CIOB
THE CHARTERED INSTITUTE OF BUILDING

Guide to **Quality Management** in Construction: **Site Production and Assembly**

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Foreword

The management of quality in project delivery is a challenge for all firms involved in design, manufacturing, and site production, whether they are large or small. The construction industry is under pressure to build more complex projects, safely, with the minimum disruption to the general public.

The old world was about balancing cost, time and quality; the new world is more wide-ranging. Safety and health of the workforce is paramount, alongside respecting the environment and the workforce. Delivering value for money for the customers and clients is critical.

Quality matters - it is the legacy that underpins a modern, innovative, and respected construction industry. Quality is at the core of everything the construction industry does, whether delivering projects with zero defects, ensuring conformity with standards and legislation, or providing the level of service provided. Culture and behaviour underpin the delivery of a quality product.

There are many great quality construction projects delivered to happy clients. Some projects occasionally do not meet customer expectations, so we must never be complacent, by learning from both the best and where we can do better.

My belief is that every organisation has two bank accounts; the financial account and the reputational account, and that they are interdependent. Both accounts matter - there should be deposits in both accounts. The construction industry must strive for excellence and to engage in continuous improvement. Customers are at the core of everything that the construction industry does. Continuous improvement will lead to happy customers and add to the reputation.

The CIOB has committed to promoting best practice and providing better education and training on quality management, both for our members and the wider construction community. The Guide to Best Practice Quality Management aims to raise standards by providing the tools and processes to help in the delivery of quality on construction projects. It is not about increasing bureaucracy and paperwork; it is about looking at how the industry can continuously improve.

Let's move forward together as an industry and ensure we delight our customers and exceed their expectations.

Mark Beard

CIOB President

Message from the **Chief Executive**

The CIOB is on a journey to add value by focusing on quality in the construction industry. Everyone involved with delivering projects, big or small, new or refurbishment, must ensure the construction industry is capable of delivering consistent and high-quality projects. Customers want the best quality. Many organisations already deliver great quality.

The CIOB wants quality management to be uppermost in the mind of its members and the industry at large.

The Quality Management Best Practice Guide has been underpinned by previous CIOB quality initiatives. It includes a framework outlining the steps to improve, maintain and sustain good construction quality management. It will be of particular interest to SMEs and those starting out in the industry.

Communication, collaboration, culture, competencies, continuous improvement, and conformance – the Six Cs - are key ingredients to successful quality management in a rapidly changing world with increasing risk, complexity, and legislation. Technology is a tool that can enable the 6Cs.

Thanks to Paul Nash, Eddie Tuttle, Roger Flanagan and Carol Jewell for bringing this work to reality. Thanks also go to the many CIOB members who have provided comments and suggestions.

The CIOB will continue to promote and develop tools to improve quality management in the construction industry. The Guide is a first step of an ongoing journey.

Caroline Gumble

Chief Executive of the CIOB

Acknowledgements

Contributors

Thank you to the CIOB members who gave their time to respond to the Call for Evidence and gave their expertise for the many iterations of the Guide. Our thanks also go to the many people in the industry that gave their comments and views on the practicalities of quality management on site and their examples of best practice.

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BEST PRACTICE GUIDE
FOR CONSTRUCTION QUALITY MANAGEMENT:

Site Production and Assembly

An Overview

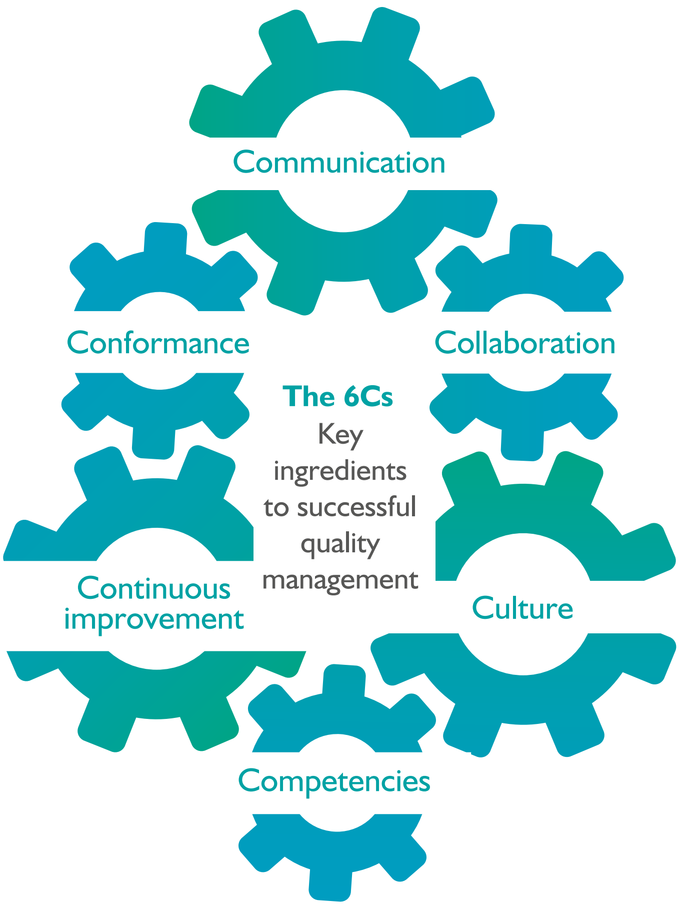
The Guide provides a single point of information on construction quality management (QM) to establish best practice for site production and assembly.

The Focus is on how quality management is achieved

during the site production process: including the requirements for quality management through the supply chain.

Quality Matters

- Quality issues are uppermost in the mind of the client
- Time, cost, quality along with health and safety, are the bedrock of the industry
- A quality product is about providing added value for the user
- Quality means more efficient use of resources, saving time, money, and the environment
- Good quality means durability, desirability and good value



Delivering Quality

Quality embraces culture, attitudes, behaviour, competencies, training, and conformance. They are all important, and so is having the right data and information on time and communicating it effectively. Project quality requirements must be clear at the project outset from inception, through design, and into production.

Business Interruption

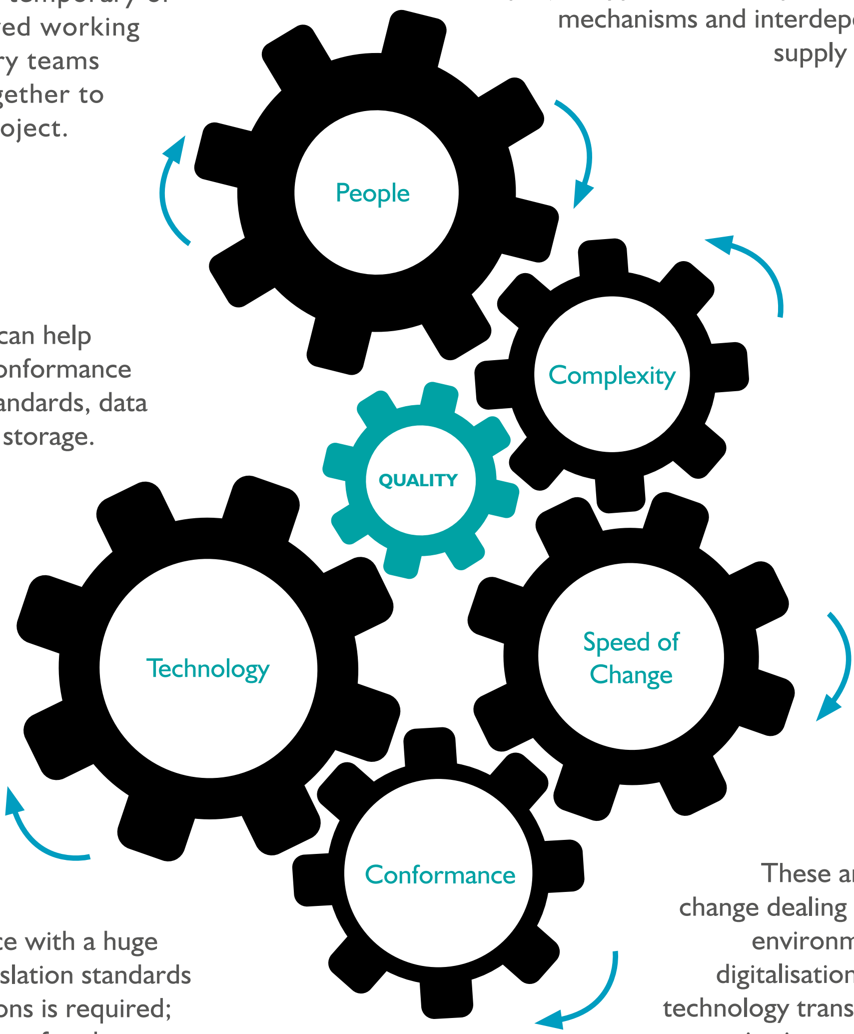
The cost of failure can be high if a construction project goes wrong and it can have serious consequences with business interruption. Loss of reputation helps nobody. The project bank account and the reputation account are equally important.

What is transforming quality in the construction sector?

The workers can be permanent, temporary or self-employed working in temporary teams brought together to deliver a project.

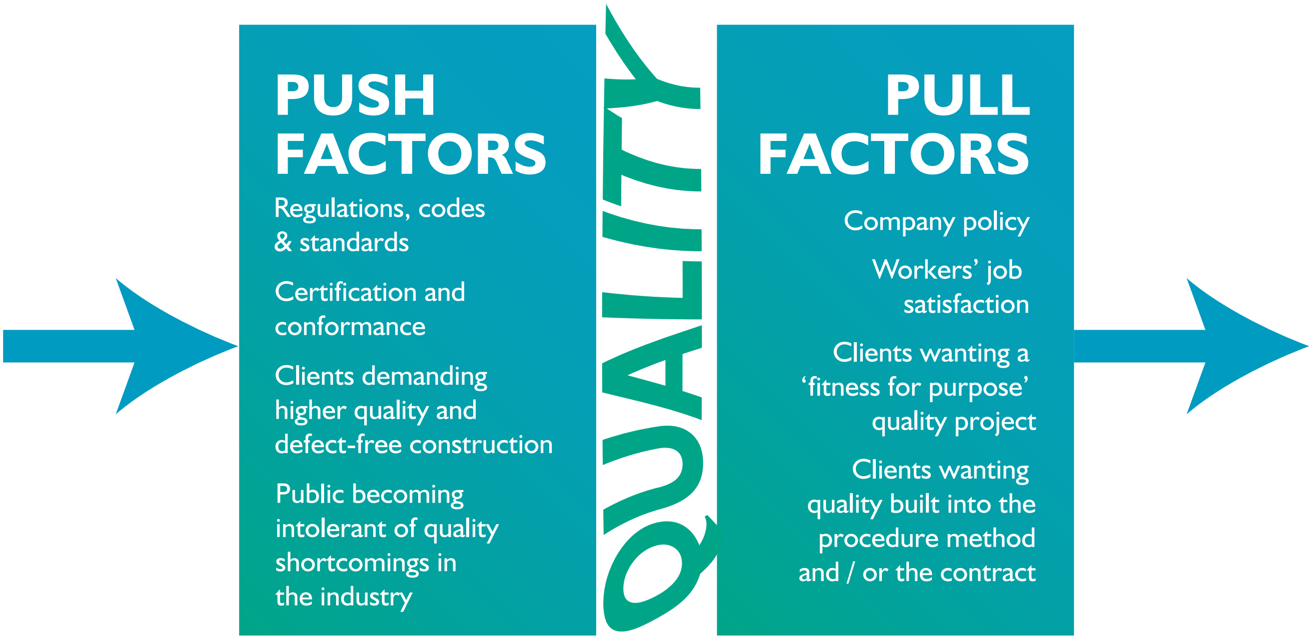
The construction sector is complex, with a proliferation of different project types, different procurement mechanisms and interdependent supply chains.

Technology can help guarantee conformance to quality standards, data capture and storage.



Conformance with a huge range of legislation standards and regulations is required; with checking often by independent inspectors.

These are times of rapid change dealing with pandemics, environmental challenges digitalisation, legislation, and technology transforming the way organisations communicate and operate.



"Quality issues need to be treated in the same way health and safety is managed, with clear ownership of the results, good lines of communication, good training, effective supervision, and robust reporting mechanisms."

The Best Practice Guide builds upon a number of initiatives (in construction and other industries) and the BS EN ISO 9000 family of QM standards. It explains how quality management is integrated into company policy and the difference between quality control, and quality assurance. Guidance is given on the role of the quality manager / clerk of works, the basics of construction quality management, and the actions needed to achieve it.

What's in the Guide?

"I am a small enterprise, I provide good quality but cannot afford the time and cost of having all the documentation. I haven't the time to learn all the new technologies to manage the paperwork."

Putting quality into context

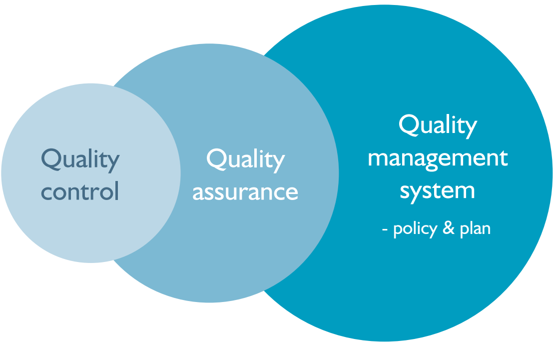
Quality management is becoming one of the most important issues for construction.

Everyone should be intolerant of poor quality.

Quality needs to be defined at the outset of a project.

Quality management is not about paperwork, it is about ensuring happy customers and conformance.

Quality is a project's legacy, it's what's left behind.



Quality management systems - the basics

A quality management system is devised to deliver a quality project or service to the highest possible standard. It provides a framework for planning, executing, monitoring and improving the performance of quality management activites in an organisation.

Construction involves numerous linked activites. The QM system has to reflect this dependency on consultants delivering information on time to the right quality, suppliers delivering materials as promised, and specialty companies meeting their performance promises.

The quality policy establishes, implements and maintains the vision and values for incorporating quality into the culture of the business. The policy must be communicated, understood, and applied within the organisation.

Quality management systems - principles of good practice

The importance of ISO standards for quality management and the applicability to construction.

The CIOB quality framework embodies best practice for site production and assembly.

The framework shows a set of cogs, driven at the top by the client / customer. Whilst the client is uppermost, many parties affect the delivery of quality.

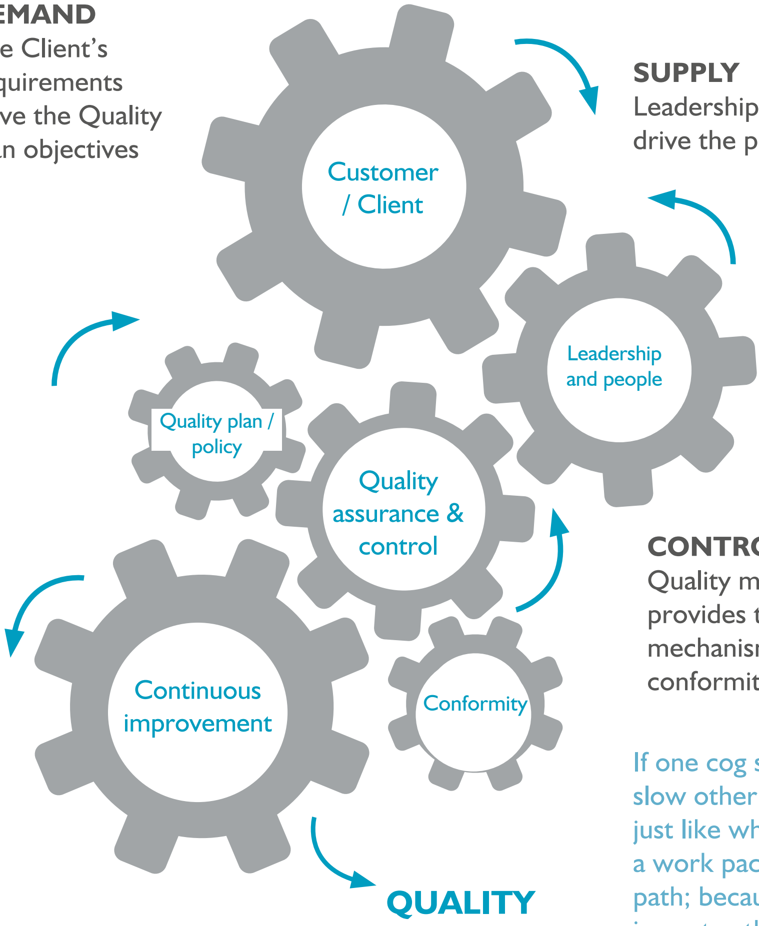
★★★★★

ISO 9001 is about the why, and what, not about how - that is where good contractors come in. Regardless of the size, the nature of business or the industry sector; the ISO 9000 family of standards is a generic management system which has evolved through the years and can apply to any organisation.

ISO 9001 doesn't build the project, it is the people with the right competencies and a contentious attitude to quality.

The CIOB Construction Quality Framework

The cogs demonstrate the interconnectedness and interdependency of site production. Each cog is reliant on the others to maintain momentum.



DEMAND
The Client's requirements drive the Quality Plan objectives

SUPPLY
Leadership and people drive the process.

PLAN
The Quality Plan is an important driver in achieving good quality management. The focus is on collaboration for success. The Plan must communicate what is expected and required.

The role of the mechanical cog, with teeth on a wheel or gear, is to engage with other teeth to transmit or receive motion.

CONTROL
Quality management provides the control mechanism to ensure conformity.

FEEDBACK
Continuous improvement delivers quality and drives the feedback loop.

If one cog slows down it can slow other interconnected cogs, just like when there is failure of a work package on the critical path; because it is critical, it impacts other trade packages.

The framework is impacted by internal and external environments

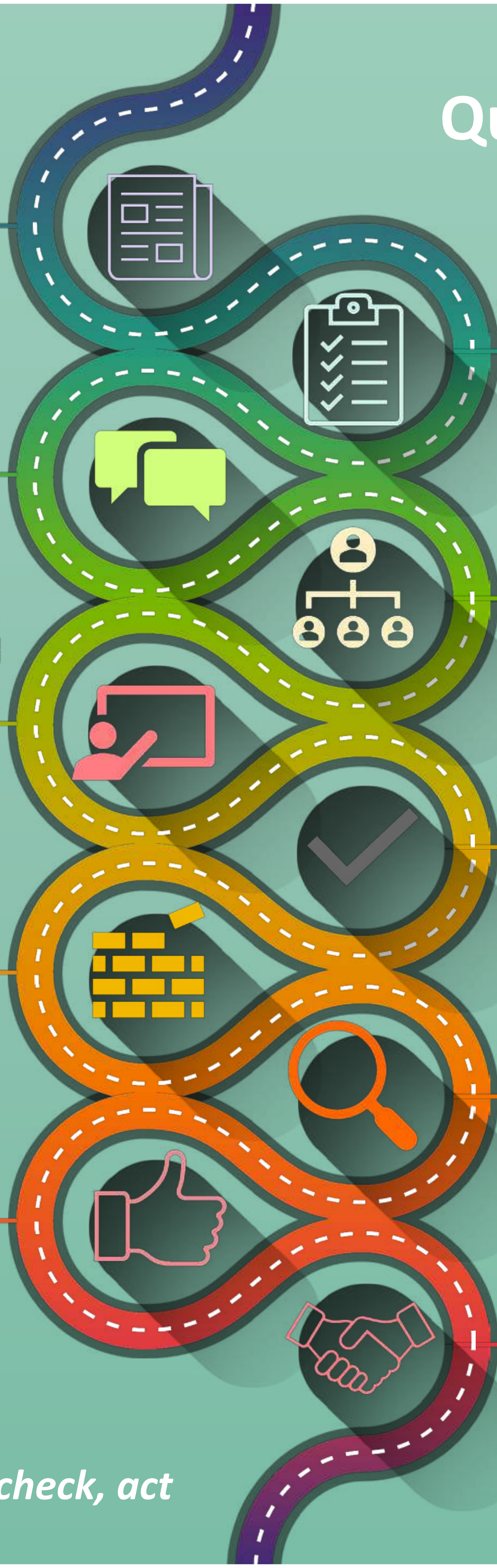
- Business
- Green / sustainable
- Social
- Professional
- Governance / regulation
- Political
- Technology / digital
- Contractual

Tender Translation

At the tender stage the principal contractor and all stakeholders must interpret the quality requirements for the project. Some tender documents can be vague about quality requirements; correctly interpreting the expectations of the client and design team is paramount.

Quality expectations must be clearly defined to ensure reliable tender translation for quality. Too often, failure occurs at the tender stage when incorrect assumptions are made about quality requirements.

Quality Plan



Background Information

- Client
- Project name and location
- Project description

Company Quality Policy

- Aims
- Objectives
- Quality Targets
- Performance

Project co-ordination & communication

- Hierarchy
- Lines of responsibility
- Communication plan

Project QM personnel

- Name and job title
- Qualifications
- Competencies
- Experience
- Duties and responsibilities

Quality training

- Site induction processes
- Specific component / process training
- Quality control and assurance skills

Codes, standards. compliance

- Relevant codes, standards & planning conditions
- Non-conformance reporting/prevention

Materials and off-site production

- Submitting process
- Traceability
- QC and QA procedures
- Unloading
- Storage
- Certifications

Inspection and testing

- Inspection plan
- Test equipment calibration
- Monitoring and measurement

Project assurance

- Quality audits
- Documentation on QA
- Meeting contractual quality requirements

Handover & Feedback

- Snagging list
- Details of sealed areas
- Details of close-down meetings
- As-built information
- Partial completion requirements

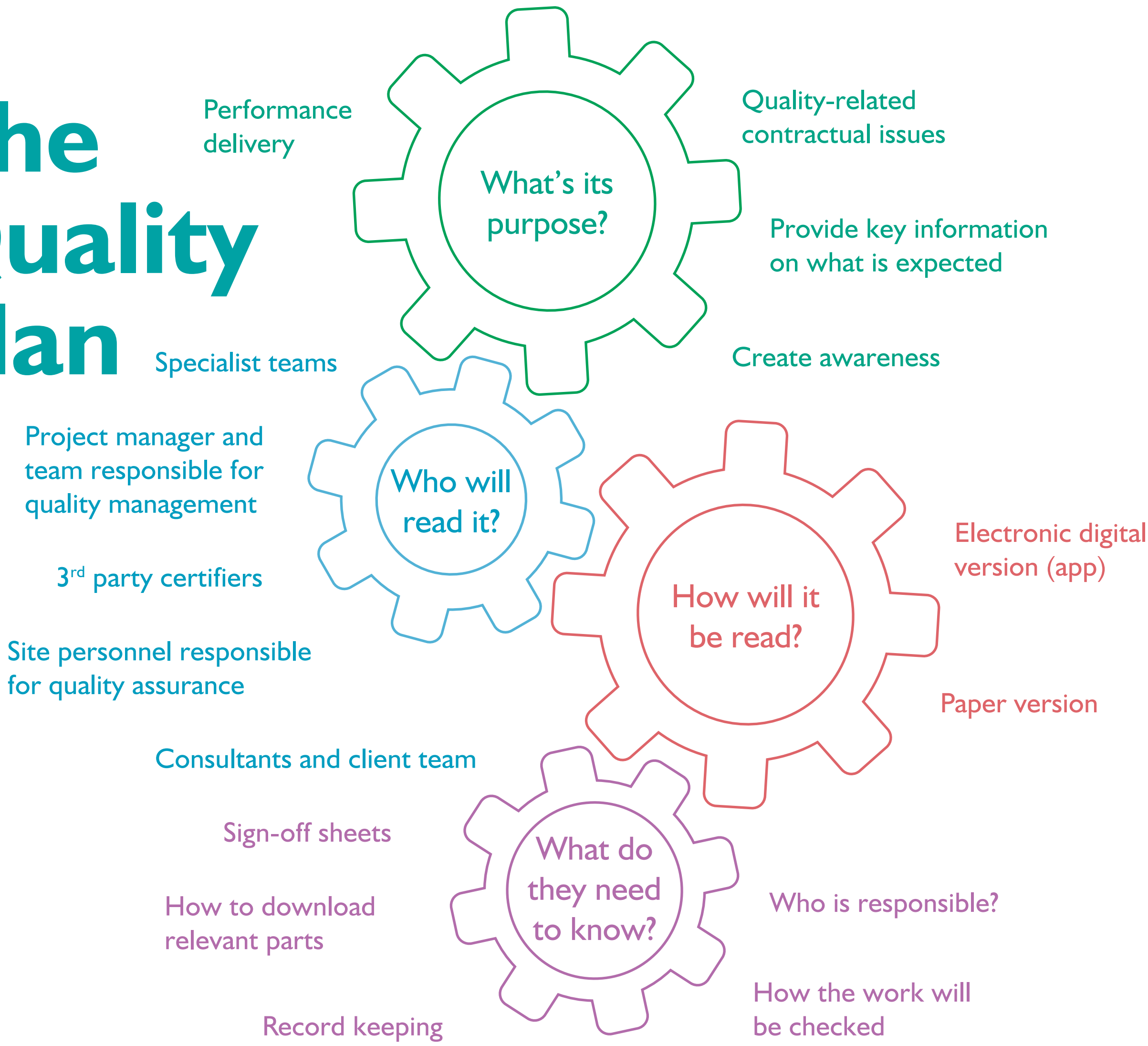
Plan, do, check, act

The **quality policy** establishes, and sets the strategic vision and values for incorporating quality into the culture of the business. Leadership is crucial to ensure commitment.

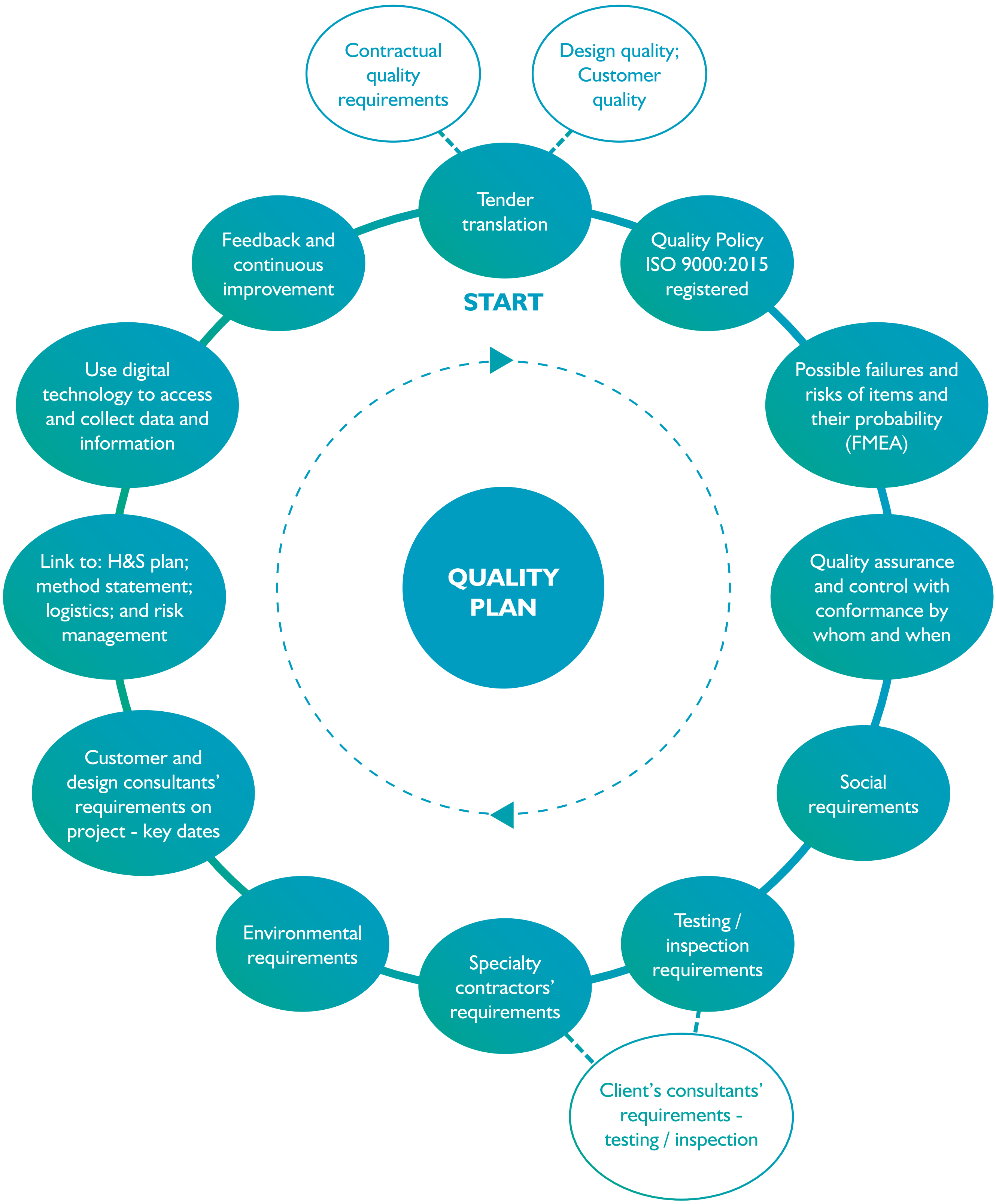
The **quality plan** identifies critical success factors and metrics by which success can be measured. Each plan is unique, based upon project requirements. Be clear about how the site team interprets the requirements.

Integrating the plan across the project with other plans, such as the health and safety, risk, logistics plan, and the method statement.

The Quality Plan



The ingredients of a good Quality Plan



Drivers, Disruptors, Enablers & Actions

There are disruptors and enablers that will either slow up the 'cogs' or make them run more smoothly. Modern management requires structure and a systems approach, so identifying the threats and opportunities from the disruptors and enablers requires planned actions.

Examples of these are given in the Guide using global drivers as the catalyst.

In a construction quality cog system, there are:

- **Drivers** (the client, the management and conformance)
- **Disruptors** (e.g. design changes and lack of communication)
- **Enablers** (e.g. leadership, people and technology)
- **Actions** (e.g. Quality Plan, inspection and monitoring)

DRIVERS

- Client / customer requirements
- Increasing legislation on quality requirements
- Importance of reputation to secure future work
- Requirements on proven quality included in framework agreements

ISSUES

- More stringent codes and standards
- Litigation when defects cause loss and expense
- Client expecting higher quality and intolerance to defects
- Long supply chains with differing expectations of quality

DISRUPTORS

- Excessive paperwork and tick boxes
- Lack of clarity - tender documents' requirements
- Reduction in professional fees putting pressure on design consultants
- Unreasonable contract terms and conditions
- Unrealistic time and cost budgets to meet quality requirements
- Constant change at the site production stage
- Re-work

ENABLERS

- Digital technology
- Culture of quality
- BS EN ISO certification
- Training
- Realistic time allocated for the tasks
- Get it right first time

ACTIONS

- Improve quality training
- Empower / motivate employees to embrace quality ethos
- Deliver on the 6Cs

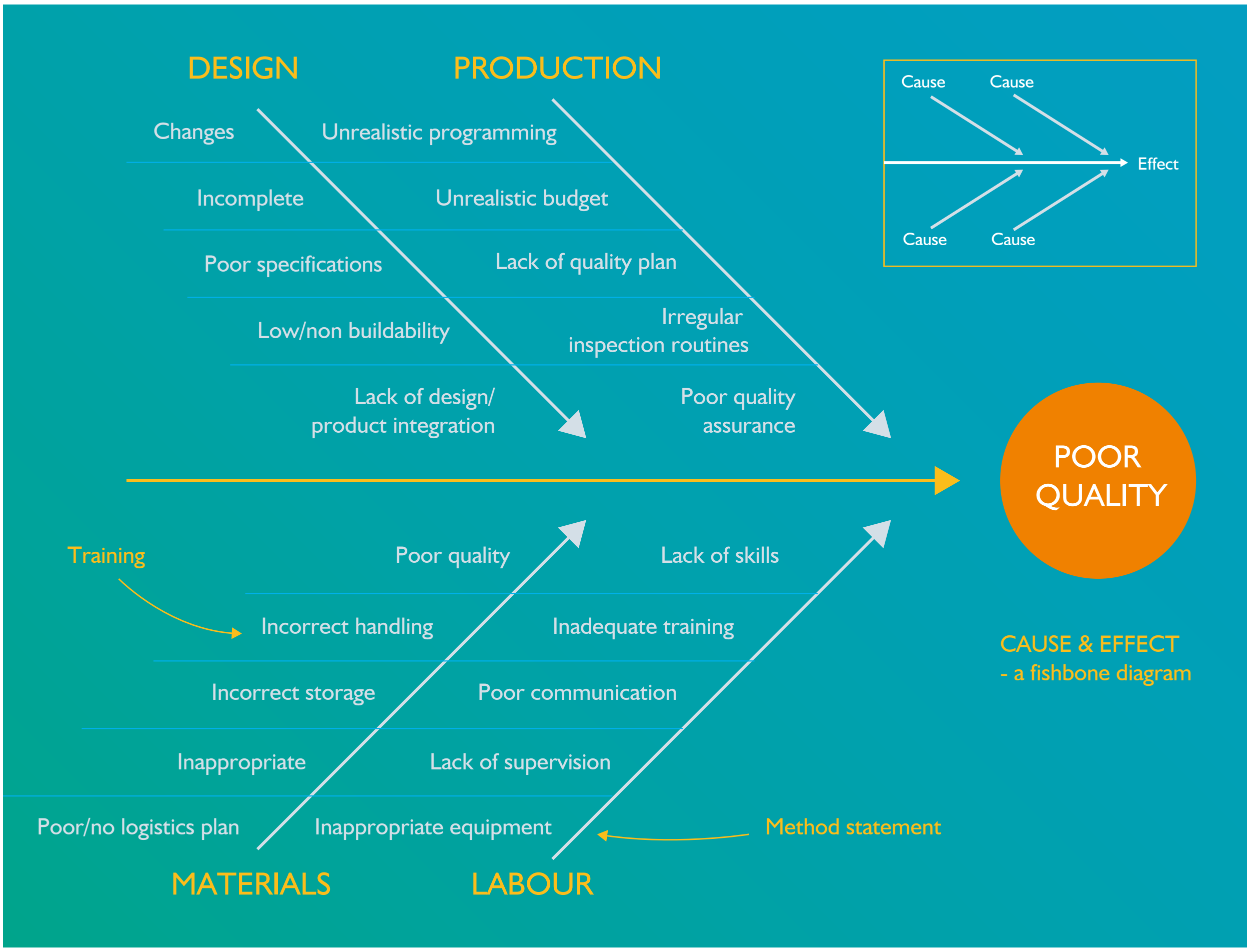
"The people in suits don't talk enough to the people in boots!"

Quality management tools and techniques

Tools and techniques are the means to implement quality management systems.

Many QM tools and systems are available, from straightforward check sheets and histograms to cause-and-effect analysis and matrices.

Tools can solve problems; for example, brainstorming can highlight relevant issues, pulling together ideas and information from a group of team members.



Technology and digitalisation have a role to play with new ways of capturing information using shared information platforms and collaboration tools.

Digitalisation is the enabler for data collection communication and real-time information.

Automatic data idenfication (Auto-ID) and collection can be achieved through a set of methods, technologies and devices such as bar code readers, radio frequency identification (RFID) magnetic stripe cards / readers and optical memory cards. The captured information is entered into a computer system without direct human involvement.

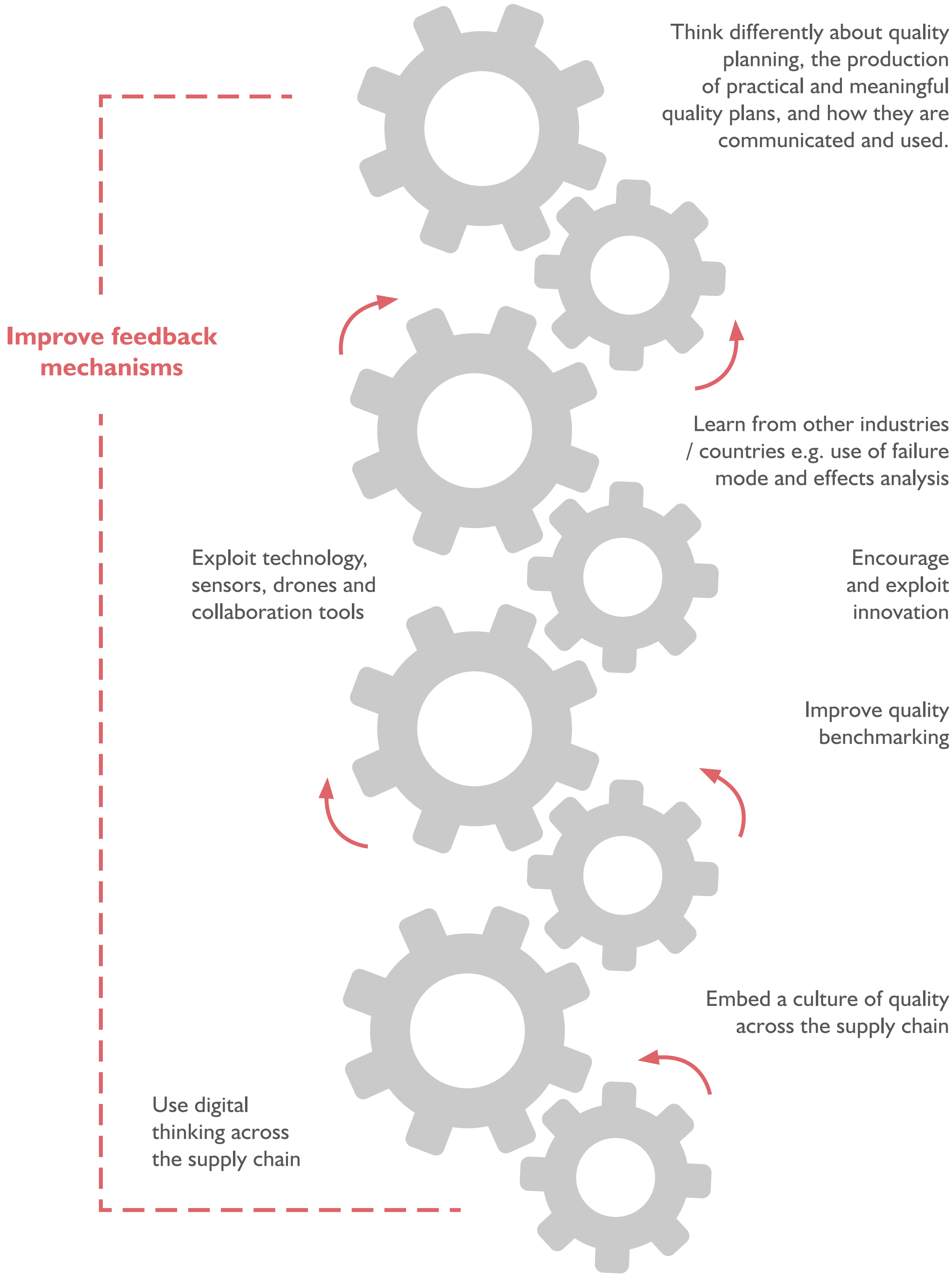
Structure of the Guide

THE ROAD TO QUALITY

Section

Putting Quality into Context

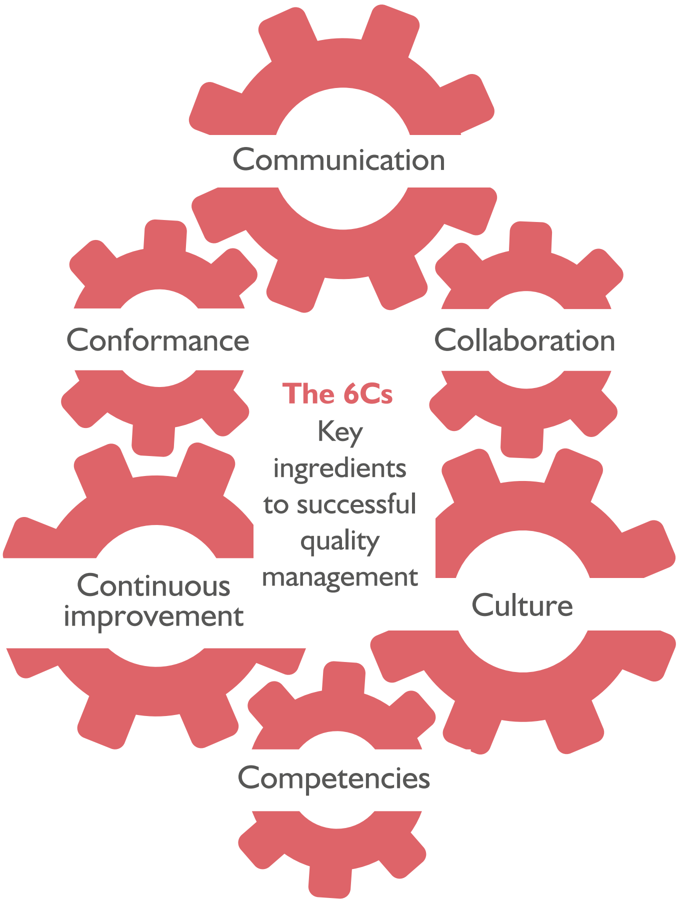
How quality can be improved



1.1 Introduction

The aim is to provide project stakeholders with a single point of information on construction quality management to improve construction quality, by establishing best practice for the quality management process for site production and assembly.

The main focus is on how quality management is achieved during the site production process, including the requirements for ensuring quality is managed through the supply chain. A transformation and improvement challenge is needed to bring quality to the fore for the construction industry. Quality engineering should be an integral part of the construction industry. The focus is away from checking and remedying defects and towards defect prevention.



"The guide will not be another report condemning the industry for bad practice - it's easy to criticise but harder to deliver. It will be a reference document for quality management for everyone involved in delivering customer satisfaction."

The 6Cs for success in construction quality management are: Communication; Collaboration; Culture; Competencies; Continuous improvement; and Conformance. These terms are explained and discussed throughout the Guide. Communication tops the list in view of its importance in underpinning quality management throughout the project's life cycle. Effective communication needs to be across all stakeholders, up-to-date and accessible, providing a 'Golden Thread' of information.

Construction is very much a 'project business', with health and safety being key. It is a complex industry sector, highly fragmented, with a largely bespoke and project-based approach that has limited standardisation and repetition of processes. There are large differences in each project, to meet cultural, geographical and customer-led demands and requirements. As the construction industry moves towards embracing modern methods of construction by fostering a manufacturing approach to construction, the importance of the supply chain will increase, and quality control and assurance will be uppermost in everyone's minds. The interface between the materials, components, and plant manufacturers and the design and site team is critical to ensure tolerances and connections are right first time. Samples need to be approved prior to manufacture and installation, with reliability, maintainability, and sustainability all being important. Material handling and product labelling are all part of providing a quality product for the client.

The quest for good quality starts at the inception/feasibility stage of a project, when the budget is established to deliver the client's requirements. Quality issues will be uppermost in the mind of the client. The thoughts and processes about product quality should start with the client, e.g. what is the 'quality' the client is expecting? What can be afforded within the allocated budget? Unrealistic budgets lead to unrealistic expectations. Low quality standards will ultimately lead to low value and unhappy customers. Quality and value go hand in hand. Nobody sets out to build a poor-quality project – that would be commercial suicide.

Design is paramount, quality must be designed into the project. Procuring on the lowest price will not add to quality on the job. Reducing professional design fees does not reduce the overall cost, it often adds to the cost of the project; passing design responsibility and risk to the principal contractor and the specialty contractors will not necessarily improve quality. The pressures are always to meet budget and the time requirements. The problem is that when bidding for a project, the bid is often based on incomplete design information and insufficient detail about the quality expectations. It is not the design team's fault; the complexity of the process creates the difficulty.

Quality matters to everyone. It is not just output; it should encompass resources as well. To achieve the right output, the right input must be provided, and the right culture must prevail; part of that input is the quality requirements. Quality touches every aspect of design, planning approvals, material and component production, off-site manufacturing, and site production, through to occupancy and using the asset. The Planning Authority may stipulate the quality standards it is expecting in order to grant approvals. The planners will stipulate the materials they expect to be used, with the design quality expectations. The design team will specify the quality requirements to meet their expectations. The needs of the client for good quality must be clearly understood, translated into requirements, technical specifications and special characteristics.

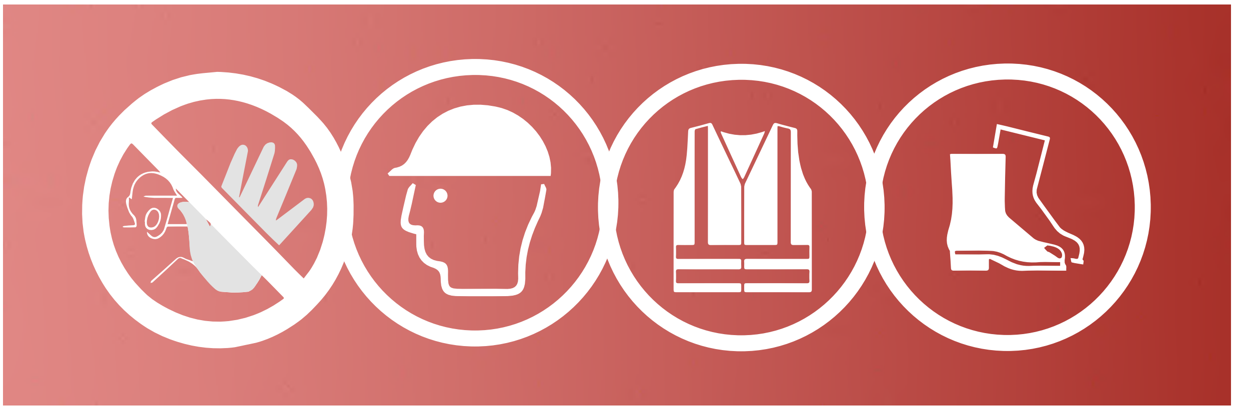
"Quality is about the product, the people, the process, the service and customer satisfaction."

Achieving job satisfaction through good workmanship needs to be the aim for all stakeholders, from the design team to the contractor's workforce to the specialty contractors[1], suppliers and manufacturers. Companies must demonstrate a commitment to deliver consistent quality products and services that are reliable, robust, and fit for purpose.

"It would be disingenuous to say that design and construction site teams are not deeply concerned with the quality of their products or services."

Quality issues need to be treated in the same way health and safety is managed, with clear ownership of the results, good lines of communication, good training, effective supervision, and robust reporting mechanisms. The UK Construction Design and Management Regulations (CDM) have led to a transformation of health and safety in building and construction work in the UK; quality management has no comparable set of regulations. Instead, there is a reliance on compliance with standards, codes, and regulations, backed up by building control, and contract terms and conditions. The plethora of rules, standards, and regulations is complex and not easily understood, or accessible by the site production team.

1 The term specialty contractor is used throughout the Guide. In some countries, the term sub-contractor, works contractor, trade contractor, specialist contractor, or co-contractor is used. Specialty contractors can be micro, small, medium, and large companies that have a specialism which may involve bidding for supply only materials, labour only services, supply and fix, design supply and fix. Specialty contractors are an integral part of the supply chain.



They face many pressures from stakeholders, with contractual requirements, and conformance with standards, regulations, and legislation. Regulatory oversight is increasing. Social media means any failure is widely and quickly broadcast.

Comment from the job site: "the people in suits don't talk enough to the people in boots!"

The cost of quality can be divided into three parts: 1) The appraisal, which is the cost of inspection, auditing, and inspection & testing. 2) Internal failure before the project is handed over to the customer, which is the cost of remedying defects, the waste, the time, and the cost of finding out why the failure occurred.
3) External failure where the projects fails in use. Such failure could result in litigation for compensation, the cost of remedying the failure, and importantly, the loss of reputation for good quality work.

The cost of failure can be high in construction; failure to deliver quality can be Draconian and examples include construction firms having their contract terminated and being barred from bidding for future work. Claims being made for business interruption costs as well as the cost of remedial work if defects occur when the asset is in use are becoming more common.

Quality is not just about the products and conformance, it is about behaviours, ethical sourcing, environmental responsibility, and safety and health. Construction invariably involves a long supply chain. Companies must verify that their supplier's quality management system is suitable for inclusion in the project supply chain. The 'project-based' nature of the industry in which projects are separate from 'head office' means that quality checks take place at the project level. It makes for a fragmented industry that must manage complexity.

