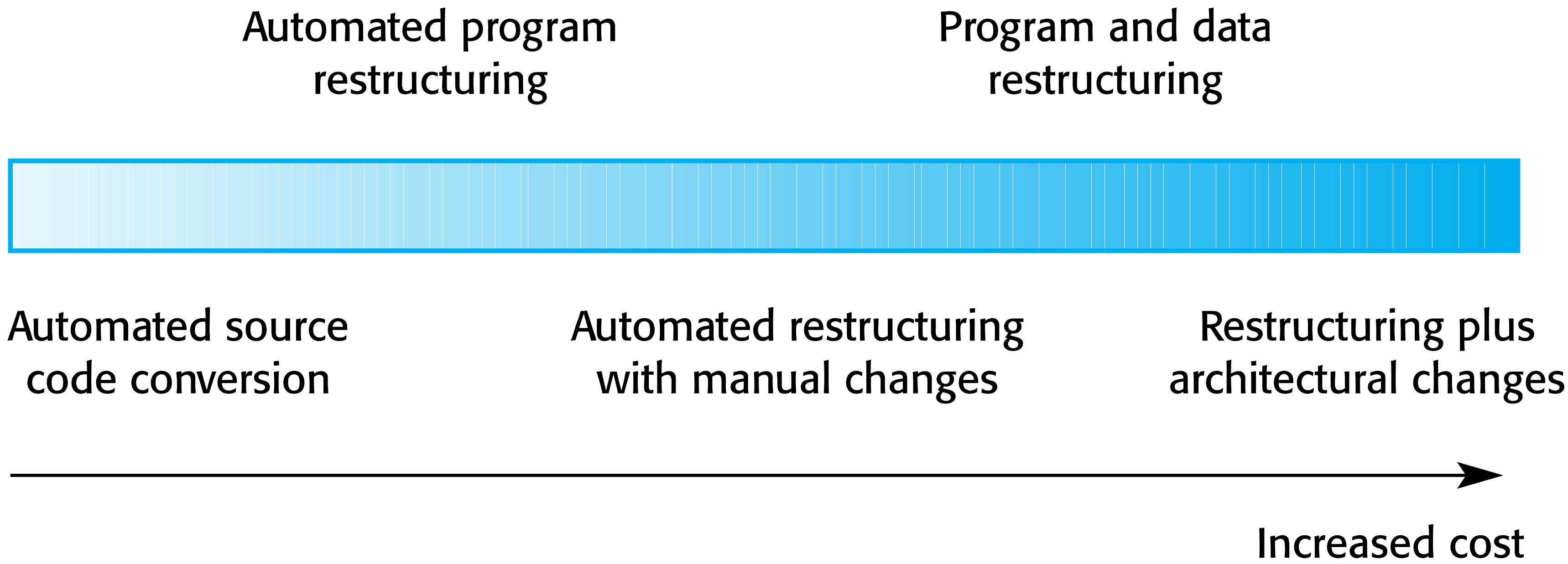
The Reengineering Process



Reengineering Process Activities

- Source code translation
  - Convert code to a new language.
- Reverse engineering
  - Analyze the program to understand it;
- Program structure improvement
  - Restructure automatically for understandability;
- Program modularization
  - Reorganize the program structure;
- Data reengineering
  - Clean-up and restructure system data.

Reengineering Approaches



Reengineering Cost Factors

- The quality of the software to be reengineered.
- The tool support available for reengineering.
- The extent of the data conversion which is required.
- The availability of expert staff for reengineering.
  - This can be a problem with old systems based on technology that is no longer widely used.

Refactoring

- Refactoring is the process of making improvements to a program to slow down degradation through change.
- Refactoring involves modifying a program to improve its structure, reduce its complexity or make it easier to understand.
- When you refactor a program, you should not add functionality but rather concentrate on program improvement.
- You can think of refactoring as ‘preventative maintenance’ that reduces the problems of future change.

Refactoring and Reengineering

- Re-engineering takes place after a system has been maintained for some time and maintenance costs are increasing. You use automated tools to process and re-engineer a legacy system to create a new system that is more maintainable.
- Refactoring is a continuous process of improvement throughout the development and evolution process. It is intended to avoid the structure and code degradation that increases the costs and difficulties of maintaining a system.

‘Bad smells’ in Program Code (1 of 2)

- Duplicate code
  - The same or very similar code may be included at different places in a program. This can be removed and implemented as a single method or function that is called as required.
- Long methods
  - If a method is too long, it should be redesigned as a number of shorter methods.
- Switch (case) statements
  - These often involve duplication, where the switch depends on the type of a value. The switch statements may be scattered around a program. In object-oriented languages, you can often use polymorphism to achieve the same thing.

‘Bad smells’ in Program Code (2 of 2)

- Data clumping
  - Data clumps occur when the same group of data items (fields in classes, parameters in methods) re-occur in several places in a program. These can often be replaced with an object that encapsulates all of the data.
- Speculative generality
  - This occurs when developers include generality in a program in case it is required in the future. This can often simply be removed.

Key Points (1 of 3)

- Software development and evolution can be thought of as an integrated, iterative process that can be represented using a spiral model.
- For custom systems, the costs of software maintenance usually exceed the software development costs.
- The process of software evolution is driven by requests for changes and includes change impact analysis, release planning and change implementation.
- Legacy systems are older software systems, developed using obsolete software and hardware technologies, that remain useful for a business.

Key Points (2 of 3)

- It is often cheaper and less risky to maintain a legacy system than to develop a replacement system using modern technology.
- The business value of a legacy system and the quality of the application should be assessed to help decide if a system should be replaced, transformed or maintained.
- There are 3 types of software maintenance, namely bug fixing, modifying software to work in a new environment, and implementing new or changed requirements.

Key Points (3 of 3)

- Software re-engineering is concerned with re-structuring and re-documenting software to make it easier to understand and change.
- Refactoring, making program changes that preserve functionality, is a form of preventative maintenance.

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