This Guide attempts to simplify the mythology that surrounds quality management and to seek a better way of understanding how to improve it.

1.2 Dealing with complexity

The construction sector is complex, as are many industry sectors. Figure 1-1 shows the breadth of projects, players, and the tangible and intangible assets. Complexity is created by the proliferation of different project types, the different procurement mechanisms, long interdependent supply chains, and the need to ensure conformity with the legislation and regulations. The workers can be permanent or temporary employees, self-employed, and working for micro, small, and medium enterprises in contract with the principal contractor.

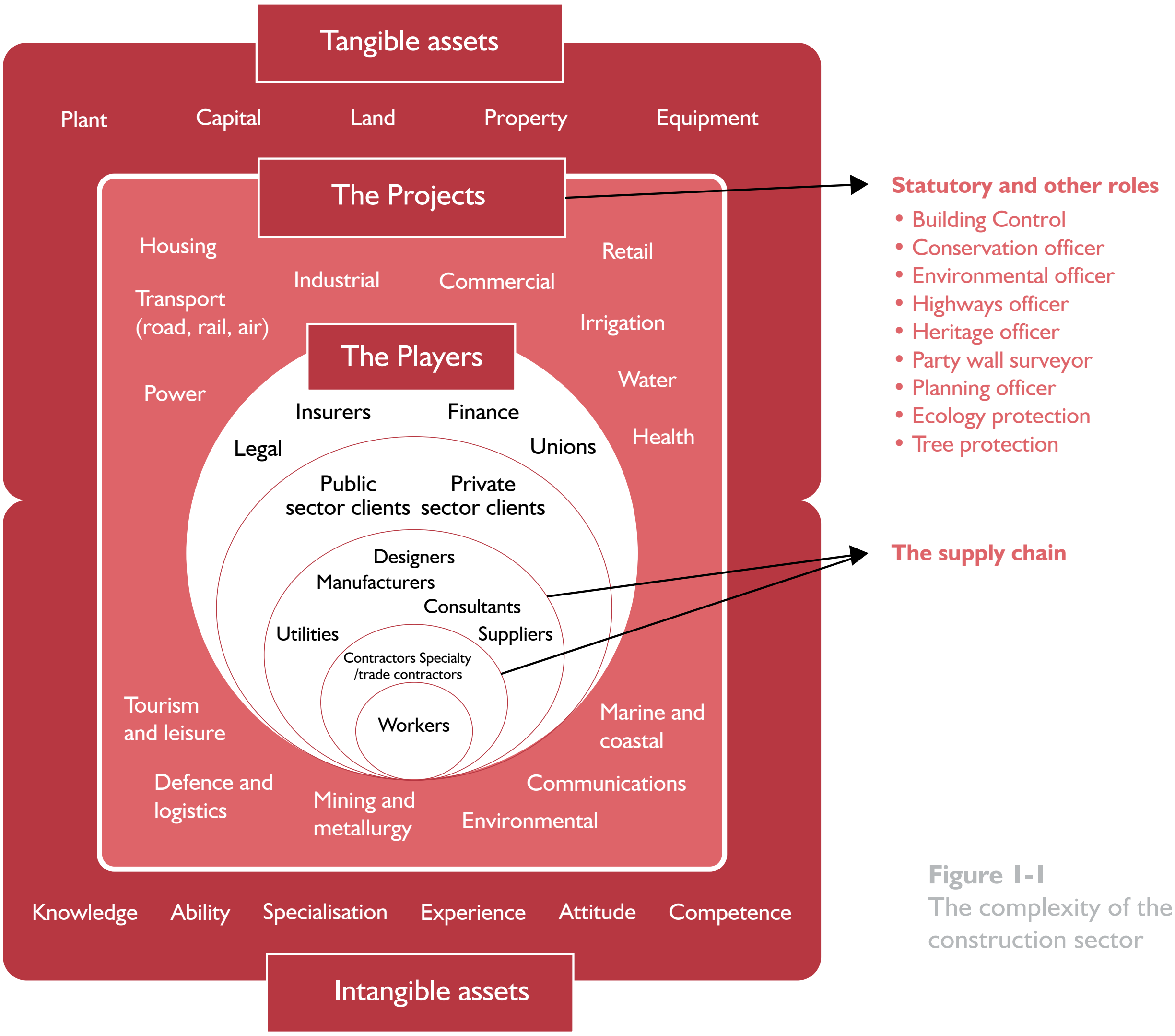


Figure 1-1
The complexity of the construction sector

Projects are undertaken by temporary teams brought together to deliver a project. Few other industry sectors use temporary teams in this way, and few have design separated from production. Understanding how quality can be managed and delivered by such an involved network is so important.

As society increases in complexity, rules and regulations proliferate. They become more complicated and consequently, less intelligible. Worse still, they impinge upon more people, who may lack the time, the inclination, or the ability to study them. Commercial pressure mean that sites are under more scrutiny whether large or small. The covid-19 pandemic has shown that the industry can be flexible and responsive to change. Quality management requires a new way of working.

The industry is dealing with new ways of working, new approaches to design with BIM, and more regulations and requirements to be considered in the project delivery process.

1.3 Push-pull factors

The 'push' pressures are from:

- Quality imposed by regulations and conformity, to be in accordance with codes and standards.
- Independent certification by accredited organisations to provide quality assurance and ensure conformance with a standard.
- Clients demanding higher quality and defect free construction. Clients becoming intolerant of failure and poor-quality standards.

The 'pull' is from:

- Clients wanting a "fitness for purpose" quality product, built into the procurement method and/or contract.
- A company's quality policy is the desire to produce quality construction, customer satisfaction, repeat business, and to increase reputation, and profitability.
- An individual's aspirations for delivering quality and job satisfaction.

Quality is about push and pull factors shown in Figure 1-2. The 'push' being the need for conformance with regulations, standards, and codes that govern construction, with registration and certification requirements. Some countries choose to licence registration for contractors, specialty contractors, and consultants. The registration system can define type of work, size of work, and the regions in which a licensed company can operate.

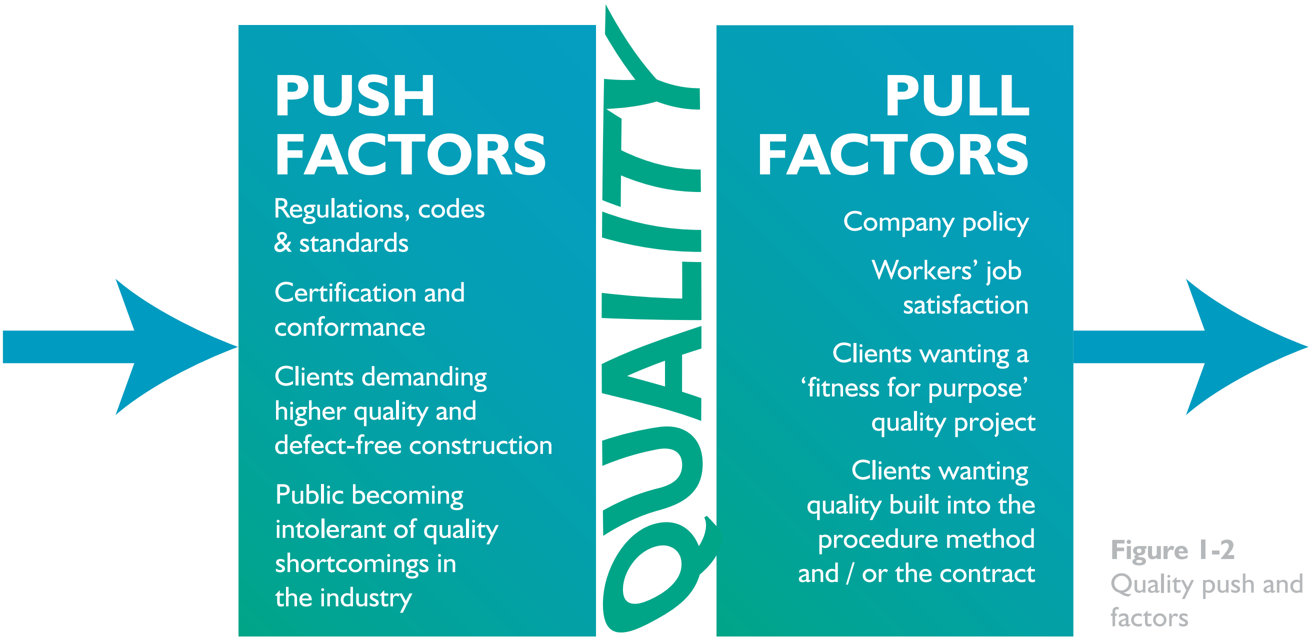


Figure 1-2 Quality push and pull factors

The UK has chosen an open approach by allowing the industry to self-regulate without registration and licensing, except for specialist trades such as asbestos removal. Those countries taking the opposite approach by requiring registration, licensing, and monitoring, include Japan, South Korea, China, and Malaysia. In Japan, a construction license is required by the Construction Business Act in order to carry on a construction business regardless of public or private works.

Under the licensing system, there are 28 classifications of work; each represents a trade or field of the construction profession. It means technical and managerial competencies can be maintained if the system is policed effectively. A contractor is licensed for each work classification for which it intends to engage. The license is for five-years and then requires review and renewal. It can be revoked if there is failure, either technical or financial. The advantage of the licensing system is creating the barrier to entry for unscrupulous companies, and the protection of standards. The disadvantage is the bureaucracy required to police and operate the system, with inspections, registration, and renewal requirements.

Framework agreements[2] and construction pre-qualification questionnaires are increasing. Customers want reliability, certainty, and evidence that contractors will deliver on their promises. To get on a framework agreement requires evidence of high-quality delivery. PAS 91:2013+A1:2017 is a standardised construction pre-qualification questionnaire produced by BSI for clients to use in the selection of contractors. Two pages in the document are devoted to proving that quality work is undertaken by the firm seeking qualification to bid for work. Proving the ability to manage and deliver quality is therefore of paramount importance. The Construction Skills Certification Scheme (CSCS)[3] is the leading skills certification scheme within the UK construction industry. CSCS cards provide proof that individuals working on construction sites have the required training and qualifications for the type of work they carry out. Holding a CSCS card is not a legislative requirement, it is up to the contractor or client whether workers are required to hold a card before being allowed on site.

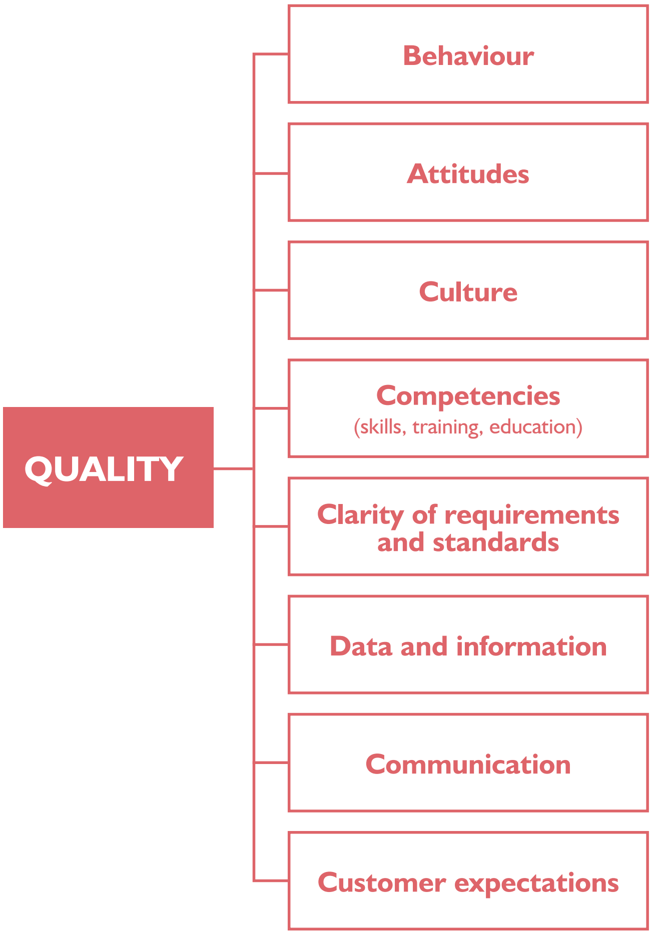


Figure 1-3
Quality perspectives

2 Framework agreement is an arrangement between two parties which commits one to buying at least a particular volume of goods, projects, or services from the other party over a period of time. The advantage is continuity of work and ongoing relationships based on trust. Quality is an important part when bidding for any framework.

3 CSCS is a not-for-profit limited company with directors from employer organisations and unions representing the breadth of the industry.

1.4 Delivering quality

Delivering quality embraces many aspects as shown in Figure 1-3. Attitudes, behaviour, culture and competencies are all important, and so is having the right data and information available on time and ensuring it is communicated effectively - sometimes called the 'golden thread' of information. If the requirements for quality are not clear at the outset, everyone will do their best to deliver a quality project within the constraints of time and cost, but it may not meet the client's expectations.

Quality is never an accident, it is always the result of high intention, sincere effort, intelligent direction and skilful execution by everyone. The design must reflect what is needed and the standards required. Quality management is about how to deliver the project and meet everyone's expectations. The client is the customer; they want defect-free, good quality, reliability, robustness, longevity, consistency and maintainability, with projects that meet their expectations and requirements.

Quality matters to everyone in the construction business from the design team through to the site workforce and all the organisations in the supply chain.

"Quality is the project legacy; it is what is left behind and so it needs to be high on everyone's agenda"

Meeting the quality requirements involves:

- Innovating and delighting customers by exceeding their expectations, not just once but ongoing.
- Ensuring a culture of continuous improvement, quality assurance, and quality control for both service and production.
- Creating pride in the job with a workforce proud of its achievements.
- Allocating responsibility to ensure work meets the required standards and is reliable, robust, and consistent.
- Correcting any snagging items in a timely and objective manner, with a no-quibble mentality to putting it right.
- Learning from mistakes and resolving issues together without blame.
- Adhering to the mutually-agreed terms of delivery and performance for quality, cost, and time.
- Making the construction industry a desirable place to work through quality of the workplace and the workforce.
- Respecting the environment, communities, and the people who work in the industry by being considerate and being prepared to meet standards.
- Creating public confidence in the industry's ability to deliver good quality. Reliable performance of products is critical to safety objectives. The durability of key components and materials significantly impacts the quality and the lifespan of buildings and construction assets.
- Displaying high ethical, and safety and health standards.

"Paying lip service to quality, ticking boxes, imposing unnecessary bureaucracy, and having procedures that do not add value, does not lead to satisfied customers, or a satisfied workforce"

A common criticism is that the pressure of time and pressure to complete within the allocated budget is the problem. That is where quality management can help by interpreting the quality requirements correctly at the tender stage of the project, i.e. tender translation. The information from the design team must be clear and make the issue of quality expectations very transparent.

Many management systems proclaim the importance of quality, such as total quality management, lean production, and six-sigma. Such initiatives all have benefits, but the purpose of this guide is to go back to basics and to consider how micro, small, medium and large enterprises deliver quality in the site production process.

Figure 1-4 shows the quality driven world, which involves a new approach to project delivery, with the integration of modern methods of construction and the use of digitalisation to engineer, design, monitor, control and record.

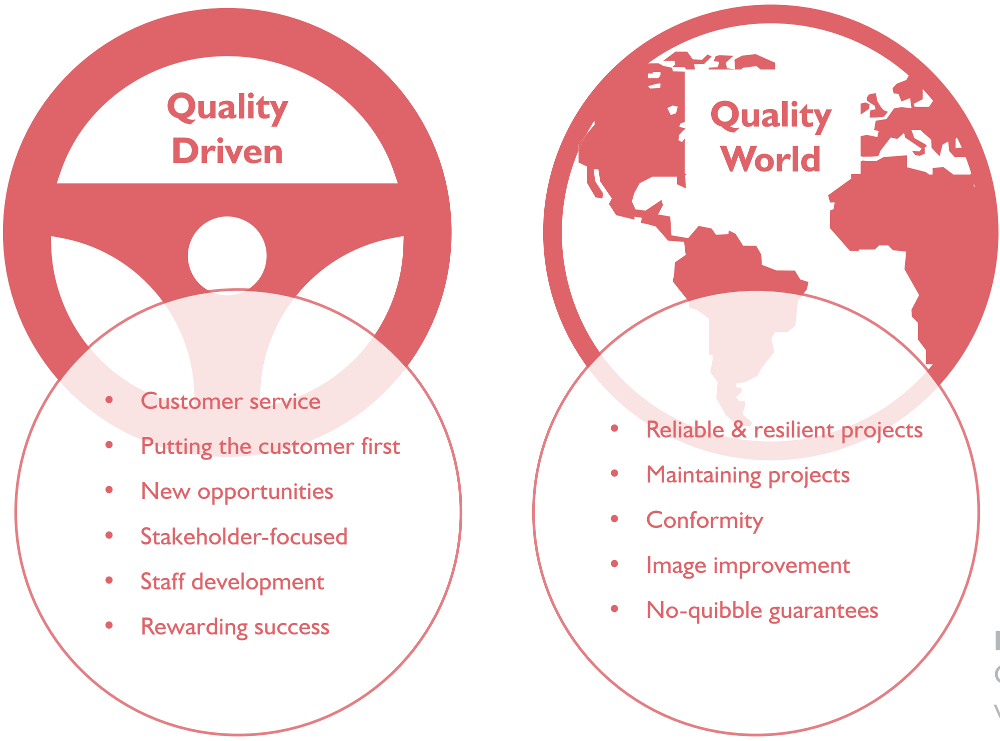


Figure 1-4
Quality driven world

Traditional craft-based skills are being replaced by cross-functional teams, who have multi-skilling. Projects still use work packages, but the packages are more integrated and can be more specialised.

Planning involves simultaneous working, with more overlapping of working. Off-site production can improve the quality, and that quality must be maintained when the product is fixed on site. Projects must be safe, environmentally responsible, energy efficient and be delivered defect free. A no-quibble guarantee must become a reality.

1.5 Design quality

The importance of quality is not new, it has its roots in history. Vitruvius[4] is famous for asserting that a structure must exhibit three qualities: firmitas, utilitas, venustas – that is, stability, utility, and beauty. These are sometimes termed the Vitruvian virtues or the Vitruvian Triad see Figure 1-5.

VITRUVIUS' THREE PRINCIPLES

Marcus Vitruvius Pollio, 1st Century author, architect and engineer, established that a structure must meet three principles:

Firmitas
Durable

Venustas
Beautiful

Utilitas
Useful

In today's world there are four more principles:

Conformity

Reliability

Design Quality

Build Quality

Figure 1-5
Vitruvian principles

In today's world conformity, reliability, design quality and build quality can be added to the Vitruvian principles of strength, function, and beauty. The conformance ensures the requirements of statutory regulations, laws and standards are met and controlled.

Design quality is about functionality and fitness for purpose, safety, buildability, and about service delivery, with the right information provided at the right time for the job site, with no delays in approving and signing off shop drawings.

The Commission for Architecture and the Built Environment (CABE) based quality on:

Functionality - will it perform?

Firmness - will it last?

Delight - does it look good?

4 Marcus Vitruvius Pollio; 80–70 BC, a Roman author, architect, civil engineer, and military engineer during the 1st century BC. His discussion of perfect proportion in architecture and the human body, explained in his book De Architectura, led to the famous Renaissance drawing by Leonardo da Vinci of Vitruvian Man.

Design quality is also about completeness of design, with sufficient information for the workforce to convert the design into production. The impact of quality of the finished product is very important; a good environment with reliable performance will improve the quality of life, and the productivity of the workforce.

Design quality is reflected in how the asset will perform and how it can be maintained, repaired, and replaced. Having a shower mixer valve behind tiling with no access will not delight the client when it starts to leak. The Design Quality Indicator (DQI), developed by the Construction Industry Council, is a toolkit promoted to measure, evaluate, and improve the design quality of buildings. It is a process that enables every aspect of design quality to be assessed at each stage of the construction process, from inception to post occupancy analysis. Its focus is on measuring design quality, whereas this Guide is concerned to ensure that good design is translated into quality production on the job site.

Architects and engineers will want to ensure that quality in design is reflected in the production process by meeting standards and project requirements. The design team must ensure effective and timely communication from design into site production; missing or outdated design and specification information can result in poor productivity, rework, delays and waste.

1.6 Defining quality

The definition of quality must be viewed from different perspectives:

- **Judgemental**, when there are uncompromising standards and high achievement, such as an airline arriving on time using a new aircraft that is clean and comfortable, or receiving outstanding service in a restaurant.
- **Product based**, when there is a measurable difference between the quality of the products, such as a computer with a faster processor and longer battery life or a Rolls Royce or Bentley car built to exemplary quality standards. The standards are measurable and reflected in the pricing structure.
- **User based**, where a higher priced product may have more attention paid to detail over another product that fulfils the same function, such as designer brand clothing, jewellery, and fashion accessories. A Dior product will have design and production quality as a priority; it will engender a feeling of exclusivity and quality by marketing the product very cleverly.
- **Manufacturing based**, where the manufacturer offers a long-term guarantee demonstrating confidence in the product's performance and reliability, such as offering a five-year no-quibble guarantee for a Kia car.

The definition of quality in ISO 9000:2015, 3.6.2 is: "the degree to which a set of inherent characteristics of an object fulfils requirements."

The definition of "requirements" given in 3.6.4 is: "needs or expectations that are stated, generally implied, or obligatory"

There is no common definition of construction quality; it embodies many of the above aspects. It is viewed from different perspectives: the investors and financiers, the client, the design team, the principal contractor, specialty contractors, end user, companies in the supply chain and the workforce. A characteristic of construction is that failure can have disastrous consequences.

Note: The terms used are generally implied and obligatory. The specification, the conditions of contract, and the codes and standards define requirements; 'generally implied' is more difficult to define precisely.

The American National Standards Institute (ANSI) and the American Society for Quality (ASQ) define quality as "the totality of features and characteristics of a product or service that bears on its ability to satisfy given needs."

Materials and components used in construction impact the quality. Under Section 14 of the Sale of Goods Act 1979, a term will be implied into a contract for the sale of goods that the goods will be fit for purpose (legislation.gov.uk, 2020), whether or not that is the purpose for which such goods are commonly supplied. 'Fitness for purpose' warranties can be expressly agreed or implied in construction contracts or consultancy agreements to ensure that whatever is being designed, built, or supplied, is fit for its intended purpose.

A fit for purpose obligation in a construction contract simply means the contractor agrees that the design will meet the employer's demands. Some contractors say, "I will not accept a fitness for purpose obligation because it is too onerous and is not insurable." The effect of including a fitness for purpose clause in a construction contract can be very significant.

"Conformance to the specification, conformance with the legislation, regulations and standards, and defect free is important to the client once the built asset is in use."

1.6.1 Building in Quality

The 'Building in Quality' report, a collaboration between the RIBA, CIOB and RICS, established three dimensions of quality:

- **Build quality** – completed asset performance.
- **Functionality** – fitness for purpose.
- **Impact** – the degree to which the asset adds social, economic, cultural and environmental value and improves the wellbeing for those that buy, use, or manage an asset.

The process is important in identifying quality issues for the client, but it needs to be agreed by the project team and, importantly, recorded and signed off impartially at pre-agreed stages. At each work stage, risk assessments may be interpreted in the context of the quality targets set out in the project brief.

"The quality baton is passed on until finally issued to the client's representative, the investors, the purchasers and / or tenants as a verified statement of the ways in which risks to quality were handled during the project".

Gaps were identified in the pursuit of quality in the industry:

- Lack of an agreed definition on the meaning of quality.
- Need for better prediction of the built asset's final quality.
- Available methods of measurement, monitoring quality using new technology.
- Data against which benchmarking can be undertaken.
- Risk control and handling uncertainty in delivering quality.

The Building in Quality initiative developed a quality tracker that provides a good framework for tracking quality; it differentiates different kinds of quality. Minimum quality, which sets out the minimum standard, and an important definition, legacy quality (Cole, 2017), which embodies functionality, aesthetics, flexibility, sustainability, social value, and health and safety. The suggestion is for a "chain of custody" for passing the quality baton (responsibility for quality) in the design and construction team. The 'golden thread' of good information suggested in the Hackitt report is strongly advocated.

"The Quality Tracker is at the heart of a chain of custody system for overcoming the often-fragmented composition of project teams and the resultant inconsistent governance of quality" (Building in Quality, p. 25)

The Quality Tracker, a digital system for monitoring the risks to quality, was designed to address the gaps detailed above. Each 'page' of the Tracker covers one of the stages in the RIBA Plan of Work (2020) shown in Figure 1-6. The manufacturing construction/production phase is Stage 5.

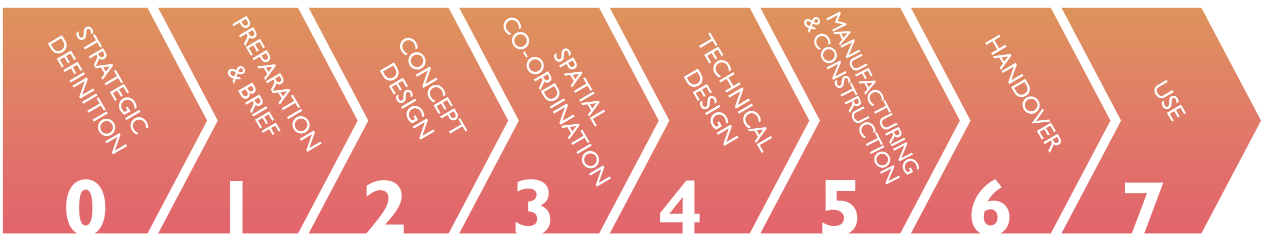


Figure 1-6
RIBA Plan of Work

The tracker was piloted by clients and their advisers between October 2018 and April 2019. Because of the number of different procurement routes, project sizes, client types, building typologies, construction methods, and sectors, it was difficult for one size to fit all. Furthermore, its adoption may be inhibited by 'process fatigue'. Further developments were seen as necessary, such as:

- Integrating processes with digital technology.
- Developing the evidence base for predictive metrics.
- Educating and wooing clients.

Digital technology does make a difference, but the difficulty with design is that it is not a linear process, it is an iterative process involving many members of the team who are specialised. Gaining approvals from regulatory and statutory bodies takes time that may not fit well with the project timeline. Projects are sometimes designed by joint venture groups, or by international companies based overseas with only a local representative office. A Swiss architect will want to build to high standards that must be reflected in the design documents. In the rush to start work on site as quickly as possible, tenders are frequently based on incomplete information, which is not necessarily the fault of the design team. None of the challenges are new, but to ensure the best quality, a more rigorous systemised approach is required to deliver quality projects.

1.6.2 The Hackitt Report

The Hackitt report is an "Independent Review of Building Regulations and Fire Safety". The report stated that there was "insufficient focus on delivering the best quality building possible, in order to ensure that residents are safe, and feel safe". The report identified the need for a new regulatory framework that would provide both positive incentives and effective deterrents to ensure competence levels are raised and quality and performance of construction products improved. A more effective testing regime is needed as well as an innovative product and system design with efficient quality controls.

Effective and accurate information management is crucial, across the project and over the life of a facility, to improve quality and performance – the 'golden thread' of information.

Dame Judith Hackitt[5] referred to three important issues:

1. **Ignorance** – regulations and codes are misunderstood and misinterpreted; this is partly because of the way the codes are written with legalistic and technical terminology. This equally applies to some of the codes and standards on quality.

2. **Lack of clarity on roles and responsibilities** – there is ambiguity over where responsibility lies, exacerbated by a level of fragmentation within the industry, and precluding robust ownership of accountability.

3. **Indifference** – the primary motivation is to do things as quickly and cheaply as possible rather than to deliver quality homes that are safe for people to live in.

"These issues have helped to create a cultural issue across the sector, which can be described as a 'race to the bottom' caused either through ignorance, indifference, or because the system does not facilitate good practice. There is insufficient focus on delivering the best quality building possible." Hackitt Report (2018)

The 'race to the bottom' is often driven by unrealistic and uninformed clients/budgets that select on lowest price, not best value.

5 Building a Safer Future, Independent Review of Building Regulations and Fire Safety: Final Report. Presented to Parliament by the Secretary of State for Housing, Communities and Local Government, May 2018

Following publication of the Hackitt Report, the Government consulted on proposals for a reform of the building safety system. In July 2020, the draft Building Safety Bill was published. The Bill will ensure that the responsibility to ensure residents' safety is in the hands of an accountable person in the form of a regulator. The regulator will have 3 main functions:

- To oversee the safety and standard of all buildings.
- Directly assure the safety of higher-risk buildings.
- Improve the competence of people responsible for managing and overseeing building work.

A new, more stringent set of rules for high-rise residential buildings will be operated and will apply when buildings are designed, constructed and then later occupied. Throughout the building's life cycle, it will be clear who is responsible for managing the potential risks and the requirements for progressing to subsequent next stage. This will enable a 'golden thread' of vital information about the building to be gathered over its lifetime.

1.6.3 Get it Right Initiative[6]

The initiative has four objectives:

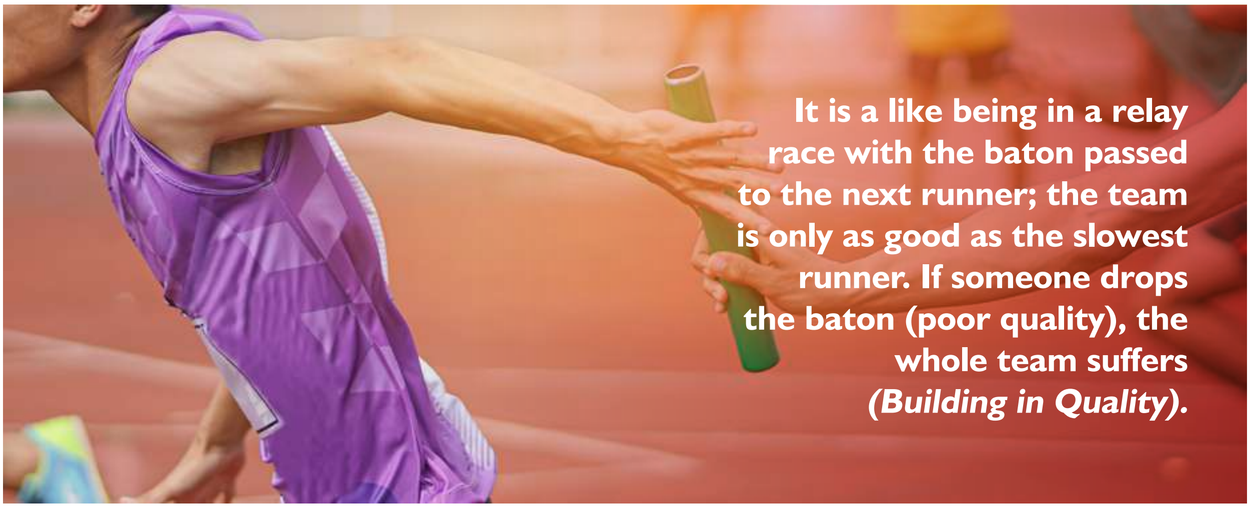
1. To generate a significant change in the efficiency of the UK construction industry through reducing the amount of errors made in construction.
2. To undertake research to identify, evaluate and prioritise the principal systemic errors in the construction process.
3. To develop a strategy to address these errors and, in particular, to address deficiencies in skills.
4. To develop new training products and processes to address the skills deficiencies.

Industry opinions were sought on the issue of 'getting it right, first time'. It identified the sources of most frequent errors, root causes of errors, cost of errors, and how to avoid making errors. The Strategy for Change outlines: a skills development programme; a campaign to change and align attitudes across the sector so that "all involved are committed to reducing errors and improving the quality of what we do", and improvements needed in management processes and systems, particularly design management and construction planning.

***Comment*: This initiative focuses on education, skills and attitudes, backed up by data on types of errors, their costs and frequencies**

6 The "Get it Right Initiative" is an organisation that is tackling avoidable error in the construction industry. Membership is by subscription. Get It Right members work together to steer the agenda and build a better UK construction industry.

1.7 Taking up the quality baton



The CIOB considered the various industry initiatives mentioned above. They recognised the lack of uniform quality standards, and a failure to use technology to guarantee quality standards. There is a general lack of attention paid to the importance of maintaining quality in the industry, which needs to be addressed by more targeted training. The key issues which are taken up in this guide are:

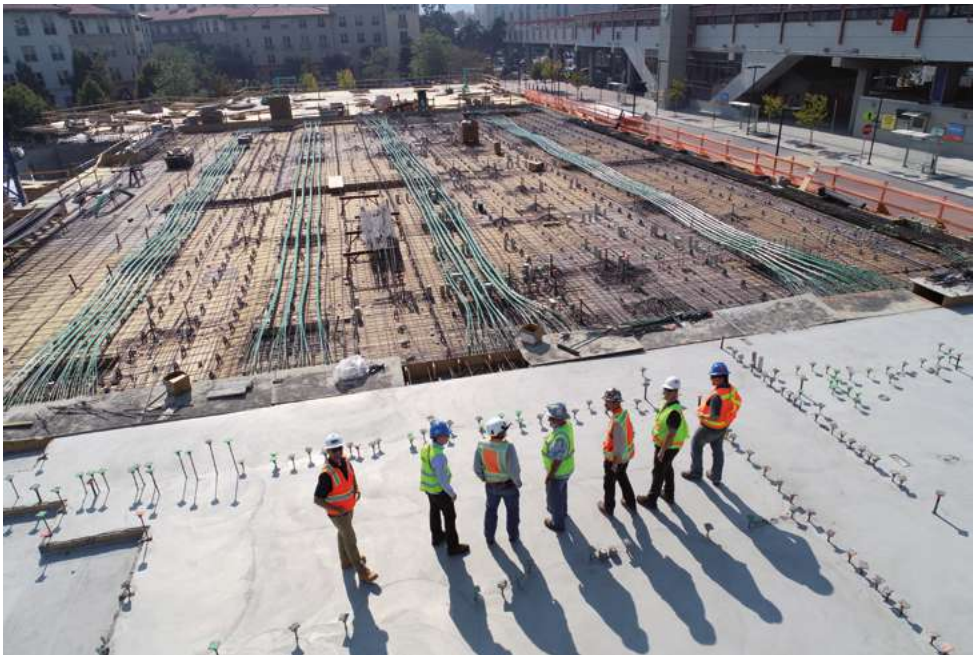
- **The importance of information management, transparency and communication; sometimes referred to as the 'golden thread'.**
- **Efficient and appropriate metrics for quality management.**
- **The importance of culture, training and education in creating quality culture.**
- **The impact of the work environment on quality performance.**
- **Embracing new technology to deliver quality management and quality assurance and control.**
- **Understanding the link between design and site production and its influence on quality management in site production.**

To address these issues, the Guide considers how stakeholders across the project and supply chain can meet the changing world of construction quality requirements. The guide stresses the need for quality management at the early (design/feasibility) stages of a project, which is communicated across the project team and supply chain. Particular attention has been paid to the role of site personnel in monitoring and maintaining quality.

Any Guide must be based on an outcomes-based framework that requires people who are part of the system to be competent, to think for themselves rather than blindly following guidance, and to understand their responsibilities to deliver and maintain quality.

Responsibility for quality management in the construction industry is often confusing. Everyone must understand the fundamental concepts, principles, and vocabulary of the quality management system. It is applicable to anyone working on projects, irrespective of size.

The Guide's aim is to increase an organisation's awareness of its duties and commitment in fulfilling the needs and expectations of its customers and interested parties. Prescriptive regulation and guidance are not always helpful; bureaucracy reigns and sometimes the worker feels ground down by paperwork and tick boxes that adds little to the delivery of quality.



An example of the lack of clarity about quality in construction is in the RIBA Plan of Work 2020 (see Figure 1-6) where the responsibility for quality is shown at Stage 5, the manufacturing and construction phase. The architect is required to inspect construction quality and to issue the Practical Completion Certificate including the defects list. There is no clarity about quality, except when there is a defect, and the legal representatives start arguing about the meaning of quality.

This is not a criticism of the Plan of Work; its purpose is to describe a process whilst recognising the professional duties, responsibilities and potential liabilities of the architect. The criticism is with the delivery system that was devised for a different era, and is now having to cope with complexity in a dynamic industry that is widely dispersed.

More clarity is needed when defining quality in the tender documents and in the production planning process, with clear lines of responsibility.

There are those that are fearful that more documents and more checking will slow the process, cost more money, and lead to confusion and unnecessary bureaucracy. The opposite is true; getting it right first time and reducing defects will save huge amounts of time and money spent on needless re-work. It will also avoid costly litigation when everyone takes up their positions if defects occur. Time spent planning, managing, and focusing on quality will pay dividends for everyone across the supply chain. Defects are disruptive, de-motivating, and costly. Delivering quality needs embedding in the culture of the industry.

Time is the enemy...
but defects cost
more than time

1.8 Culture and behaviour matters

Creating a culture of quality means being passionate about quality as a personal value rather than simply obeying an edict from on high. It means having an environment in which people 'live' quality in all their actions; they feel quality all around them. Individuals must hold quality as a value and not just a priority. They must be willing and able to react to their sense of responsibility to deliver a high-quality project. Culture and attitude are vital in achieving success and should begin at the tender stage with effective quality planning to win the project.

Traditional strategies to delivering quality by offering financial incentives, education and training, and sharing best practice all help, but embedding a culture of quality in the minds of people is a much stronger tool. Attitude must start at the top of the organisation; the messages being delivered must be credible. Driving the right behaviour to make sure that good quality is a pre-requisite to a successful project is crucial.

A workforce lacking motivation will underperform. Motivation may be financial or non-financial. The important aspect is to motivate a worker to maximise their potential, ensure work satisfaction, and to maintain good quality standards. Motivation can be at project level though a 'pain and gain' contract[7] such as the NEC 4 suite of contracts.

Figure 1-7 shows some of the pieces necessary to develop a culture of quality. Any policy must be credible, with involvement from the top of the organisation. Moving away from the rules-based approach with box ticking will engender greater commitment and responsibility. Moving from a rules-based environment for quality to developing a culture of quality will take time and effort. Assessing the current culture of quality in the organisation helps identify the extent to which all employees understand the philosophy and approach to quality, as well as the degree to which quality is integrated into everything they do. Going beyond rules and requirements matters, by creating ownership of quality by organisations and individuals.

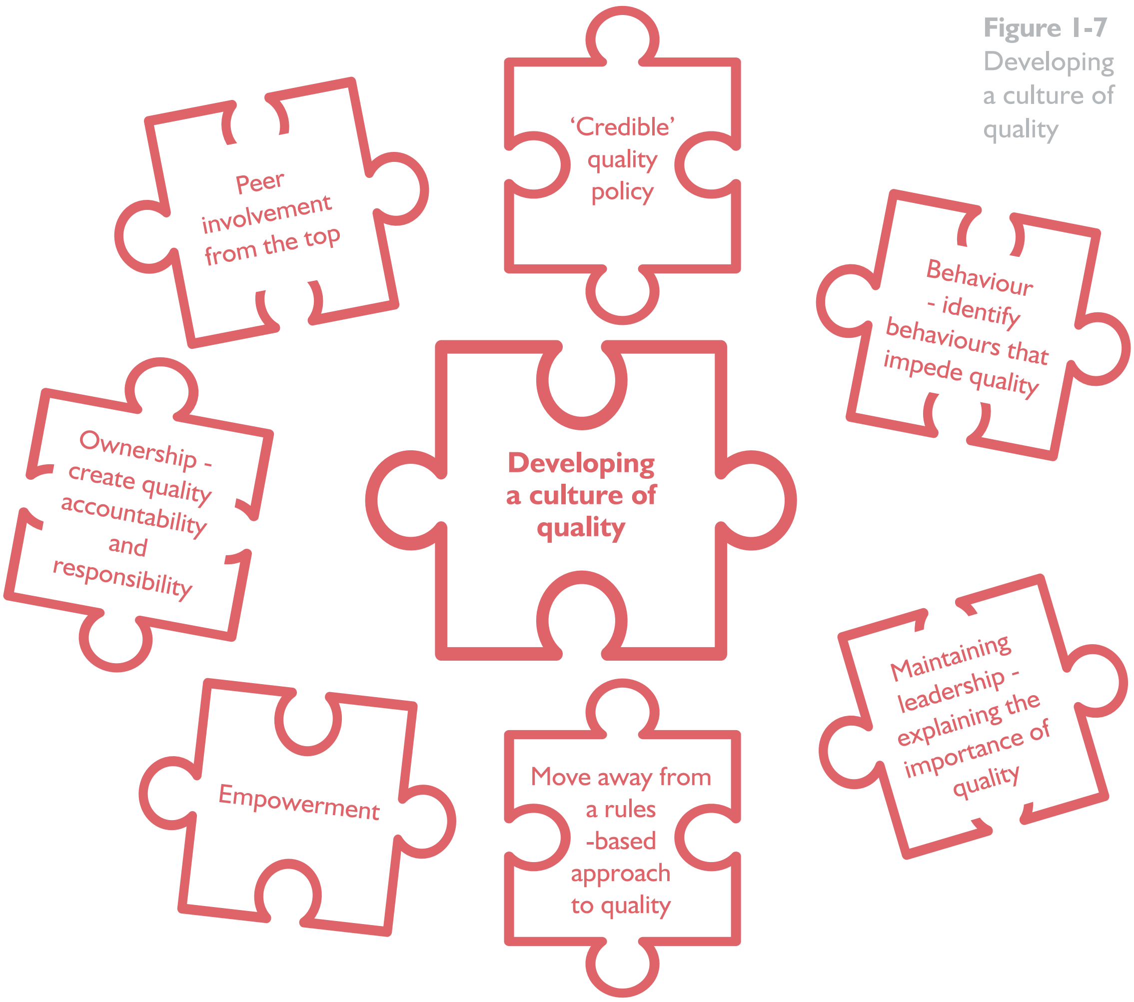


Figure 1-7 Developing a culture of quality

7 NEC4 stipulates that at the end of the contract, a comparison is made between the final Defined Costs and Fee (the final "Price for Work Done to Date") and the target costs. If the final Price Work Done to Date is less than the target, then the Contractor will receive a share in the saving depending on the level agreed. If, however, it is greater than the target cost, the Contractor will pay a share of the difference (again at the level agreed).

Nice words, but not always easy to achieve in construction, with the gaps between head office and the site, and the gaps between companies in the supply chain, all of whom want to produce a good quality job but are often reliant upon other organisations.

One weak link in the supply chain causes disruption and potential defects. That is why it is so important to use trusted and reliable firms, or those that have pre-qualified through a robust selection procedure.

1.8.1 Behaviour-based quality

Behaviour-based quality is very important. A good example was demonstrated when working on a new crematorium. The workforce were very respectful of the situation and recognised the distressed feelings of people in difficult circumstances and they took pride in producing high quality work that was right first time. Their behaviour was exemplary with everyone working to achieve the highest possible quality – collaboration and trust was key.

Behaviours can be categorised into three parts:

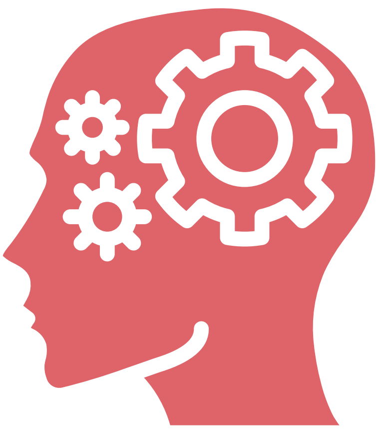
1. Activators - which include capability, motivation (desires, wants, needs), physical opportunity (resources, site environment, time allocated for the task), physical affordance (processes, procedures, supervision), relationships (good site manager and good quality manager) and financial rewards.
2. Behaviours - which show professionalism and competence and desire to deliver good quality.
3. Consequences - with praise for excellent work delivered on time, or criticism and the need for re-work.

Behaviour-based quality management uses a bottom-up approach with the workforce on site being given responsibility to deliver quality with support from the leadership of the site and the business.

A key strategy in pursuit of a culture of quality is ensuring all employees:

- Know the product and the process.
- Know the quality expectations of the customer/client.
- Know the design/engineering team quality expectations and have a metric to measure that quality delivery.
- Seek continuous improvement in skills and competencies.
- Embed ownership of the task and the product by creating accountability for quality.
- Are empowered to go beyond the rule book on quality and to exceed customer expectations.

Having a competency framework is a valuable step in understanding the underlying principles of delivery in the environment that can help delivery of quality on a project.



1.9 Competency Framework - Chartered Quality Institute

The Chartered Quality Institute (CQI)[8] believes quality comes down to three things: strong governance to define the organisation's aims and translate them into action; robust systems of assurance to make sure things stay on track, and a culture of improvement to keep getting better. They suggest every product, service, process, task, action or decision in an organisation can be judged in terms of its quality – how good is it, is it good enough and how can it be better?

Figure 1-8 shows the CQI Competency Framework. It sets out the abilities and types of behaviour that quality professionals need in **leadership, governance, assurance, and improvement within a context**.

Governance is the set of rules by which a company operates. The rules fall into two categories - firstly, those dictated by legislation, codes and standards, and secondly, the corporate 'rules'. The latter cover the infrastructure and processes the company puts in place to ensure conformance. Ignorance, lack of clarity on roles and responsibilities, indifference, and lack of controls and enforcement are all challenges for the governance of quality management in the construction industry.

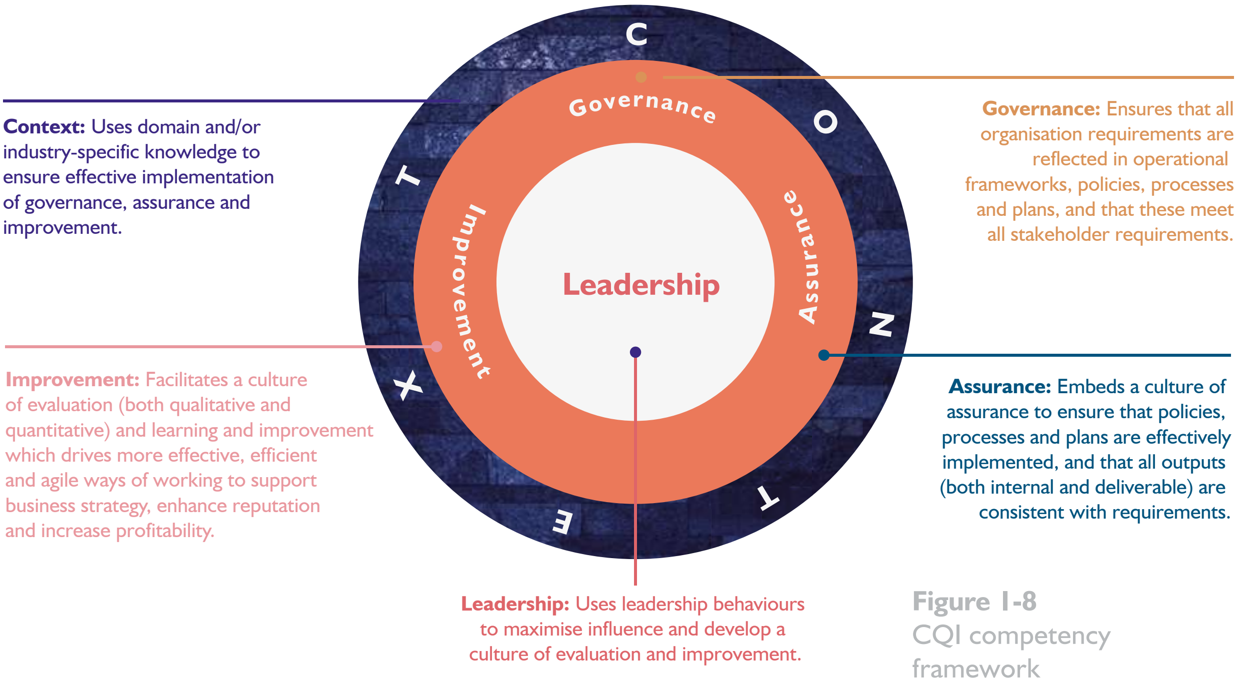


Figure 1-8
CQI competency framework

The competency framework is important. It sets out areas that must be considered in any quality management system.

1.10 Quality professionals

Quality professionals have titles such as quality manager, quality engineer, quality agent, quality director or assurance manager, while others deal with quality as part of a broader remit. The role of the Clerk of Works[9] has been as a quality checker on-site employed by the client.

8 The Chartered Quality Institute, formerly known as The Institute of Quality Assurance, is the chartered body for quality professionals. It improves the performance of organisations by developing their capability in quality management.

9 The Clerk of Works, sometimes called Site Inspector, is drawn from experienced tradesmen with a wide knowledge and understanding of the building process. The role is based on the impartiality of the incumbent in ensuring value for money for the client, achieved through detailed inspection of materials and workmanship throughout the build process. The person that must ensure quality of both materials and workmanship must be impartial and independent in their decisions and judgements.

The Institute of Clerk of Works and Construction Inspectorate of GB Inc. is the professional body in the UK that supports quality construction through inspection. Independent third-party inspection helps to protect a client's interests throughout the construction process, the client will benefit from experience and the reassurance that their interests in quality are being safeguarded. The Clerk of Works' role is to ensure conformance with the specification, codes and standards, and to monitor workmanship and materials.

Large construction companies will have a quality management team, whereas smaller companies often cannot afford to have a dedicated quality person and resort to inspection by the site manager or trades specialist.

Quality professionals must lead, develop and coach individuals to build high performing teams and create a pipeline of talent for the organisation.

1.11 Quality standards

Quality is embedded in everything. The tendency is to view standards as relating to legal and contractual conformance, and to technical standards. However, the remit is much broader. A quality project requires respect for the environment, ensuring behaviour does not breach acceptable social standards, such as playing radios on site. Industry standards must be maintained by ensuring the contractor is considerate in all kinds of ways, examples being keeping the roads clear of mud and having a good traffic management plan for deliveries to the site. Figure 1-9 shows the breadth of standards to be considered.

The most dominant standards are the technical, legal and regulatory, and contractual standards. There is a plethora of quality-related legal and technical regulations, standards, and codes; the site team needs to be aware and understand their requirements and implications. However, their format and language are not always conducive to quick reference by the busy site team. Time is money, site teams are always time constrained, they need information in a form that is user friendly and easy to obtain.

Figure 1-9
Breadth of standards

Financial standards are important. Accounts and taxation standards must be maintained otherwise no business can survive. Reducing waste on site and the requirements for re-work are products of meeting standards.

Details of codes and standards are given in Section 8. These have been divided into work sections to make it easier for referencing during a project. Bringing all the relevant codes and standards in one place and classifying them within project processes should save time and ease their complexity. The tables also give advantages, disadvantages of components and the quality issues.

1.11.1 International Organization for Standardization (ISO), British Standards

The International Organization for Standardisation (ISO) is an international agency composed of the national standards bodies of more than 160 countries. It provides guidance and certification on a range of issues. ISOs are used throughout the world and are created in collaboration with a group of experts from all over the world. Since the audience is broad, the standard is quite broad to allow for differences between countries. They are used by the European Union (EN-ISO) and become BS-EN-ISOs when adopted in the UK. ISO standards are important, despite being pan industry they are highly relevant for quality management on the job site.

The British Standards Institute (BSI) is famous for its kitemark which was released in 1903. The British Standards predominantly take into account the UK industry requirements, but the standards are used in many countries.

ISO 9000/9001/9002/9004 is the definitive family of standards across industry sectors for quality management. Regardless of the size, the nature of business or the industry sector, the ISO 9000 family of standards are a generic management system that have evolved through the years and can apply to any organisation.

The ISO 9000 family of international quality management standards and guidelines has earned a global reputation as a basis for establishing effective and efficient quality management systems. The ISO 9000 series defines the quality management system applicable across all industries. Standards continue to play a crucial role in construction work. For the quality profession, they are a tool for both measurement and improvement, while providing confidence to the market.

ISO 9001 is the only standard in the ISO 9000 series to which an organisation can certify. Achieving certification means that the organisation has demonstrated that they follow the guidelines of the ISO 9001 standard. An audit is undertaken to ensure the process is being followed. In some industries certification is mandated, but not in construction.

It is tempting to say construction IS DIFFERENT because of the bespoke nature of every project, the separation of design from site production, and the large number of specialty contractors and suppliers of goods and services. Every industry has its fragmentation, claiming to be different is not a reasonable excuse!

Experts say production line manufacturing is different; quality assurance and control is easier in a factory environment than on a job site. Whilst that argument may be true, a modern economy demands efficiency, certainty, safety, reliability and embedded quality, delivered in a fast-changing complex environment.

1.11.2 European Foundation for Quality Management (EFQM)

The EFQM Excellence Model is a framework for assessing applications for the European Quality Award. The model is used as a management system that encourages the discipline of organisational self-assessment and is a practical tool to help organisations to measure where they are on the Path to Excellence; helping them understand the gaps and stimulating solutions. It is applicable to organisations irrespective of size, structure, and sector. Self-assessment has wide applicability to organisations large and small, in the public as well as the private sectors. The outputs from self-assessment can be used as part of the business planning process and the model itself can be used as a basis for operational and project review.

1.12 Good communication - the 'golden thread' of information

The site production team need information in a form they can easily understand and act upon. They do not have time to access vast amounts of irrelevant information. They want to know: how do I use the information; how does it affect me; what is required to ensure quality assurance on the job site; who will be responsible for inspection and testing?

The production process involves many organisations, all of whom must be clear about the quality requirements, the inspection and testing regime and how the work packages are interrelated.

Good communication is essential to ensure that the 'golden thread' of information connects everyone. Figure 1-10 shows the layering and interdependencies of the industry. Everyone must be connected, informed, and focused on the quality requirements.

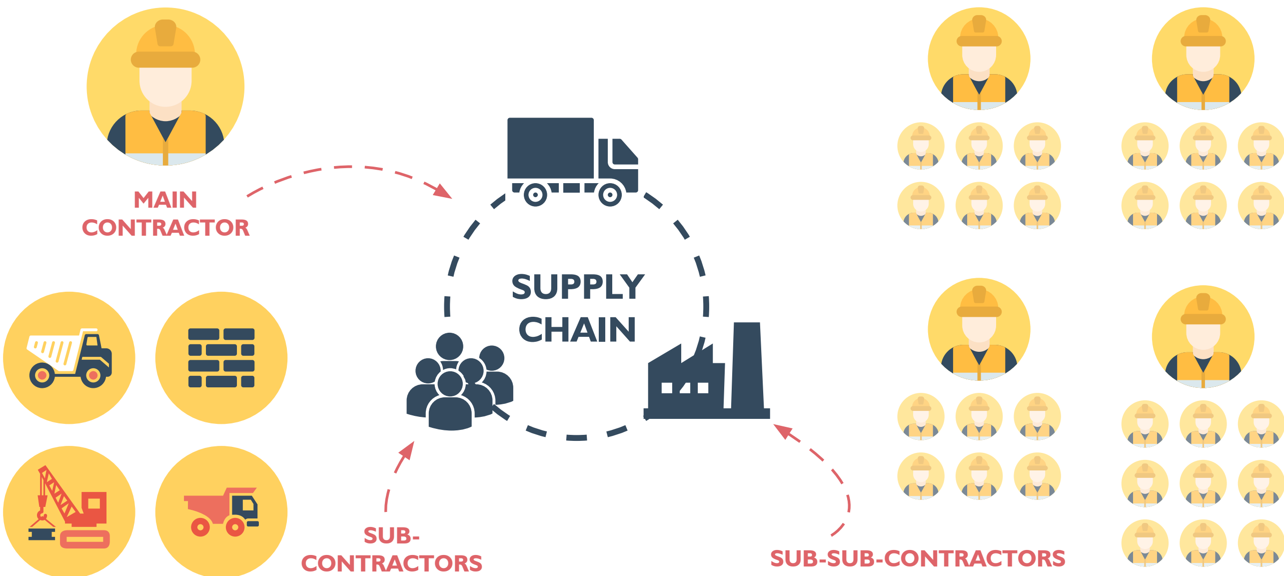


Figure 1-10
The multi-layered and interdependent site production team

The importance of good communication is paramount as Figure 1-11 shows. Different stakeholders have different requirements and different ways of communicating. The design team do not need to be overloaded with information, but they do need to have access when they need the information.

1.13 The cost of quality - balancing cost, time, and quality

Quality costs are both direct and indirect - the direct costs are getting it right first time and the cost of any remedial work - the indirect costs are loss of reputation and future work, as well as client and user dissatisfaction. There is always a balance between time, cost, and quality, with each taking on varying degrees of importance across the project. It is about the apportionment of risk and managing uncertainty.

Early planning will identify significant (delaying / costly) issues such as:

- Key dates for statutory and regulatory approvals, and design approvals.
- Client / design requirements on completion / phased completion.
- Incomplete design items where more information is required.
- Long delivery lead-time for materials and component items.
- The interface between off-site manufactured components and goods, the quality checks, and the site delivery and installation requirements and the question of accuracy.
- Requirements for approval of samples.
- Planned dates for project audits.
- Commissioning, testing and hand-over requirements.

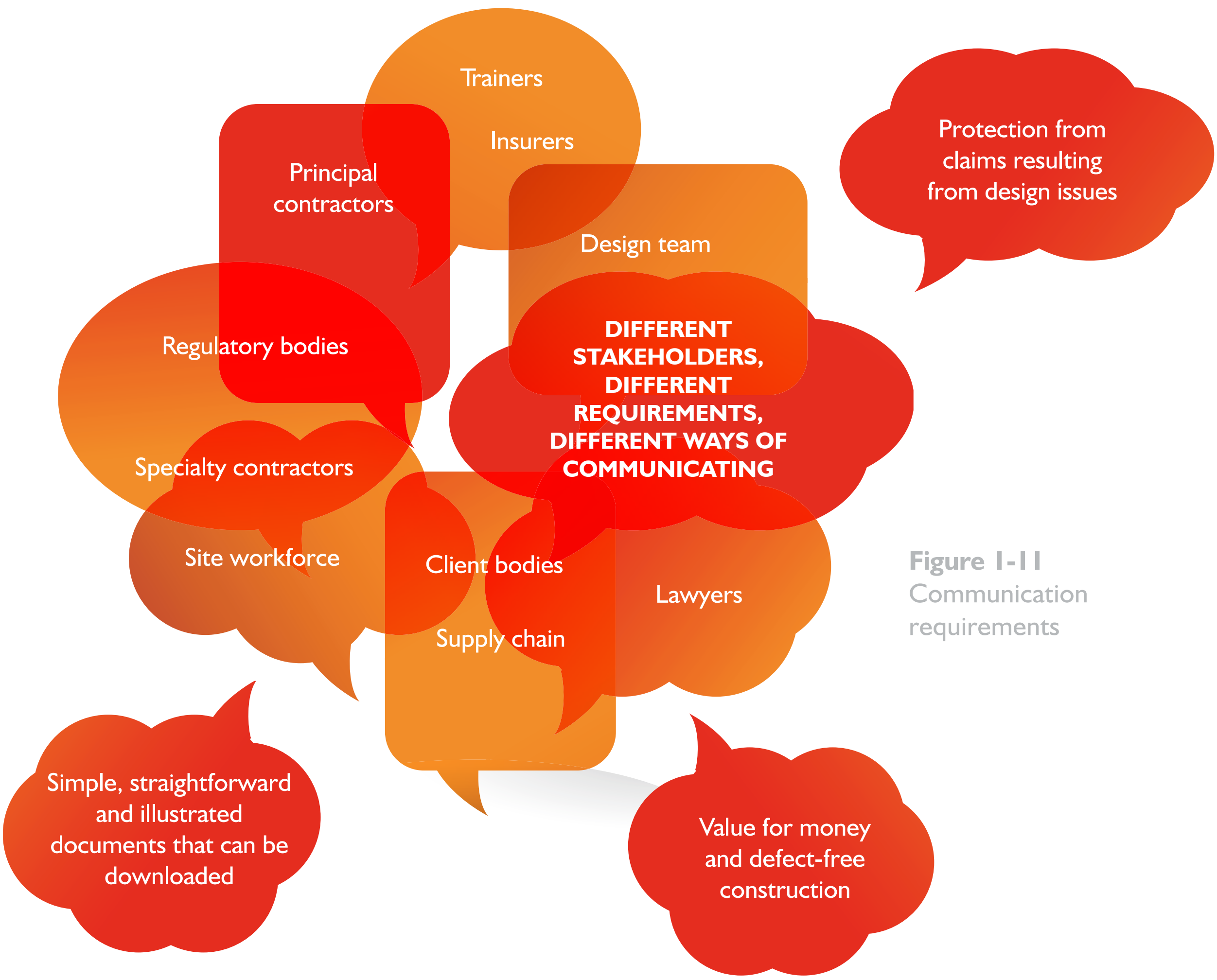


Figure 1-11 Communication requirements

Quality is profit to the maker, value to the user, and satisfaction to both. Defective work, re-work, remedial work, and poor quality means everyone loses.

Delays caused by uncertainty can affect quality on site. Lack of design information will cause frustration and delay.

In the quality process, everybody is reliant upon each other. One weak link and it all falls down. Thus, the system needs to be more robust than it is today.

Poor quality installations could cause bigger problems than those they are seeking to solve, such as being detrimental to the health of occupants, possible property damage, short term remedial costs, and longer term damage to the industry's reputation and consumer trust. OFGEM's Technical Monitoring Report inspected 6.9% of the almost 1.5 million measures installed during the first ECO period between January 2013 and March 2015. Of these, 9.9% did not meet the necessary installation standards in the first instance and required additional work to be undertaken. The majority of these failures are not due to intentional poor performance, but the result of gaps in standards or the training provided.

Identifying where, why, and how defects occur is important, either internal or external. The associated costs may be the result of defects during and post production, non-conformance to the specification, inappropriate standards and codes, poor information not communicated effectively, and the cost of quality management to reduce/eradicate failures. The consequential economic and reputational loss caused by poor quality can be significant.

Quality manifests itself in all aspects of site production, in health and safety, managing risk, minimising waste of materials, avoiding re-work, and in the use of plant and equipment. When a scaffold collapses because of high winds, was there a quality management failing in some aspect of the work, whether it be in the temporary works design, the materials used, or in the erection process that failed to meet the standard required? Or, was it caused by some other failing which resulted in the collapse.

The specification, bill of quantities, local, national and international standards, building codes/regulations, codes of practice, and conditions of contract stipulate the requirements for quality on the project. The contract will state there is an absolute obligation to carry out and complete the works "in a proper and workmanlike manner and in compliance with the contract documents". The contractor must perform the works where there is this obligation to carry out and complete the works with reasonable skill and care. Responsibility for setting out is usually the responsibility of the principal contractor. Once datum points and vertical lines are established, the specialty contractors will be able to align their work for accuracy.

“It is no longer acceptable to think of quality as merely meeting the technical and performance specifications in the contract... that will lead to mediocrity.”

The principal contractor and the specialty contractors will embed a quality management system in the site delivery process on large projects, with manuals, checking, and conformance procedures. For a smaller contractor they may not be formalised in manuals, but they will exist; such systems may be, not paying for work until it meets the required standard, or not giving a poor performer further work. Unless everyone on the project understands the quality standards expected, the project can only be as good as the weakest link; there is no satisfaction in the client saying the quality of the joinery on the project is wonderful, but they are experiencing water leaks in the building! Specialist consultants understand process; they must understand site production, with everything in construction becoming more complex and interdependent.

The key to success is the variety of people who come together to construct a project working as a temporary team, many of whom work on casual contracts.

1.14 The quality roadmap

The quality road map in Figure 1-12 gives the direction of travel for a quality management system. The system outlines the quality proposition, from which the project quality plan is produced within the context of the project constraints and operating standards. From every project there must be lessons learned to take forward into the future. New technologies can help, but people need to have an open mind and adapt tried and tested technologies from other industries.

The roadmap provides a clear direction of travel. However, the construction industry faces many challenges:

- How to manage the interface between design and site production to ensure the correct information is available at the right time and that shows the level of detail required to construct the project.
- How to ensure the tender documents reflect fully all the quality requirements of the project, and they are priced correctly by all the parties.
- Ensuring the project construction quality plan reflects the client’s and design team requirements and conformance for quality.
- Making sure that the quality plan has meaning and is not seen as a box ticking exercise.
- Ensuring that organisations in the supply chain are aligned to the quality plan for the project and meet the client’s requirements.
- Managing the conformance for quality of off-site production components when they are manufactured and then assembled on site.
- Developing a culture for quality delivery and behaviour-based quality in the industry that puts the client at the centre for customer satisfaction.
- Embracing digital systems that can help to manage and improve quality on the job site.
- Learning from mistakes by having targets and a robust feedback system.

Figure 1-12
Quality roadmap

None of the above can be achieved without a quality management system that includes the corporate quality policy, a project quality plan, quality assurance and control procedures, and feedback systems to learn from success and failure which ensure continuous improvement.

Ensuring the public image of construction activities is also important, quality is reflected in the tidiness of the site and the image the site portrays to the public at large.

Section

2

Quality Management Systems

The Basics

2.1 Quality management system

A quality management system is devised to deliver a quality product or service to the highest possible standard. It provides a framework for planning, executing, monitoring and improving the performance of quality management activities in an organisation. Consistency and improvement of processes is important in meeting the customer's requirements.

The system must be dynamic and kept under review, it must evolve over time through periods of improvement and must be appropriate for the organisation. A quality management system is also a system for documenting the structure, procedures, responsibilities and processes needed for effective quality management. The scope of the quality management system must be clear on what it covers

Construction involves numerous linked activities so the quality management system in construction organisations has to reflect the way the industry works, with dependency on consultants delivering information on time to the right quality, suppliers delivering materials as promised, and specialty companies meeting their performance promises.

The utility companies, local authority control officers, and the inspection authorities all play an important role. The weather cannot be controlled and adverse weather can impact quality. Building or refurbishing an existing asset is not like working in a controlled factory environment; risk has to be recognised and managed. The quality management system must therefore be realistic, dynamic, and responsive. The system must recognise changes and risks associated with that environment.

The design team has an important role to play, they should provide timely information about their design requirements to ensure quality management on site. Late changes to the design cause re-work and loss of motivation to the site workforce.

A review was undertaken with site managers to understand the drivers and issues influencing quality in the production phase. Figure 2-1 shows a network diagram with the linkages. The quality policy and the quality plan were seen as being important. The company quality policy needs to be clear and relevant, and not full of general statements with little meaning. The quality plan defines what is to be done, by whom, and sets out the responsibilities. Hiding behind pages of codes and standards does not help to engender trust and collaboration.

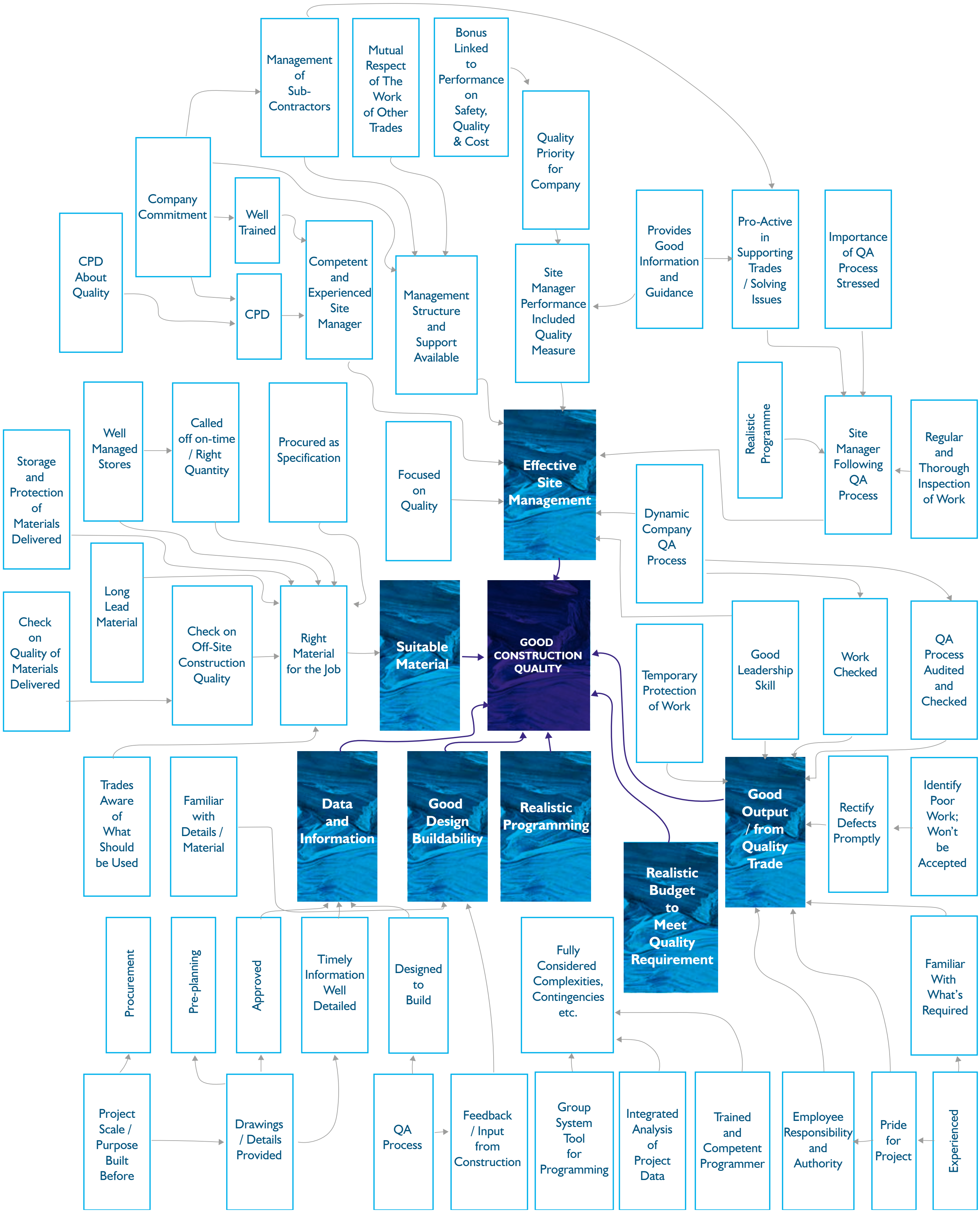


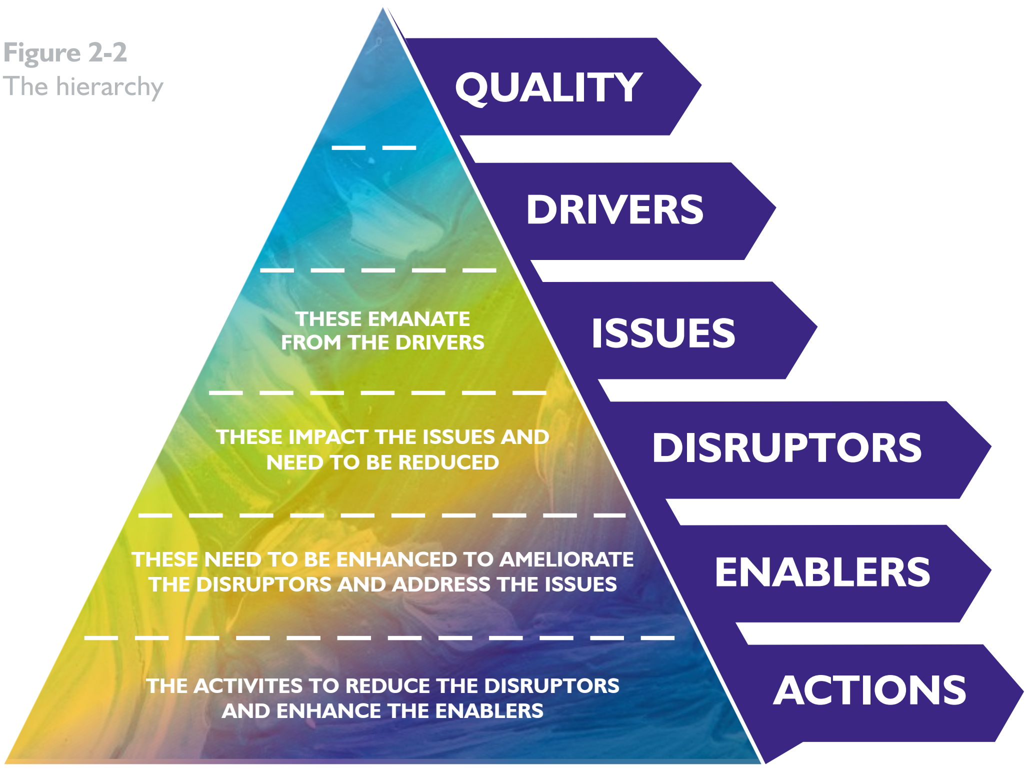
Figure 2-1
Quality management on the job site

Trust and empowerment are important. Trusting to deliver on promises and empowering individuals to take responsibility. Empowerment is being able to make decisions in the workplace that are accountable and responsible, which is especially important for quality; being free to speak out about something that is poor quality allows someone to take responsibility and pride in their work.

Empowering workers so that they feel an integral part of the whole process/company can be motivating. Relationships across the project and the supply chain must be developed and maintained, they do not just happen. The company's quality objectives should be explained, and attention drawn to the quality management plan with the supervisory, monitoring and testing processes at site induction.
A hierarchy was devised that considered the drivers, issues, disruptors, enablers, and actions that influence the delivery of quality on the job site. This underpins the development of quality management and quality plans. Figure 2-2 shows the pyramid that provides a structure when producing documents and actions on quality.

The hierarchy is discussed later in section 5 of the Guide. The purpose is to structure an approach to thinking about the planning of quality management. Certification and accreditation are an important part of the whole process, they are an enabler and underpin the quality control process.

Figure 2-2
The hierarchy



2.2 Certification and accreditation

Standards, conformity assessment and accreditation are the established three pillars on which most quality infrastructures are built.

As construction becomes more specialised, so conformity assessment is increasing in importance. Most organisations are faced with the choice between accreditation and certification when implementing a quality management system.

Certification is the third-party endorsement of an organisation's systems or products. It represents a written assurance by a third party of the conformity of a product, process or service to specified requirements. Certification relates to the company as a whole. Over one million organisations have been certified world-wide for ISO 9001 across all industry sectors.

Accreditation is the formal recognition by an authoritative body of the competence to work to specified standards. Accreditation is an independent third-party endorsement of the certification.

The United Kingdom Accreditation Service (UKAS) is the national accreditation body for the UK that assesses organisations that provide testing, inspection, calibration, and certification services. There are many specialist testing organisations, for example testing a pile loading, or an air leakage test. In both circumstances it may be better to employ a specialist organisation that undertakes the testing, rather than a generalist who is overseeing the BS EN ISO 9001:2015 standards.

By providing assurance that organisations are compliant with their regulatory responsibilities, accreditation reduces the need for government and regulatory bodies to employ their own specialist assessment staff.

2.3 Conformance ISO 9001:2015

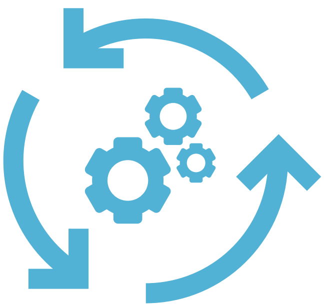
Being ISO 9001:2015 certified, provides a level of confidence in an organisation's ability to deliver products or services that meet the needs and expectations of the customers.

ISO 9000:2015 describes the fundamentals and vocabulary for quality management systems. These are shown in Figure 2-3. The quality management system should be capable of being third-party certificated to an international standard.

Where ISO 9001:2015 has been adopted or certification is sought, every effort is made to integrate the ISO main requirements into the company's quality policy. The standard's principles involve a process approach, using a systematic definition and management of processes, and their interactions, through a Plan-Do-Check-Act (PDCA) cycle, which enables the:

1. Understanding and consistency in meeting requirements.
2. Consideration of processes in terms of added value.
3. Achievement of effective process performance.
4. Improvement of processes based on evaluation of data and information.

The challenge in construction is the diversity of organisations in the supply chain and their interdependence to produce a final project. Small, medium, and large projects have the same characteristics, with supply chains and organisations being dependent on each other to meet project requirements. Ultimately, it is about responsibility, and a willingness to deliver the best quality possible.



2.4 Other standards

ISO 9004:2018 Quality management - Guidance to achieve sustained success is recommended for organizations whose top management wish to extend the benefits of ISO 9001 in pursuit of systematic and continual improvement of the organization's overall performance. However, it is not intended for certification or contractual purposes.

ISO 10006 (BS EN 10006) gives guidelines for the application of quality management in projects. It covers quality management systems in projects (Clause 4); management responsibility in projects (Clause 5); resource management in projects (Clause 6); product/service realisation in projects (Clause 7); and measurement, analysis and improvement in projects (Clause 8).

Figure 2-3
ISO 9001:2015 quality management systems

BS 8000:2014 is a series of standards that details workmanship on construction sites. The documents all relate to the improvement of better quality on the job site. The codes of practice have many specialisms, such as a code of practice for plastering and rendering, concrete work, glazing, excavation and filling, masonry and below ground drainage. It takes the form of guidance and recommendations rather than specifications and creates awareness of adjoining / dependent trades and work packages in the construction sequence. Conformance to an ISO or BS does not confer immunity from legal and contractual obligations.

The standard is designed as an overall preventative approach and provides the foundation for a long-term and sustainable management system. If ISO 9001:2015 is adopted, then a quality plan should be prepared to conform to its requirements for each project. ISO 10005:2018 Quality management – guidelines for quality plans, provides guidance that may be used independently of ISO 9001. There is significant correlation between the two standards, neither standard is construction specific.

Many suppliers and manufacturers in the construction supply chain adopt the principle of putting the customer first; they understand the customer, whereas on construction projects the focus has been on delivering the project to the contract requirements and the specification. The relationship with the client/project sponsor for the companies in the construction supply chain can feel distant because of the layering of the contract arrangements. However, the realisation is that without the project sponsor there would be no construction project. The client is therefore paramount in ensuring customer focus is achieved. The fundamental concept of a quality management system is shown in Figure 2-4.

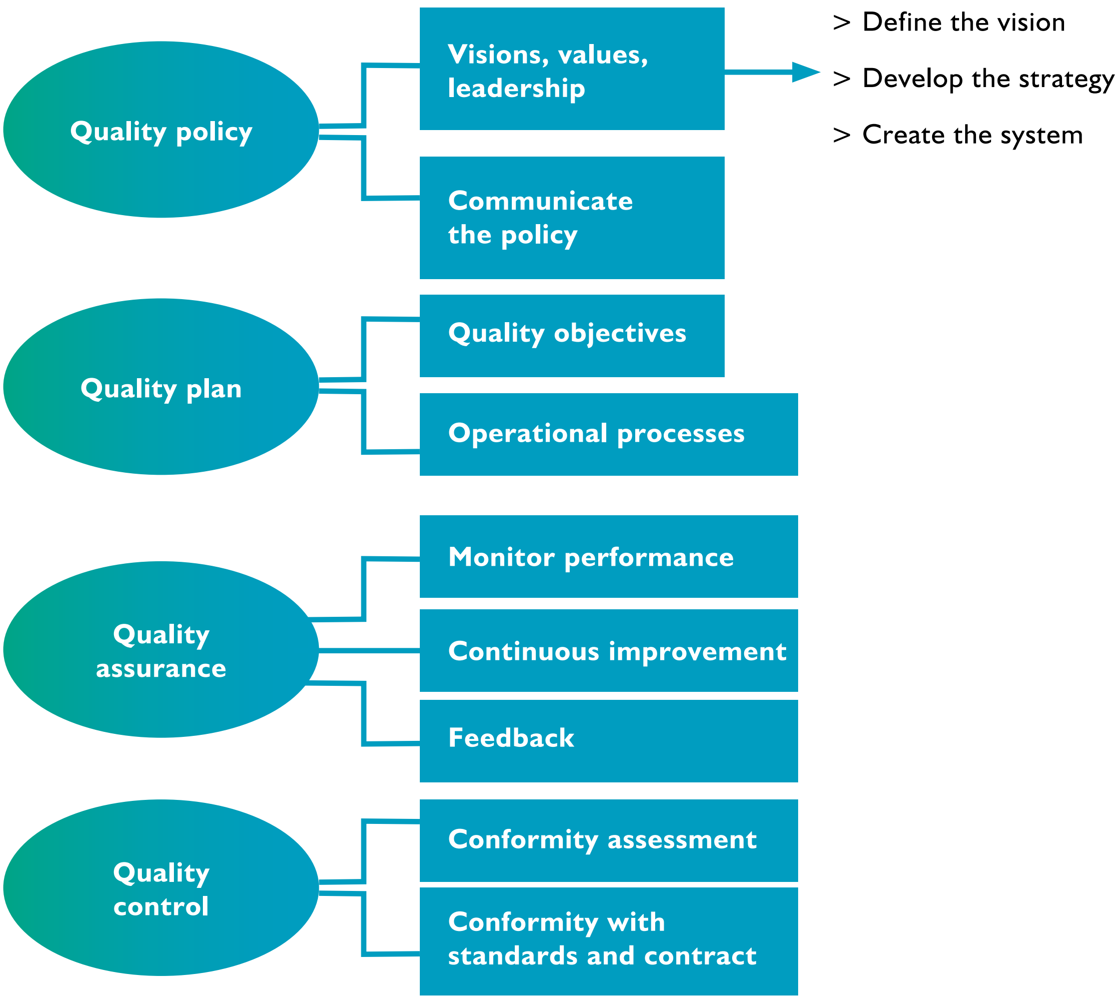


Figure 2-4
Fundamental concept of the quality management system

The boundaries of the quality management system must be taken into account, with consideration given to the infrastructure of the organisation, the different project sites and activities, commercial policies, and centrally driven, or externally-provided functions and services, such as outsourcing to a third party the responsibility for conformity checking of quality. A private house buyer's requirements will be different to a large water utilities company.

Having one overarching centralised quality management system for the whole organisation may not be appropriate for a highly diverse business, such as a construction firm engaged in infrastructure, commercial development, and the private housing sector. The organisation should determine the inputs required and the outputs expected from its processes.

Construction has a product that is often large, immobile, and assembled at the point of consumption using materials and components sourced from a variety of suppliers and manufacturers. But, the design and assembly process is reliant upon a system that delivers a quality product; that is why the quality management system is so important. The world is moving towards a circular economy, away from the linear approach of take, make, and throw away. Understanding and managing quality is at the heart of the project delivery.

2.5 Quality policy

The quality policy establishes, implements and maintains the policy that sets out the strategic vision and values for incorporating quality into the culture of the business. The policy must be communicated, understood, and applied within the organisation. It needs to be made available to all the interested parties. There must be strong governance to define the organisation's aims and translate them into action. Increasingly, clients and consultants are requesting the company quality policy to be submitted when considering tenders for a project. General terms are difficult to interpret and have little meaning, such as 'being world class!'

The quality policy should be about describing the vision, values, and leadership aspects. It must be appropriate for its purpose and context of the organisation.

A large company will have a different policy to a small business, even though the vision is the same. The vision must be realisable and show commitment to quality values and to customers. Having metrics to measure quality is part of the values, such as getting it right first time and learning from mistakes.

Respecting that everyone has a role in creating value in a business is important. There must be a commitment to continual improvement of the quality management system, and to ensuring the processes deliver their intended outputs. People working under the control of the organisation should be made aware of the implications of not conforming to the quality management system requirements.

The quality policy is sometimes perceived as no more than a set of slogans, however the requirement is for every person to embrace the company's quality policy. Its objectives and effectiveness should be subject to audit on a regular basis, at least annually, to ensure targets are met and that the policy remains effective in a changing business, construction and compliance / legislation environment.

VISION

Clearly stated

Understood

Continuously updated

Compelling

Realisable

Commitment

Customer satisfaction

VALUES

Clearly stated

Understood

Continuously applied

Supported by metrics and incentives

Respectful of all contrubutions to improve quality

Continuous improvement and learn from mistakes

LEADERSHIP

Senior management commitment

Lives the values

Supports the team

Ensures operational procedures are carried out

Monitors performance

Creates the systems

Ensures the vision

2.6 A quality policy in practice

Some of the terms that may be used in a construction quality policy statement are:

- The company is committed to meeting the highest levels of quality in all its business activities. It will practice and promote the highest quality standards across all operational business units, and on all projects, including joint ventures. Responsibility for quality delivery lies with everybody from the Chief Executive to everyone in the business.
- There will be no compromise on the commitment to meet client requirements, deliver exceptional service and identify and eliminate all unnecessary quality-related costs. The commitment to manage quality is taken very seriously.
- It is a requirement that good quality management is a primary consideration and that all activities are carried out right first time, and to the highest standards.
- The Chief Executive is committed to complying with the requirements of the quality management system, and continually improving the effectiveness of the quality management system.
- Continuous improvement is part of the culture of the business.
- A risk-based approach is taken to address the requirements of quality management.
- The company will:
  - Systematically eliminate abortive work in all workplaces.
  - Meet or exceed the expectations of customers.
  - Strive to achieve zero defects and no waste by constantly learning from feedback and continuous improvement.
  - Engage everyone's commitment across the supply chain at all levels of the company.
  - Continually improve performance through regular reviews.

- o Maintain quality management systems meeting the requirements of ISO 9001, which will be integrated across all the systems to manage health and safety and the environment.
- o Ensuring the integrity and appropriateness of quality inspection and testing activities to provide open and honest reporting.
- o Carry out regular quality assurance and control audits.
- o Set and achieve clearly defined annual quality objectives.
- o Ensure all personnel are fully competent to carry out their assigned task.
- o Provide all necessary information, training and supervision to all personnel and subcontractors.

- With this policy; we accept quality as an integral part of our corporate culture and business and undertake the responsibility to carry our knowledge and experience from the past to the future.
- This policy will be reviewed annually and as and when changes in legislation or circumstances occur.

It is a requirement that all employees are made aware of their individual responsibilities in relation to quality, implement this policy, and promote the company's quality management system.

2.7 Leadership in developing the quality policy and the plan

Leadership is critical - without leadership there will be no commitment from the team. Leaders must demonstrate that they live by the values as shown in Figure 2-5. They must align the organisation to ensure employees are clear about what needs to get done to execute the quality policy.

Leaders are under unrelenting pressure to innovate and help their organisations stand out in a sea of ruthless competition. The reputation of a business is part of the assets in the balance sheet.

Figure 2-5
Leadership attributes

Good leaders must have attributes that show a passion for quality and customer satisfaction, with a will to win and develop the team to deliver on the quality policy. Leadership involves being accountable and holding others to be accountable to deliver on their promises for good quality.

Technology can help, but it should never replace the human element. Leaders must ensure that employees have complete clarity in terms of the company's vision to do their jobs effectively.

2.8 Quality planning at the outset

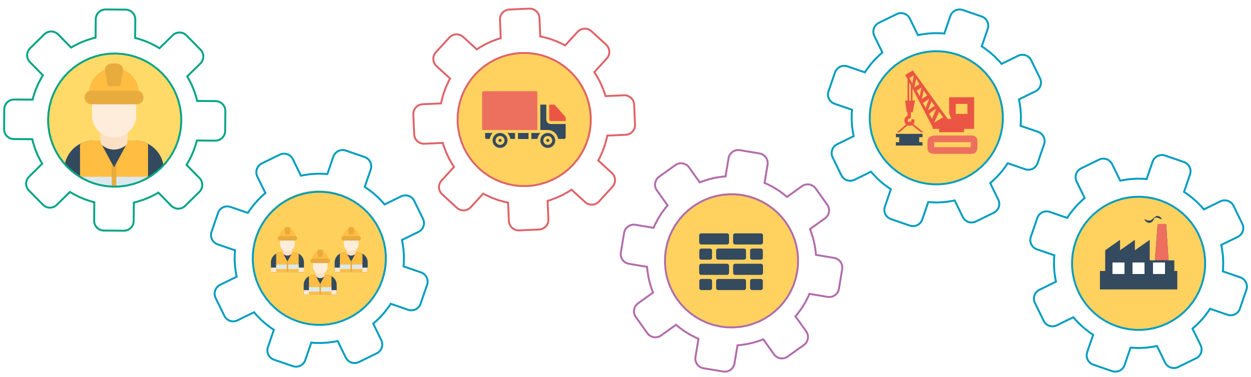
Quality planning is not new, but its importance has increased significantly over the past decade because the construction industry is now expected to improve its delivery in line with manufacturing. Failure is not tolerated, and every aspect of quality must be considered, and that includes the quality of health and safety on the job site. Quality must be embedded as an integral part of the pricing process and not seen as an add-on.

The cost of quality is embedded into the tender price, by pricing the work items to reflect the quality requirements and expectations; it is the starting point for the contractor's quality planning for a project. Meeting and pricing the quality requirements can be a pre-requisite for the selection criteria at the tender stage, where weighted evaluation criteria is used. Quality can be measured in a variety of ways. Part of the tender submission may require evidence to show that the contractor has a quality management system in place that will be applicable through the supply chain.

Attaching a cost to quality is unrealistic. Unit price rates reflect the cost of labour and the time requirement, productivity, materials, wastage, plant and equipment, site and head office overheads, and profit. There is no one line item that says cost of quality. The cost must be an integral part of the pricing process, that is where experience and knowledge matters. BIM and artificial intelligence can help, but there is no substitute for professional judgement.

The contractor needs to be confident in the ability of a supplier/specialty contractor to deliver to the required quality standards, with due allowance for the cost and time. The evaluation of each supplier/specialty contractor is based on set criteria for comparisons to be made. Failure to make these checks could result in late delivery and poor standards of work, which may have cost and reputational implications. The methods to monitor and control suppliers/specialty contractors during production should be agreed between both parties.

Quality planning has to recognise the reality of long and interrelated supply chains. Typically, between 50% and 75% of the total value of the work on a project is accounted for by a small number of major specialty contractors, but projects also involve a large number of low-value transactions within each supply chain. Much of the value of construction work is aggregated in this way and delivery of the work packages is undertaken by a disaggregated supply chain. Complex sub-contracts might involve elements of design, complex components and integration with other sub-contracts, such as the structure or building services. The material producers, plant hire businesses, and intermediaries such as builders' merchants have an important role in facilitating the ready availability of construction products and services for small and low value transactions. These organisations operate at all tiers in the supply chain. Hence, planning for quality has become more important to get right.



2.9 Planning and scheduling

If planning and scheduling is to add value, then it should look at both costs and benefits. Remedying defects cost time, money, and reputation; it leads to unhappy clients and a demotivated workforce – nobody wins! The benefits of planning are satisfied and informed clients that will lead to repeat business.

Companies have two accounts, financial accounts and reputation accounts; poor quality affects the reputation account, which ultimately impacts the financial account and balance sheet

Construction planning and scheduling is about ensuring the effective use of resources (people, plant, equipment, and technology) as well as space, information, time, and money to deliver on time, on budget, safely to the required quality.

Failing to plan = Planning to fail

Quality planning is a process that quality departments, quality managers, and quality professionals undertake in their organisations to identify the quality initiatives to best manage quality today and into the future. If quality fails and defects occur, the customer will be unhappy and repeat business is at risk. Quality means reliability, resilience, and fitness for purpose. The challenge is that the construction industry has become more complex, with more specialisms and more organisations involved. Perhaps that is true of society today. To ignore complexity and risk is folly.

Robust planning and programming require the integration of inspection and testing requirements, achieved through an Inspection and Testing Plan, which defines roles and responsibilities, employs continuous or discrete checking, and identifies hold points where appropriate.

The plan should include inspection procedures, testing (and their frequency), incorporating a contingency should remedial work be necessary, and commissioning. Quality assurance protocols need to be established.

2.10 Quality plan

All projects should have a quality plan prepared specifically for the project.

The quality plan is an operational document produced for the project to ensure there is clarity about the responsibilities, standards and conformance to be met. It aims to create a get-it-right-first-time culture and to ensure there are no legacy issues.

It describes the special quality requirements, the client expectations, what will be done, what resources will be required, who will be responsible, when it will be completed, how the results will be evaluated, methods of conformance for assurance and control, testing and inspection, documentation and control of records, and non-conformance procedure to be followed.

The plan should show that people/organisations are competent on the basis of their training, and experience. In some circumstances documented information may be required as evidence of competence. The statutory and regulatory requirements should be stated and complied with.

The plan should address both the risks of failure to comply with the requirements for the project, and the opportunities to satisfy the quality requirements.

Quality assurance of how site activities are to be part of the quality plan, including control through the supply chain. This is even more important with the increasing use of off-site manufacturing; the plan must show how quality is to be maintained at the factory and when the components arrive on the job site. It may be necessary to inspect the goods during the manufacturing process.

The fundamental requirements to meet ISO 9001:2015 is compliance with the Plan, Check, Do, Act (PDCA) cycle by taking into account the risk-based thinking that affects the context and the environment for the project – see 2.10.2. The quality plan is defined in the contract documents and can be accepted or approved by the client / client's representative prior to commencement of work; this is common for infrastructure works. ISO 10005:2018 sets out the processes required in the production of a quality plan. The guidelines are intended for any industry, and applicable to construction. Table 2-1 shows a comparison between the ISO 10005 headings and those found in industry practice.

Figure 2-6 shows in simple terms what the quality policy and plan give the organisation. The alternative of no plan is to hope that everything will be OK, but if something serious does happen, there can be financial consequences. The Quality Plan is covered in more detail in Section 4.

2.10.1 Accuracy and risk

Many documents specify accuracy; it matters because of the need for component and material alignment; if cladding panels are intended to align but fail to do so, re-work and cost will be incurred. Accuracy is specified by the design team by reference to standards, manufacturers' specifications, installation instructions and other guidance documents.

BS 8000:2014 states: "in the absence of any reference, the legal principle of normal skill and care applies."

ISO 10005: 2018	Industry practice
Scope of the Quality Plan Quality objectives	Project-related information e.g. scope, phases, schedule, risks, company quality policy Special client/customer requirements Contract conditions impacting quality
Quality Plan responsibilities	Roles, responsibilities and hierarchy
Documentation Resources	Key personnel, their responsibilities, competencies Role of a potential clerk of works Reporting lines/communication Document strategy – filing, numbering, security Plant use and restrictions
Design and development	Codes, standards and specifications and planning consents and conditions Design development and management
Procurement	Supply chain - externally provided processes, products and services
Identification and traceability	Identification and traceability
Storage and handling	Materials, components, systems – storage, access, delivery and handling
Monitoring and measurement	Inspection, testing and verification plan - internal and third party
	Performance monitoring and project reporting
Non-conformance	Control/monitoring of non-conformity plan Plan for rectification of non-conforming items
Commissioning and testing	Testing and commissioning including by whom Special client tests Documentation requirements

Table 2-1
Comparison between the ISO 10005 headings and those developed from industry practice

Figure 2-6
What a quality policy and plan gives you

Understanding accuracy needs the recognition that meeting the tolerances is an important part of the quality assurance process. Any discrepancies such as out of tolerance substrates, edges, surfaces or openings should be reported immediately before undertaking subsequent operations.

Risk is inherent in every project, irrespective of size and complexity. ISO 9001 stipulates that "risk-based thinking enables an organization to determine the factors that could cause its processes and its quality management system to deviate from the planned results, to put in place preventive controls to minimize negative effects and to make maximum use of opportunities as they arise". The construction industry is well used to managing risk - clarity is required in the plan to explain who takes responsibility. Preventive actions should be highlighted to avoid non-conformities. If any non-conformities do occur, the plan must make clear the actions to be taken to prevent recurrence.

Quality management procedures are much less expensive than litigation!

2.10.2 Plan, Do, Check, Act (PDCA)

A PDCA approach for construction has been devised and shown in Figure 2-7 using the principles embedded in ISO 9001:2015. The diagram shows the four PDCA actions based upon a set of cogs. If one cog fails, it impacts the whole quality management system. In the same way if one of the cogs is not functioning efficiently, the system slows and does not operate effectively. The concept of the cogs will be explained in Section 3.

Feedback is important, both good and bad. Feedback is the bedrock to continuous improvement. Positive feedback provides motivation, whereas negative feedback matters, it gives the opportunity to learn from mistakes, but it must not be a de-motivator.

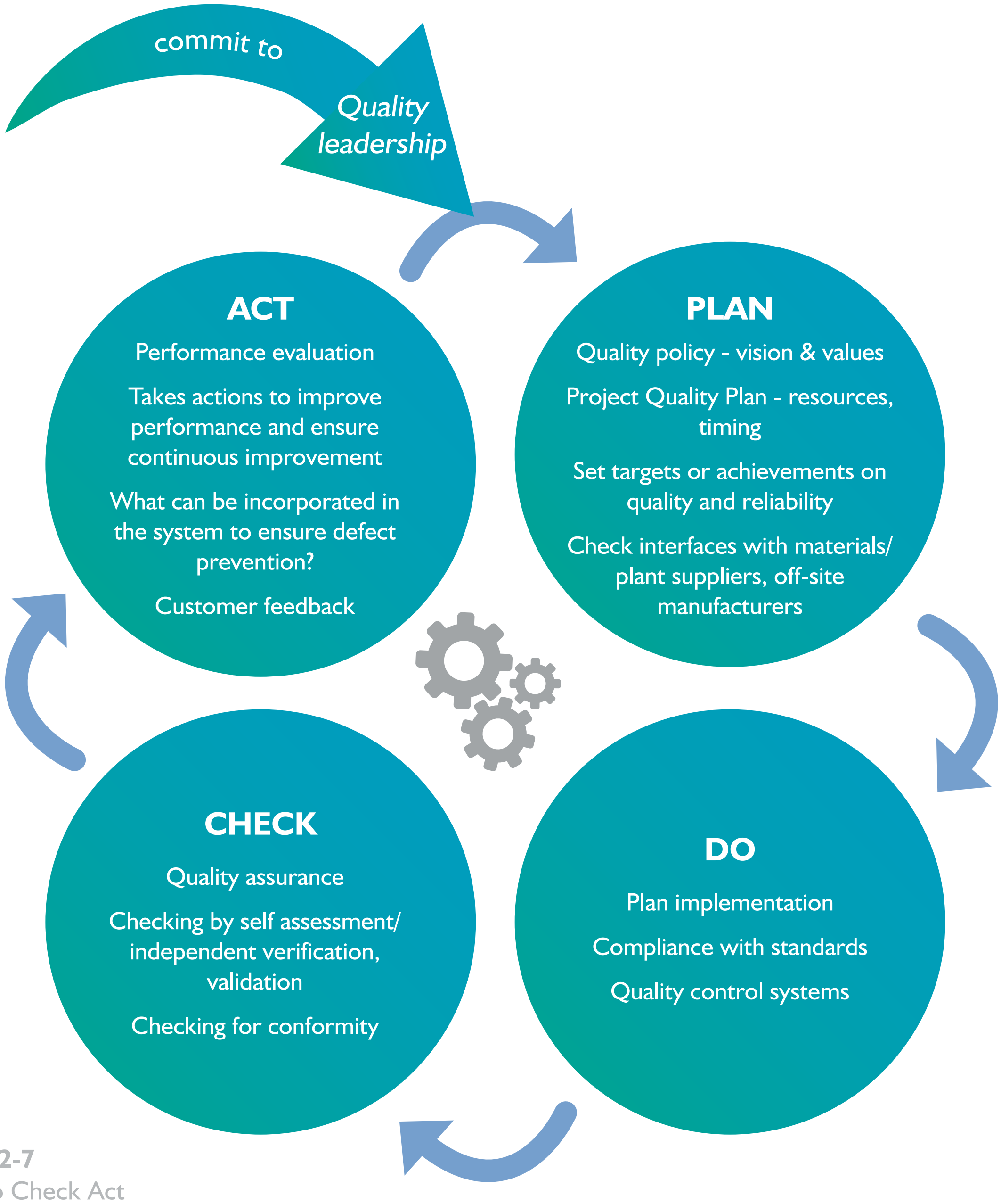


Figure 2-7
Plan Do Check Act

- FEEDBACK	+
☒ Waste left on site	☑ Good work, worthy of praise
☒ Evidence of damage to other trades' work	☑ Zero defects, very impressive overall performance on cost, time and workmanship
☒ Need to work together to ensure teams arrive on time with the right equipment	☑ Good, clean, tidy work
☒ Important to attend all meetings when invited	☑ Excellent attitude to collaboration

2.11 Quality assurance and control

Quality management is a whole-business system approach to managing quality. Figure 2-8 shows the relationship between the quality management system, quality assurance, and quality control. Many people get confused between the differences of quality assurance and quality control.

Quality control is based on inspection and removes defects; quality assurance is based on processes and builds quality in.

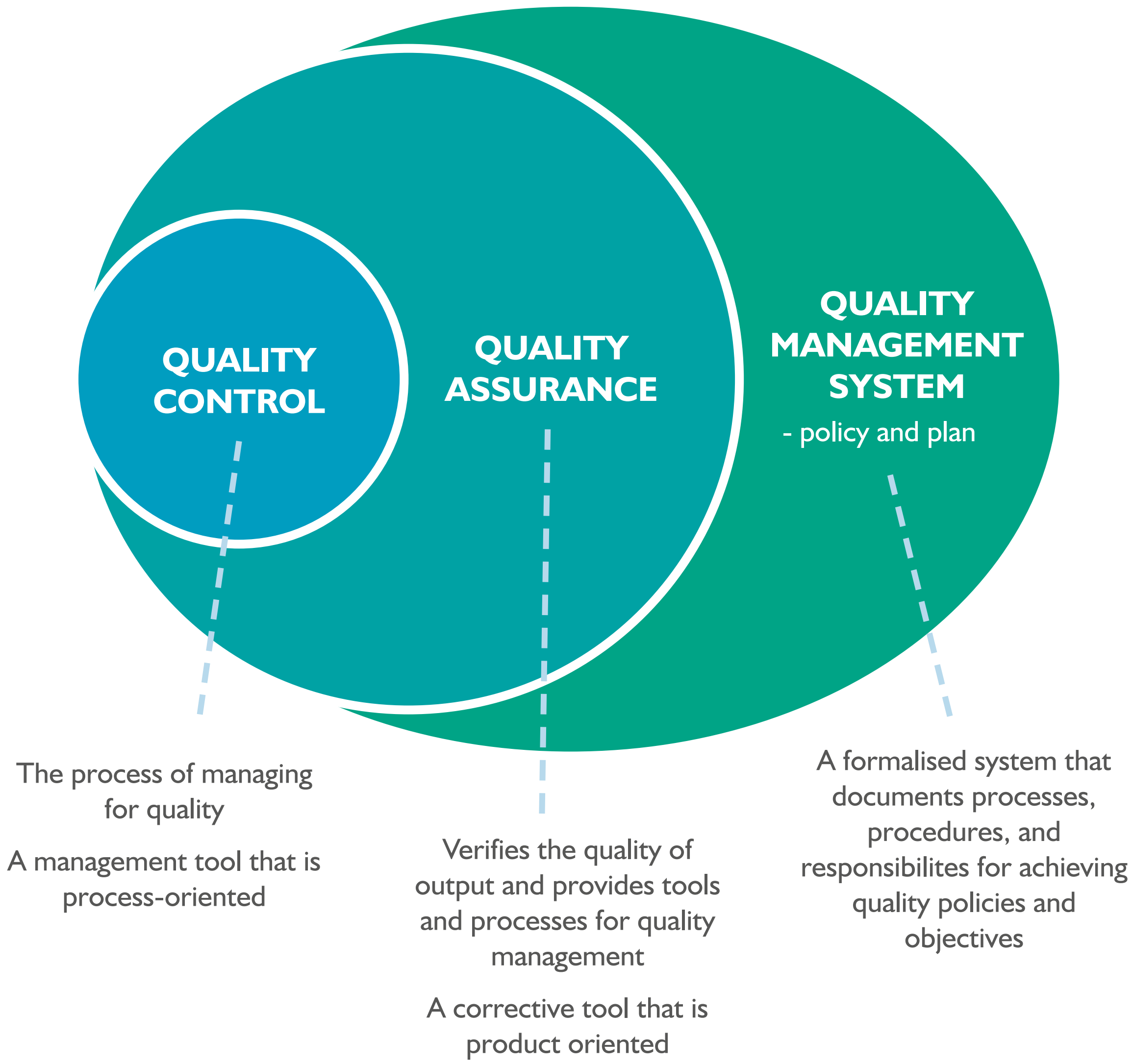


Figure 2-8
Quality hierarchy

The drivers of construction quality assurance and control have four approaches:

1. **Regulatory/conformance-led**

   Regulatory conformance means conforming to a rule, such as a specification, policy, regulation, standard, or law. Contractual compliance is equally important. Checks and penalties are used, with responsibility allocated through national and international standards, such as the ISO 9000 family of quality management systems that helps organisations ensure they meet customers and other stakeholder needs within statutory and regulatory requirements. Meeting such standards can be contractual or voluntary. Many clients require organisations to be ISO 9001 certified in order for them to be included on a tender list. The project specification defines the conformance requirements to meet the standard required, controlled in-house, or by independent parties, and validated by specialists (e.g. clerk of works, independent consultant).

   Some overseas governments have set up quality assurance agencies to help with conformance. For example, established in 1989 as a non-profit-distributing organisation by the Hong Kong Government, the Hong Kong Quality Assurance Agency (HKQAA) helps industry and commerce in the development of quality, environmental, safety, hygiene, social and other management systems.

2. **Going beyond conformance and being market-led**

   Companies decide on the establishment of their quality policy and the assurance and control procedures. BMW proved this worked in the automotive sector, where the product has a long-term guarantee that demonstrates the commitment to excellence in design and quality control, ensuring functionality, longevity, and regulatory conformance and most importantly, customer satisfaction. Companies may choose to incorporate the ISO requirements into their management system.

3. **Industry-led registration and conformance schemes**

   Trade bodies establish minimum standards and conformity requirements; members must comply with those standards to ensure membership of the body, such as Checkatrade, Corgi, and the Considerate Constructors' Scheme.

   In Ireland for example, the CIRI is an online register, supported by the Government, of competent builders, contractors, specialist sub-contractors and tradespersons who undertake construction works. Its objective is to be recognized as the primary online resource used by consumers in the public and private procurement of construction services. Builders included on CIRI are regarded as competent for projects consistent with their registration profile.

4. **Compensatory/insurance-led**

   Offering warranties and guarantees, such as the UK National House Building Council; clients seek an external body to validate the quality guarantee and to provide a guarantee should problems occur.

Legislation is due to come in for the creation of a New Homes Ombudsman. "There will be a statutory obligation for developers of new build homes to belong to the New Homes Ombudsman. The scheme will meet the requirements to be an ombudsman. It will have powers to hold developers to account and to require them to put matters right. This will provide new-build homebuyers with the protection they require" (Ministry of Housing, Communities and Local Government, 2020, p.5)

Health and safety in UK construction has benefited greatly from the regulatory/conformance nature of the Construction Design and Management (CDM) Regulations, with a legal requirement subject to punishment by fine/penalty. These set out the roles and liabilities of the client, designer, and contractor in a project.

Construction can learn from other industry sectors, the rail, petrochemical, oil and gas, water, and energy industries that stipulate clearly what they need from a quality management system and what they are prepared to accept.

It is not just about getting paid to deliver good quality construction; quality should be a given right.

In order to win projects under the JCT Framework Agreement 2016, an organisation must demonstrate its commitment to quality control and assurance. The examples of quality failure in completed projects, such as the Edinburgh Schools, and the Carillion plc PPP hospital projects where serious defects were discovered following the company going into liquidation, in the case of Carillion it has led to increases in project cost running into tens of million pounds. In such cases the impact of the failure must be measured on a scale that has some meaning.

Some projects use a tender evaluation process using weighted criteria to determine the tender that offers the best value, which will include a weighting for quality. Non-price qualitative criteria are used to normalise the tender offers. Quality can rate as high as 20% of the project criteria.

2.12 Quality assurance

Quality assurance focuses on providing confidence that the quality requirements are maintained. The aim is to maintain and improve processes in order to prevent defects. Quality assurance is the responsibility of everyone involved in a project.

Quality assurance can be classified into four main headings:

1. **Prevention and planning**: to develop activities that ensure right-first-time performance through leadership, good governance, and continuous improvement. Good communication and effective management of the interfaces between design and production is crucial with all members of the supply chain. Design management is important to quality assurance by ensuring design details are available at the right time. Prevention also includes planning for any failure that may take place, and for temporary protection measures required during the site production process.
2. **Appraisal, inspection, and testing**: activities that check whether right-first-time is achieved, not ticking a box, but really ensuring the quality requirements have been met from manufacture, delivery, storage, through to site installation, testing, commissioning, and handover.
3. **Correction**: remedial activities that result from not conforming to getting it right-first-time, through failure to meet the specification and conformance requirements, or failure in a testing process. Failure causes delay to the project and costs everyone money. Making corrections in the short term does not improve the system and/or the process in the long run.

   Corrective action involves understanding the defect that caused the problem and addressing the root cause so that it does not occur again. Preventive action is better as it can assess the risk of the defect occurring before it happens.
4. **Understanding implications**: there is a desire to hunt the guilty in a litigious world, for instance, equipment failure can result in significant consequential financial loss. Someone has to take responsibility. Insurers are not charities; they will only pay for gross neglect, not poor quality. The challenge is that a small failure can cause huge consequential loss. Any small failure on a rail or power project can result in huge claims. An example is a temporary hoarding that collapsed in high winds in London's Oxford Street resulting in the temporary closure of the street and the traders claiming against the principal contractor for interruption of business and loss of revenue.

2.12.1 Inspection and Test Plan (ITP)

The ITP is a plan of when, what, who, and how inspections will be conducted to ensure work is meeting necessary standards. It details the critical points at various stages within a project for scheduled inspections and verifications to make sure the project is progressing as it should do. The ITP should specify details of the verification and inspection bodies where specialist inspection and testing is required.

The ITP is essentially a safeguard against making significant mistakes that can cost time, money and reputation. It is a record that checks have been performed to particular standards throughout the process.

The ITP needs to be incorporated into the quality plan for the project. Digital technology is providing tools to ensure the ITP is complied with through linking video and digital pictures to items that can be viewed remotely.

The ITP should be linked to any failure mode effects analysis (FMEA) that the design team or the pre-construction may have identified to alert the site team to potential failure.

For engineering services, utilities installation, and specialist work the ITP will be very important. For example, electrical cables in ducts laid underground must be checked constantly. The installation is dealing with major health and safety issues and the need for conformance to rigorous and important standards is vital. It may mean the inspections must be signed off by the independent checker, the principal contractor's quality inspector, the engineering consultant, and the power company. Similarly, in hospital installations, rail infrastructure, power plants; all have specialist ITP requirements. At the tender stage, allowances must have been made for the cost of ensuring the ITP is included.

One of the important parts of the inspection and testing process is at the completion and handover stage. This often takes longer than anticipated because of the need to ensure everyone is happy with the project. Sometimes the project handover is seen as crossing the finishing line, where complacency can creep in. The inspection records must be part of the handover process, showing records of conformance.

2.12.2 Measurement and Failure Mode Effects Analysis

Failure Mode and Effects Analysis (FMEA) is an approach used by many industries aimed at allowing organisations to anticipate possible failure during the design stage by identifying all of the possible failures in a design and production process. FMEA is not new, having been used extensively in the defence and automotive sectors, but rarely in construction. In part, construction does take account of failure through the risk register identifying issues, but the risk register is not just about the quality issues, hence items can get lost in the whole risk management process.

Two principal categories are used for FMEA

DESIGN

Failure Mode and Effects Analysis explores the possibility of defects or malfunction at the design stage. It is not a substitute for good architectural design and engineering. Nobody wants failure, but that does not mean the effects of failure should be ignored. The challenge in construction is the traditional separation of design from production. The design team needs to consider how they can benefit from FMEA, bearing in mind the issues on liability for any failure, and the professional indemnity insurance requirements.

PROCESS

Failure Mode and Effects Analysis considers how failure impacts the production process on or off-site. Construction is difficult because of all the interdependencies between materials and work packages. However, in an increasingly litigious world, the impact of failure must be considered when preparing the quality plan. Infrastructure delivery has been effective in using FMEA to identify possible failure. This is partly a function of the independent design check undertaking within infrastructure delivery.

With the high cost of business interruption and unforeseen events happening more regularly, FMEA is something that should be embedded into quality management systems. Late discovery of failure on a construction project will have serious cost and time consequences.

FMEA can be linked to the risk register for the project, it should not be ignored because of the consequences of failure caused by defects. There is an argument that the risk register will cover the eventualities of failure, but the purpose of the risk register is to deal with the source, the event (and its likelihood), the effect, and actions. As risk registers have grown in importance and size there is always the possibility of a major defect occurring being missed. What is needed are multiple choices to mitigating the risk of failure.

Full function failure	Partial function failure	Intermittent function failure

Failure modes are considered in a hierarchy where their frequency and impact are important:

- Full function failure such as a roof collapse, basement flooding, wall collapse and boiler leaking. Such modes can be catastrophic with a low likelihood of happening.
- Partial function failure, where the item will function but on a reduced impact, such as poor fitting windows with air leakage and draughts.
- Intermittent function failure that is irritating but may not be catastrophic, such as persistent leaks in showers, or electrical systems constantly tripping.

In a refurbishment project FMEA can be particularly valuable where damage to existing work could cause major problems.

Failure Mode and Criticality Analysis (FMECA) is another approach used to prioritise the effect of critical elements; however its use is limited with preference to using FMEA.

Measurement scales are used to measure quality and defects across different industry sectors. When defects occur on a construction project, the first task is to remedy the defect, but depending when the defect is discovered there may be serious consequences. If it has been covered up by other work, the result may be very costly to remedy. The automotive sector uses the scale shown in Figure 2-9. The two scales are consequence/impact on the vertical axis and frequency on the horizontal axis.

Frequency / Consequence	1 Very Unlikely	2 Remote	3 Occasional	4 Probably	5 Frequent
Catastrophic					
Critical					
Major					
Minor					

Figure 2-9
Planning performance and potential defects

The UK Construction Best Practice programme suggested measuring defects in construction on a scale of 1 to 10, with 8 being some defects with no major impact on the client, and 1 being totally defect free. 10 is regarded as a catastrophic defect with serious consequences.

Measurement scales for the construction industry are poorly developed, primarily because this is a new area that requires better understanding and use. However, it is important to identify the critical items that could have serious consequences. This may seem obvious for every project, but there must be a link between the quality plan and the risk register.

The term high-path dependence in Figure 2-10, refers to items that have a heavy reliance on another activity/work package. Some activities can be isolated, but some have high path dependency.

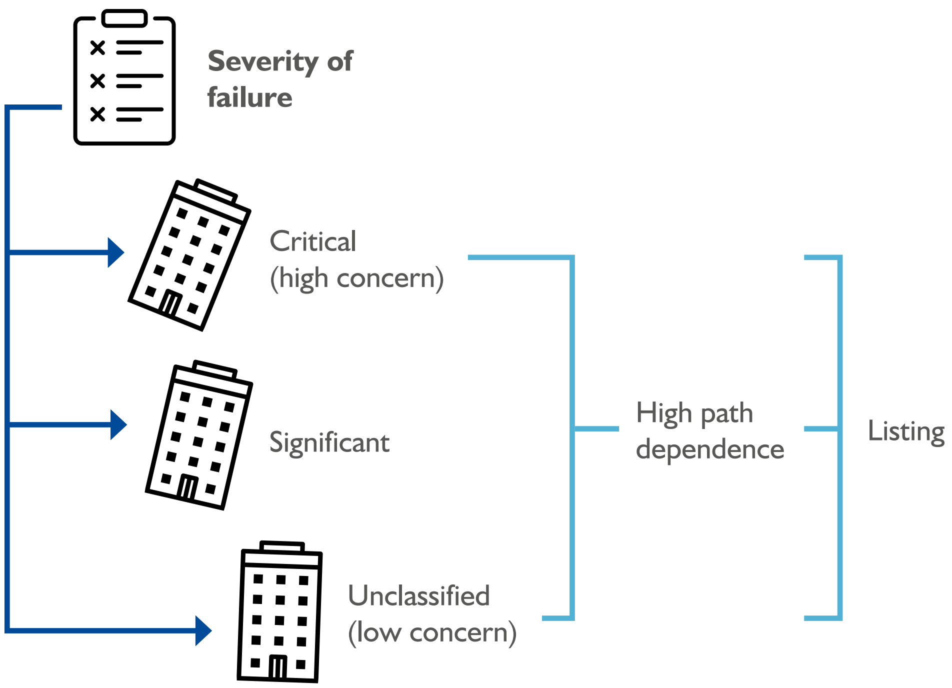


Figure 2-10
Severity of failure

2.13 Quality control

Quality control's goal is to verify, validate, and identify and correct defects as soon as possible. It is about controlling workmanship for conformance, verification, and inspection.

Quality control is usually the responsibility of a specific team/person. This may be an external verifier or self-verification may be undertaken. It must ensure that the material, component or system conforms to the relevant standards and the required performance. Inspections during the production stage may be non-destructive, such as visual, ultrasound, or thermography. An inspection undertaken later than planned, may involve dismantling the construction. Accuracy depends upon the people involved (level of human error), instrument accuracy and the efficiency/thoroughness of the inspection routine planning and operation.

Most construction projects specify that the contracted works are subject to inspection by the client or the client's representative. Specialised testing and inspection may be a requirement of the manufacturer's specifications and/or the specialty contractor. For example, the need to detect cracks, heat build-up and so on.

Manufactured goods come under the manufacturer's quality control procedures, but these should still be checked for conformance before use. Being aware of the level of stringency used by the manufacturer/supplier can give the contractor confidence in the material or component.

Figure 2-11 shows that quality control can be discrete or continuous. Discrete control is based on inspection and testing following completion or at some stage in the process. Continuous control is different and requires the use of technology. Concrete pouring is a good example where traditionally, concrete cube tests are produced and tested in a laboratory, the results take time to receive, by which time if a failure occurs there are huge problems of breaking out defective concrete - even identifying the batch has challenges.

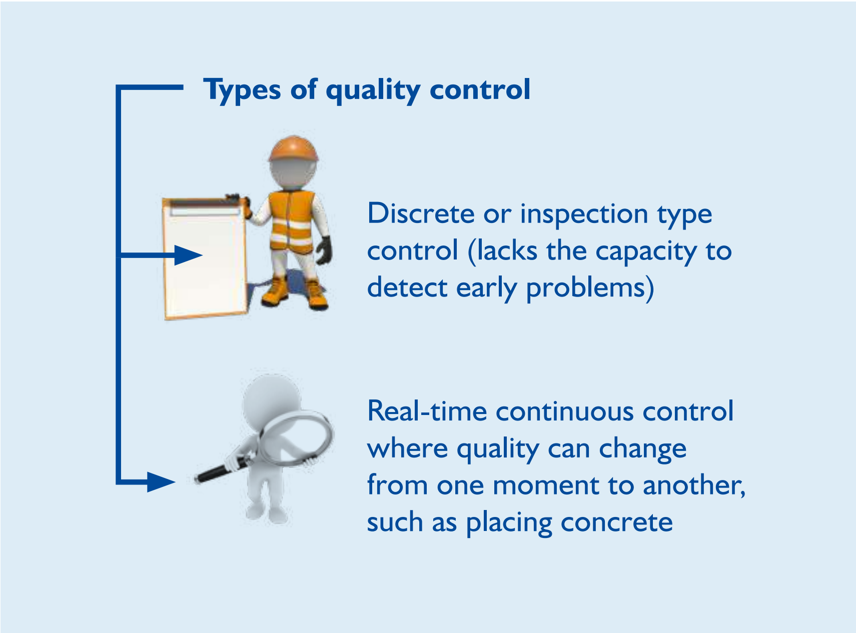


Figure 2-11
Discrete or continuous control

Real time strength data can now be transmitted using sensors embedded in the concrete pour. A specialist company provides the sensors and the software platform for monitoring the temperature of the concrete which can be used to check the strength over time.

Where the contract terms require an on-going exposure of responsibility for work that is completed long before final handover of the whole project, there is a risk of damage. The site manager must ensure that the completed work is signed-off by the quality management team and the subsequent specialty contractors made aware that they will be held responsible for any damage to completed work.

Operatives will hand over their work to following trades/work package/specialty contractors for further operations; adjoining trades should liaise directly on issues, such as accuracy and protection related to the interfaces.

This is where tender translation (see 3.6) is so important. The pricing must take due account that the time and cost of such temporary protection is included in the unit price rates, or a contingency sum is included for all temporary protection, but that is not easy on a large project.

Sometimes the need to return to a site to repeat work will not be because of deficiencies on one's own work, but to reinstate consequential damage after a deficiency in the work of others has been rectified. The repair must be carried out to the same standard as the contract requirements. This often creates conflict with disputes about contra-charges and the level of charging for the cost of remedial work. Nobody wins in these situations.

2.13.1 Three stages of quality control

1. **Preparatory (pre-commencement on-site, ensuring off-site production conforms to the quality requirements, checking on material requirements and any material substitutes).**
2. **Initial (first work-in-place, samples of materials and components).**
3. **Follow-up (daily/routine inspections, conformance checks, testing).**

The stages allow the planning, scheduling and installation work in an orderly, consistent way that minimizes rework. Reality is that personnel and teams change during the project, which is why digital and photographic records are so important.

1. **Preparatory** – a pre-installation meeting involving the principal contractor, specialty contractors, client and design team (and other interested parties). The aim should be to prevent defects rather that detect them. The following documents should be available at the meeting:
    1. The quality policy and quality plan. If the project is a refurbishment or conservation project, special attention must be paid to quality assurance and control procedures in the context of the occupants and protecting existing work.
    2. Failure Mode and Effects Analysis identified during the design phase with a view to development of the process FMEA.
    3. Special requirements impacting quality of the project, such as alignment requirements.
    4. Details of work packages with special requirements to ensure quality is maintained.
    5. Off-site components and materials needing inspection at source.
    6. Materials safety data sheets.
    7. Contract drawings.
    8. Specification/bill of quantities.
    9. Construction programme and schedules of work.
    10. Available shop drawings.

11. Manufacturer's installation instructions for key items.
12. Safety hazard analysis.
13. Logistics and transport plan for deliveries.
14. Inspection checklists and inspection report forms.

2. **First work-in-place** meeting and inspection should be undertaken prior to commencement of the relevant activity that requires special attention to ensure all the quality processes will be followed. For significant items, the meeting / inspection should involve the client (or their representative), a member of the design team, relevant consultants, the site manager/trades supervisor and any manufacturer's representative.
3. **Follow-up** inspections should be conducted on a regular basis, preferably daily using an inspection checklist. The follow-up ensures conformance, quality workmanship, testing and safety considerations have been met, and the required certifications, calibrations and measurements are accurate. Increasingly, project collaboration systems allow documents to be stored in the cloud or a central server, with the opportunity to download/upload documents and records.

2.13.2 Testing

Testing involves the electrical works, water, gas, plumbing installation, any lift installation, and the mechanical / air conditioning system balanced, fire protection, and lightning protection. On small projects, the requirements are on a smaller scale, but equally important. Quality is compromised by insufficient time spent on ensuring all the tests are complete.

An effective testing regime with clearer labelling and product traceability is needed, including a periodic review process of test methods and the range of standards in order to drive continuous improvement, higher performance and encourage innovative product and system design with better quality control. This is not suggesting more paperwork, but acceptance that the client is seeking more reliability and traceability should something not be right. They want certainty on whom to contact when something goes wrong. On handing over the acceptance test certificate, the supplier confirms that the supplied goods meet the requirements stated in the order documents (drawing, parts list, specification) by listing the test results of the specified tests.

The contract and the quality plan will set out the required testing and inspection, with their timing/frequency of work and materials. Testing and inspection requirements may be drawn up for particular work packages, which may include factory tests, quality control inspections, installation verification tests, and acceptance tests. Inspections should be performed by qualified personnel, either by the company's employees, or third-party inspections. Apart from regular testing and inspections, the on-site inspections that require the presence of a specialist contractor (or designated third party) are electromechanical systems, conveying systems, and electrically operated equipment.

Testing may be undertaken in three stages:

1. **Preparatory** (related to specific work packages) Review the specifications, plans, and sequence of work. The testing and frequency should be discussed. The safety plan needs to be checked against the quality requirements and the level of workmanship required for a particular work package. Figure 2-12 shows the discussion points for a preparatory meeting, with the minutes/report stored and distributed in accordance with the documentation control policy/procedures.

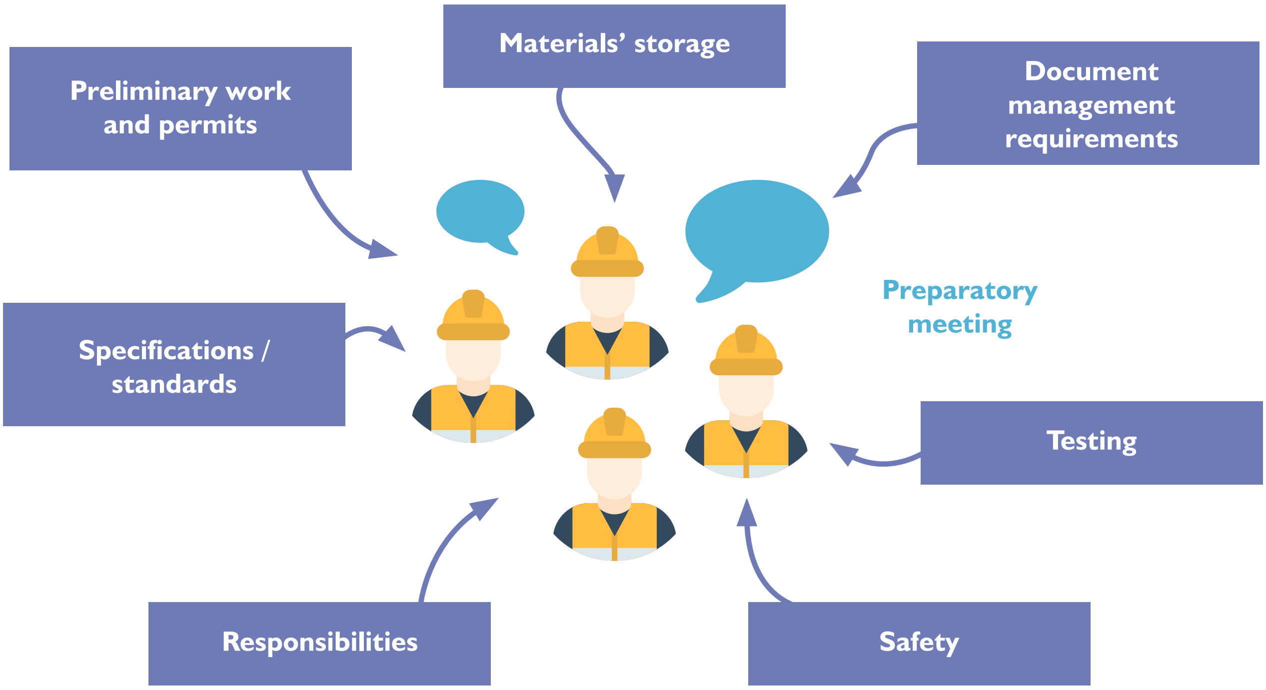


Figure 2-12
Preparatory meeting

2. **Initial inspection** at the start of a work package should be repeated whenever new operatives are assigned to the work, focusing on the workmanship and inspection and testing. The initial inspection meeting should review the items discussed in the preparatory meeting ensuring that raised issues are addressed. The minutes/report of the meeting are distributed in accordance with the documentation control plan. Figure 2-13 shows a generic checklist that might form part of the initial inspection(s).

3. **Follow-up inspections** should be undertaken frequently to ensure that the work meets contractual and compliance requirements. Any non-conformity is recorded and the procedures in the quality policy followed.

If replacement materials/components, or repairs are required, these need to be re-inspected and re-tested. Documentation from these inspections should follow the agreed control procedures and communicated to the relevant stakeholders.

Ongoing as-built surveys help to identify any quality issues. If these are identified at an early stage, it avoids mistakes being repeated. Failed tests will lead to a non-conformity report and they should be cleared by one of the following:

1. Re-test – Re-test if there is any doubt that the first test was not adequate.
2. Rework – Re-inspect and re-test.
3. Failed material – Remove, replace, re-inspect and re-test.

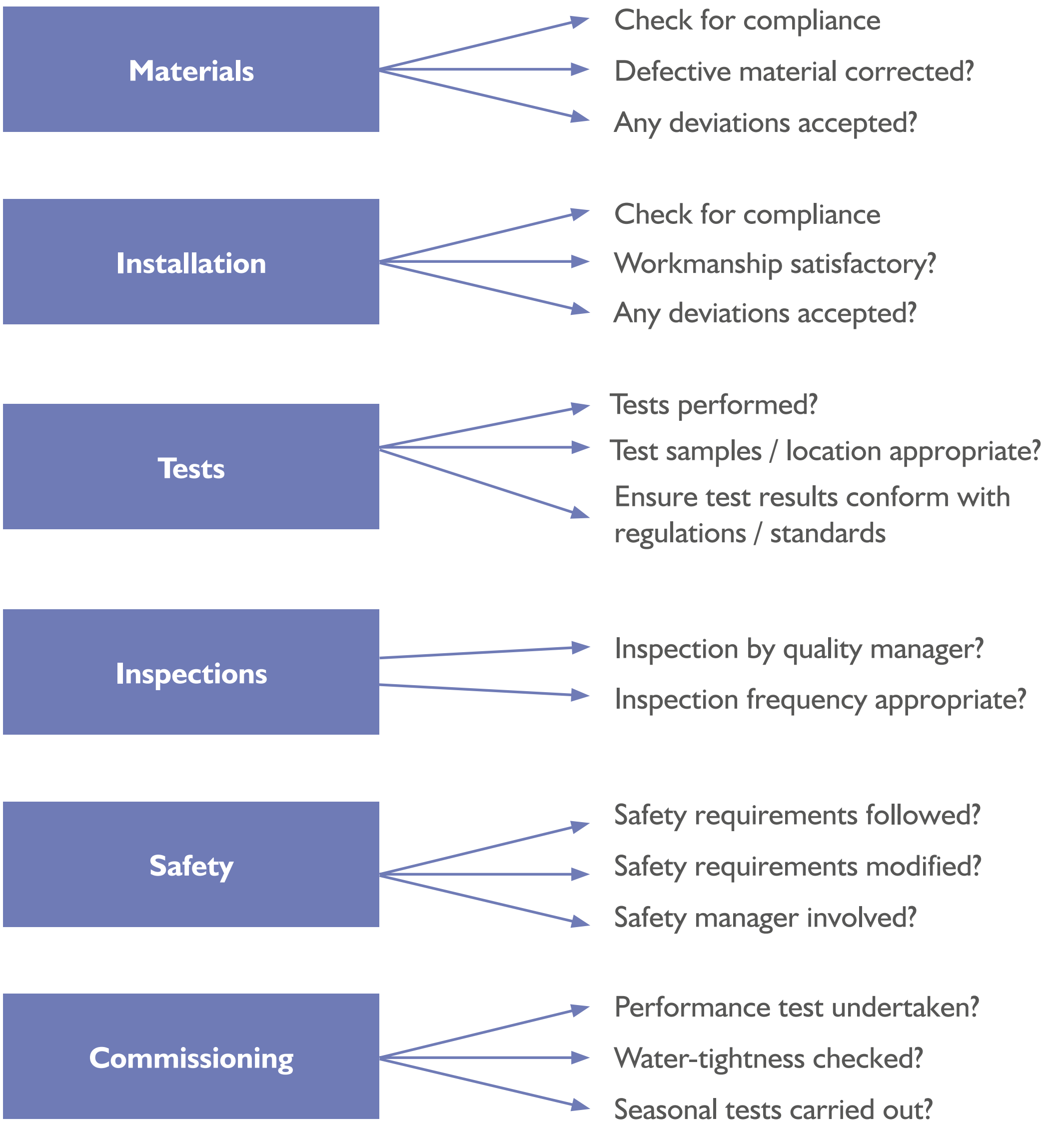


Figure 2-13
Initial inspection checklist

When a project is close to handover, there is often pressure to shorten the testing and commissioning tests. Commissioning sets up the plant and equipment, followed by performance testing; when a series of tests, with adjustments and balances to the various building services systems comes into operation. The quality plan should monitor testing. Under performance, or failure of the engineering services in-use will lead to client dissatisfaction and quality concerns. Static testing happens before the services become live.

Live testing is required before handover as part of the commissioning. Services cannot become live until completion of the quality checks, with the relevant certificates.

Testing water tightness of the fabric and roof is an integral and important part of testing in the quality plan. Sound tests should be undertaken, with air pressure testing to detect leakage. All works approved under Part L of the Building Regulations are required to be commissioned in accordance with the design intent.

Digital installations have increased the pressure on testing and quality planning. IT systems are an integral part of any project; they must be robust, and reliable.

2.13.3 Commissioning

Commissioning is a series of tests, adjustments and balances that are undertaken when building services systems are brought into operation. It may be carried out by the principal contractor if the system is a simple one, but more complex systems are undertaken by the relevant specialty contractor. The processes and results need to be monitored under the quality plan.

Not all aspects of the commissioning of a building and its engineering services systems can be carried out during the normal contract period. The concept of seasonal commissioning recognises that some aspects of the systems need to be commissioned when the external temperatures and indoor occupancy patterns are close to peak conditions.

The Chartered Institution of Building Services Engineer's (CIBSE) Commissioning Codes set out clearly and systematically the steps required to commission buildings and building services in a proper and timely manner. Good commissioning leads to better reliability and quality.

A co-ordinated approach to commissioning and testing is necessary to ensure all specialty contractors understand the key dates. Leaving it to the last minute and rushing the handover compromises quality.

2.13.4 Conformity, certification, verification, and accreditation

Certification, verification, and accreditation is part of the independent process to ensure independent checks in the system. The clerk of works acts as the independent verifier of quality. Verification, testing and certification by an independent accredited body for quality assurance can be part of the contract conditions, with the client wanting independent checks to ensure quality is maintained.

Conformity is the need to meet a variety of requirements as listed in Figure 2-14. The drawings and specification set out the project requirements embodying the statutory, regulatory, contractual, and performance standards. Failure on any one requirement leads to dissatisfaction. Non-conformance must be accompanied by traceability, which means why and how the problem occurred, and the people responsible. Conformity is given by self-assessment or by an independent party.

Figure 2-15 shows the levels of conformity in accordance with ISO 17000:2004. Any independent assessment organisation must be accredited. Conformity can add substance to credibility or claims that specified requirements are fulfilled, giving greater confidence that a standard has been met.

Accreditation is the formal tool to provide assurance that the organisations implementing these processes (activities or tasks) are meeting the required standards. Accreditation delivers confidence in certificates and conformity statements. It underpins the quality of results by ensuring their traceability, comparability, validity and commutability. Outcomes and performance by accredited organisations are important to maintain accreditation. Accredited checkers check quality management systems. Samples, products, services, or management systems are evaluated against specified requirements by laboratories, certification bodies, and inspection bodies.

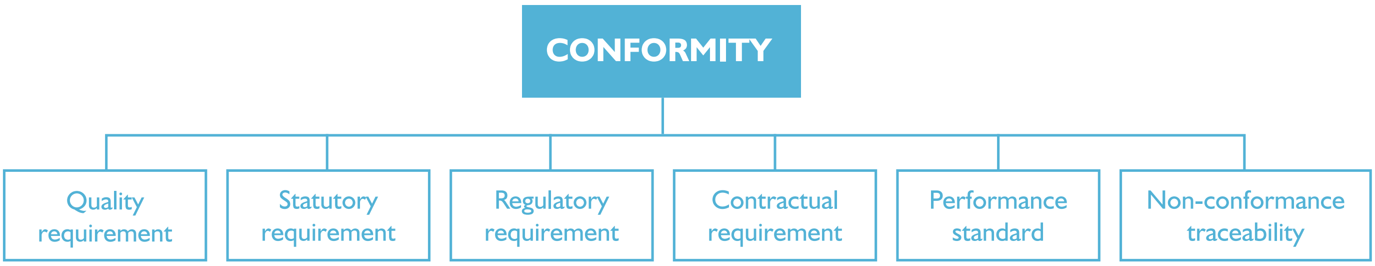


Figure 2-14
Conformity requirements

Accreditation is the independent evaluation of these conformity assessment bodies against recognised standards to carry out activities to ensure their integrity, impartiality, and competence. It provides the assurance for the client to rely on commercial providers of evaluation and inspection services. The United Kingdom Accreditation Service (UKAS) is the sole national accreditation body for the UK. The government recognises UKAS for the assessment of organisations that provide certification, testing, inspection and calibration services against internationally agreed standards.

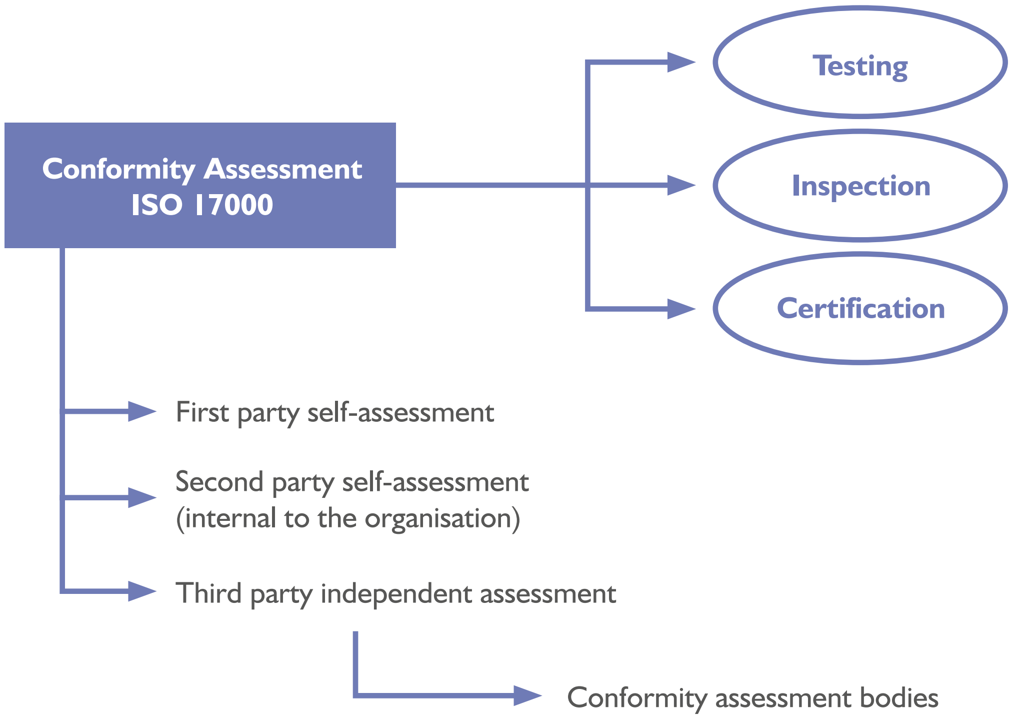
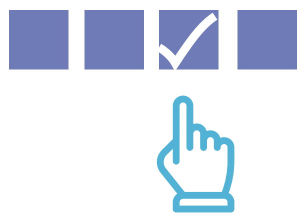


Figure 2-15
Conformity assessment – ISO 17000:2004

Accreditation by UKAS demonstrates the competence, impartiality and performance capability of these evaluators.

In short, UKAS checks the checkers.

Surveillance visits from the certification body aim to find out whether a quality management system really works in everyday operations, or not. It focuses on whether all corrective and preventive actions are recorded and implemented, and whether the top management really supports the quality management system. Most importantly, certification should not be seen as a box-ticking exercise. The Hackitt report said there is ambiguity over where responsibility lies. Quality control should verify and define, and, if something fails after it has been verified, identify where the responsibility lies.



The need for conformance with regulations, standards and codes that govern construction as well as registration and certification requirements are the 'push' factors in the drive to achieve quality that was shown in Figure 1-2. Conformance is increasingly important; companies face a growing amount of regulation and legislation to document and report activities on site. All the stakeholders have an obligation to ensure that work on the project complies with the legislation. Failure can result in fines, and legal action.

Table 2-2 shows a range of certification schemes covering construction materials and components.

CE	From 2014, the CE (Communauté Européenne) marking of structural steelwork and aluminium was mandatory. CE is a "declaration of performance" not a quality mark. It covers 400 products including: Timber; Wood flooring, wood panelling, cladding; Concrete, wall elements, Beam: precast blocks; Glass blocks and pavers. Note: With the departure of the UK from the EU, companies may no longer be able to certify the goods and apply the CE mark, which would impact working in or for EU countries e.g. Ireland.
	The Kitemark, which indicates that a product has been independently tested by BSI (the British Standards Institute) to confirm that it complies with the relevant British Standard, and has been licensed by the product manufacturer.
FSC	FSC stands for 'Forest Stewardship Council' - an international non-profit organisation dedicated to promoting responsible forestry. FSC certifies forests all over the world to ensure they meet the highest environmental and social standards.
BBA	The British Board of Agrément (BBA) is a construction industry approvals body that was set up in 1966 by the UK government offering product and installer approval. Agrément certificates cover 200 different product sectors; the largest of these are insulation and roofing. The BBA runs an insulation Approved Installer Scheme, linking installations of injected cavity wall insulation to BBA approval and dealing with both the system supplier and installer. BBA approvals show compliance with Building Regulations and other requirements, including installation quality. The BBA also inspects for the Fenestration Self-Assessment Scheme (FENSA) and the Federation of Master Builders.
UKAS	The United Kingdom Accreditation Service (UKAS) is the sole national accreditation body for the United Kingdom. UKAS is recognised by government, to assess against internationally agreed standards, organisations that provide certification, testing, inspection and calibration services. UKAS provides accredited testing, calibration, inspection and certification to give consumers, suppliers, purchasers and specifiers the assurance that construction projects run efficiently, construction sites are safe and reliable materials are used. They also provide Government and Regulators with reliable evidence that completed projects meet regulatory compliance.
bre	BRE Global, a UKAS accredited certification body, provides independent, third-party certification of fire, security and environmental products and services.

Table 2-2
Selection of certification schemes covering construction materials etc.

2.14 The quality manager/clerk of works/site inspector

The quality manager may be site or office-based and is responsible for the quality plan on the job site. They may be a quality specialist, or the role taken by the site manager as part of their daily duties. Not all sites will have a quality manager to call upon; somebody must take responsibility to review and manage submission of materials, including design data, samples, and shop drawings. The independent clerk of works/site inspector can be responsible for quality control and checking on conformance. The clerk of works must have ability, integrity and vigilance. They may be appointed for a single project or multiple projects, on a full-time or part-time contract. The authority to stop production to correct quality problems should rest with the personnel responsible for conformity to product requirements.

The site should be walked every day to check for compliance, and to ensure quality and safety requirements are met.

Irrespective of who carries out the role, the duties of the quality manager are wide ranging on both large and small projects:

Coordinate the quality assurance and control efforts of the company, the specialty contractors, and the third party inspectors in complying with the quality plan.

Provide direct feedback and advice to the project manager and site manager on the effectiveness of quality control and quality assurance activites.

Review work-in-place for conformance reports, monitor correction and completion of non-conforming work items on a non-conformance report register.

Ensure the site is tidy and any rubbish is removed, with responsibility for removal being clearly defined amongst the parties.

Confirm all inspections and tests are performed in conformance with project requirements.

Ensuring the specialty construction teams are working in accordance with the quality plan. Ensure conflicts are not arising between specialty work packages.

If there is disruption to the construction programme caused by failure of one of the parties, or by unforseen events, ensure that the quality of the workmanship will not be compromised by delays, or inclement weather.

Ensure the work is properly protected during work in progress, with temporary protection following completion, to ensure no damage ensues from other work / trade packages.

Have the authority to stop work if workmanship or materials do not conform to project requirements.

2.15 Driving the quality agenda

Figure 2-16 shows the drivers of quality and how the cogs fit to form the quality management system, with the drivers making the system operate. The next sections explore the principles of good practice for quality management and the development of the quality plan. The idea of using cogs is to explain the importance of interdependence and interconnectivity.

2.16 Summarising the actions for quality management

Figure 2-17 summarises the quality hierarchy and the steps to achieving better quality management on site. The project starts at the top with the design and regulatory conformance for planning and building codes/regulations. The design may be highly innovative which will require a lot of attention to detail by the design team.

For BIM compliant projects, the model must be populated to reflect with quality requirements. The tender is one of the most important stages for any project, yet it is often left for the contractor to interpret the quality requirements through the design and the specification documents. At the contract award stage, there is alignment of all the documents to ensure the required quality is delivered.

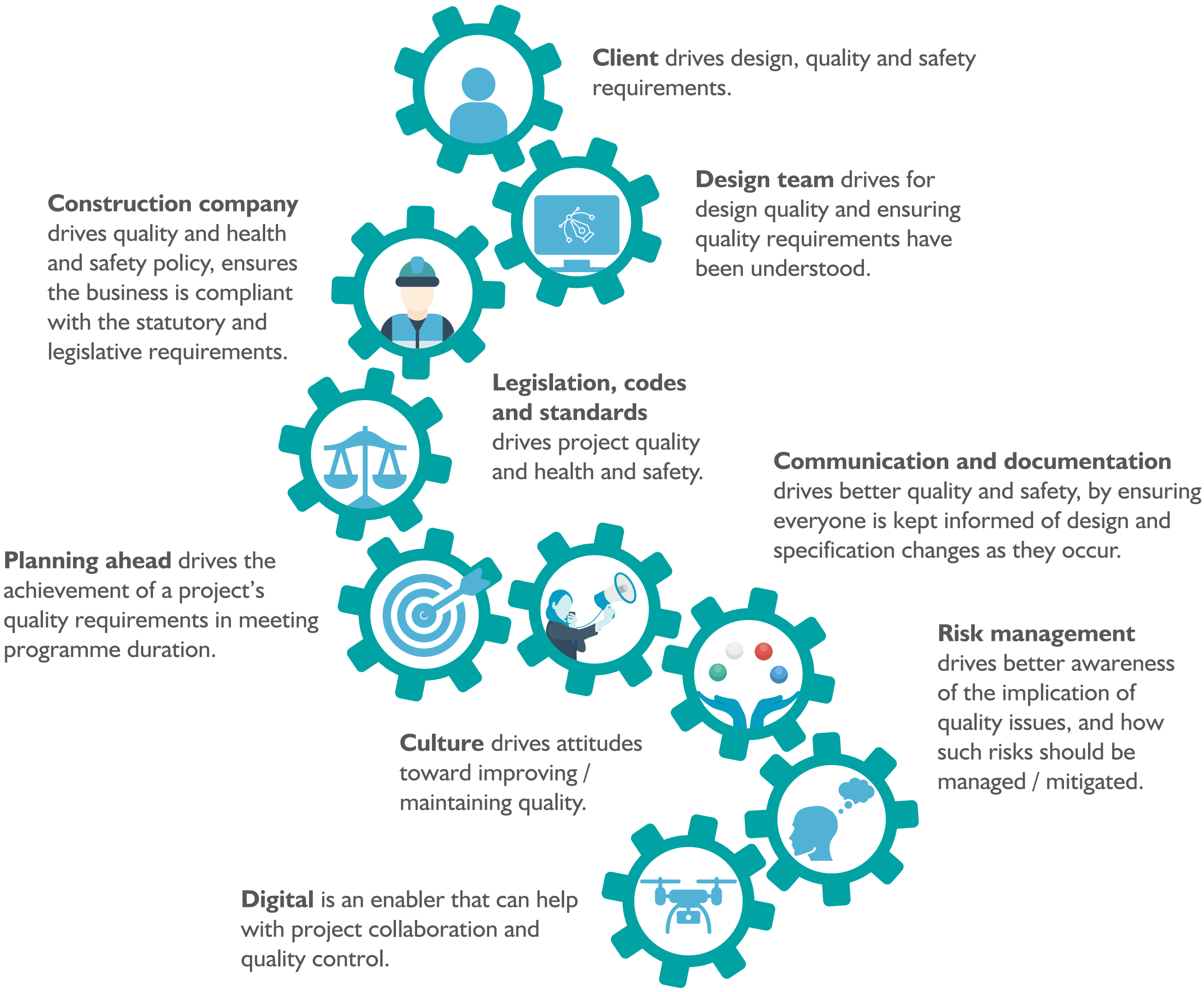


Figure 2-16
Drivers of quality

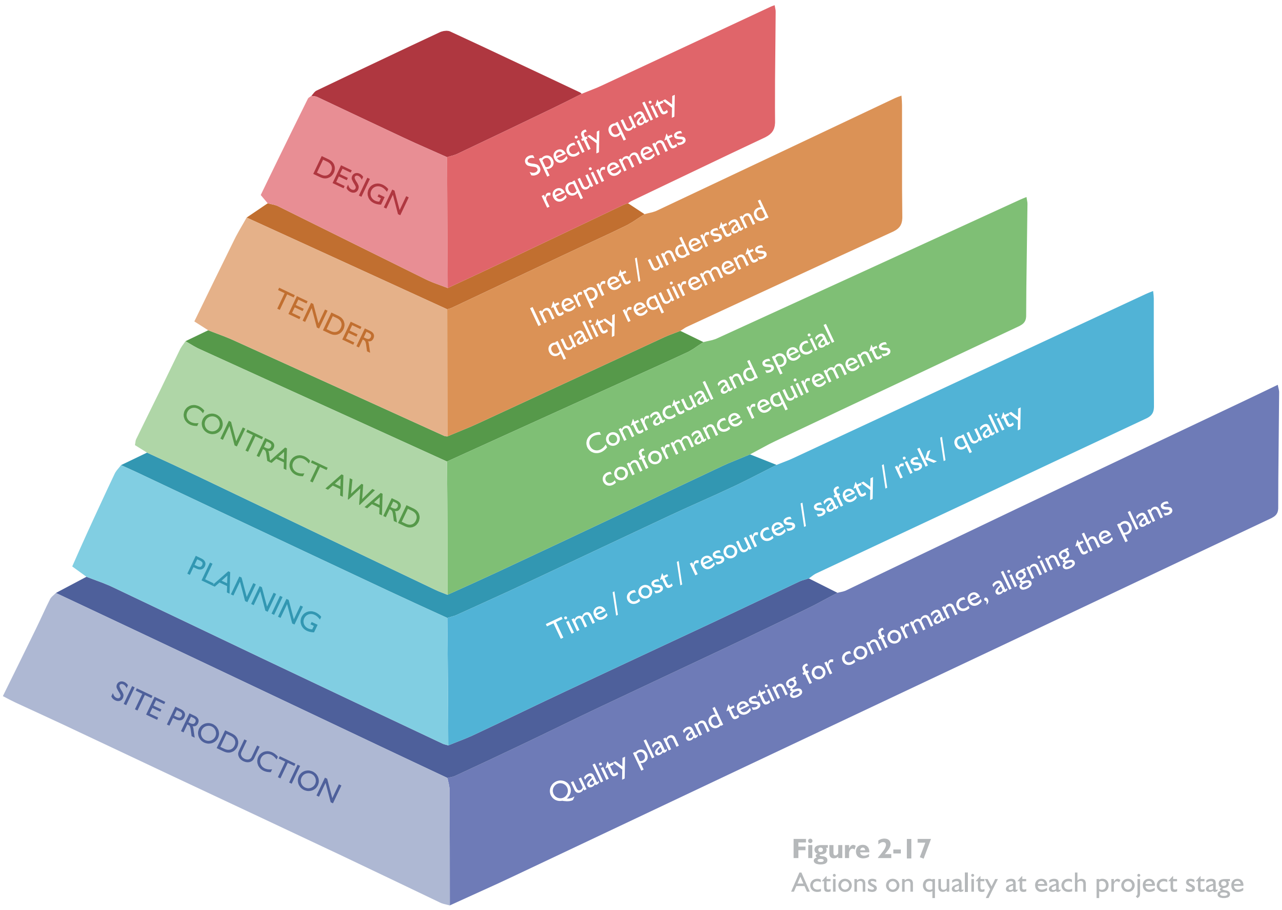


Figure 2-17
Actions on quality at each project stage

Pre-construction planning involves ensuring all the specialty work packages align with the quality requirements, and the time, cost, resources/safety and health/risk and quality plans are fully aligned. Quality must be planned, and the quality plan will show how the testing and work packages are interdependent. Specific quality requirements are needed at each project stage – see Figure 2-17.

Section

3

Quality Management

Principles of Good Practice

3.1 Delivering quality

The big question is how to deliver quality in an industry that builds bespoke products, with too little standardisation and off-site assembly, that builds projects that are not fully designed at the outset, and has a reliance upon a long supply chain that is interdependent.

Quality standards, standardisation, automation, and just-in-time approaches have revolutionised the manufacturing sector, particularly in aerospace, defence, and medical appliance sectors. In the automotive sector the Advanced Product Quality Planning (APQP) approach, based upon IATF 16949:2016[10], is used extensively. The aim of the standard is defect prevention and reduction of waste in the supply chain. APQP supports the early identification of change, both intentional and incidental. The automotive sector can guarantee quality, whereas construction struggles with the concept of guarantees and liability. This is mainly because of the procurement approaches, with the separation of design and production, the fragmented supply chain, and the way the contracts allocate risk and responsibility between client and contractor. Roles and responsibilities are often poorly defined across the whole project lifecycle, but particularly lacking during the pre-construction phase.

A company's drive for quality management must involve the development of a planning mentality that focuses on problem prevention. Preventive actions will reduce the overall cost of quality.

It is no use having the mentality that there is always time and money for re-work, but insufficient time to do the job properly in the first place!

Re-work to remedy defects costs time, money, reputation, motivation, and leads to unhappy clients and an unhappy workforce. Very often, the true cost of time, labour and attitudes is not recorded, and rework is 'accepted' on a day-to-day basis. It is often easier to identify the cost of quality, where things may go wrong i.e. the cost of re-work and remedying defects. Getting it right first time saves money, stress, and leads to satisfied customers.

Estimates suggest that between 2-5% of construction cost is spent on remedying defects and getting it right. In an industry with wafer thin profit margins of 1-3%, improving quality and customer satisfaction should have high priority.

Digitalisation makes communications faster and more reliable and, alongside virtual reality, augmented reality, artificial intelligence, and automation, has improved the link between design and production. However, these are just tools; on the job site it is the people that matter. Given the right tools, the information, and the right materials, they want to produce a good quality product.

10 The International Automotive Task Force is a group of automotive and component manufacturers and trade associations formed to ensure quality products in the automotive sector. IATF 16949:2016 is the international standard for automotive quality systems, and supersedes ISO/TS 16949. It is fully aligned with ISO 9001:2015

3.2 Driving construction quality - the CIOB Construction Quality Framework

The CIOB is focused on how quality can be improved across the construction industry. A framework has been developed that embodies best practice, and which takes account of the context of construction. The importance of ISO standards and the valuable work that the standards and codes provide across all industry sectors has been incorporated.

The attitude that construction is different is wrong - all industries face special and different challenges. The Competency Framework developed by the Chartered Quality Institute has influenced the CIOB construction quality framework by recognising the importance of leadership, governance, assurance, improvement, and context. Lessons have been learned and incorporated from best practice internationally developed by major manufacturers and service providers, who all emphasise the importance of customer satisfaction and putting the customer first. CIOB members' views have been incorporated to reflect the reality of quality management on job sites.

A framework is "a basic structure underlying a system, concept, or text". Oxford Dictionary

The purpose of the CIOB Construction Quality Framework is to provide a guideline to keep quality management as an ongoing process. The aim is to keep developing the Framework as circumstances change. Brexit and Covid-19 have presented new challenges to the construction industry where the quality management system must adapt to cope with change.

The framework has not been called a competency framework because competencies are about:

- Knowing what to do.
- Knowing how to do it.
- Knowing when to do it.
- Knowing why it is being done.
- Knowing when to seek help and advice.
- Doing it consistently well.
- Learning from feedback of successes and mistakes.

Competencies involve skills, knowledge, culture, behaviour, and professionalism; showing a person/organisation has the qualifications, training, skills and experience relevant to the task being undertaken. Having a competence framework provides a way of measuring the professional competence of a group or individual. The Chartered institute of Ecology and Environmental Management uses a competence framework which is divided into activities and competencies measured as basic, capable, accomplished, and authoritative.

The aim of the CIOB quality framework is to provide a structure to better understand the players, the process, and the context in which the activities will take place. Construction involves assembling and managing supply chains who are dependent on each other to deliver on their promises. When errors occur, clients want them rectified and for organisations to take responsibility for their actions. Because of the nature of the supply chain it was decided to use the concept of a series of cogs. The quality management process, under the influence of the internal and external environments, is interconnected and interdependent – see 3.3.

Figure 3-1 shows the CIOB Quality Framework that drives construction quality. The focus is site production following contract award. All companies want to achieve excellence through quality delivery and in order to do that there needs to be a framework that shows the interconnectivity of the different systems and influences.

The CIOB's Quality Framework for site production recognises the growing importance of quality management. Construction grows in complexity to cope with new technology, legislation and customer expectations. Quality management has become one of the key drivers for the construction industry and manufacturers. This is a result of modernisation of the industry with modern methods of construction with more off-site manufacturing, greater impact of digitalisation, and pressure from clients who have zero tolerance toward defects, and rightly so. Increasing legislation and liability issues are placing more responsibility on the delivery teams. When defects occur, nobody wins.

The framework shows a set of cogs, driven at the top by the client / customer; without the customer there is no project, they are key to everything. Whilst the client is uppermost, there are many interested parties affecting the delivery of quality. The principal contractor must satisfy the client and also possible end users of the project. An education authority may commission a new primary school, but the teachers, students, and parents must also feel happy with the quality of the end product. The design consultants will care about the aesthetic and engineering design criteria being fully met in the quality of the construction and the end product. The project delivery team will include shareholders / owners, stakeholders (which includes employees), and joint venture partners who want to produce a good project and have a satisfied customer.

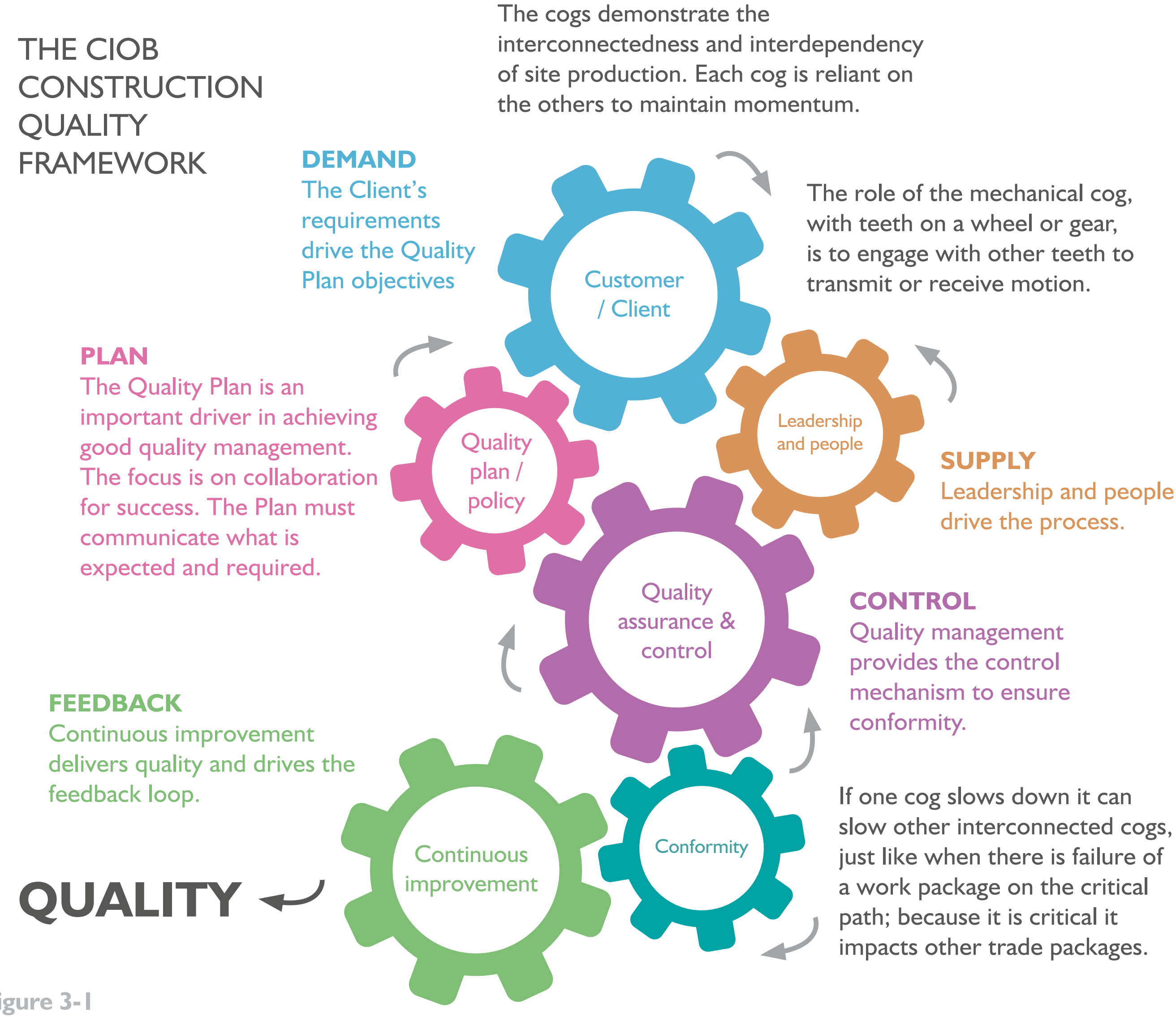


Figure 3-1
CIOB Construction Quality Framework

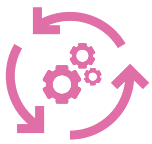
The quality policy sets out the ethos, culture and company strategy for delivery of quality. The quality plan, sometimes called quality control plan, has become an important part of the control process. The quality plan reflects the policy and deals in detail with all the special requirements to deliver a quality project. The plan is central to assurance and control processes, with control driven by the need for conformance to standards, codes, regulations, and contract requirements. These processes, along with ensuring continuous improvement, deliver quality and drive the feedback loop. The context of the project influences every aspect of the system. Legislation is increasing and awareness of new situations occurs frequently. The system must be flexible, adaptable, and constantly updated.

3.2.1 The client/customer

The whole system is geared to ensuring customer satisfaction. Everyone must focus on their requirements.

Knowing the customer must be part of the construction sector's key requirements. Irrespective of how far along the supply chain an organisation is working, at the top layer is the client.

The challenge is the gap between the site and the client. With a transient workforce working for specialty contractors and moving from site to site, it is difficult to fully understand the needs of the customer. In the mind of the small firm working for the principal contractor, the client is the principal contractor, whereas who matters is the project sponsor, the real customer. For any product, the client must come first; that has been a failing in construction projects. The Framework is focused upon ensuring everyone in the project delivery process fully understands the client's requirements, what they want, expect, and their intolerance towards defects.



3.2.2 Leadership

Leadership, skills, education, training, culture of continuous improvement, and attitude are important ingredients in the quality mix. A knowledgeable, motivated and empowered workforce backed up by a committed management (to the highest level) can deliver quality construction given the tools, the time, and the opportunity.

Corporate behaviour can demonstrate leadership from the top, stressing the importance of quality as part of the company's conscience. A company's quality policy sets out quality aims and objectives for employees and sends a message to both the client and the supply chain.

Effective senior management that takes a holistic view, underlines the company's commitment to quality. Furthermore, it can generate innovative activities, which can lead to process improvement. Leadership should provide an environment for realising people's potential, which will have a professional and personal impact and can engender a level of accountability for improving quality and performance.

3.2.3 People and culture

Maintaining continuous quality depends on the daily behaviour of employees and companies in the supply chain. The competency of both the site workforce and the managers/supervisors is key to the success of the quality plan. Continuous briefing and training should be in place, keeping competencies up-to-date and relevant.

People must be empowered to deliver quality work and they must be prepared to take ownership of the results.

The quality manager works closely with the construction/project manager and site manager on day-to-day issues, keeping in close communication with other stakeholders including the design team, health and safety manager, risk manager, compliance officer, and contracts manager. On small projects the relationships will be more personal and informal, but equally important.

The culture of quality was mentioned in section 1.8. Developing a culture of quality in the workforce engenders quality throughout the site delivery process.

KEY WORDS FOR PEOPLE ARE:

- RESPONSIBILITY
- BEHAVIOUR
- EMPOWERMENT
- OWNERSHIP
- ATTITUDE

Behaviours and culture matter. There should be emphasis on building the "conscience of the customer's requirements" into the fabric of the site organisation.

On small projects the people and culture are equally important, the people working on site must demonstrate that they care about quality and satisfying the customer. A small family business will trade on its reputation for being engaged with the customer to ensure they get the quality they want, quality is embedded in the reputation of the business to secure future work.

3.2.4 The policy, plan, assurance, and control

The quality plan has increased in importance on projects because of the changing nature of the project delivery requirements. Clients expect more, rightly so, and the construction sector is transforming itself to deliver on quality; this is change driven by the desire to improve the offering. These are discussed in more detail in Section 4 of the Guide.

3.2.5 Conformity and continuous improvement

Because every project is unique, there are few mechanisms for sharing feedback and lessons learned, but technology is changing that. Feedback enhances motivation - positive feedback can act as a motivator that improves behaviour. It should be specific by pointing out the behaviours that warrant praise. Sometimes it is necessary to deliver constructive feedback, which is objective in pointing out failings, either large or small. Constructive feedback refers to what behaviours somebody needs to change to reach the desired result/attitude. Using feedback in conjunction with goal setting provides a clear objective for the individual, so a combination of goal setting and frequent feedback produces maximum behaviour change.

On a production line continuous improvement makes sense. However, as more modular construction is used on sites, so continuous improvement will increase in importance.

For continuous improvement to have any meaning there must be goal setting, and a measurement system that can measure performance against the goals that must be realistic and meaningful. The goals should be set in collaboration with the site production team rather than a decree by management. The goals may be project specific and short term, they should show the behaviours required to deliver the quality goals. The measurement system must encourage the workforce to see benefit in the measurement by the leadership. It shows their commitment and enthusiasm to deliver quality.

3.3 Internal and external context

The internal and external contexts are vitally important. The context of any project affects the decisions on quality. One example is the production environment, which is crucially important. The different environments are:

- Production
- Contractual
- Social
- Green/Sustainable
- Business
- Professional
- Digital
- Information management

3.3.1 Production environment

Construction takes place in a complex environment. Having the right work environment adds to quality; nobody works well in a cluttered and untidy site, or for a domineering supervisor, or for an unreasonable clerk of works. Creating the right environment is not just about the physical environment, it involves many factors - see Figure 3-2.

The environment involves social, psychological, and physical conditions. Imposing unrealistic time frames and harsh contractual conditions may seem to be a way of driving performance, but in reality, the quality of the output will suffer.

The Covid-19 pandemic has highlighted the importance of the work environment, with the need to ensure the workforce is safe and healthy and feels comfortable. Protection will include having personal protective equipment that can offer protection against the spread of the disease. The priority will always be keeping everyone safe and healthy.

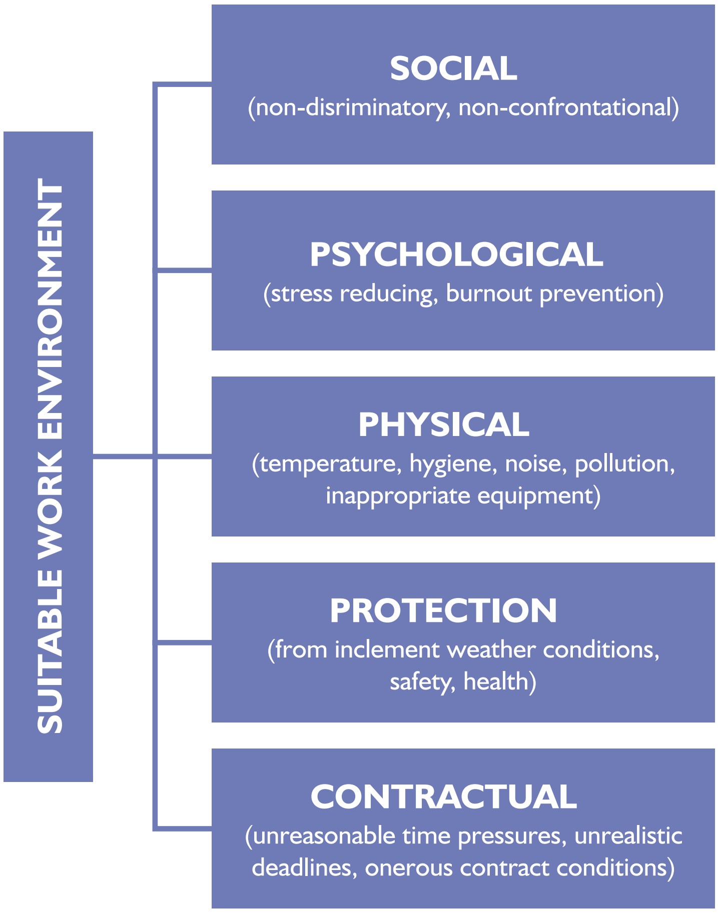


Figure 3-2
Work Environment

Providing the right documentation and detail is important, poor information will lead to stress and frustration. Everyone must work as a team, including designers, engineers, the site production team, and the supply chain.

Managing a construction site is stressful, with long hours of work, the unsociable hours sometimes required to be worked to get the project on programme and dealing with a transient workforce. Projects are delivered by temporary project teams brought together to deliver a project. Balancing cost and time to ensure the project meets its targets can be difficult if the bid was too low. The stress manifests itself in mental illness, lack of tolerance, and cutting corners to meet targets. Quality will suffer in stressful situations.

Consistent quality on site is reliant upon having the skills available, learning from mistakes, continuous improvement, and a mind-set that recognises quality is paramount. However, it cannot exist in a silo. Quality depends upon everybody playing a part, from the client / consultant team to the site production team. Good design and suitable specifications delivered at the right time develop confidence and collaboration. A design detail that fails to reflect the reality of how the production team will construct it can lead to difficulties. Buildability will make a difference, a poorly planned project with an untidy site will not deliver good quality work; pride in the job is important. Materials, components, and systems must be assembled and constructed in a way that is safe and fit for purpose. Timely delivery matters: turning up on site to find the materials have not arrived creates aggravation and mistrust. Service quality is an integral part of delivering quality.

Comment: Site-based quality management is a very broad and multi-faceted area, involving the supply chain and a complex team of stakeholders across the value chain. The Quality Guide addresses the need to focus on the detail of the production process and what is required from the project/construction/site manager. It can be an important part of a quality management toolbox alongside the Quality Tracker.

On medium to large projects, site management relies upon a team of people working together. They must deliver to specification, the required standards, and within the contract conditions. On megaprojects, large teams are assembled to take responsibility for quality management, often with sophisticated control and checking systems. On smaller projects, there may be just one site manager who may also be the contractor. Whatever the size of the project, the aim is the same; it is about planning and co-ordination of production to deliver on time, on budget, to the required quality. It is not about size; it is about attitude to quality.

On small projects, clients are sometimes unclear about what they want at the outset; they think it can be designed and changed as the work proceeds, which is where confusion arises. Any change of mind will have consequences for time, cost, and quality.

Time becomes a cost pressure, and time becomes the biggest enemy of quality management because of the need to deliver to an agreed target. Multiple layers of specialty contractors exacerbate the complexity. Often the organisation at the bottom of the chain becomes remote from those at the top, with pressure on cost and time to deliver the task/work package to ensure other packages are not delayed. Pressure manifests itself in stress for the workforce with the target to deliver on time irrespective of the consequences.

A tidy, well managed job site will improve quality management, where waste is controlled and disposed of effectively.

3.3.2 Contractual environment

Standard forms of contract require quality management plans to be incorporated within the contract. NEC4 (NEC, 2017) refers to quality management where the contractor must prepare and issue a quality management policy statement, and plan. If defects occur, the plan should identify the procedure and timing to be followed.

In Joint Contracts Tribunal (JCT) contracts, the emphasis is on the responsibility of the "Employer" to provide drawings/bill of quantities/ specification/schedule to define quantity and quality. They also address the issue of risk related to different types of procurement.

The FIDIC[11] suite of contracts has a quality management requirement. It uses the term quality assurance, where the contractor must institute a quality assurance system to demonstrate compliance with the contract requirements. Details of all procedures and compliance documents must be submitted to the engineer before each execution stage is commenced. The Quality Management (QM) system must ensure co-ordination and management of interfaces between the specialty contractors and the submission of documents to the client for review. If the contractor is required by the quality assurance certification to be subject to external audit, the client must be informed of any failings. FIDIC also requires a compliance verification system requiring tests, inspections, and verification to be undertaken.

If a contractor is registered under ISO 9001:2015 and enters into a project joint venture or alliance, with a construction firm that is not ISO 9001 certified, then that firm must register and be certified to meet the requirements of a single quality management plan for the project.

The terminology used in certain forms of contract is not conducive to achieving good quality. For example, the term 'practical completion' condones projects being handed over incomplete with 'snagging items' permitted to be cleared post-handover. Good practice is to provide a definition of quality assurance for the project.

3.3.3 Social environment

The social environment where construction takes place has changed significantly in the past decade. The social expectations of society continue to grow; all companies must be accountable for the impacts of its decisions and activities on society and the environment.

11 FIDIC is the International Federation of Consulting Engineers suite of conditions of contract for construction, published by FIDIC, Geneva, Switzerland

Social environment has the organisation as its focus and concerns an organisation's responsibilities to society and the environment.

A construction project will cause disruption, whether it be noise, dust, vehicle and pedestrian congestion, or mud on the road. Construction work on roads is never popular or easy. Quality is part of the social fabric; expectations of society are that the construction team will behave responsibly and keep them informed. Corporate social responsibility is part of the responsibility to put something back into society by giving time, finance, or some way of helping communities. A company should determine who has an interest in its decisions and activities, so that it can understand its impacts and how to address them.

The UK Considerate Constructors' scheme is part of the conformity to quality and behaviour. The Code of Considerate Practice produced for the scheme takes account of: 1) The appearance of the project and site facilities, making the workforce proud to be associated with the project, 2) Respect for the community by recognising construction work can be disruptive to the local community. Keeping people informed about disruption is important, 3) Ensuring environmental considerations are taken into account on the project by protecting ecology, wildlife, trees and the habitat. Behaving ethically in the sourcing of sustainable materials is an important requirement, 4) Ensuring safety, health, and hygiene are a priority and 5) Valuing and caring for the wellbeing of the workforce. Projects, companies, specialty contractors, and professional suppliers can all register under the scheme.

Any site, company or supplier that registers with the scheme makes a commitment to meet the minimum requirements of the scheme's Code of Considerate Practice. Scheme monitors visit offices, depots and individual projects or work areas, and use the appropriate checklist to confirm a score against each of the five Code headings – appearance, community, environment, safety, and workforce.

Archaeology and heritage are an important part of the social environment by ensuring due account is taken of the legacy.

In the broader context of the social responsibility. ISO 26000:2010[12] describes the elements of social responsibility as reflecting the expectations of a society at a particular point in time. The ISO states: "an early notion of social responsibility centred on philanthropic activities such as giving to charity. Subjects such as labour practices and fair operating practices emerged a century or more ago. Other subjects, such as human rights, the environment, consumer protection and countering fraud and corruption, were added over time, as they received greater attention" (ISO, 2010, p.5). Quality in the social environment must be maintained by acting ethically, respecting ethnicity, and gender equality.

12 ISO 26000:2010 Guidance on social responsibility in management systems

Micro, small, and medium sized companies have some advantages because they are less hidebound by procedures; they can be flexible and nimble in making decisions on social issues. They may not have the strongest balance sheet, but they do not have the overheads of bureaucratic procedures.

3.3.4 Green / sustainable environment

The green environment is having an increasing impact on every project. Climate change has become a fact of life. Responsible behaviour is a factor in quality delivery. Environmental aspects include ensuring materials are sourced from responsible and registered suppliers. Managing and disposal of waste, protecting trees and managing ecological issues with no pollution of air, water, and land are all part of acting responsibly. Rescue and relocation of protected species will be undertaken by specialists. Ensuring due account is taken of energy conservation and use of renewable sources of energy are part of being responsible and being a quality focused business.

Environmental legislation is increasing, with more inspections and more conformance requirements. Covid 19 is shining a light on the importance of the natural world, and the positive impact nature can have on health, well-being, and survival.

3.3.5 Business environment

The business environment embodies many aspects. Corporate social responsibility and improving prospects for disadvantaged people span both the social and business aspects. Some public sector clients are seeking information on social procurement policies.

3.3.6 Professional environment

Where an individual is a member of an appropriate professional body they should act in accordance with their own code of professional conduct in all aspects of their work and in their relationships with others. They should also be aware of, and uphold, any particular requirements of their code of conduct. When companies are members of a trade federation, they must comply with the standards of professional behaviour.

3.3.7 Digital environment

The digital environment embraces every aspect of design, manufacture and project delivery. Digital transformation is about connecting workers through digital tools. BIM is just one facet of the digital environment. Laser scanning, digital twins, Blockchain, auto-ID, 3D printing, artificial intelligence (AI), cloud computing, internet of things, wearable devices, virtual reality, remote sensing, data analytics, and many more technologies all have an influence on the modern construction industry. The line between physical and virtual space will forever be blurred, with AI technology built to connect people at a human level and drive them closer to each other, even when physically they are apart.

Digitising operations can be daunting and disruptive, but the benefits far outweigh the costs in the long run. However, implementing IT without interoperability can cause major problems, bearing in mind that many users will want simple and easy access to information on the job site. Digital makes it easier to collaborate – working in a virtual environment, making adjustments to models, which allow the cost implications to be seen quickly. Communication and digital records are important, if there is a claim, it becomes important to establish who was responsible for what. The rapid development of digital twins, virtual replicas of physical devices, will support a systems-level transformation of the construction sector.

Digital can provide a 'single source of truth' for projects, by storing documentation and photographs of the construction process.

Low-latency 5G networks will resolve the lack of network reliability for mobile communications and allow for more high-capacity services that are especially important on job sites where real-time monitoring is required.

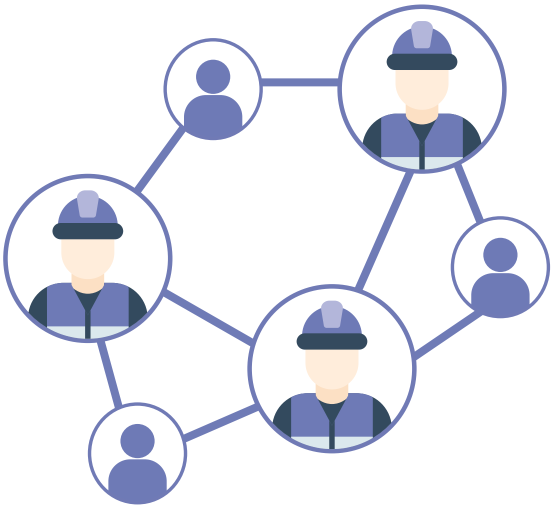
The cloud has changed the way the internet is used, and the way data is exchanged. It has created the ability to work remotely, and how data is stored and accessed. Accessibility has changed the way individuals can work, documents such as the quality plan can be accessed easily from the workplace on the jobsite.

Digital requires the documents to be authentic - there must be integrity of the stored information. Authenticity refers to the capture of the electronic information. It provides assurance that electronic information captured is a "true copy" of the paper document from which it originated. Safeguarding stored data is about integrity; the assurance that the data are trustworthy and not corrupted by, for example, changes in the system, malevolent attacks, server relocation or user errors.

Connected workforce

A connected workforce is about how workers connect with each other through IT systems and applications. The smart phone, the laptop, the electronic tablet, and even the smart watch are enablers, linked through the cloud with the internet. It is also about enabling remote working and the accessibility of documents, applications, and systems. On the job site the connected workforce is about more than just practicalities. It is about using smart technologies to improve productivity and prevent delays. Site workers use 21st-century technology as tools and building blocks. Smart devices enable workers to be fully connected.

Collaboration platforms are common on larger projects which can improve workflow and interdependence. For quality management this means accessing the quality plan and all the information necessary to install and test the products. Having access to electronic installation manuals means costly mistakes can be avoided. Having access to real time data saves time and money.



Using pictures and video helps to connect the site with the office. It shows items before they are covered if they cannot be inspected. Sign-off may be required using electronic signatures and providing a record for future reference. Wearable web cameras are now easily available, affordable, and reliable.

As augmented reality and mixed reality develop at a fast pace, worn eyewear provides the opportunity to see the location of utilities and other items on the job site.

Connectivity is about:

- Access in real time of documents and plans that will aid quality assurance and control.
- Communication with remote expertise to help with quality management.
- Having records of work completed before it is covered up using video and pictures.
- The ability to communicate with the client and consultants rapidly to get decisions on issues as they arise.
- Creating a record for capturing the why and what decisions.
- Providing a hub for operational knowledge and lessons learned that can be shared.
- Tracking plant and equipment.

Document control

Documentation must be controlled, accessible, transparent, and kept up-to-date. Automatic, electronic systems formalise naming and version procedures, help track, store, and retrieve documents, as well as sharing them across stakeholders. It should be controlled to ensure it is available and suitable for use, where and when it is needed, and it is adequately protected from loss of confidentiality, improper use, or loss of integrity.

Document control provides a framework for regulatory conformance. Quality management documents should be searchable and tamper resistant. Revision control should be clear with a formal process in place to ensure any changes are transmitted to affected parties.

Quality management used to be a paper-based manual checklist, but that is not dynamic. When there has been a refurbishment where defects are identified, if there is a claim, it becomes difficult to establish who was responsible for what. There needs to be a 'single source of truth' for all projects, which is where digital comes in.

Laser scanning the built asset, with artificial intelligence can be used to check if all the assets match the design model. For instance, if the fire stops are not in the right places, that will quickly be identified. Laser scanning involves digitally capturing the dimensions and spatial relationships of objects using the reflection of a laser light. Laser scanning in construction can also help document where errors were made and identify a solution faster, this is particularly important for quality assurance. Scans can be performed and accessed immediately, thereby improving operations, streamlining productivity and reducing rework. 3D scanners allow comparison to original CAD models to ensure accurate production processes. Realism must prevail, whilst scanning can help lower overall project costs, there is a significant cost to implement the technology and the high upfront cost can deter many companies. Laser scanning is going to be used extensively as the cost of the process reduces. Handheld 3D scanners have quickly become an industry standard, allowing precise measurement with consistently accurate readings.

If documents are electronic, control can be greatly simplified. Documents stored on the main file server using cloud technology and accessed via an application on a mobile phone, ensures that records are available and indicates who has downloaded what information. Document control is important when ensuring information has been effectively communicated and is up to date. Document control must be simple to understand and use.

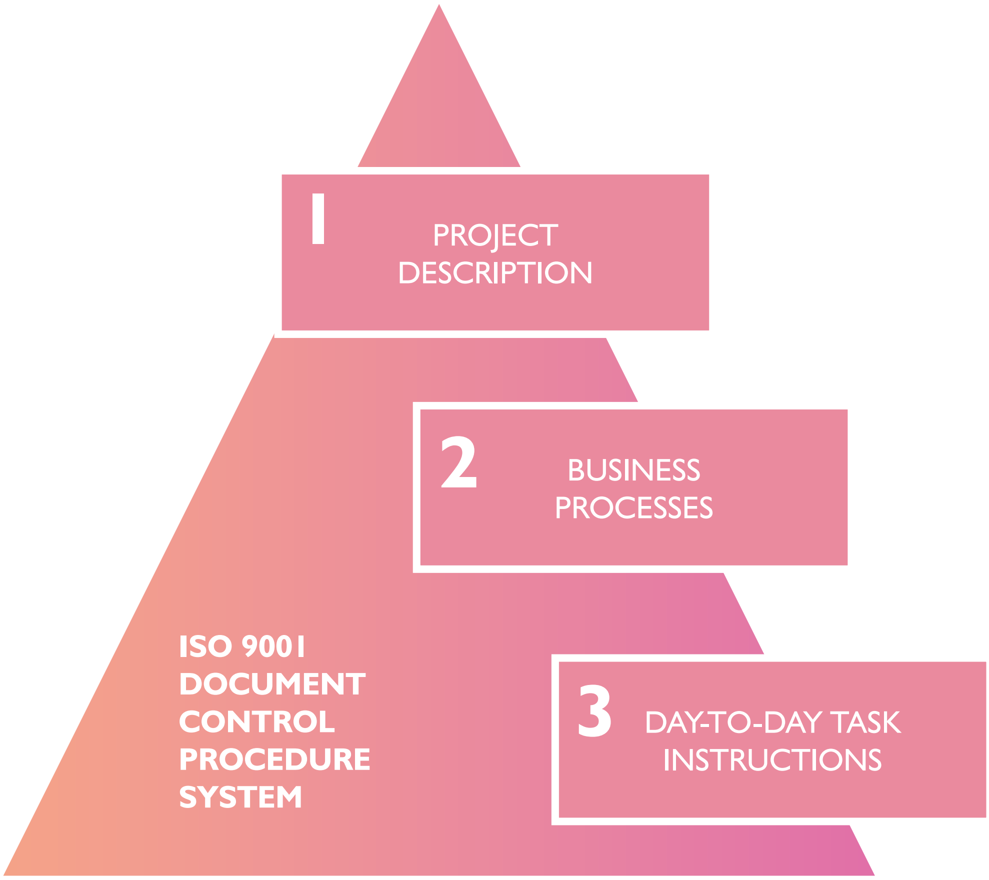


Figure 3-3
ISO 9001 document control procedure system

ISO 9001 has a document control procedure system for quality management. It classifies project documents in a 3-tier system (Figure 3-3):

Level 1: The top level of the quality documentation includes all documents describing the project. These include quality policy (short, concise statements of the project's guiding principles), general responsibilities, general administrative rules and references to quality procedures.

Level 2: Procedures provide organisational know-how that briefly show inputs, outputs, activities and responsibilities for each business process. Process is a system of activities that uses resources to transform inputs into outputs. Procedures document the specific realisation of a process in a project. They are useful for analysing the existing project, identifying overlaps and gaps and confused responsibilities.

Level 3: Instructions, the day-to-day instructions for a task. Levels 1 and 2 form a network that connects the instructions, which contain technical or professional know-how. It is important to find the balance between what is essential to record in order to do the job properly, and what can be assumed from the performing operator's knowledge through their training and education. The instruction must ensure that every appropriately-trained operator is able to follow it.

Organising documentation into a process map or a flow chart helps to show the processes, with the people involved. These types of graphics are important for stakeholders to see their role in the process. Keeping track of any changes need to be organised in a classification system (nomenclature) that is easy to understand and is transparent, with the responsibility for updating being specified.

Different types of important information that need to be distributed:

1. Test certificates.
2. Commissioning (testing) installations, including safety rules.
3. As-built drawings and information.
4. Technical manuals.
5. Design and performance specifications.
6. Spare parts list and source information.
7. Warranties and guarantees.
8. Record of the equipment and services installed.
9. Operating and maintenance instructions, including safety rules.
10. Building/asset logbook (key responsibilities and schedule of contacts; a description of services, building's operational strategies; Health and safety requirements; maintenance requirements, and; building performance in use).
11. Health and safety requirements.

Digital signatures ensure the document is an official document. A digital signature is not a typed signature or an image of a person's signature, it is a code that becomes embedded in the document. A digital signature can be authenticated and verified.

Data security on every project is important, and how and for how long the data will be stored. Archiving periods need to be defined for quality-relevant documents and records kept by the specialty contractor/supplier. All quality records must be legible and protected appropriately from damage and loss.

Small projects also need to have documents that show the client where they can get replacement parts and how equipment operates. They may be in printed form or scanned into a digital file.

3.3.8 Information management

Information technology has become a critical enabler for facilitating quality management. Every industry sector suffers from information overload. In quality management, there is a plethora of information on codes, standards, legislation and associated contract clauses, but it cannot be ignored. Ignorance costs money. The cost of non-conformance can be high for any rework of a particular element, and the work involved in reaching / uncovering that element.

Computer-based systems can support information management and speed up the processes, but they need management to follow the correct procedures. Such systems may cope with large amounts of data, but the input matters. Collecting the right data and information can be costly, but it will pay dividends in the end. Information storage must be secure and accessible, especially lessons learned about quality failures or non-conformance.

Whilst information and communication technologies (ICT) play an important role in construction quality management, the effectiveness of face-to-face meetings and physical system/component checks is paramount. 'Human' approaches can be supported by using auto-ID systems, such as bar codes, QR codes, radio frequency identification tags (RFID) and so on. As much information as possible is needed about the quality required, how to achieve it, and how to manage it, how to share documentation, pictures, and video. Innovation is helping by enabling information to be embedded into materials using sensors and tags. Technology is available, but the cost of collecting the data to 'service' these systems can be too high for small and medium enterprises. However, most companies can use Quick Response (QR) codes with free software readers; digital technology is the future for managing communications and information.

Quality management software systems enable quality management teams and engineers to increase close-out rates and shorten time to rectification by streamlining forms, records management, and workflows.

Checking and approval systems need to be part of a document management system (DMS), while the use of templates (if an automatic system is not being used) can help formalise/standardise documentation. Documents created externally that need to be part of the system should be controlled by the DMS. A process map or a flow chart can help by showing the processes, and people involved with the iterations. Stakeholders need to see their role in the process.

The quality plan should include a strategy for document control, setting out the means of filing / numbering and distribution / routing and archiving of all project documentation. Documents may be controlled by site and administrative staff, but the procedures for document control should be audited by the quality manager on a regular basis.

3.4 Quality through the supply chain

Supply chains present plenty of possibilities for failure. The traditional construction supply chain has been characterised as a series of sequential operations by short-term group members who rarely care about others. That is a cynical view of the supply chain. An analogy can be used of a game, when the only way to win is to show that an individual in a group of players participating in a game will be better off when that person considers the outcome of the group as well as his/her own performance. The effect of such a situation becomes apparent while controlling / maintaining quality across a diverse set of stakeholders in the supply chain. Collaboration, trust and respect are essential. The win/win collaboration on the supply chain could benefit everybody; trust, reliance, interconnectivity and interdependence through the supply chain are all important. A failure by one of the parties can bring major problems.

Specialty contractors should submit their quality plan/policy as soon as possible in the site production process. The specialty contractor's quality plan should focus on their work package and comply with the principal contractor's quality plan. All specialists must adhere to the contractor's quality plan in every respect. They need to submit material certificates, product data, installation instructions, warranties, personnel qualifications, and results of any independent laboratory tests. The specialty contractors may need to provide their own test/inspection personnel where the material/component/system is specialised.

Training/induction on quality issues is as important for the specialty contractors as it is for the principal contractor's site workforce; it must take place before starting work on site. Regular meetings with all specialty contractors must review the procedures, critical activity inspections, and other quality-related issues. The quality manager must work closely with the supply chain to ensure compliance with the quality requirements.

3.5 Quality management - materials, plant and equipment

The quality of materials/components is a key ingredient of a quality plan, i.e. to produce, as effectively as possible, a product that meets all the quality requirements of the client, the relevant regulations and any quality management standard/certification.

Construction shop drawings show the detail of manufactured or fabricated items, indicate proper relations to adjoining work, amplify design details of equipment in relation to physical spaces in the structure, and incorporate minor changes of design or construction to suit actual conditions. Shop drawings must be submitted on time so as to avoid delay.

Where appropriate, any manufacturers' data, including dimensions, characteristics, capacities, and operation and maintenance information/schedules, must be reviewed. Copies of the documents should be kept electronically as part of the document control system. Colour samples and mock-ups should be regularly compared with site production. Photographs are useful in identifying specific requirements of a product, component, or material. Increasingly, video documentation is used to record and inform. A submittal register may be kept and maintained by the construction/project manager.

The delivery, storage and handling of materials affects the quality of materials and processes/standards. If a materials (logistics) plan is available, this should be integrated in the quality plan. The delivery and handling of materials requires resources – human, plant and equipment – and this should be considered within the quality plan or in the correlation between it and the method statement. Reference should be made to the requirements of Building Regulations 2010 Approved Document 7 – Materials and workmanship.

The materials and components suppliers may be specified by the design team. The details of the source and any necessary certification e.g. FSC certificate, Agrément Certificate, CE mark etc. are required (see Table 2-2). The responsibility for the controlling documentation needs to be assigned to ensure that material and supplier traceability can be maintained.

3.5.1 Materials' quality conformity

Materials delivery should be checked for the right quantity and quality. Packaging protects goods in transit, with the supplier's aim to deliver materials and components in perfect condition. More thought is now given to handling the packaging and recycling of packaging material. Before installation, materials are vulnerable to damage in handling, storage, and adverse weather conditions. Damage costs money and time; expensive materials need respect. Vulnerable materials may need temporary protection after installation, which is important to ensure maintenance of quality.

An inventory tracks the type, quantity, quality, and placement of materials on site as well as the control of a material's information (e.g. existing materials on site, existing stock, and despatched materials). Digital technology helps in tracking information. QR (Quick Response) codes, 2D and 3D bar codes are mature technologies that simplify tracking materials. Handheld scanners are now affordable and cost effective, cutting out paperwork and unnecessary box ticking.

Purchase and supply contracts might have their own particular conditions. Materials from third parties should be inspected to confirm that the delivery is what was ordered and/or specified and to confirm as far as is reasonably possible, quality, viability (e.g. shelf life), conformity and type. Delivery documentation, including any third-party certification, should be checked and the delivery signed for.

Where materials are to be mechanically handled, a risk assessment should be made of the danger of damage to the quality of the materials and any health and safety hazards. Overloading machinery frequently causes accidents and injury.

Both internal and external controls can be carried out. For example, the control of concrete received by the contractor can be carried out by an independent entity.

Materials include manufactured products such as components, fittings, items of equipment and systems; naturally occurring materials such as stone, timber and thatch; and backfilling for excavations in connection with building work. Approved Document 7: Materials and workmanship, Building Regulations 2010

3.5.2 Certification of materials, components and systems

The specifications should include certified materials/systems/components in order to satisfy performance requirements. Performance specifications are written for projects that are straightforward and are well-known building types. Prescriptive specifications are written for more complex buildings, or where the client has requirements that might not be familiar to suppliers and where certainty regarding the exact nature of the completed development is more important to the client.

3.5.3 Plant and equipment

Any plant and equipment that needs to be repaired/replaced should be identified as soon as possible and non-conformance to quality or safety standards recorded and acted upon. For example, calibrations that need to be undertaken on a regular basis according to manufacturers' advice. Equally, maintenance schedules for plant and equipment need to be in place and adhered to.

3.6 Tender translation - Integrating quality into project delivery and pricing at the tender stage

3.6.1 The challenge of tender translation

At the tender stage the principal contractor and all the stakeholders through the supply chain must interpret the quality requirements for the project. Projects may be won on the lowest price or on a mix of criteria.

Identifying opportunities to use alternative materials which fulfil all the quality requirements may give a competitive advantage if offered as an alternate at the tender stage. An alternative should only be used when there is a benefit to the customer. If the specification specifies using Brand X but using Brand Y would save money, time, or provide some other benefit then it would be good to offer an alternative using Brand Y. The alternative bid should not normally replace a compliant bid but be submitted in addition to the compliant bid. The reason being that the decision maker normally wants to be able to compare like-with-like. The reason tender panels normally want to be able to compare like-with-like is that tendering is about being innovative, technically sound, and being aware of market pressures.

Some tender documentation can be very vague on the quality requirements. Standard specification clauses are used where quality must meet a particular published national standard. The contractor and specialty contractors must interpret the expectations of the client and design team. Where necessary, a risk contingency may be included to allow for the unexpected. Many assumptions will be made about productivity, production method, plant utilisation, and the risks involved.

If the quality expectations of the design team are not met, nobody will be happy. It is important that they are very clearly defined to ensure reliable tender translation for quality. Too often the failure occurs at the tender stage when incorrect assumptions are made about what is required.

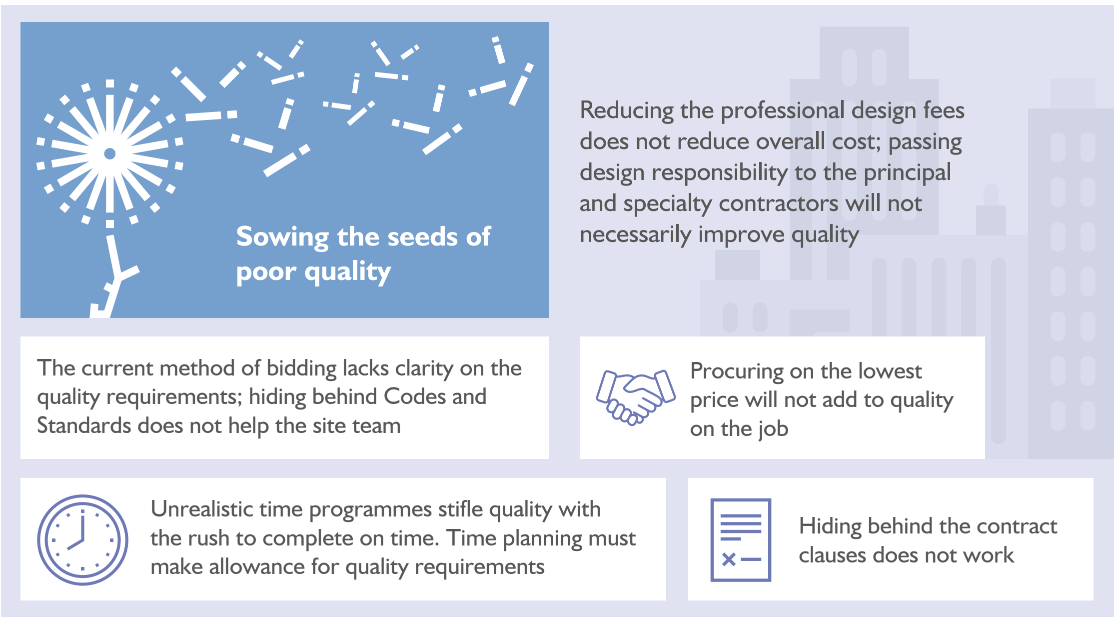


Figure 3-4 Sowing the seeds of poor quality

Figure 3-4 shows some of the common issues on quality that arise at the tender preparation stage. Poor quality design information leads to unreliable tender pricing. All the stakeholders in the supply chain will price according to the best information available, recognising that if lowest price is the sole selection criteria then they must be very competitive; however, they will ensure the products and standard of work is the best possible for the price being paid.

When information is lacking, assumptions must be made and recorded, and an allowance added for risk to both the project duration time and the tender price rates. Under-pricing items because of a misunderstanding of the quality requirements will ultimately lead to problems on the job site, it will have a negative effect on project performance as the impact of under-pricing ripples through the supply chain.

Where a project has very high design standards and quality standards, the price must reflect the time required to meet expectations. A project with an external façade curved on plan and elevation will present challenges for tolerances between the frame and the cladding. The finishes and services will also be affected.

Reducing the professional design fees will not lead to higher quality; good professionals need to be properly compensated and given the opportunity to develop their design ideas in a timely way. Low and unrealistic professional design fees are a false economy. Passing design responsibility to the contractor may seem to be a cost saving on professional fees, but nothing is free, the design cost must be paid, it is a fundamental part of the service.

3.6.2 Integrating the documentation and processes

Integration of the processes and data/information for stakeholders is key to developing an effective quality management system. Figure 3-5 shows the documents from the beginning of the process (post-contract award and pre-production prior to commencement on site), the contract, drawings, and bid documents. If quality management is to be taken seriously, both to deliver client satisfaction and engender a good reputation, then a quality management plan should be as important as a health and safety plan, and risk management plan. If something fails, the consequences can be catastrophic.

The role of the principal contractor is to interpret and devise an appropriate method of construction that will meet all the health and safety requirements, and to ensure the project can be built within the stipulated duration in a safe fashion with zero defects. A quality plan will not be produced at the tender stage unless specifically requested. However, all the quality requirements will be built into the method statement and the risk register.

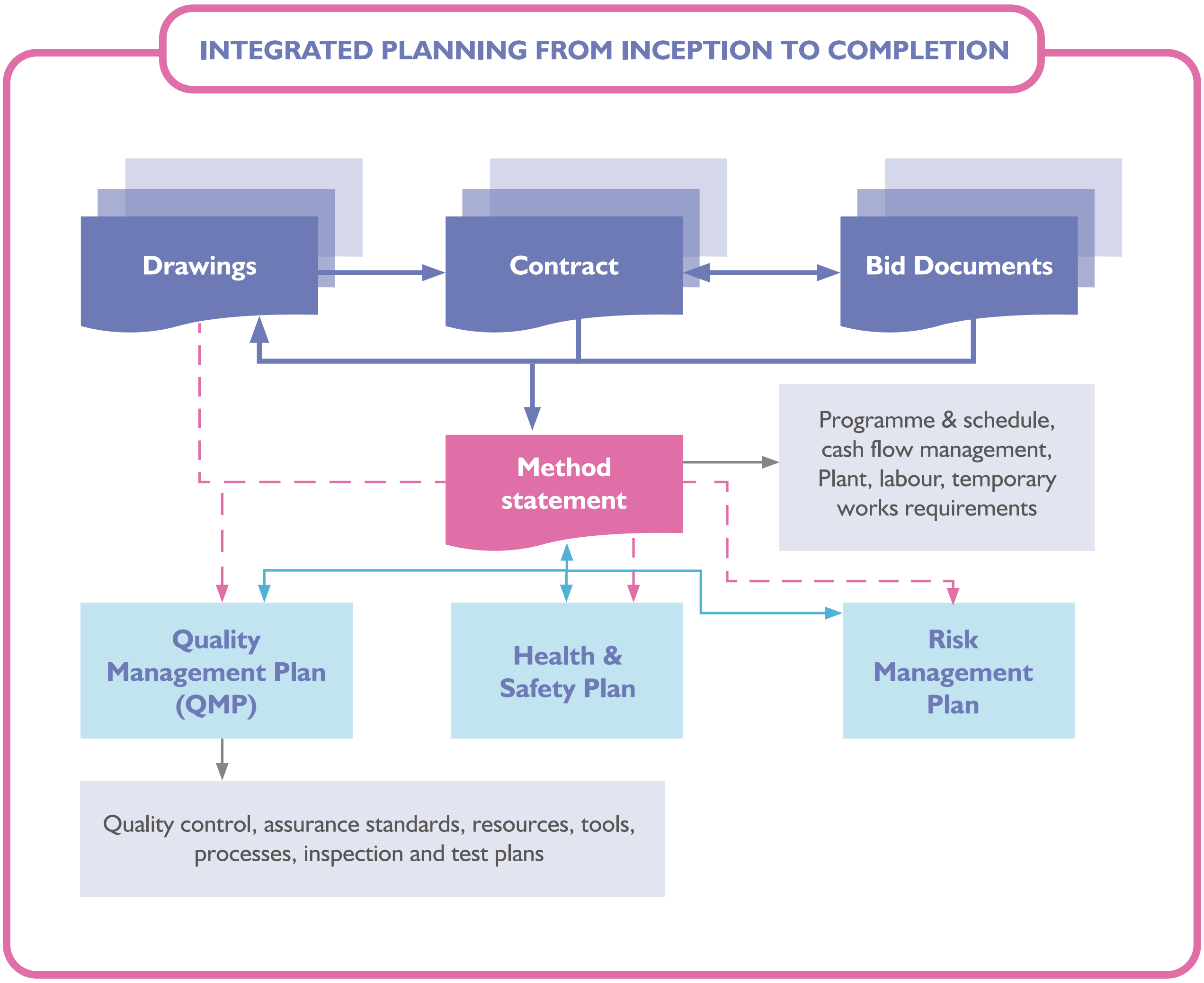


Figure 3-5
Integrated planning from inception to completion

Planning for consistent good quality should be considered alongside risk, and health and safety.

Once the contract award is made, pre-construction planning will take place building upon work undertaken during the tender preparation phase. Long-lead delivery items will be identified, and the quality requirements embodied in the specification will be incorporated into purchase orders. A balance must be struck between undue haste to commence on site and the need to ensure the quality requirements have been properly interpreted. Agreeing to deliver the impossible does not lead to better quality, with everyone under pressure to meet deadlines.

3.7 Temporary works

Temporary works can constitute a significant part of the project cost. Their design, execution, and management are important for quality, engineering, safety, and efficiency. Temporary works includes façade retention, needling, heavy propping, basement and excavation support, and special formwork.

The quality plan should include information about temporary works with the monitoring / inspection processes. The design of temporary works should follow a design brief and involve independent checking of the temporary works design. The erection / installation is inspected regularly to ensure compliance with temporary works legislation, e.g. formwork, falsework, shoring etc. The temporary works requirements, with the quality implications, must start early in the production planning process.

BS 5975:2019 - Code of practice for temporary works procedures and the permissible stress design of falsework, gives recommendations for temporary structures on construction sites, with practical guidelines for design, specifications, construction and the use and dismantling of falsework. The drawings, specification, and the contract documents will make reference to the Code - the specialists must know what is in the code and the conformance requirements. The quality plan must ensure how the work will interface with other work packages and specialisms.

Incorporating the cost of temporary works is always a challenge because of the nature of the work. Temporary works design has become an important part of the production process, with all the checks and balances required.

3.8 Off-site manufacturing

Design for Manufacturing and Assembly (DfMA) has increasing importance as modern methods of construction are introduced. The interface between off-site manufacturing and the site assembly and production process is key to ensuring quality assurance. The quality plan must show the process of checking quality and sign-off once the site team takes delivery. The manufacturing plant may require a quality audit to ensure conformance.

Manufacturing on a mechanised production line is different to site production in that before manufacture can take place there must be design approval and conformance approval. Once the production line starts there is a commitment to accept the products. The products must be clearly labelled.

Whether supplied as fully volumetric models, structural insulated panels, laminated timber framing systems, or plumbing and electrical systems assembled off-site, the result is that specialist companies will price their part of the work on a supply-only or supply-and-install basis. Understanding of the interfaces and specialisms to incorporate such systems into the project and the impact on the quality is important.

The factory-based production of the components can lead to a better-quality product as cutting, aligning etc. involves accurate computer numerical control machines connected to the digital drawings. Waste will be minimised and just in time delivery can be used. However, quality cannot be assumed and will depend on the quality assurance/control procedures within the factory.

Whilst off-site manufactured components/modules may go through stringent factory quality controls, once on site they need careful supervision to ensure continuing quality. This type of product is often large scale and requires specialist transport and handling as well as the space and expertise to put them into place. Thus, on projects involving a high degree of pre-assembly, the role of experienced site management staff becomes more important. Site workers become assemblers rather than traditional builders. The system will have been quality assured at the factory; however, its performance in the proposed structure will only be as good as its assembly/installation on site. The factory may stipulate installation by specialist contractors if any guarantee/warranty is to be given.

Figure 3-6 is adapted from the categories used in the Digital Built Britain report (Bryden Wood, 2017). It shows the level of quality assurance needed for each of the different off-site approaches. Off-site systems take full advantage of 'production line' techniques. Integration into complex designs takes time and consideration regarding how quality can be achieved. The integration of the system into the existing framework on site is crucial to ensure weather tightness, durability, and achieving fitness for purpose. It requires skills and relies upon regular inspections to ensure good quality materials and components.

The construction industry can learn from the manufacturing sector. Advanced Product Quality Planning was developed by the automotive sector.

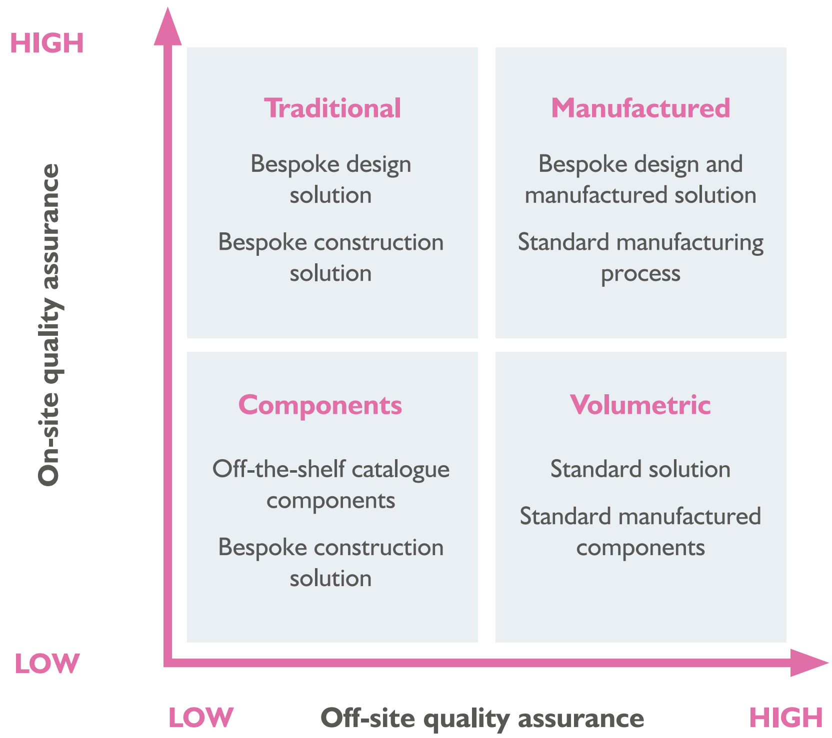


Figure 3-6
Off-site and quality

3.9 Repair, maintenance, refurbishment, renovation and conservation

Almost half of all construction work in developed countries involves repair, maintenance, refurbishment and conservation projects. Most common reasons for damage include risky design solutions, shortcomings with management at construction sites, errors in construction site implementations, maintenance violations and natural wear-and-tear, or structural damage at the end of service life.

In existing buildings, quality starts with the analysis of the building. The opportunities for quality are dominated by knowledge, skills and initial pathology/condition assessments. Whilst the same basic principles for quality management will apply, their implementation and focus will be different. Knowledge of conservation, material, science, building physics and occupier behaviour are all very different from new build. A different set of skills and requirements are necessary to create a high-quality environment/project. For example, in heritage buildings, traditional binders consist of clay, lime and gypsum for mortars, render, and plaster. These were later complemented by the development of natural and artificial cements. Lime-based mortars are of central importance for traditional (pre 1919) buildings and are the materials of choice for repair, maintenance and conservation of these. BS EN 459 Building Lime gives guidance on this type of material.

Renovation is more challenging than new construction. There are many things to consider and you have to be prepared for changes during the work. An occupied building will present challenges to ensure all the stakeholders are happy; it is not just the quality of the workmanship and materials. Disruption to the daily life of the tenants will influence their perception of quality. They will remember the driven piles with the noise and vibration, whereas an alternative may have alleviated the problem. Only by setting parameters is it possible to reliably evaluate the success of a repair. Converting them to numbers does not make sense in this context even though it would make it easier to measure success.

The quality plan must reflect the nature of refurbishment and conservation. The context will be very different to a new build project, but the principles are the same. The quality plan and the inspection and testing plan must recognise the special nature of the work. Modifying a standard template for a quality plan will create difficulties. Noise, dust, temporary protection, controlling humidity, storage of materials, fire protection and health and safety will need careful consideration. Working in a building with priceless artefacts will need a quality plan that takes account of the working environment. There have been examples of buildings catching fire during renovation work because of poor attention to detail. In heritage buildings, the clients will require an extensive pre-qualification that will include an assessment of quality performance before any contractor is appointed.

Section 4

The Quality Plan

4.1 Introduction

Project quality must be clearly defined at the outset to meet the standards and expectations of the client and of the company's quality policy.

In some industries and internationally, the quality plan is called the quality control plan.

A quality plan should identify critical success factors, and metrics by which success can be measured. Each plan is unique, based upon the project's requirements. Quality objectives must be set as part of any quality plan, which are:

- Consistent with the quality policy.
- Taking account of special requirements of the project and the design team requirements.
- Conformity requirements of products and services.
- Method of monitoring procurement, installation, construction, conformity, testing, commissioning and maintenance.
- Organisation structure and reporting lines for the project.
- Communication requirements to ensure the plan is transmitted through the supply chain and ensure that specialty contractor's quality plan requirements are incorporated.
- Define who is responsible for certifying that compliance/declarations of conformity with the requirements have been achieved.
- Define measurable targets.
- Kept updated when changes occur.

Good on-site communication of the plan is seen as the most critical driver of performance, emphasising the importance of the ability to combine knowledge, experience and soft skills to manage the process. Digitalisation is important in ensuring effective communication.

The quality plan is created as early as possible during the pre-production phase of the project, prior to work starting on site. The stakeholders are the project manager, quality manager, site manager, key specialty contractors, and any people whose support is needed to carry out the quality plan. It is not about making the paperwork look good for the project, it is about stating clearly how things can be done to achieve quality. The plan must be a working document that is easy to understand and relevant.

Figure 4-1 shows the quality plan as an integrator - it should not stand alone. It should be integrated into all aspects of the construction process. It is not just about avoiding defects, it embodies all aspects of project delivery. The risk management plan, the logistics plan, the health and safety plan and the method of working will all impact the ultimate quality.

The risk register will report on the possible source of risk, the effect, and the mitigation measures. An example is the Glasgow School of Art fire in the Mackintosh Building under renovation in 2014, where the Scottish Fire Service report concluded that the fire on site was caused by flammable gasses from a canister of expanding foam which came into contact with a hot surface. Production quality includes having a tidy site and ensuring people and capital assets are protected.

Figure 4-1
The quality plan as an integrator

4.2 Quality plan - best practice

A quality plan is a document, or several documents, that together specify quality standards, practices, resources, specifications, and the sequence of activities relevant to the delivery of a construction project. It should include the service level expectations, and the organisation and responsibilities for the delivery of quality. The quality plan should reflect the aims in the corporate quality policy.

A quality plan is a specification of the actions, responsibilities and associated resources for a specific project/object (BS, 2018)

The Inspection and Testing Plan (ITP) is part of the quality plan. It sets out the inspection and testing requirements to ensure conformity. Some fundamental questions need consideration when putting the quality plan together as shown in Figure 4-2. The document will be produced early in the project, but site teams have to ensure the project is kept on track and the plan takes account of changes and variations as they occur.

The person responsible for the execution of the quality plan should ensure that inspection and testing routines are in place and at the set frequency. The test status is identified by labels, tags, stamps etc. Reports should be monitored for any flagged-up items/issues. Final inspections will be part of the handover process, with the relevant documentation, test certificates etc. handed over to the client.

The Quality Plan

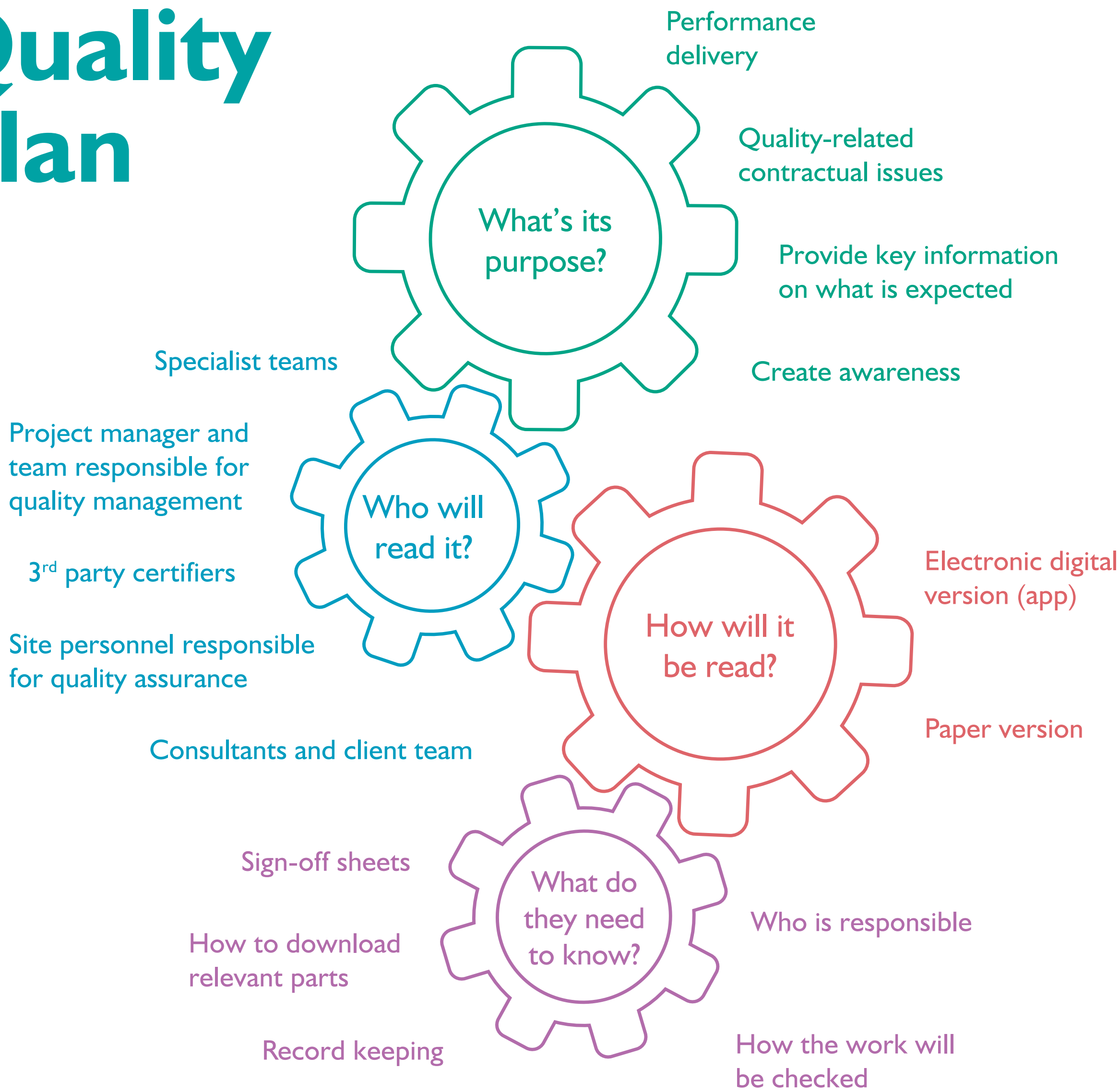


Figure 4-2
Fundamental questions about the quality plan

The plan should reflect the complexity of the project. A quality plan for a power plant is very different to a plan for an extension to a village hall. Always reflect the requirements of the audience reading the plan, whilst ensuring the contractual conditions are complied with; it may be needed if an audit is undertaken.

The plan should describe how contractual, or other relevant traceability requirements are identified and incorporated into documented information. Identifiable and retrievable records should be maintained to furnish evidence of activities affecting quality. Records will be retained for a minimum of five years.

Recognising how the information is used ensures relevance. The external façade specialty contractor may be responsible for design, manufacture, and install; any changes to the structural frame could have significant consequences to the cladding, which may ultimately affect the quality. The façade contractor is interested in their section of the work and work packages that impact their operation. They have little interest in the piling package or the site de-watering package that finished months previously. Modern construction is heavily reliant upon digital information and records. The paper-based plan has increasingly been taken over by digital systems. Having the ability to interrogate clash detection and to download a 3D BIM model improves productivity and performance. If the quality plan is simply textual information, many people will get lost in the text.

A good quality plan will have text, graphical representations such as process charts, tables, work-flow charts, visual media, and possibly QR codes that link to other documents or web sites.

Modern methods of communication have impact. There may be interfaces with other plans provided by the specialty contractors that are important for certain work packages.

The cost of producing the quality plan will be included as an allowance in the project preliminaries section of the tender price. Head office and site-based overheads will make allowances for producing documentation and managing the process. All projects require management, with allowances for health and safety, quality management, logistics planning, and resource planning. The cost of managing quality will be paid back many times over by the reduction in the cost of re-work and correcting defects.

In an increasingly litigious world, whilst reading documents takes time and effort, such efforts will be repaid if something does not go to plan. Understanding the process, the contractual requirements, having an audit trail, and keeping photographic and digital records will be valuable. Paper records worked well for over a century but digital and visual records are now the important items.

Figure 4-3 shows the inputs to the quality plan, which must be seen as a working document that helps the production team. It must have relevance and realism, otherwise the production team will see little purpose, other than another document produced to pass the risk. There must be a link to other documents; the quality plan should be a stand-alone document. It is intended to be a "what to do, why, and whom" document, helping with the "how to do" approach. Figure 4-4 shows a roadmap for a quality plan.

The method statement produced at the tender stage sets out how the project will be delivered. Digital design has enabled very sophisticated method statements to be produced for large projects, on small projects the method statement is equally important, but less formalised.

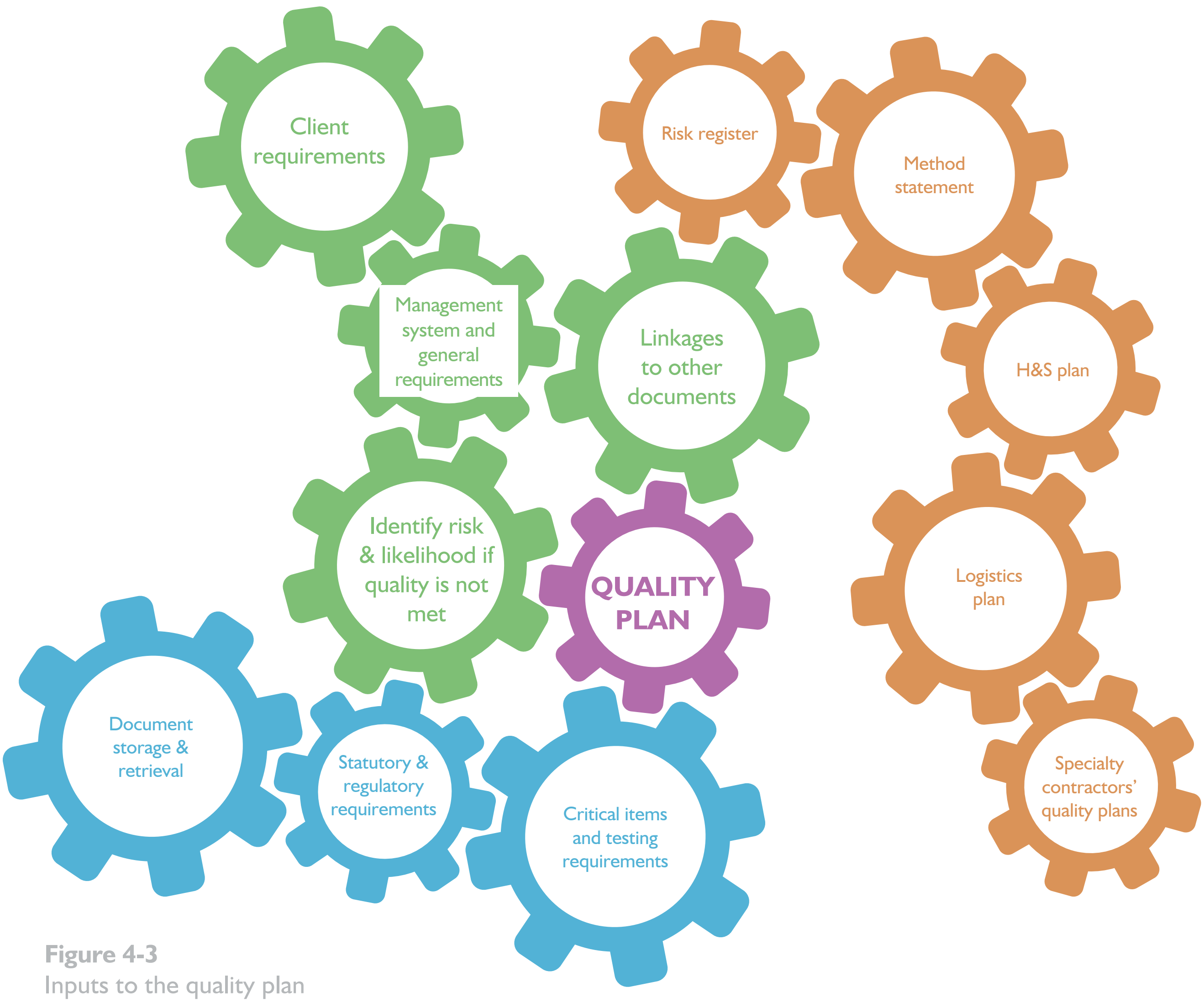


Figure 4-3
Inputs to the quality plan

The production programme - either a bar chart, network diagram, or critical path - shows the sequence and milestones. The risk register identifies the risks and how they will be mitigated and managed. The health and safety plan takes into consideration all the requirements to meet the legislation. The logistics plan considers the transport and deliveries and the ordering of materials. The quality plan must take account of all the items that can affect quality and how it will be delivered.

A quality plan must make sure that there is a common understanding with companies in the supply chain about how the quality plan requirements will be met, and what testing and inspection will be required.

The principal contractor should decide what level of monitoring is required to assess the specialty contractor's performance, such as ongoing monitoring, acceptance checks, assessment and auditing.

Items such as confidentiality of information and protection of intellectual property will need consideration.

The inspection and testing plan is divided into delivery stages with:

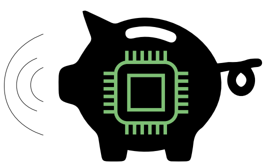
- Pre-construction requirements ensuring the tests are carried out at the right time.
- Materials conformity.
- Off-site manufacturing tests and inspection.
- Site production inspection and testing.
- Testing and commissioning requirements.
- Post-construction.

4.2.1 Digitalisation

Quality plans are not new, but digitalisation has changed the way the plan is used. A requirement is a single source of truth for a project. A flexible common data environment provides powerful document and information management in the cloud for construction projects and built assets. Software helps to improve the management and control of digital information to drive improvements across every stage of a project. Even the smallest projects are now using cloud storage for access to information.

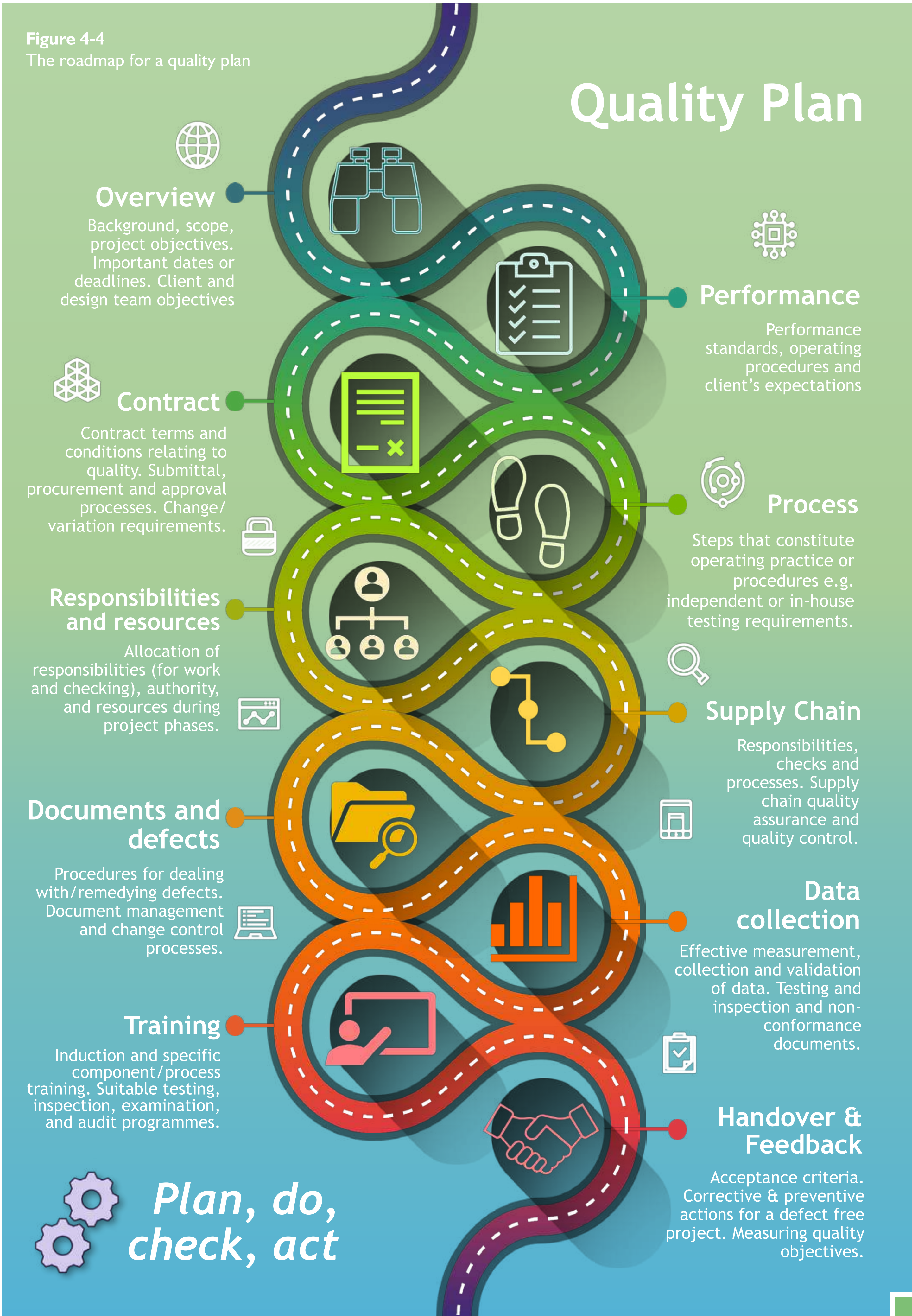
Investment in information technology costs time, money, and commitment. The capital cost is the first part of a long process, with training costs, software updates and equipment renewal. The alternative is to carry on and hope that the paper-based systems will suffice.

The quality plan documents need to be accessible, retrievable, and capable of being searched. The workforce on site do not want to learn about the complexities of software use; they need simple, instant answers, hence using tried and tested software has many advantages. It must be capable of use on a desktop, laptop, tablet, and phone. It should be easy to use, secure, customisable and configurable for the project. If reference is made to an obtuse standard, the workforce needs to know the key requirements that affect their work. They need access to the document and the ability to download information required. Importantly, site teams should be aware of items that have been identified as critical in the failure mode and criticality analysis (FMEA) - see 2.12.2.



Cost of capital
Investment in technology
to improve quality
control and assurance

Figure 4-4
The roadmap for a quality plan



4.2.2 Standards

ISO 9001:2015 defines the requirements for a quality plan. The plan will be influenced by a company-wide quality policy and the contract requirements. It provides a system for inspection, monitoring and testing processes. The quality plan helps in the management of resources (people, materials, plant and equipment) to accomplish quality targets, including setting out the risks that affect quality.

The company's quality policy should be reflected in the plan; someone coming to a job site for the first time to work on a project may be unfamiliar with what the principal contractor demands of the workforce. The policy will demonstrate the company's commitment to quality.

The quality plan needs to be dynamic, responding to changes during production. Changes to the plan need to be agreed by the stakeholders and communicated to the project team. It must be clear, understandable, not ambiguous, and in a format that is easily accessible. Printed documents are fine, but digital documents have become the preferred format for everyone. The quality plan should become a core document used by everyone throughout the supply chain. Construction projects have a transient workforce; some people remain with the project, but most will visit and go to other projects, hence good communication is vital. Employee behaviour and preferences now focus on digital transformation, the working environment must shift towards the digital age. Smart devices have changed the way people seek information on site, and the ability to access videos, pictures, and information through the cloud. The "datasphere" using the cloud technology is changing the way project information is distributed.

Figure 4-5 shows the steps for which the quality plan can be used.

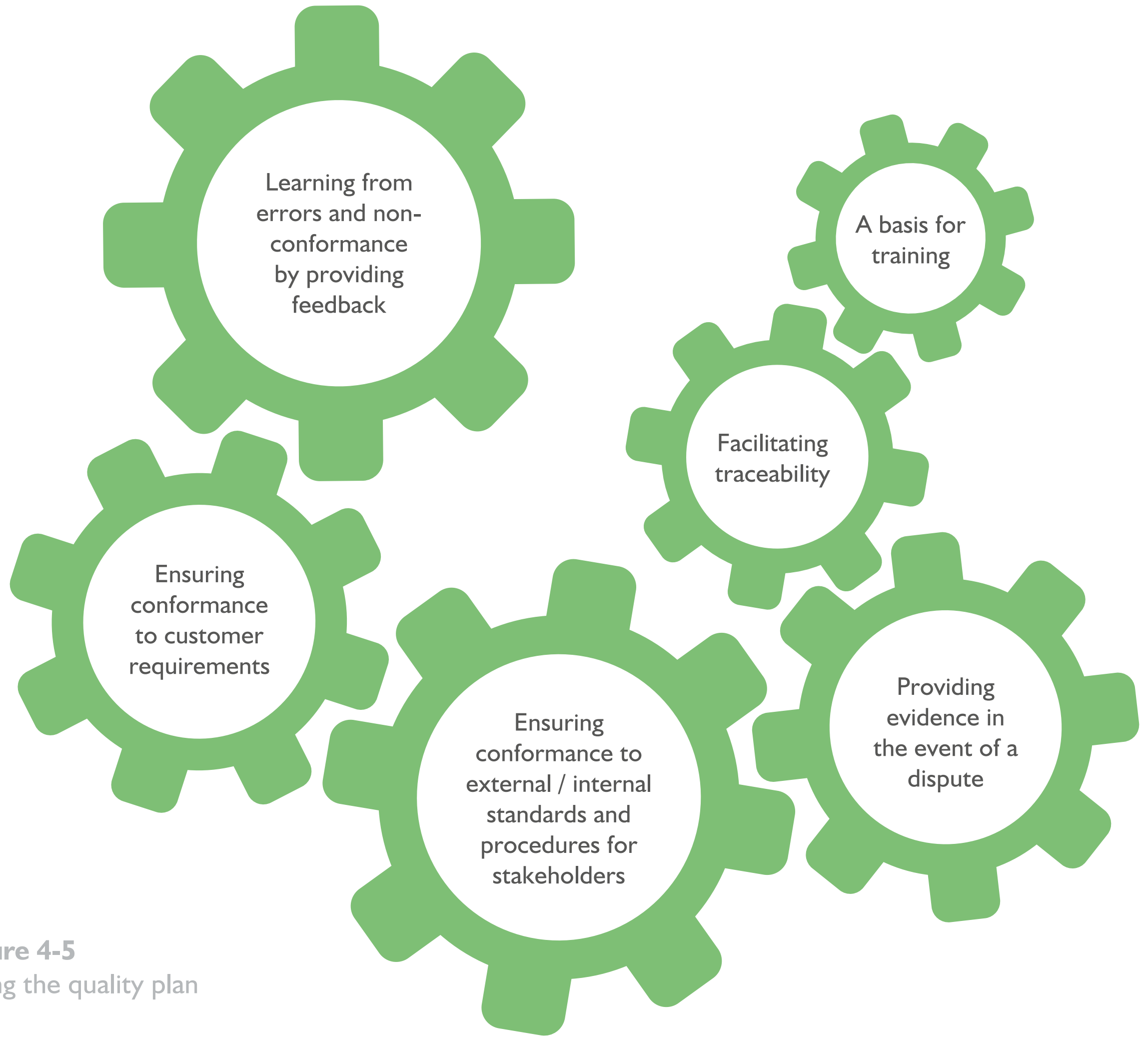


Figure 4-5
Using the quality plan

Integrating the plan with other schemes such as the health and safety, risk, logistics plan, and the method statement can provide a more holistic view and allow a greater ability to identify the resources (time, labour, money, materials etc.) required.

Managing a project involves uncertainty. It is stressful with uncontrollable events changing the work plan every day. Incomplete design, design change, and late variations are a cause of significant waste, causing disruption to progress of the work, reducing efficiency and increasing site management workload. Good on-site communication is seen as the most critical driver of performance. Another critical driver is ensuring any changes are reflected in the programme of work, the health and safety plan, and the quality plan. It is only when something goes wrong that everyone looks for the records and the evidence.

4.3 Defining project quality

Defining project quality is more than defining compliance and conformance with certain standards. If there are parts of the project where special attention will be needed, these must be defined for the construction team. Hiding behind a code or standard, without clear definition of what is required on the project will not satisfy anyone. Everyone has the same aim - to ensure client satisfaction and to be proud of the quality that is achieved.

The simple breakdown should be:

- This is what we want for the quality requirements on the project, defined in sufficient detail and with as much clarity as possible.

- This is how we will plan and deliver the quality required, with the acceptance criteria.

- These are the checks and balances we will perform to ensure the quality is maintained to the required standard in a consistent way, with the audit and recording process.

- These are the tests and validation processes we will undertake, validated by an accredited body.

- This is how we will hand over the project following inspection and any snagging.

4.4 Integrating the quality plan

Developing the quality plan does not happen in isolation. Many other plans, schedules and project members are impacted. It needs to follow the context of the project, with the requirements on health and safety, contract terms and conditions, and environmental considerations.

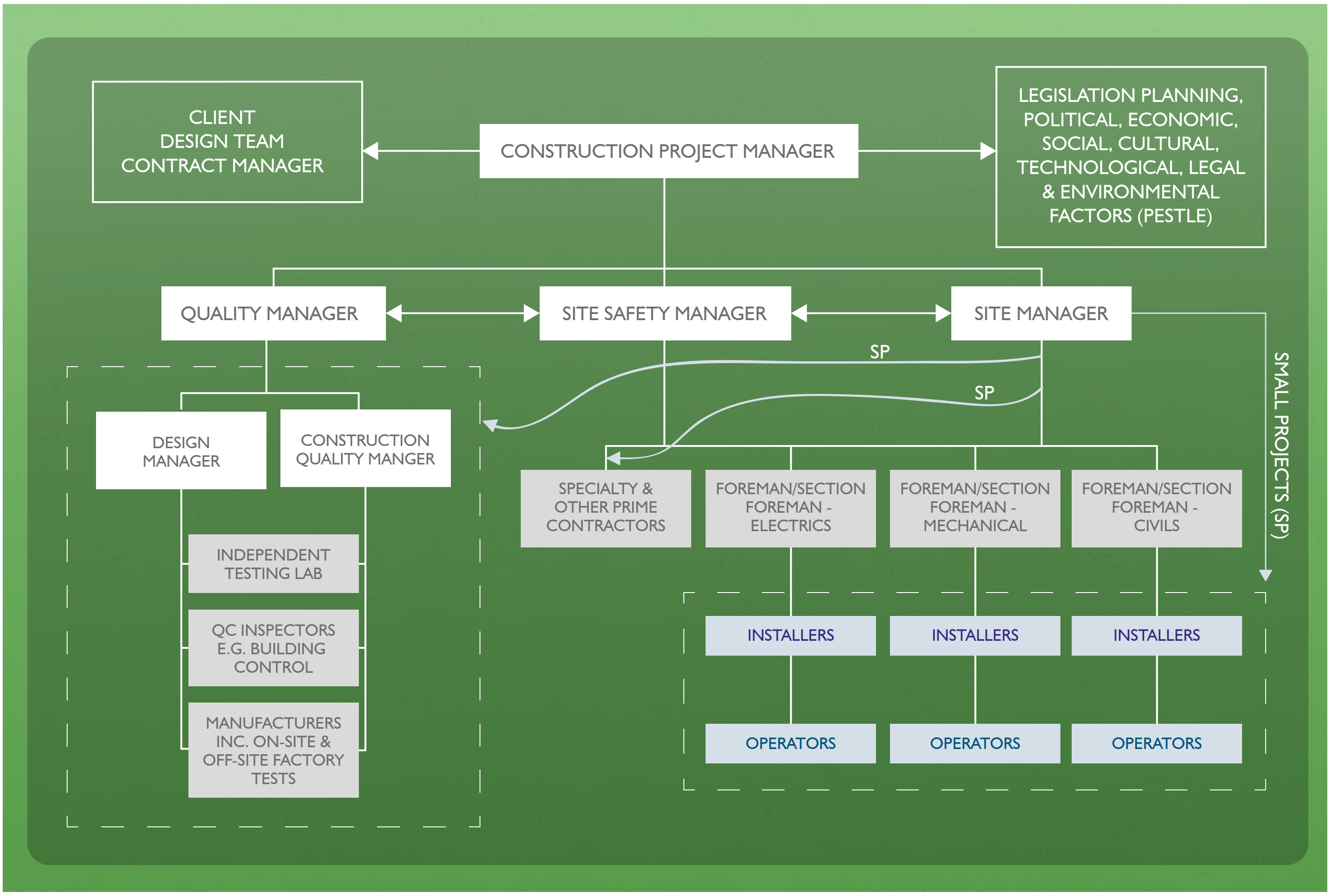


Figure 4-6
A generic organisation chart

Figure 4-6 follows the headings developed from construction practice and ISO 10005:2018. For the roles and responsibilities and the reporting lines, an organisation chart is useful. This should be widely available to all the project team, including the supply chain. Such organisation charts may look daunting for the micro, small and medium sized enterprises who do not have large staff, with specialist departments. They rely on individuals to take responsibility to deliver quality on site. However, whilst the approach may be different, the principles remain the same.

The quality plan is an important document in every respect. For example, in the USA, construction quality is also important. If working for the US Department of Defence, NASA, Federal Highway Administration, or any governmental facility, they must approve the quality control plan prior to work commencing on site, they can impose changes to the plan and require personnel to prove their qualifications.

4.5 Effective quality planning

The plan should show the integration between project personnel, inspections/tests and audits, records and reports – see Figure 4-7.

It should not be filed and kept in a drawer, or in a remote document management system, it is important to the project. It must be structured to reflect the activities/work packages and special circumstances of the project. For example, working in an occupied building carries many responsibilities to respect the occupants. Noise, radios, dust and unsocial behaviour are a reflection of the quality of the site personnel.

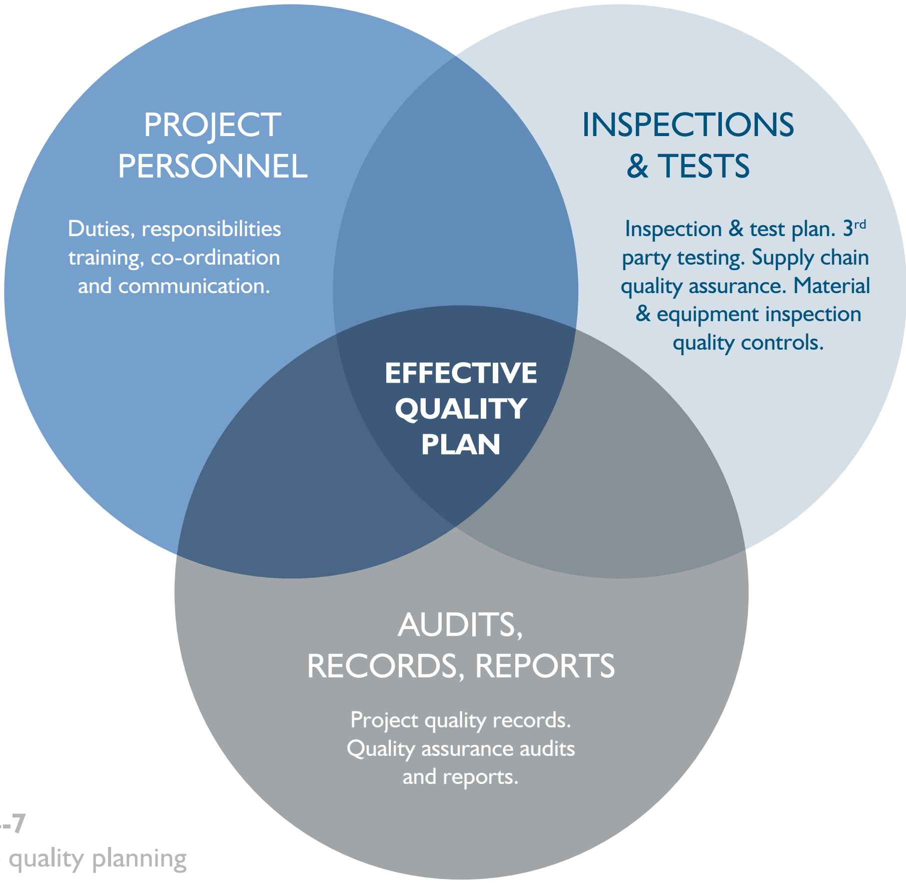


Figure 4-7
Effective quality planning

Whilst there are general items applicable to all work packages, the piling contractor will only be interested in the piling work package, whereas the decorations contractor does not want to be burdened with all the details on the piling.

For that reason, a good quality plan is structured carefully with reality in mind. Monitoring and updating the quality plan is an ongoing task for the quality manager who needs to:

- Prepare, approve and implement the quality plan.
- Carry out and participate in weekly progress and quality assurance and control meetings.
- Focus on moving from a paper-based system to digital working for the plan, recognising the cost, the timing, and the familiarity of the users with the system.
- Ensure that document control fits with other system requirements.
- Maintain documentation of inspection/testing status of materials.
- Maintain documentation for material and administrative approvals.
- Ensure that all materials and construction are in accordance with the requirements for the completeness, accuracy and constructability, in accordance with applicable building regulations.
- Maintain documentation of inspection of work executed by specialty contractors.
- Ensure the latest version of the plan and the agreed curation and dissemination is being used.
- Ensure the interfaces between stakeholders are identified and monitored to avoid any communication breakdown.
- Maintain material/component traceability.

4.5.1 Specialty contractors

Specialty contractors should submit a site-specific quality control plan for approval to the quality manager/ site manager before work commences. The plan should describe measurements, inspections and testing regimes. Inspection checklists should be provided, accompanied by photographs where applicable. A site quality representative should be identified by the specialty contractor as the responsible person. Figure 4-8 shows the items to be included in the specialty contractor's quality plan which must align with the project quality plan. The aim is to pick up on special items relating to their work package that may impact other aspects of quality.

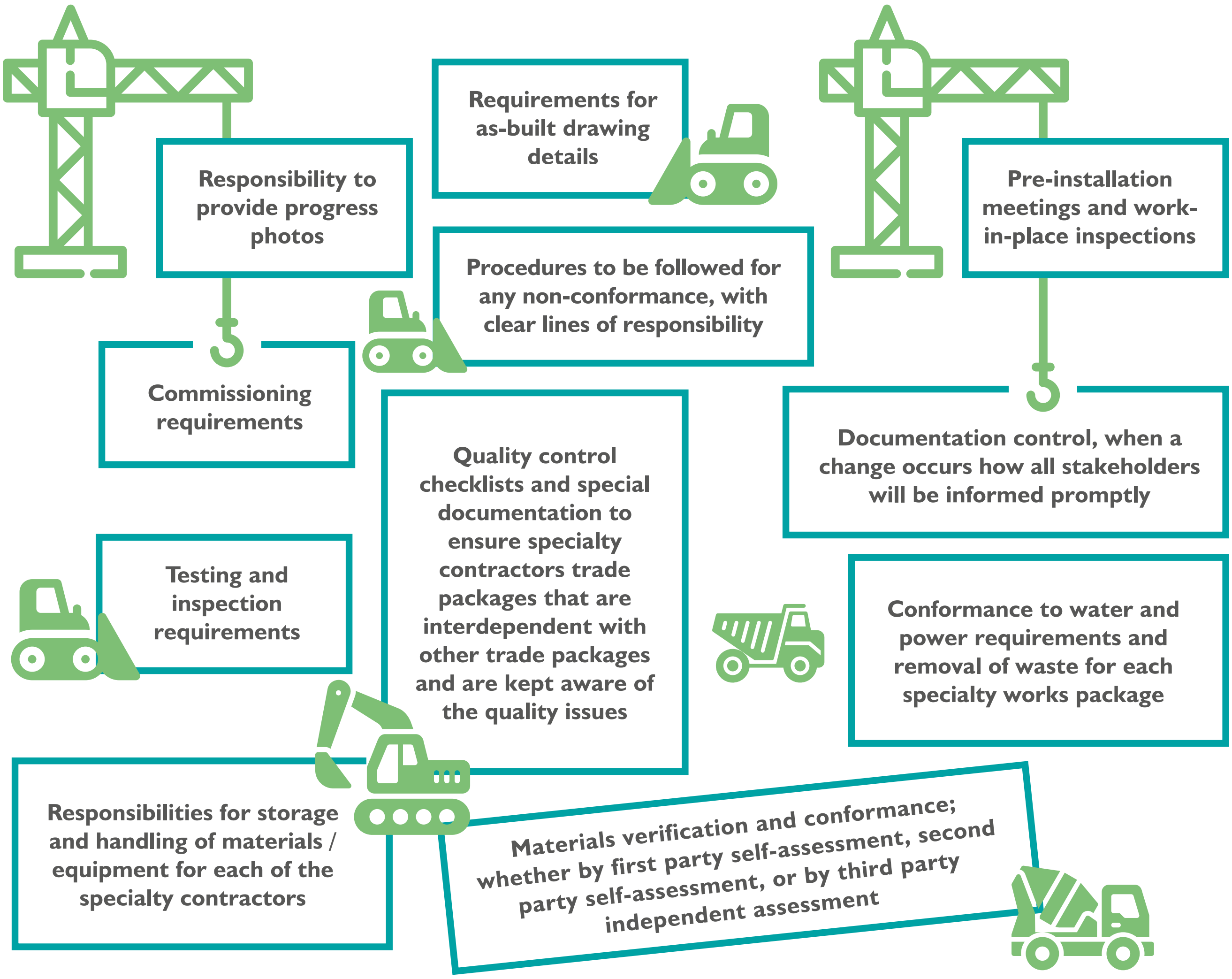


Figure 4-8
Specialty contractor's quality plan

4.5.2 Digital photography

Photographs should be an integral part of each project-specific quality management plan. Digital equipment needs to be readily available to ensure a photographic record of construction progress and quality-related issues are accomplished. As-built conditions should be photographed during the course of construction. The photos should be taken on a regular basis and labelled and stored accurately - they can provide evidence of work conforming to contract (and other) conditions. The digital library should be on a platform that allows sharing across the production and client team. Pre-cover-up photographs are particularly important.

4.5.3 Key tasks

There are a number of key tasks in the production process where quality control is particularly important. Table 4-1 shows these tasks and their appropriate test requirements.

Task	Test Requirements
Cut and fill	Plate load test
Concrete foundations	Concrete cubes
Drainage & manholes	Water test level and air test
Ground floor slabs	Level survey to RL and formation concrete cubes
Masonry	Panel to be built for inspection and kept
Masonry	Setting out and openings
Masonry	DPC and wall ties, lintels
Steelwork	Plumb line and level checks
Task	Test Requirements
Roofing	Visual inspection to confirm specifications and drawings, leak record
Electrical installation	Dead and live load
Mechanical pipework	Air pressure test
Gas pipework	Air pressure test
Chlorination of water	Sample taken of water in installed system
Fire alarms	Sound check
Fire strategy	Drawings to be issued to Building Control
Windows and doors	Hose pipe test
Building air test	Air leakage
Finishes	Room to be set up as sample of acceptable finish
Fixing pull-out tests	Ensure fixings are secure

Table 4-1
Key tasks and their appropriate test requirements

4.6 Quality risks

The development of a quality plan takes into account any risks that significantly affect project quality. The contractor's risk management plan will identify the risks, analyse them, and identify ways of mitigating or removing them. This plan needs to be integrated with the quality plan and a dynamic link established.

Risk ownership is an important consideration in quality-related activities as failure and non-conformance risks are related to poor quality management.

Areas susceptible to risk should be addressed in the plan at an early stage to avoid any impact on quality or safety:

- Setting out – regular checks need to be undertaken.
- Drainage – a testing regime of the system should be put in place; CCTV may be used. Figure 4-9 shows an example of the items that need checking in the drainage installation.
- Movement of bulk excavated material – an on-site vehicle management system should be developed to avoid impacting critical parts of the site.
- Pre-cast elements – a strict quality assurance regime needs to be in place to ensure quality in terms of strength, durability and aesthetics
- Ineffective waterproofing system – this can have a knock-on effect and once covered up, be difficult to locate
- Concrete pour – pre-pour inspections are important as well as checking the formwork and positioning. Post-pour inspections can help identify any concrete quality issues
- Concrete test results – sampling is crucial to ensure the concrete meets the quality standards required.

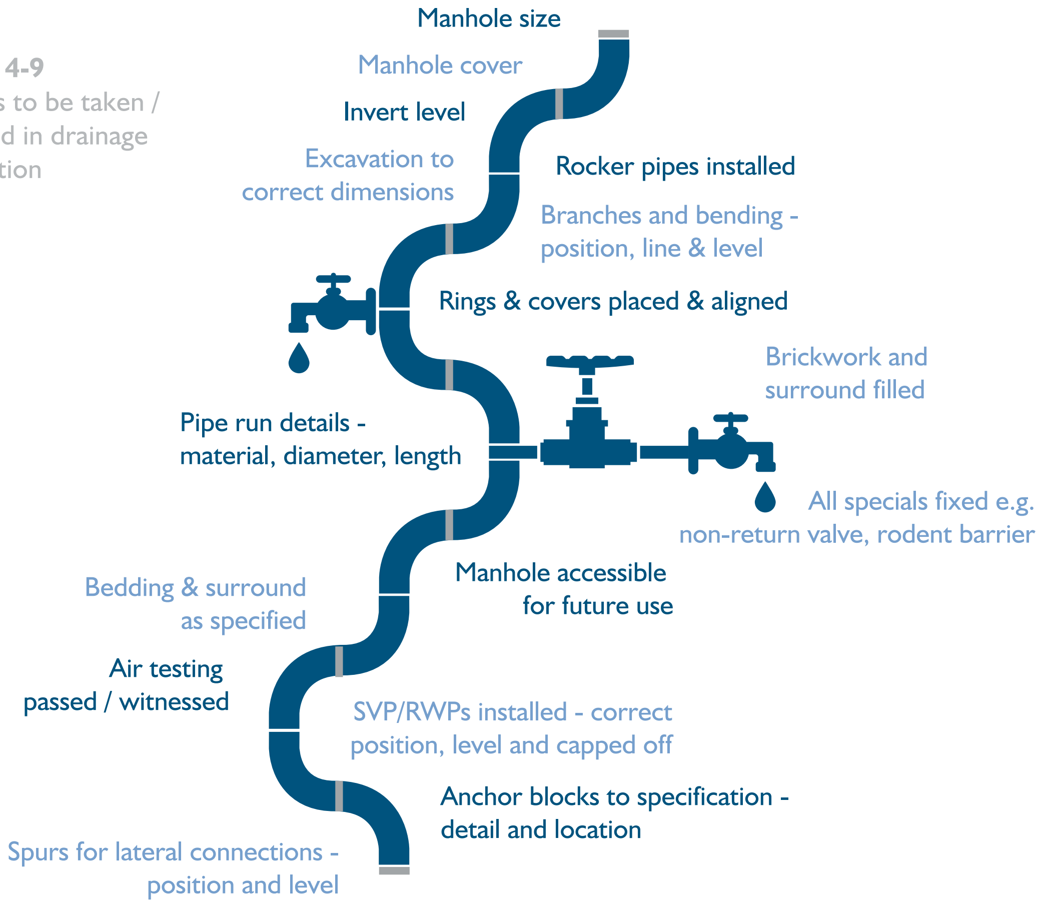


Figure 4-9
Actions to be taken / checked in drainage installation

4.7 Post-tender-award reviews leading to development of the quality plan

4.7.1 Design and constructability review

A design and constructability review is undertaken to consider the impact on the quality requirements. This ensures that they are adequate, comprehensive and integrated. Compliance checks (with manufacturers, suppliers, codes and standards) also need to be made. All or part (e.g. specialist areas) of the work may be peer reviewed.

4.7.2 Review of drawings and specifications

An in-depth review of the contract documents is important as early as the plan/specification development allows. This should be undertaken by the project / construction manager and site manager and is aimed at identifying conflicts or unclear/incomplete items. For example:

- Dimensional conflicts between civil, architectural, and structural drawings, etc.
- Dimensional conflicts between plans and details.
- Incomplete details.
- Conflicting fixture and equipment locations, designations or quantities.
- Location or routing conflicts among architectural and mechanical, electrical and plumbing items.

Resolution of any conflicts / discrepancies is the responsibility of the client.

4.7.3 Documenting existing conditions

The existing site conditions need to be identified and recorded. The use of photographs / video is particularly useful to record:

- Existing structures within or directly adjacent to the construction limits which are to remain.
- Adjacent buildings and structures outside the construction limits which may be affected by construction activities.
- Pavements, kerbs, paving and drainage structures.
- Trees and existing vegetation, with details of any tree preservation orders requiring special protection.
- Above-ground utilities, including overhead cables. Details of below-ground utilities locations.
- Streams, culverts, groundwater/flooding.
- Topography.
- Access.

4.7.4 Samples, documentation and procurement

The quality of materials / components is a key ingredient of a quality plan, i.e. to produce, as effectively as possible, a product that meets all the quality requirements of the client, the relevant regulations and any quality management standard / certification.

Samples may be required as part of the contract requirements if suppliers are being considered / selected. After selection they may need to demonstrate compliance with what the supplier can produce the material / component to the required standard / specification.

A register / file identifying the documents submitted and their due date should be compiled by the project / construction manager as soon as possible. The register should include details of submittal review/ approval processes, including that required for revision / re-submittal, as well as the fabrication time, transportation and delivery to the site. The register should be kept by the contractor at the site.

Submittal samples should be an indication of the level of material quality expected by the client / design team. Mock-ups may be required to establish workmanship guidelines and will be preserved to establish a quality base line. All variations or substitutions must be approved by the client and be in accordance with contract requirements. Any variations should be accompanied by the reasons for the change.

The project/construction manager should ensure that all purchased building materials, equipment, and supplies conform to project requirements and conform to any approved submittals. They need to make sure that suppliers can produce and deliver the materials / components on time, and that they are suitably protected during loading, unloading and storage on site. Material verification throughout the production process is important, particularly for drywall tapes, drywall joint compounds, mastics, caulking, grout, fasteners, welding supplies, and other consumable supplies.

4.7.5 Mock-ups

The contract will state any requirements for mock-ups. Further mock-ups may be necessary for high-risk construction assemblies, either in-situ or freestanding. For example:

- Exterior skin - particular attention should be devoted to transitions between dissimilar materials (windows to skin, skin to parapets, brick to the exterior insulation and finish system, etc.) and construction details that do not conform to the manufacturer's standard details, and concerns expressed by the building skin specialty contractors over the approved construction documents.
- Roofing.
- Window and door penetrations.
- Pre-cast or GFRC panels.
- Drywall finish/texture.
- Wall/ceiling finishes.
- Floor finishes.
- Cabinets.
- Countertops and fixtures.
- Landscaping.
- Mock-up units, such as bathrooms, and kitchens.

4.7.6 Factory/shop inspections

The contractor should provide the client, design team and other consultants with a draft list of construction assemblies, equipment or materials for their review and/or comment and, where applicable, request their written approval. The client and/or their representatives may wish to attend and witness any critical destructive or non-destructive tests.

4.7.7 Quality control manager activities

The quality plan should outline the inspections and tests required from the contractor and specialty contractors to ensure conformance with the quality of materials, workmanship, fit, finish and performance as defined in the contract.

Implementation - All testing data should be shared with the site manager and specialty contractors' quality manager(s).

Documentation - This should be maintained for all quality control activities, inspections and tests by both the contractor's quality control manager and that of the specialty contractors. It includes the quality management plan, the inspection plan and log and any relevant checklists.

Inspections - The quality manager should inspect and verify (if appropriate) items that will be covered up by subsequent work. Photographs should be taken of the work that will be covered up.

Inspection and testing plan - This should cover both the contractor's and the specialty contractors' work. It will follow the same format as the log (see below). It is best practice to involve manufacturers' representatives in inspections and approvals for high risk building elements, e.g. roofing systems and specialised installations.

Inspection and testing log - All inspections and tests should be recorded in the log, specifying details of the test (e.g. description, location, date, performed by and so on) and any relevant remarks. The log should be shared with/made available to the relevant sub-contractors.

Final inspection/snagging - The contractor's quality control manager will inspect the work near completion and produce a list of non-conforming items. The list should include the estimated correction date and details of the follow-up inspection.

Final acceptance - This involves final system testing, system and sequence verification, operation and maintenance manuals, delivery of recorded drawings and warranties and instruction and training procedures.

4.7.8 Non-conformance procedures

A non-conforming (or deficient) activity/material/component is one that does not meet the contract requirements. Non-conforming items may be found by any member of the design or contractor's teams and should be documented in a non-conformance report/log. The items in this log need to be tracked to ensure correction of the work/item and its acceptance is recorded.

4.7.9 Zero defects

The contractor's team, especially the quality control manager, needs to be aware of any zero-defect policy the client may have or that has been included in the contract.

4.7.10 Water intrusion / vulnerable materials

Water intrusion needs to be controlled as early identification of this sort of problem is important. The inspection regime set up by the quality control manager should include this type of inspection on a daily basis. This is particularly important during long periods of inclement weather and at critical stages of work such as the installation of critical building envelope components. Water intrusion should be dealt with quickly and prevention steps taken e.g. temporary roofing, additional floor protection and so on. Efforts should be made to ensure that vulnerable materials are not exposed to elevated moisture conditions.

4.8 Quality plan documentation

4.8.1 Documentation

Records of quality-related actions such as inspections, testing, compliance etc. should be carefully archived, easily retrievable and part of the project's permanent records. The storage should be protected from loss, fire, and flood. The records include:

- Daily reports on progress, inspection reports, and any quality issues to be resolved.
- Conformance with the Inspection and Test Plan (ITP). Test reports and logs, with results of miscellaneous tests, inspections and examinations performed by any responsible party.
- Required records of personnel qualifications, as applicable, with inspecting technician's certifications for specialist items.
- As-built information, where at least one set of completed as-built drawings, photographs and special information, should be available at all times, including information from specialty contractors.
- Quality audit reports.
- Certifications of materials.
- Non-conformance reports and records of related remedial work and acceptance.
- Photo and video documentation.

- Final system testing, as applicable.
- Commissioning reports, as applicable.
- Operation and maintenance manuals for equipment.
- Warranties and guarantee documents.
- Copies of local authority inspection reports.
- Copies of Certificates of Occupancy from building officials.

Documentation is important in helping to resolve any disputes that arise. It can help support certification and compliance. The Irish Building Control Amendment Regulations (BCAR) is a comprehensive system of monitoring and control of certain buildings or works and requires mandatory design certification, lodgement of plans and particulars, builder's supervision and certification. Compliance must be verified by a mandatory inspection plan prepared by an appointed Assigned Certifier (AC).

4.8.2 Warranties

Failures in design/specification, or those due to poor materials or bad workmanship can lead to a project not meeting the client's expectations.

Defects can be either patent or latent.

- Patent defects can be discovered by 'reasonable' inspection.
- Latent defects may not immediately be apparent and will not be found with 'reasonable' inspection.

For example, problems with the foundations may not arise until several years after completion. Once the latent defect becomes apparent it is referred to as a patent defect.

Defects must be rectified in a reasonable time before a certificate of practical completion can be issued. If the certificate is issued yet there are defects outstanding, the organisation issuing the certificate may be liable for any problem caused by this action.

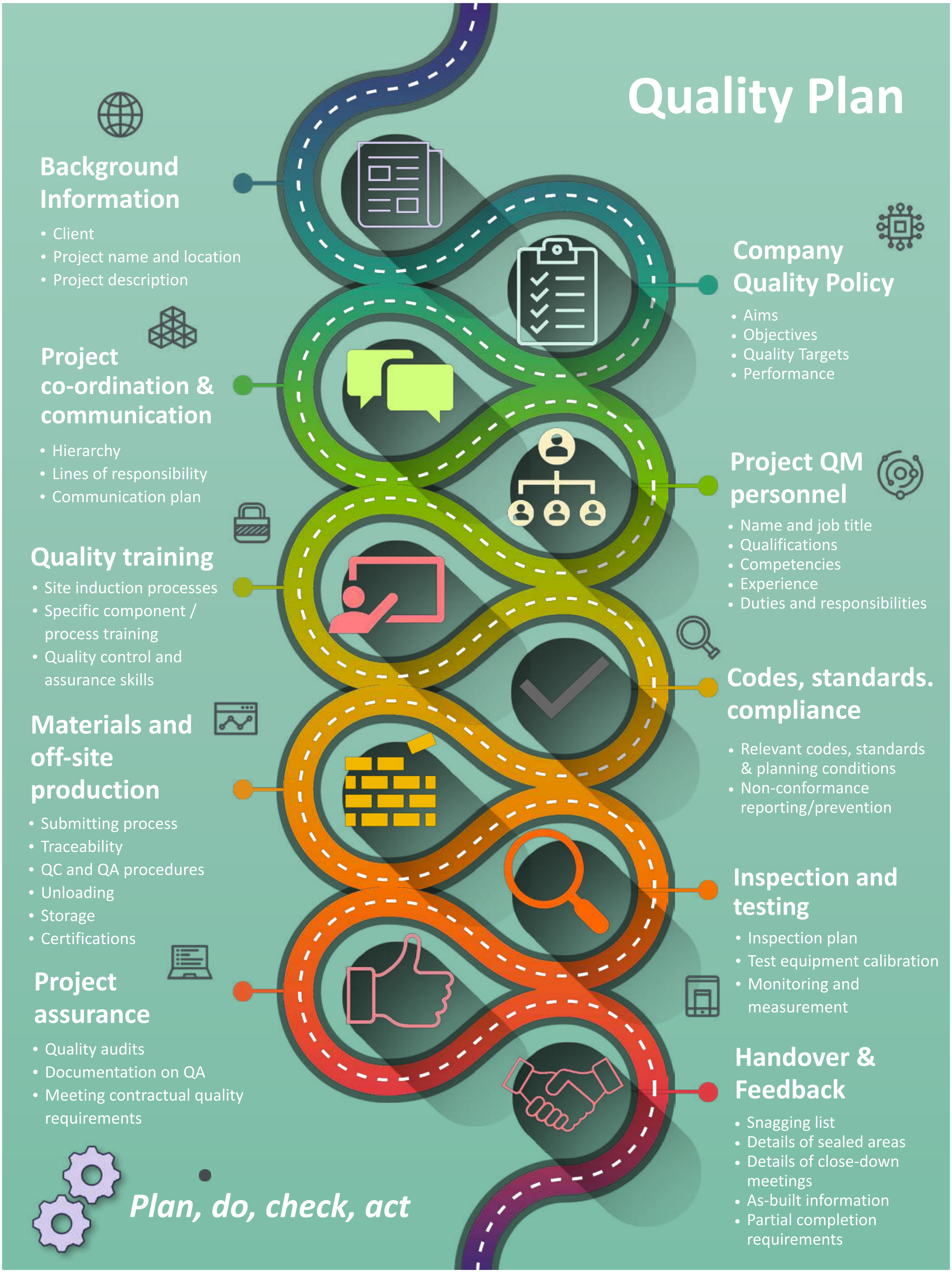
The contractor will have warranties in place and will endeavour to satisfy their conditions and any post-construction issues during the warranty period.

4.9 Quality plan outline for a project

Figure 4-10 shows the headings for a project quality plan. A standard template may be used for some items, but the special requirements of the project should be broken down into work packages to reflect the special nature of the project. For example, the special requirements in the codes and standards applicable to the particular work package; it will be a combination of the quality plan provided by the specialty contractor and the requirements of the principal contractor.

There must be mutual benefit for both the principal contractor and the specialty contractor on the project, they must communicate, collaborate and find win/win solutions, with a factual approach to decision making.

Figure 4-10
Headings for the quality plan



The starting point is the background information with the details of the project requirements, information about the project, the client, the design team, the local authority, and the key personnel. A clerk of works may have been appointed by the client to check quality on site - they have the authority to represent the client. Having background information on the project may seem obvious, but remember that some of the smaller specialty contractors may not have familiarity if they have signed a contract with the principal contractor and are unaware that, say, the architect is a Swiss design practice with a representative office in the UK.

Having the detail helps to ensure the delivery team understands the quality requirements. The principal contractor might be ISO 9001 certified and have independent third party checking. That carries a responsibility for all the companies in the supply chain and the workers on site. If they fail in their task, they may jeopardise the principal contractor's ISO 9001 certification. The company's quality policy will state their certification. It may be unfamiliar to many on site.

Details on communication and documentation, with the allocation of responsibilities will alert the team to the management hierarchy. It is when a project goes wrong that everyone reaches for the documentation to check on liability, hence signing the contract means acceptance of the terms and conditions. Having a tidy site and having good facilities for the storage of materials helps everyone. Minimising waste is everyone's responsibility. Requirements for unloading and availability of plant must be clearly defined. Water and temporary power are necessary for most tasks; leaving a hose running is irresponsible and will cause damage.

The training is not like a safety induction, it is about creating awareness, empowering the site team to recognise and report anything of concern, and communicating any items flagged as being critical in the project. Awareness is important, as is taking responsibility for actions. Re-work costs money and causes frustration. The tenuous link between design changes and variations and the impact on site production is often poorly understood.

The codes and standards set out the principal requirements for quality and workmanship, with the testing and conformance. Visits to factories to inspect goods under assembly may be a requirement where extensive use is made of off-site pre-fabrication.

The handover requirements for the client are very important, for the site team it signals the end of their involvement, unless there is a problem with defects. Nobody wants a snagging list and the quality plan should reduce (eliminate) the amount of snagging required.

As-built information is important for the client, so often it is an afterthought. Buildings and infrastructure have become increasingly complex, having the right information is important. Digitisation has helped, but when changes occur or materials are substituted, the client needs to know. Updating the as-built information should be done through the construction process.

Section

5

Drivers, Issues, Disruptors, Enablers, & Actions

5.1 Overview

Producing a quality plan may seem daunting, but just like planning, it should follow a logical path and be broken down into sections. Quality plans are not new, but how they are used is changing because of the use of apps and digital technology giving access to information and documents. There must be a link between the different plans produced for production on site.

One approach when developing the quality plan is to identify the drivers, issues, disruptors, enablers, and actions.

An example is shown in Figure 5-1. This approach emanated from the work undertaken to understand the logical process for items to be included in the quality plan. The plan must communicate what matters, when, and why.

Figure 5-2 shows a hierarchical system of drivers, issues, disruptors, enablers, and actions, with expansion of each item. The issues come from the drivers. For example, climate will create a multitude of issues, such as productivity on site and requirements for temporary protection of finished work against inclement weather to ensure quality standards are maintained.

The disruptors and enablers are the items that will influence each of the drivers and issues.

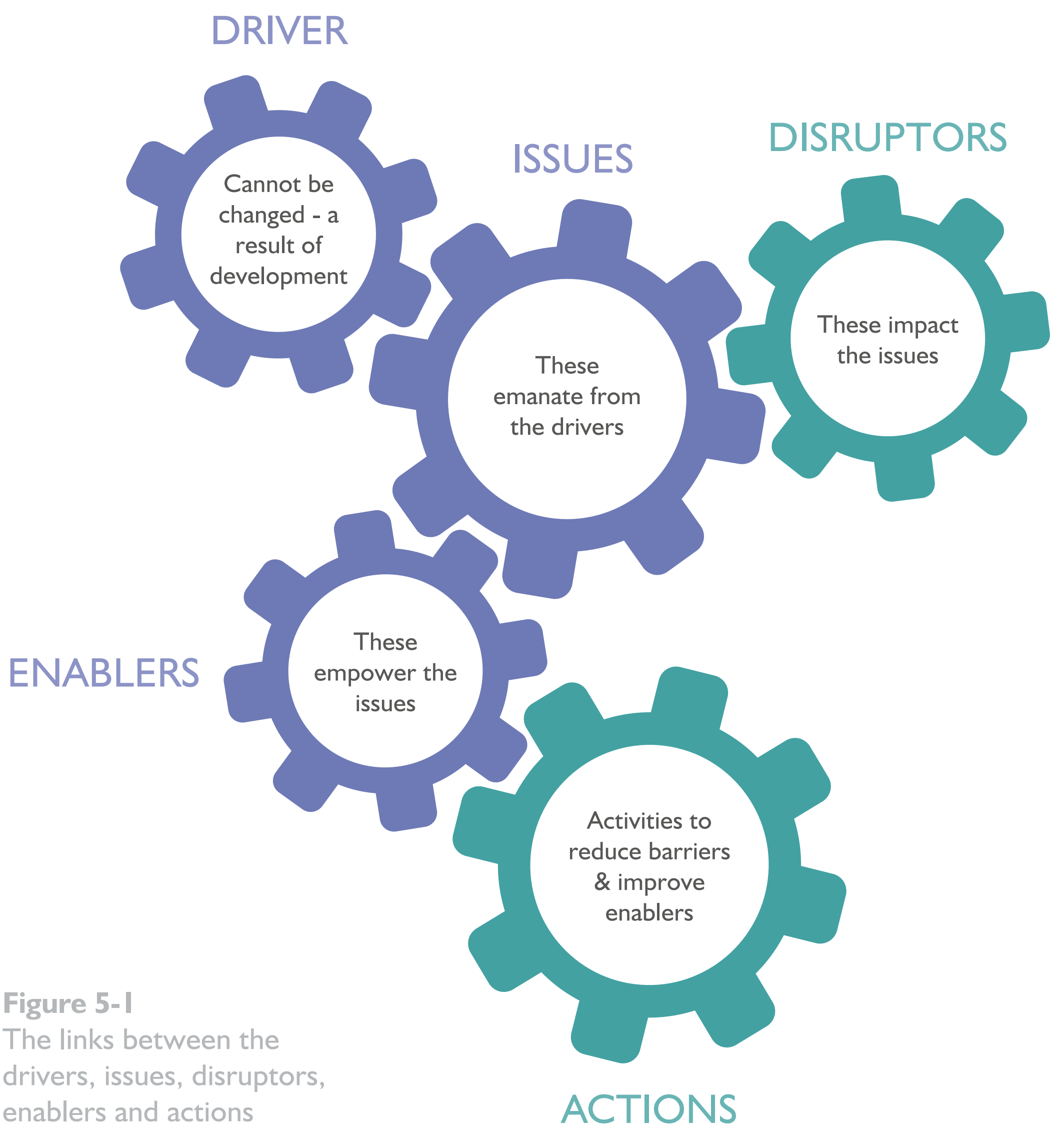


Figure 5-1
The links between the drivers, issues, disruptors, enablers and actions

It may be necessary to increase expenditure on plant commissioning by an independent team to ensure all the plumbing systems are tested and working effectively.

Disruptors may be the weather, such as high winds that mean the crane cannot operate on the day all the workforce have been called in for a concrete pour that is reliant on using the crane.

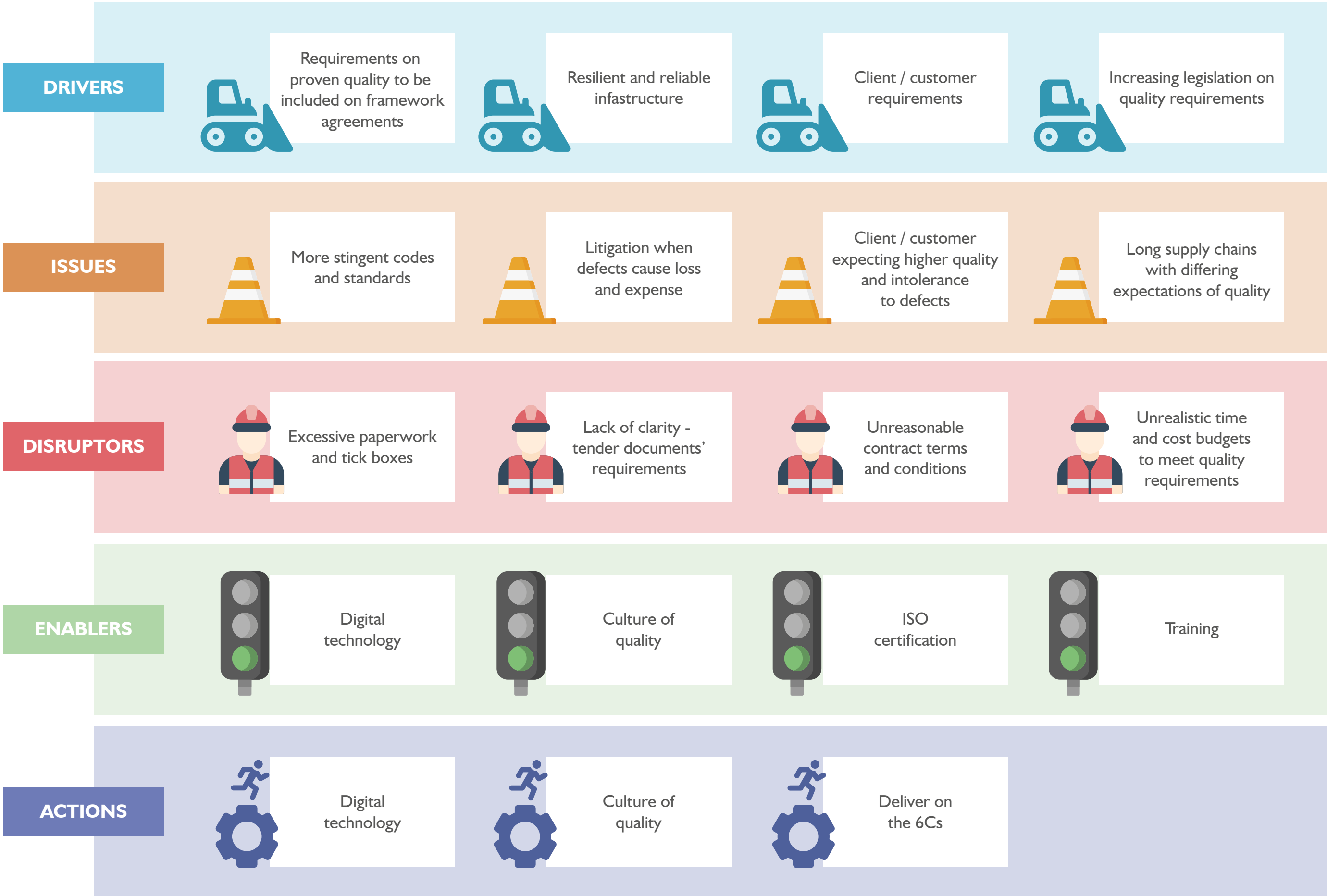


Figure 5-2
Drivers, issues, disruptors, enablers and actions

An enabler could be using concrete line or boom pumps to pump the concrete to the placing teams, whilst recognising the additional cost and time required.

The actions are a summary of the items to be included to ensure the maintenance of the quality standard. The enablers may be digital applications but will also include more traditional approaches. Having a quality culture is an enabler, although more difficult to measure.

5.2 The drivers, issues, disruptors, enablers and actions

The CIOB Call for Evidence (CIOB, 2019) and the subsequent research identified major drivers that influence construction quality, summarised into eleven main drivers, three of which are expanded upon in Tables 5-1 to 5-3:

1. **Good design** means design that is buildable and sufficiently complete at the contract award stage to allow commencement on site without information gaps and excessive requests for information. Everyone suffers when there is a lack of information and lack of design detail. Providing design details in accordance with the site production programme and schedule of work are key to delivering a quality project.

   Design management is an effective tool for the design team and the construction team to plan effectively.

   Good design is a catch-all term. The design team may be large, geographically dispersed and dealing with a local authority that is fragmented and slow in decision making. They can delay the design delivery process unintentionally, which can have a major impact.

   Design is complicated; particularly where there are "with design" work packages that need to be co-ordinated.

   Liability is a major concern, such as where shop drawings need to be signed off by a member of the design team. Professional indemnity insurance will cover the professional who acts responsibly and professionally. It is not there as a catch-all where the designer takes responsibility for failure.

2. **Realistic project programming** from the outset of the project, with allocated float time, and a programme that reflects the delivery of good quality and contains contingency allowances for unforeseen events. An unrealistic project programme will create difficulties from the start. It puts pressure on the site team and causes friction and stress. Adequate time must be allowed for testing and handover.

3. **Climate and the impact of weather** on materials, manpower, plant and equipment and process. Over-optimistic assumptions about the weather lead to delays and poor quality.

4. **Timely and relevant data and information** provided by the design team and by the principal contractor to the supply chain to ensure that when they arrive on site the team has all the information to meet the programme and the schedule of work.

5. **Site management and production**, with a production team that has the appropriate competencies and experience for the project type. Ensuring that the production area and materials are ready for the specialty contractor undertaking the work package. Ensuring there are adequate power and water supplies. Health and safety must be uppermost in the delivery process with the right Personal Protective Equipment and conformance with the health and safety plan.

6. **People and performance**, by motivating the workforce, training the workforce, and respecting the work of others. Embedding a culture of quality throughout the delivery team, irrespective of how long they will be on site.

7. **Clients** recognising the impact that design changes can have on quality delivery once site production has commenced, and not fully appreciating the disruption late changes make to a production schedule. Clients seem to have little idea of how site operating procedures work.

8. **Governance** structures and principles identify the distribution of rights and responsibilities among different stakeholders and include the rules and procedures for making decisions. Governance should provide transparency. Good governance for quality systems should be clear, simple, and understandable. Over burdensome governance and regulations/procedures that add little to improve quality take time and add unnecessary paperwork on site.

9. **Corporate behaviour** demonstrating leadership from the top about the importance of quality. Corporate culture needs to focus on customer care and demonstrate a commitment to quality. Regulations, codes and standards require conformance, which in turn, necessitate a programme of monitoring / supervision.

10. **Realistic budgeting** at the outset, taking account of risk and uncertainty, and building in contingencies to take account of the unexpected. Avoiding the blame culture and focusing on commitment to quality.

11. **Materials** procurement, storage and handling, with clear information about the requirements to ensure the materials and components meet their design specification.

Realistic programming and budget are key to the success of a project and will heavily impact quality.

"Design is about buildability and appropriate specifications as well as the importance of being close to 100% complete before production begins." Call for Evidence (CfE) respondent

Timely information avoids the last-minute rush because the information was not available when the work package started. Many will change their minds, but there has to be recognition that late changes are de-motivating for the workforce and can slow the project, putting pressure on the workforce to deliver top quality in an unrealistic time frame.

People's attitude to quality and their underlying culture cut across all the drivers. They are particularly important in site production, the delivery team/supply chain, corporate culture, and data and information e.g. their willingness to share information and collect data effectively, and to share lessons learned, both good and bad.

Site issues such as the procurement, correct delivery, storage and handling of materials, keeping the site tidy, fast decision making and removal of waste will all influence quality. The materials specified need to be appropriate to their designed function and fit for purpose.

Table 5-1 (Good design), Table 5-2 (Site management and production) and Table 5-3 (People and performance) show selected drivers with their issues, disruptors, enablers and actions.

The aim of these tables is to stimulate ideas. There is no one way of producing the quality plan; each company will seek to have its own style of communicating. ISO 9001:2015 sets out recommendations of items to be included in a generic quality plan. The purpose is to develop new ideas for the development of better-quality plans, leading to best practice.

Driver	Issues	Disruptors	Enablers	Actions
Good Design	• Design readiness, the completeness of the design at the tender stage with clarity on items still under design and subject to change • Clear specifications that define quality expectations • Design & Build projects require consideration on how the design team is managed and controlled through the design and production process • Design management process to be used by the construction team. Is there a design manager, who will co-ordinate all the design? • Information requirements and requests for information responded to quickly? • What level of BIM is being used and by whom? If no BIM is required how will the process be managed? • Is the RIBA Plan of Work 2020 being followed, or is some other system being used? • Is a digital collaboration tool being used to share design information, what system will be used? • How will change orders / variations be communicated? • What are the critical items for quality testing? • Is all the conformance information available?	• Excessive design changes required by client and design team without due thought being given to production implications • Excessive changes to a standard form of contract passing all the risk to the principal contractor without due consideration (e.g. passing all ground conditions risk without sufficient information on ground conditions) • Specification of low quality materials, not fully fit for purpose • Material / component changes without consultation when materials are already on-site • Lack of integration between design and construction • Design omission / errors should be openly and transparently discussed and solutions offered • Inappropriate design scope • Lack of integration across the design team can be a major disruptor • Difficulty of co-ordinating design on site caused by lack of integration • Insufficient temporary power and water availability • Insufficient design detail of key items • Outsourcing of design services	• Designs 100% complete before being released • Failure mode and criticality analysis report showing the risks of failure of critical items (FMEA) • Benchmarking of similar projects (design, construction method, cost, duration, advanced technologies etc.) to create targets • Understanding of project scope and complexity • BIM compliant processes that allow project clash items to be identified • Quality goal setting and monitoring targets • Integrated design management team on-site • Establishment of design integrity checklist on site • Design management of engineering and architectural design • Review / approval of drawings issued for construction given quickly • Design risk control and management plan • Design interface management between different production parts • Management of design interface between international design and engineering firms	• Training - Design Team - training in site processes in order to recognise site/ time constraints and the importance of buildability • Training - site management – better co-ordination with design team as part of integrated design management • Education – inclusion of quality management processes in architecture syllabi • Encourage better integration between design, production/ assembly and the suppliers / manufacturers e.g. incorporating information into specifications/drawings • Transparent application of codes and standards • Develop industry-wide quality plan framework • Include the requirement for a quality plan in standard contracts

	• Performance requirements other than those in the form of contract	• Poor understanding of design documents • Lack of skilled and experienced human resources in the design firms • Lack of design quality assurance practices • Complexity of the design with lack of repetition and complex design details that take little account of production techniques • Vague / deficient drawings and specifications • Design / specification change not tested sufficiently	• Early contractor involvement • Effective co-ordination between various disciplines of design team	

Table 5-1
Good design - the issues, disruptors, enablers and actions

Driver	Issues	Disruptors	Enablers	Actions
Site management and production	• Constructability is embedded in the design • Complex / state-of-the-art technology • Speciality contractors – availability, ability and experience • Poor / inappropriate construction materials specified • Rework must be eliminated/minimised • Allocation of labour resources • Delivery control synchronised though the logistics plan • Construction duration is sufficient to meet deadlines • Construction productivity has been carefully considered to reflect the complexity of the project delivery • Staged completion • Construction equipment supply and use • Site security • Quality of temporary works • Extent of enabling works	• Poor quality materials / components • Delayed construction • Low productivity • Non-conforming work • Poor construction quality • Inexperienced and unskilled specialty contractors • Unsuitable construction method • Loss of material on site • Late installation / delivery of crane and lift • Demolition / relocation of structures • Inadequate labour and equipment relocation • Defective formwork (transient use / inadequate specification) • Concrete pouring / vibration failure • Caisson and piling faulty • Failure of steel structure assembly • Inadequate installation of temporary utilities • Inadequate waterproof method / material / application • Poor construction of fireproofing • Deflection of curtain wall member • Poor finishing – method & material • Low quality delivered concrete • Insufficient geotechnical investigation • Lack of experience about new construction technologies	• Constructability embedded in the design • Complex / state-of-the-art technology • Speciality contractors – availability, ability and experience • Allocation of labour resources • Delivery control synchronised though the logistics plan • Construction duration is sufficient to meet deadlines • Construction productivity carefully considered to reflect project delivery complexity • Staged completion • Construction equipment supply and use • Site security • Quality of temporary works • Extent of enabling works	• Training – site management – quality ethos, logistics, supervision and monitoring. • Training – labour - quality ethos, logistics and productivity. • Education – professionals – increase understanding of quality plan, site management, logistics, resource allocation • Develop industry-wide quality plan framework • Include the requirement for a quality plan in standard contracts • Tighter control / management of codes, standards, building control (government) • Quality risk effectively analysed and managed • Contractor involvement in apprenticeship schemes • Quality plan to form part of the contract • Independent and accountable quality control function • Practical guidance on design drawing • Prioritise quality risks

Table 5-2
Site management and production - the issues, disruptors, enablers and actions

Driver	Issues	Disruptors	Enablers	Actions
People and performance	• Skills • Knowledge • Experience • Productivity / performance • Supervision • Safe working practices • Having a culture of good workmanship • Attitudes and behaviours • Education/training • Monitoring • Measurement of targets / goals • Absence of a quality plan • Poor materials management – quality, time and cost issues • Absence of logistics plan	• Level of education • Language, culture barrier • Lack of training • Unskilled labour on contract and no continuity of work • Poor work ethic • Low motivation to deliver quality work • Employment insecurity • Inexperienced worker • Inadequate supervision • Unqualified worker • Inadequate labour allocation • Lack of specialised quality-control team • Accidents / injuries causing disruption • Earthwork collapse • Late delivery of materials and components • Fire test failure • Water test failure • Labour shortages	• On-site training / apprenticeships • Regular inspections and supervision • Periodic safety checks / inspections • Health and safety strategy • Promotion and rewards for best practice • Having efficient employee feedback systems – employee empowerment • Creating inspiration, enthusiasm, and motivation for involvement in total quality • Recruitment and retention plan • Incentivisation • Regular monitoring of material, equipment and workforce • Performance feedback • Quality metrics and baseline goals • Good resource planning • Leadership training • Continuous progress monitoring • Application of quality management system • Co-ordination of mechanical and electrical engineering services • Effective supply chain management • Allocation of personal protective equipment • Computer simulation for constructability and clash detection • Running a field laboratory on site	• Create more apprenticeship schemes (government) with a focus on the importance of quality • Education – inclusion of quality management processes in further education syllabi. • Recognise the importance of behaviour-based quality • Create a culture of 'quality matters' in the company and workforce • Have a clear quality policy • Ensure the feedback and measurement system for goal setting is realistic

Table 5-3
People and performance - the issues, disruptors, enablers and actions

Section

6

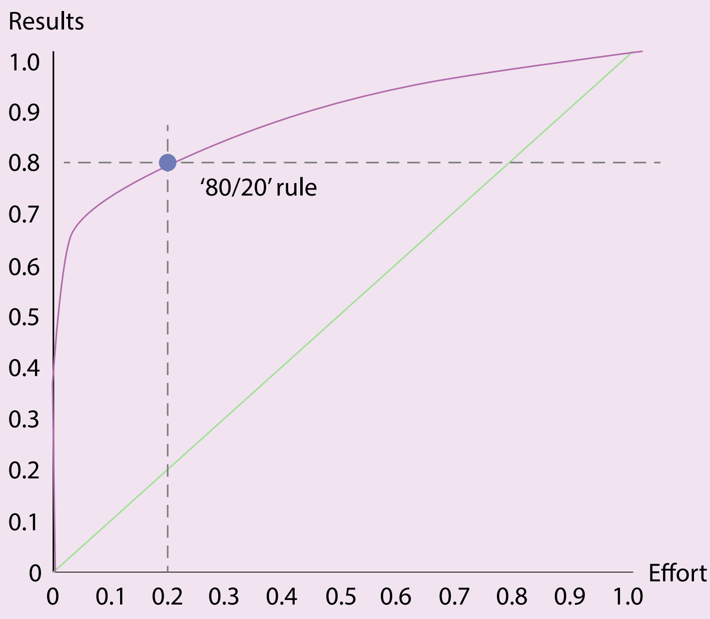
Quality Management Tools & Techniques

Tools and techniques are the means to implement quality management systems. Tools can solve problems; for example, brainstorming can highlight the relevant issues pulling together ideas and information from a group of team members. Techniques use statistical methods to interrogate and make sense of data collected on quality issues.

The tools help to provide a basis for control of quality, workmanship and feedback. Having targets and goals is vital, it provides a target to aim for. Tools can help to determine why something is failing or whether the output is stable. To formulate the targets, various tools and techniques can help in framing the situation. The process is to choose the appropriate tools, choose the time period, collect the data, and consider what the charts/diagrams are showing. If something is failing consistently, there must be reasons.

6.1 The tools

1. Check sheets are a valuable way of collecting data, which then transforms into information to inform the quality process. It is a simple document that is used to collect data in real-time and at the location where the data is generated.
2. Histogram charts how often something happens and therefore highlights its likelihood. Histograms are used to show distributions of variables, while bar charts are used to compare variables.
3. Scatter diagrams can be used to verify a cause and effect relationship and find the correlation between two variables – dependent and independent.
4. Pareto analysis helps to evaluate the importance of items where resources may be best focused. Pareto observed that 80% of the country's wealth was owned by just 20% of the population. Better known as the 80/20 rule, it stipulates that 80% of the outputs result from 20% of the inputs. Frequency data are input along the x and y axes – see Figure 6-1.



According to the Pareto principle each level of effort does not achieve the same result; there is an unequal distribution. The majority of results come from a minority of inputs. Thus, if 20% of workers contribute 80% of results, then a focus on rewarding those employees is needed. If 20% of customers contribute 80% of revenue, then focus on satisfying those customers.

Figure 6-1
A Pareto chart showing the 80/20 rule

5. Cause and effect analysis (fishbone diagrams). The benefit of the diagram is its level of detail, which is linked to a larger network, linked to another wider network and so on – see Figure 6-2. The causes and effects may be identified by various project teams undertaking brainstorming. It can bring together issues whose relationship they may not have seen previously as being connected and help to identify root causes.

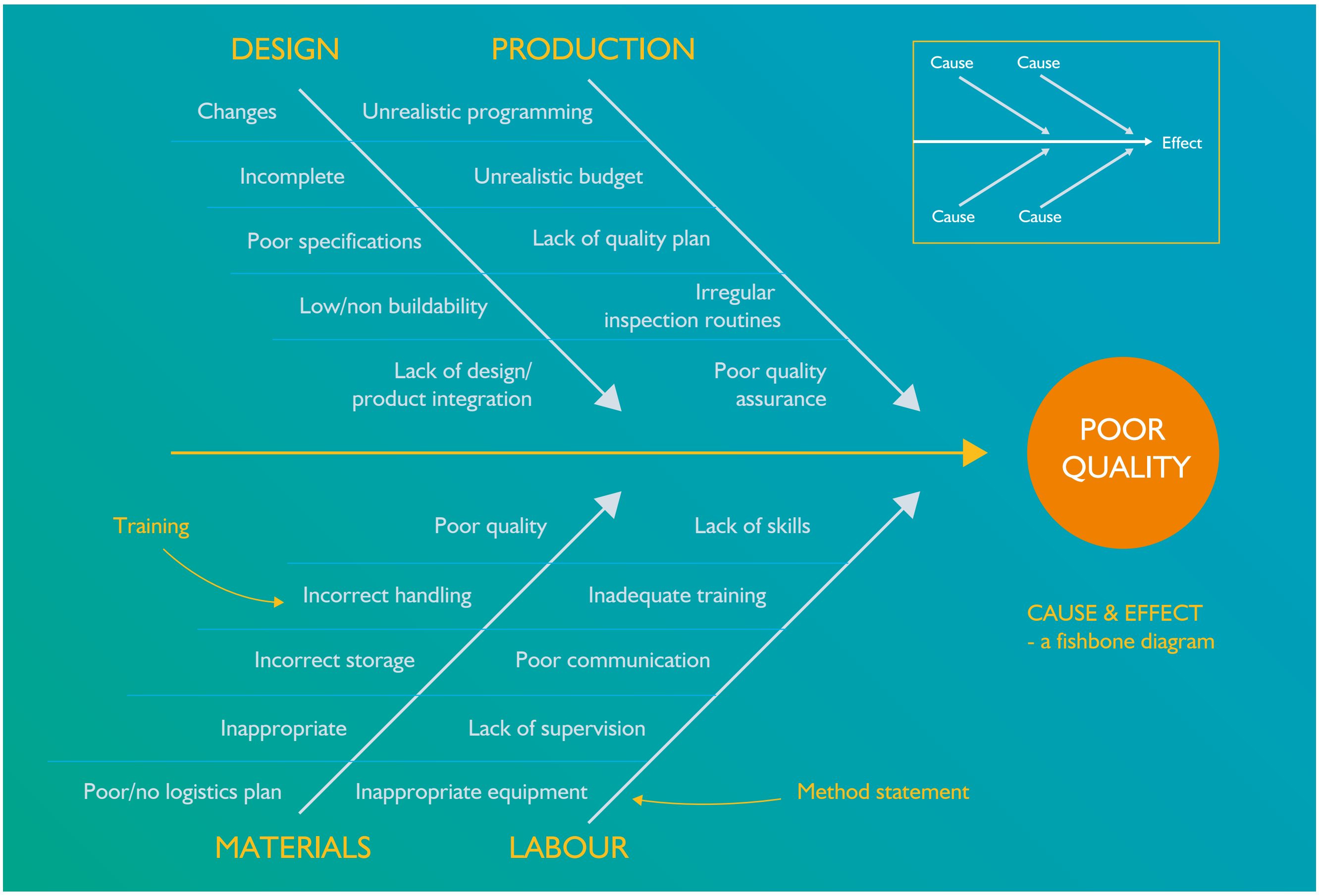


Figure 6-2
Simplified fishbone diagram of the causes and effects of poor-quality construction

6. Control charts measure and control quality by monitoring the production process. Quality data is collected in the form of product or process measurements or readings from various machines or instrumentation. The data is collected and used to evaluate, monitor and control a process.

7. Affinity diagrams encourage creative thinking about a complex issue, where the known facts follow no particular pattern/organisation. Unlike brainstorming, the issues / causes are identified by individuals (without discussion) and then pulled together and sorted into homogenous groups and then under affinity headings. The headings need to be in production/process order.

8. Inter-relationship digraphs show cause-and-effect relationships and help analyse the natural links between different aspects of a complex situation – see Figure 6-3. The relationship arrows created are crucial to the end result. A digraph can be used after an affinity / fishbone diagram has been developed to further investigate cause and effect, even when there is no data to support them. It should transcend any disagreements among team members.

9. Tree diagrams (also called a systematic diagram, tree analysis, analytical tree, or hierarchy diagram) show all the possible outcomes of an event. It can be used to calculate the probability of possible outcomes. It begins with an item which branches into two or more; each of those branches have multiple branches and so on. The tree enables systematic thinking about a process and can help to identify a solution or the steps in a plan. The tree can be used to explain the problem/process and can be used after an affinity diagram has uncovered key issues.

10. Matrix diagrams identify and graphically display connections among responsibilities, tasks, functions etc. Data analysis can be performed within an organisational structure to show the strength of relationships between the rows and columns of the matrix.

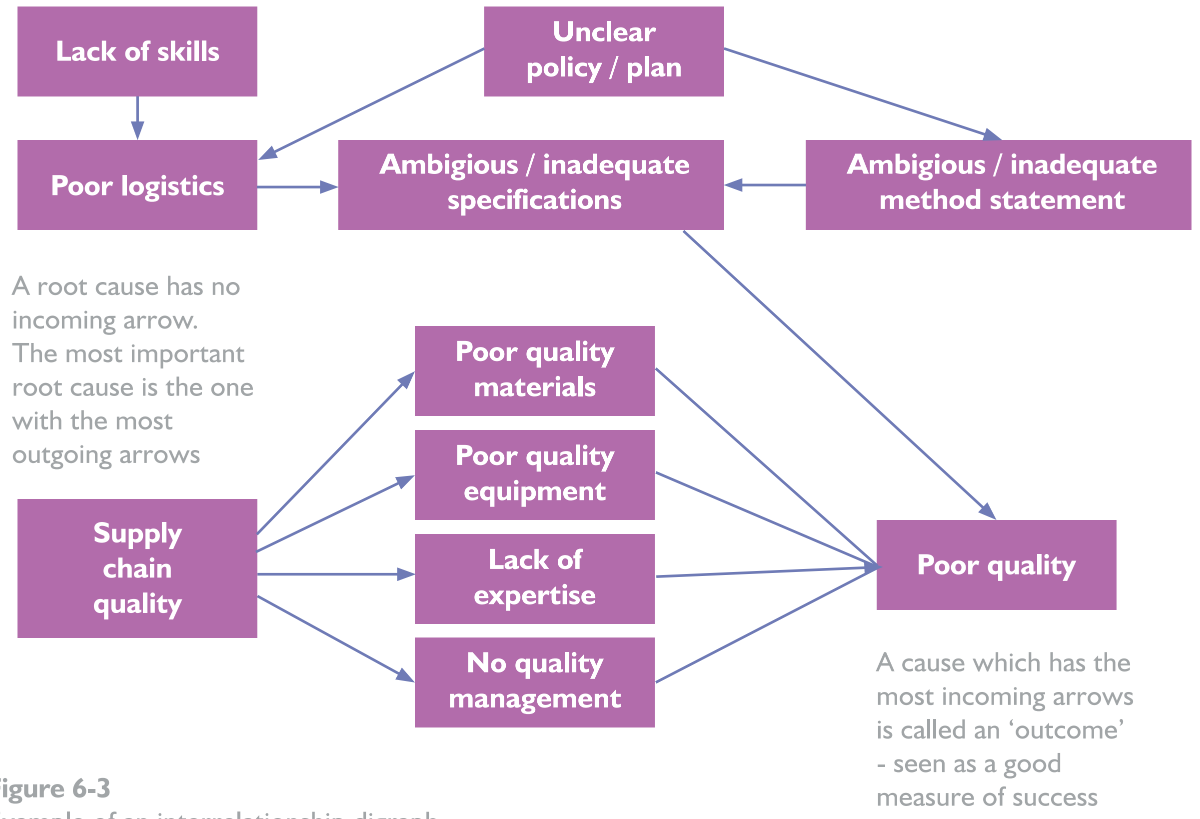
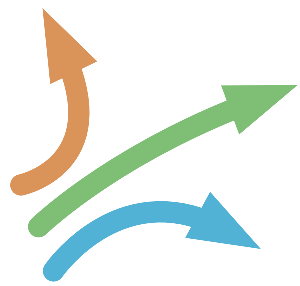


Figure 6-3
Example of an interrelationship digraph related to poor quality

6.2 Scenario planning

Scenario planning identifies a set of uncertainties and different 'realities' of what can happen in the future. It is not about predicting events or determining the most likely scenario but developing plausible stories that describe how the environment in which an entity (e.g. an individual or organisation) lives or operates and how it may develop, given certain future events, trends, and developments, to explore possible 'discontinuities' and 'surprises'.



A scenario is a storyline with a range of interconnected and uncertain future events and their possible consequences. Scenarios are often employed for decision-making activities in which some parameters are uncertain or poorly defined.

Section

7

Background Information & Research

7.1 Learning from other industries about quality management systems

The construction industry must learn from other industries. It must discard the idea that it is different to other industries; every industry sector has unique challenges. Yes, construction is a bespoke industry, it cannot stock its products in a warehouse, nor have stocks of unsold goods. It does not hold an annual sale where prices are reduced. It cannot rapidly generate work by having a special sale. It is governed by contracts that clearly allocate responsibility and liability. It works on long time frames from concept through design and approvals, to site ready, which can take years. It separates the design of its products, from the production process. The payment system can be slow and laborious. The quality control procedures are not central to everything it does. Quality is seen as a matter of compliance, meeting standards and fitness for purpose. It is not about exceeding customer expectations.

It all sounds familiar, but unlike an aero engine manufacturer, it is not reliant upon winning work by firstly exploiting advanced technology and then selling to the customers. It does not have long gestation periods for research and development of new projects. It does not have to prove to the legislators and approval agencies that its products are reliable and robust for every eventuality. Quality control, quality assurance, and quality management are central to everything the aero manufacturer does, it is at the core alongside safety, innovation, and exploiting technology.

Rolls Royce in the aero engine sector has 8 quality management principles:

1. Customer focus.
2. Leadership.
3. Involvement of people.
4. Process approach.
5. Systems approach to management.
6. Continual improvement.
7. Factual approach to decision making.
8. Mutually beneficial supplier relationships.

This would be a different list for construction companies who might have quality management principles including:

- Leadership and engendering a culture of quality management.
- Process approach.
- Ensuring the supply chain is fully aware of the quality standards expected and delivered.
- Mutually-beneficial supplier relationships.
- Systems approach to management.
- Factual approach to decision making.
- Customer focus.

7.2 Learning from overseas

The Construction Quality Assessment System (CONQUAS) was introduced in Singapore in 1989 and it serves as a standard assessment system on the quality of building projects. A de facto national yardstick for the industry, CONQUAS has been periodically fine-tuned to keep pace with changes in technology and quality demands of a more sophisticated population. In 1998, BCA introduced a number of new features to CONQUAS resulting in the launch of CONQUAS 21. The latest CONQUAS 9th edition was launched in 2016 to promote the adoption of DfMA which supports both high quality and productivity, and to ensure the score commensurate with end users expectation on workmanship quality.

Construction is assessed, based primarily on workmanship standards through site inspection. Each component is divided into different items for assessment. The sum of the 3 components gives the CONQUAS score for the project. By using CONQUAS as a standardized method of quality assessment developers are able to use the CONQUAS score to set targets for contractors to achieve and also assess the quality of the finished building.

If a similar scheme was introduced into the UK construction industry, it could provide a good standardisation tool and a level of benchmarking / competition.

The global benchmark for good quality is demonstrated by the Japanese construction industry. Figure 7-1 shows how Japanese contractors embrace the concept of Monozukuri, which is a mind-set embodied in the culture of quality delivery.

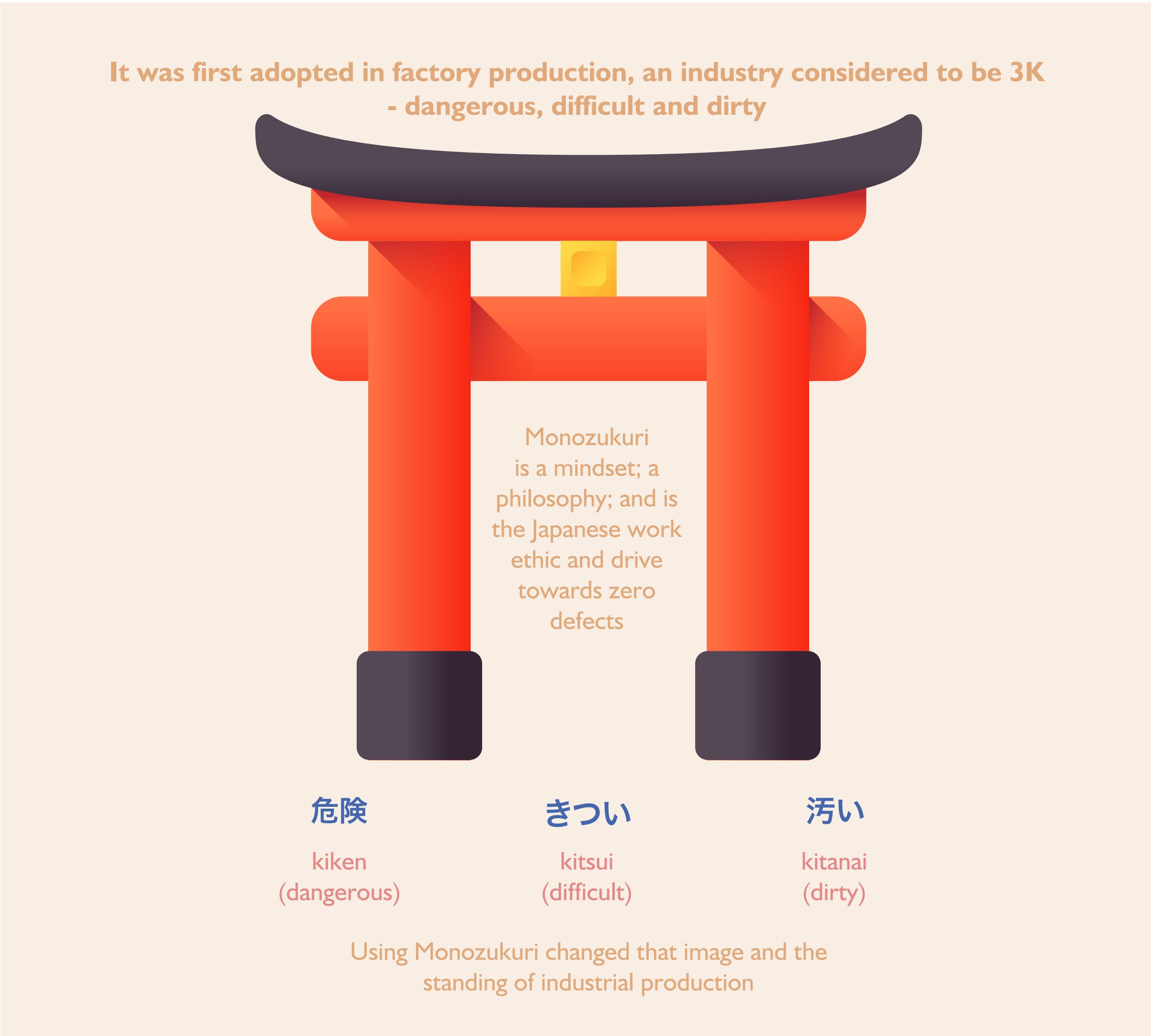


Figure 7-1
The origins of the monozukuri culture

7.3 Practitioners' views

The Call for Evidence issued by the CIOB, prompted valuable insights into the management and state of quality in the construction sector. Members were asked a series of questions and the feedback can be divided into the 5 main actors / areas in construction that impact quality: 1) Clients, 2) Designers, 3) Company, 4) Workforce and 5) Governance.

It is hard to find anyone who is against quality.

Based on the number of times an actor was mentioned, the company and the workforce came out on top. Clients and designers were referred to in equal measure and governance mentioned the least – see Figure 7-2. The words 'experience' and 'training' were widely used as being an issue in the delivery of quality. On-the-job training was considered essential by many respondents, who emphasised the need for the training to be consistent and relevant.

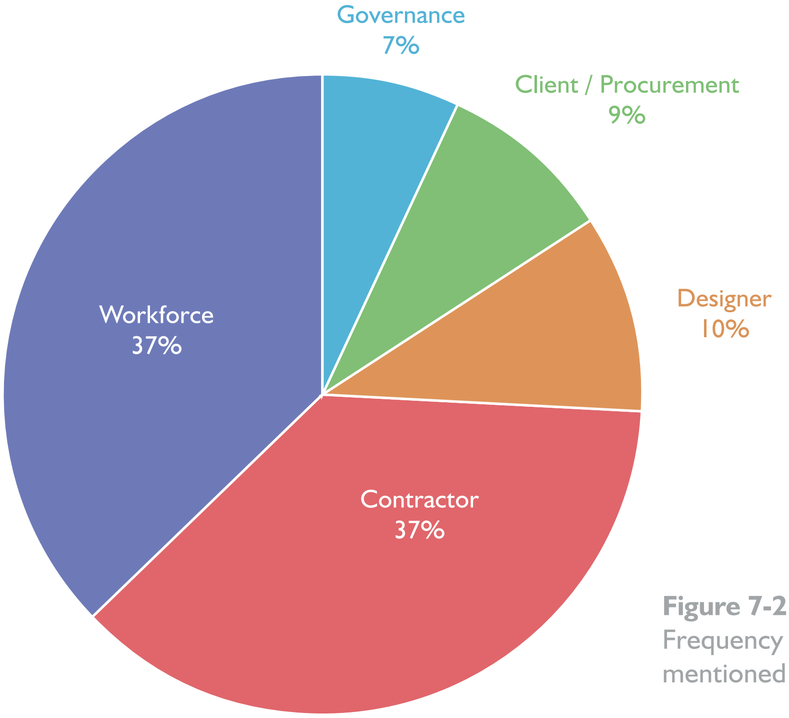


Figure 7-2
Frequency of the players mentioned in the replies

The inclusion of quality in a curriculum, either at a university/college, or on-site, is seen as important. Views on the responsibility for training were mixed. Some saw the government as responsible, others saw either the companies or construction organisations, such as the CITB, needing to take greater accountability. There was a perceived lack of specialist/professional skills. Management and leadership skills were highlighted as being essential, but often seen as lacking. Questions asked were whether or not the current management of quality is adequate in three areas - supervision, sign-off, and workmanship.

"NVQs are no substitute for experience, skill and knowledge."

7.3.1 Supervision

Site supervision is seen as the key factor in quality management. Lack of quality checks is seen as the responsibility of both a contractor and client. Respondents remarked on the inadequate supervision at the construction stage provided by design team architects and engineers. This criticism may be unfair, it fails to recognise the contractual liability issues of the design team, the reduction in the level of fees paid for professional services, and the consultant's obligation to use skill and care normally used by professionals.

The principal contractor has a responsibility to check each trade at the end of its work with the sign-off process being a tracking procedure rather then something undertaken at the end of a task. Trade contractors can be engaged in the checking of previous trades' work before it is covered up/continued. The consultant is not liable for a defect unless they fail to carry out skill and care in their professional duty. The consultants' role is to check compliance once the scope requirements have been specified. Design and build is different where the contractor carries responsibility for both design and site production.

The demise of the independent clerk of works position was seen as a retrograde step. The reduction in staff numbers on site puts pressure on the ability to provide adequate supervision. Fees for independent inspections are an additional cost that will pay benefits in the long run by saving money on the cost of re-work, and the cost of defective workmanship. Identifying faults early will save time and money.

7.3.2 Sign-off/taking over the works/practical completion

Most respondents felt that the sign-off process at the end of the project was inadequate. A lack of assigned responsibility was cited as a reason; Inspection and Test Plans (ITPs) were suggested as one solution. There was concern about the clarity of the sign-off process, particularly the documentation involved, e.g. Building Control Completion Certificate or a Practical Completion Certificate, neither of which are proof of quality. As-built information is often not sufficient to reflect the changes made during the site production stage.

"The sign-off stage needs to be quality focused and not merely getting payment and let's hand this over."

7.3.3 Workmanship

Workmanship is closely linked to supervision. Both can benefit from good training. Incentivisation could be used to reward quality, as well as quantity, of work.

Programme pressures due to contract terms can lead to work being rushed/accelerated, which, in turn, can lead to poor workmanship. Rework and snagging may be viewed by some as a way of making more money, but this is a short-term naïve perspective.

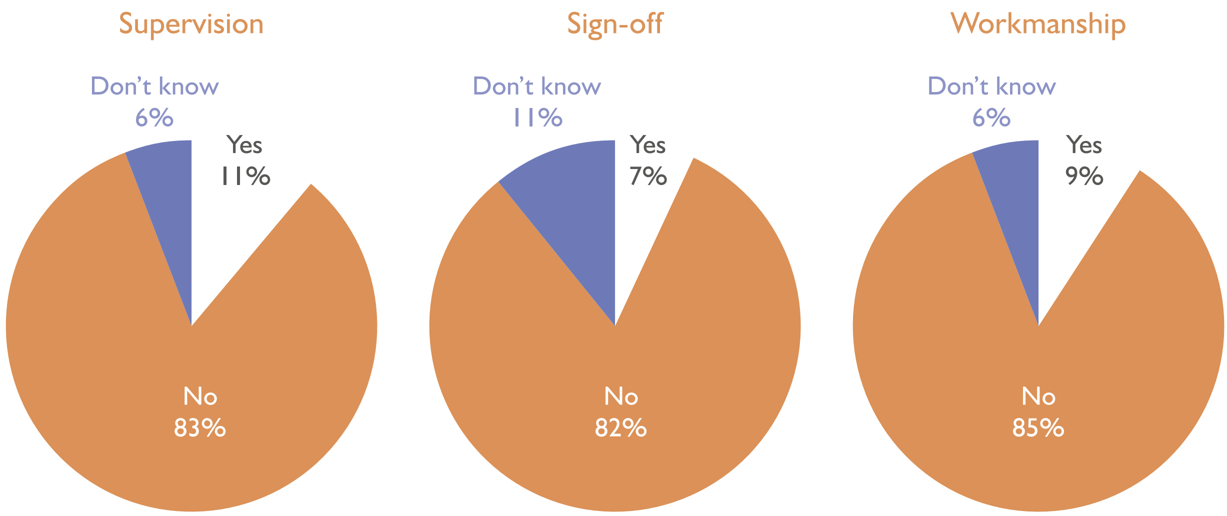


Figure 7-3
Responses to the questions about the adequacy of existing quality management in three areas

Figure 7-3 shows the responses from the three questions. Whilst training, incentivisation and supervision can make a difference to quality, placing a greater emphasis on individuals to produce good workmanship is a more sustainable approach, with long-term benefits for both the company and the individual.

Section

8

Relevant Standards by Work Section

This section looks at the work sections across a project with the relevant standards shown for each sub-section; there are three types:

BS British Standard

BS EN British Standard European Norm

ASTM[13] Globally recognised standard

8.1 Temporary works

Parts of the works that allow or enable construction of, protect, support or provide access to, the permanent works and which might or might not remain in place at the completion of the works.

Type	Description	Requirements	Quality Issues
Formwork	• A temporary mould into which concrete is poured and formed. It is usually fabricated using timber, but it can also be constructed from steel, glass fibre reinforced plastic and other materials. Formwork may be part of the falsework construction and used in 4 main areas; walls, columns, beams and slabs. • There are 3 main types of formwork: engineered systems; timber, and; re-usable plastic.	• Desired shape, size and fit according to the drawings / specifications. • Select material to ensure required finish of the poured concrete. • Able to withstand the loading (wet and dry concrete) as specified. • Should be dismantled and moved as easily as possible so that construction can move on. • Ability to fit and fasten together both tightly and easily. • Should be simple to build.	• Type and temperature of the concrete pour is important information. • The strength / loading of the formwork sides must comply with specifications, particularly important in terms of the initial dead load of wet concrete. • Sufficient strength reached before striking. • High risk with workmanship and inspection necessary to ensure a high standard and appearance of the resulting concrete structure.

ASTM International, formerly known as American Society for Testing and Materials, is an international standards organization that develops and publishes voluntary consensus technical standards for a wide range of materials, products, systems, and services

Falsework	• Falsework generally relates to the structural vertical support of concrete decks etc. • Supports shuttering and formwork.	• Desired shape, size and fit according to the drawings / specifications. • Select material to ensure required finish of the poured concrete. • Able to withstand the loading (wet and dry concrete) as specified. • Should be dismantled and moved as easily as possible so that construction can move on. • Ability to fit and fasten together both tightly and easily. • Should be simple to build.	• Damage to concrete on removal of formwork / falsework.

Relevant standards

PAS 8812:2016	Temporary works. Application of European Standards in design. Guide.
BS 5975:2008+A1:2011	Code of practice for temporary works procedures and the permissible stress design of falsework.
BS 8410:2007	Code of practice for lightweight temporary cladding for weather protection and containment on construction works.
BS EN 12813:2004	Temporary works equipment. Load bearing towers of prefabricated components. Particular methods of structural design.
BS EN 12811-2:2004	Temporary works equipment. Information on materials.
BS EN 12811-1:2003	Temporary works equipment. Scaffolds. Performance requirements and general design.
BS EN 12811-3:2002	Temporary works equipment. Load testing.
BS 5974:2017	Planning, design, setting up and use of temporary suspended access equipment. Code of practice.
BS EN 13374:2013	Temporary edge protection systems. Product specification. Test methods.
BS 7909:2011	Code of practice for temporary electrical systems for entertainment and related purposes.
BS EN 1004:2004	Mobile access and working towers made of prefabricated elements. Materials, dimensions, design loads, safety and performance requirements.
BS EN 12063:1999	Execution of special geotechnical work. Sheet pile walls.
BS 7962:2000	Black materials for masking existing road markings. Specification.
BS 4363:1998+A1:2013	Specification for distribution assemblies for reduced low voltage electricity supplies for construction and building sites.
BS 1139-4:1982	Metal scaffolding. Specification for prefabricated steel split heads and trestles.

8.2 Substructure

Substructure is defined as: All work below underside of screed or, where no screed exists, to the underside of lowest floor finishes including damp-proof membrane, together with relevant excavations and foundations (this includes walls to basements designed as retaining walls). There are four types of substructure:

Foundations (up to and including the DPC); lowest floor assembly; basement excavation, and; basement retaining walls (up to and including DPC)

8.2.1 Foundations - shallow

	Description	Advantages	Disadvantages	Quality Issues
Pad	• Isolated footings, often used to support a column. Constructed of a block or slab, which may be stepped to spread the load.	• Less material needed.	• Individual pad foundations may interact with each other.	• Ground conditions. • Presence of water. • Load calculation e.g. dead load, imposed load, wind load. • Minimum width related to type of soil. • Design needs to be approved by Building Control.
Strip	• Support a line of loads – a wall or a line of columns.		• Needs more material and reinforcement than pad footings.	
Raft	• Concrete slab that spreads the load over a wide area. May be stiffened by ribs / beams within foundation.	• Can reduce differential settlements. • Can be used on soft or loose soils.	• Prone to edge erosion.	

Relevant standards

BS 8004:2015	Code of practice for foundations.
BS 8103-1:2011	Structural design of low-rise buildings. Code of practice for stability, site investigation, foundations, precast concrete floors and ground floor slabs for housing.
Approved Document 10A	Structure.

8.2.2 Foundations – deep: piling

	Description	Advantages	Disadvantages	Quality Issues
Foundations (up to and including the DPC)	• Column-like structures made from steel, reinforced concrete or timber. A piled foundation is where the depth is three times that of the breadth. • Classified by their design function – end-bearing, friction (or a combination of both) – or by their method of construction – displacement (driven) or replacement (bored).	• Can transfer loads in relatively weak soil structures. • Can be precast to specifications. • Bearing capacity increases when screw piles are driven into granular soil. • Can be used when working over water.	• Reinforcement needed for precast concrete piles – transporting and piling. • Heavy equipment necessary. • Difficult to determine the required pile length in advance. • Unsuitable for soils with poor drainage. • Vibrations from piling operations may impact neighbouring structures.	• Variability of ground conditions. • Knowledge of ground conditions - detailed site investigation. • Contractor's skill and experience. • Good quality materials. • Appropriate construction procedures. • Good workmanship and site supervision. • Programme and budget pressures. • Ground movements (traffic etc.) during concrete hardening. • Appropriate method for trimming pile head.

Relevant standards

BS EN ISO 22477-4:2018	Geotechnical investigation and testing. Testing of geotechnical structures. Testing of piles: dynamic load testing.
BS EN 1993-5:2007	Eurocode 3. Design of steel structures. Piling.
BS EN 12794:2005	Precast concrete products. Foundation piles.
BS ISO 11886:2002	Building construction machinery and equipment. Pile driving and extracting equipment. Terminology and commercial specifications.
BS EN 12063:1999	Execution of special geotechnical work. Sheet pile walls.
BS EN 1997-1:2004+A1:2013	Eurocode 7. Geotechnical design. General rules.
BS 8008:1996+A1:2008	Safety precautions and procedures for the construction and descent of machine-bored shafts for piling and other purposes.
BS 8004:2015	Code of practice for foundations.
BS 8002:2015	Code of practice for earth retaining structures.
ASTM D8169/D8169M - 18	Standard Test Methods for Deep Foundations Under Bi-Directional Static Axial Compressive Load.
ASTM D4945 - 17	Standard Test Method for High-Strain Dynamic Testing of Deep Foundations.
15/30326284 DC	BS EN 16907-2. Earthworks. Part 2. Classification of materials.
Approved Document A	Structure.

8.2.3 Basement excavation

	Description	Advantages	Disadvantages	Quality Issues
Underpinning	• Mass concrete or reinforced concrete underpins may be used to increase the depth of the existing foundations.	• Tried and tested methods available.	• Poor specifications or structural engineering can cause collapse. • Soil conditions. • High water table.	• Depth and quality of existing foundations. • State of existing building's fabric or structure. • Sufficient information regarding the construction / state of existing building. • Ground-bearing concrete floors. • Party wall issues. • Soil, geology and hydrology.
Piling	• Reinforced concrete or steel sheet piles can be used.	• Tried and tested methods available.	• Need a permanent inner reinforced concrete wall or box to provide horizontal strength and waterproofing. • Needs space around the drilling head, thus there is a gap between the pile edge and the existing wall. • Pile size is limited by rig size which is restrained by the available working height and access. • High water table.	• Contractor inexperienced in basement construction.

Relevant standards

BS 8004:2015	Code of practice for foundations.
BS EN 13967:2012+A1:2017	Flexible sheets for waterproofing. Plastic and rubber damp proof sheets including plastic and rubber basement tanking sheet. Definitions and characteristics.
BS EN 13969:2004	Flexible sheets for waterproofing. Bitumen damp proof sheets including bitumen basement tanking sheets. Definitions and characteristics.

BS 8102:2009	Code of practice for protection of below ground structures against water from the ground.
BS 8103-1:2011	Structural design of low-rise buildings. Code of practice for stability, site investigation, foundations, precast concrete floors and ground floor slabs for housing.
Approved Document A	Structure.
15/30326284 DC	BS EN 16907-2. Earthworks. Part 2. Classification of materials.
Approved Document A	Structure.

8.2.4 Basement retaining walls

	Description	Advantages	Disadvantages	Quality Issues
Basement retaining walls (up to and including DPC)	• A basement wall designed to resist lateral pressure of surrounding ground and built structures. Normally constructed in concrete or brickwork.	• Construction uses tried and tested methods of brickwork / blockwork.	• Requires accurate / professional load calculation. • Site / soil investigations need to be thorough before construction starts. • The impact of bad or lack of proper drainage.	• Badly designed or incorrect temporary works. • Depth and quality of existing foundations. • State of existing building's fabric or structure. • Sufficient information on construction / state of existing. • Ground-bearing concrete floors. • Party wall issues. • Soil, geology and hydrology.

Relevant standards

BS 8004:2015	Code of practice for foundations.
BS 8103-1:2011	Structural design of low-rise buildings. Code of practice for stability, site investigation, foundations, precast concrete floors and ground floor slabs for housing.
BS EN 13967:2012	Flexible sheets for waterproofing. Plastic and rubber damp proof sheets including plastic and rubber basement.
+A1:2017	Tanking sheet. Definitions and characteristics.
BS EN 13969:2004	Flexible sheets for waterproofing. Bitumen damp proof sheets including bitumen basement tanking sheets. Definitions and characteristics.
BS 8102:2009	Code of practice for protection of below ground structures against water from the ground.
Approved Document A	Structure.

8.2.5 Diaphragm wall and embedded retaining walls

The design, specification and construction details of retaining walls must be provided by the project's engineer. Quality (and safety) issues can arise with backfilling, which can cause instability. Any pressure on the area immediately adjacent to the wall (surcharging) can create a horizontal force which may destabilise the wall. The type of materials used for a retaining wall must depend on the load, which is a crucial element. Soil type will need to be taken into account as well as cost but aesthetics should always be secondary. The International Building Code requires retaining walls to be designed to ensure stability against overturning, sliding, excessive foundation pressure and water uplift. There are four main types of retaining wall, each requiring careful consideration to ensure that they are strong enough for the designed purpose: gravity; cantilever; sheet piling, and; anchored.

	Description	Advantages	Disadvantages	Quality Issues
Gravity / Crib	• Rely on their mass / weight to hold back a load. Gabions may be used for this.	• Easy to install and remove. • Crib walls: Can be built by hand; easy and quick to build; crib sections can be pre-cast; free draining; top level easily varied. • Gabions: Can be built by hand; easy and quick to build; no specialist equipment required; rock fill may be locally sourced; free-draining; can be placed directly on soil.	• Gabions: Possible loss of material through gabion; not suitable for varying ground levels; relatively low unit weight. • Crib walls: often requires a concrete base; uneconomic for short runs; relatively low unit weight.	• Excessive water / moisture. • Poor quality materials. • Inappropriate choice of retaining wall / techniques. • Level of mobilisation of passive earth resistance. • Poor / lack of guidance and supervision. • Lack of structural engineering drawings / advice / specifications. • Proper drainage must be provided to reduce any hydrostatic pressure of ground water behind the wall. • Impact on surrounding structures.

Cantilever	• Made from mortared masonry or reinforced concrete. The reinforced base means that there is vertical pressure from the ground behind the wall, rather than horizontal. This type of wall has an inverted 'T' shape.	• Unobstructed open excavation. • Tiebacks below adjacent properties not required.	• Excavation depth limited to 6 metres. • Not recommended for use next to adjacent buildings. • Deep excavations may require the rigidity of the wall to be increased considerably, limiting available space within the excavation.	
Sheet Piling	• Sheet piles are driven into the ground with the added strength of ground anchors with a cement grout.	• Quicker than constructing reinforced concrete walls. • Narrow form of construction, thus maximising usable site space. • Suitable for all soil types. • No requirement for pre-excavation. • Relatively little disturbance of existing ground. • Immediate load bearing capacity. • Can be used on several projects.	• Temporary structures rarely can be used for permanent structures. • Rocks or large boulders will impede piling.	
Anchored	• Anchored by cables which are secured by concrete.	• Can be both slender and withstand high loads. • Used where footing size is an issue. • Ideal for smaller areas that need earth retention.	• Requires specialist equipment and qualified engineers. • Difficult to secure anchors in weak soil and / or at any great depth. • Can impact surrounding construction works.	

Relevant standards

ASTM C1372 - 17	Standard Specification for Dry-Cast Segmental Retaining Wall Units.
BS EN 15258:2008	Precast concrete products. Retaining wall elements.
BS 8002:2015	Code of practice for earth retaining structures.

BS EN 1538:2010+A1:2015	Execution of special geotechnical works. Diaphragm walls.
BS EN 16907-5 Draft for public comment	Earthworks.
BS EN 771-4:2011+A1:2015	Specification for masonry units. Autoclaved aerated concrete masonry units.
BS 8006-1:2010+A1:2016	Code of practice for strengthened/reinforced soils and other fills.
BS EN 1993-5:2007	Eurocode 3. Design of steel structures. Piling.
BS EN 16228-5:2014	Drilling and foundation equipment. Safety. Diaphragm walling equipment.
BS EN 1538:2010+A1:2015	Execution of special geotechnical works. Diaphragm walls.
Approved Document A	Structure.

8.3 Superstructure

8.3.1 Stairs, walkways and balustrades

	Description	Requirements	Quality Issues
Utility stair	• A stair used for escape, access for maintenance, or purposes other than as the usual route for moving between levels on a day-to-day basis.	• Stairs may be constructed from a number of different materials including: Timber, Brick, Stone, Concrete, Metal and Glass. • Requirement K1 of the Approved Document K can be met by ensuring that the steepness, rise and going, handrails, headroom, length and width of any stairs, ladders and ramps between levels are appropriate to afford reasonable safety to people gaining access to and moving about buildings. • Key considerations are: • Width • Length of flight • Handrails • Guarding • Fire safety.	• The type and strength of the materials used need to meet the required use and loading. • The quality / strength / durability of the surface of the stair. • Poor installation which affects the integrity/safety of the stairway.
General access stair	• A stair intended for all users of a building on a day-to-day basis, as a normal route between levels.		
Private stair	• A stair intended to be used for only one dwelling.		
Protected stair	• A stair discharging through a final exit to a place of safety (including any exit passageway between the foot of the stair and the final exit) that is adequately enclosed with fire resisting construction.		

Firefighting stair	• A protected stairway communicating with the accommodation area through a firefighting lobby.		
Common stair	• An escape stair serving more than one flat.		

Relevant standards

Approved Document B	Part B Fire safety.
Approved Document K	K1 Stairs, ladders and ramps; K2 Protection from falling; K3 Vehicle barriers and loading bays; K4 Protection against impact with glazing; K5 Additional provisions for glazing in buildings other than dwellings; K6 Protection against impact from and trapping by doors.
Approved document M	Access to and use of buildings.
BS EN 16954:2018	Agglomerated stone. Slabs and cut-to-size products for flooring and stairs (internal and external).
BS 5395-1:2010	Stairs. Code of practice for the design of stairs with straight flights and winders.
BS EN 15644:2008	Traditionally designed prefabricated stairs made of solid wood. Specifications and requirements.
BS EN 14843:2007	Precast concrete products. Stairs.
BS 585-1:1989	Wood stairs. Specification for stairs with closed risers for domestic use, including straight and winder flights and quarter or half landings.
BS 585-2:1985	Wood stairs. Specification for performance requirements for domestic stairs constructed of wood-based materials.
BS 5395-2:1984	Stairs, ladders and walkways. Code of practice for the design of helical and spiral stairs.
BS 5578-2:1978	Building construction - stairs. Modular co-ordination: specification for co-ordinating dimensions for stairs and stair openings.
BS 4592-0:2006+A1:2012	Flooring, stair treads and handrails for industrial use. Common design requirements and recommendations for installation.
BS 4592-3:2006	Industrial type flooring and stair treads. Cold formed metal planks. Specification.
BS 8203:2017	Code of practice for installation of resilient floor coverings.
BS EN 13318:2000	Screed material and floor screeds. Definitions.
BS EN ISO 16283-2:2018	Acoustics. Field measurement of sound insulation in buildings and of building elements. Impact sound insulation.
BS 5385-1:2018	Wall and floor tiling. Design and installation of ceramic, natural stone and mosaic wall tiling in normal internal conditions. Code of practice.
BS EN 15254-7:2018	Extended application of results from fire resistance tests. Non-loadbearing ceilings. Metal sandwich panel construction.
BS EN 115-1:2017	Safety of escalators and moving walks. Construction and installation.
BS 9991:2015	Fire safety in the design, management and use of residential buildings. Code of practice.

BS 9266:2013	Design of accessible and adaptable general needs housing. Code of practice.
BS EN ISO 2867:2011	Earth-moving machinery. Access systems.
BS 6349-2:2010	Maritime works. Code of practice for the design of quay walls, jetties and dolphins.
BS 8103-3:2009	Structural design of low-rise buildings. Code of practice for timber floors and roofs for housing.
BS 5385-5:2009	Wall and floor tiling. Design and installation of terrazzo, natural stone and agglomerated stone tile and slab flooring. Code of practice.
BS EN 516:2006	Prefabricated accessories for roofing. Installations for roof access. Walkways, treads and steps.
BS EN 1168:2005+A3:2011	Precast concrete products. Hollow core slabs.
BS EN 14716:2004	Stretched ceilings. Requirements and test methods.
BS 8204-4:2004+A1:2011	Screeds, bases and in-situ floorings. Cementitious terrazzo wearing surfaces. Code of practice.
BS 8204-3:2004+A2:2011	Screeds, bases and in-situ floorings. Polymer modified cementitious levelling screeds and wearing screeds. Code of practice.
BS 8204-5:2004+A1:2011	Screeds, bases and in-situ floorings. Mastic asphalt underlays and wearing surfaces. Code of practice.
BS 8204-1:2003+A1:2009	Screeds, bases and in-situ floorings. Concrete bases and cementitious levelling screeds to receive floorings. Code of practice.
BS 8204-2:2003+A2:2011	Screeds, bases and in-situ floorings. Concrete wearing surfaces. Code of practice.
BS 8000-9:2003	Workmanship on building sites. Cementitious levelling screeds and wearing screeds. Code of practice.
BS EN 13892-5:2003	Methods of test for screed materials. Determination of wear resistance to rolling wheel of screed material for wearing layer.
BS EN 13892-7:2003	Methods of test for screed materials. Determination of wear resistance to rolling wheel of screed material with floor coverings.
BS EN 14231:2003	Natural stone test methods. Determination of the slip resistance by means of the pendulum tester.
BS 8204-7:2003	Screeds, bases and in-situ floorings. Pumpable self-smoothing screeds. Code of practice.
BS EN 13892-1:2002	Methods of test for screed materials. Sampling, making and curing specimens for test.
BS EN 13892-2:2002	Methods of test for screed materials. Determination of flexural and compressive strength.
BS EN 13892-4:2002	Methods of test for screed materials. Determination of wear resistance-BCA.
BS EN 13892-6:2002	Methods of test for screed materials. Determination of surface hardness.
BS EN 13892-8:2002	Methods of test for screed materials. Determination of bond strength.
BS EN 13101:2002	Steps for underground man entry chambers. Requirements, marking, testing and evaluation of conformity.
BS EN 13813:2002	Screed material and floor screeds. Screed material. Properties and requirements.
BS EN 12825:2001	Raised access floors.

BS EN 13213:2001	Hollow floors.
BS 6767-2:1998	Transportable accommodation units. Recommendations for design and installation of services and fittings with guidance on transportation, siting and aspects relating to habitation.
BS EN 1195:1998	Timber structures. Test methods. Performance of structural floor decking.
BS EN ISO 7519:1997	Technical drawings. Construction drawings. General principles of presentation for general arrangement and assembly drawings.

8.3.2 Precast concrete

Using precast concrete in a variety of buildings is well established. The method allows for a wide variety/complexity of layouts, shapes and façade treatments. Precast concrete has the advantage over on-site cast concrete as it is less labour and time intensive and it is more durable, of better quality and affordable.

	Description	Advantages	Disadvantages	Quality Issues
Precast concrete	• Precast concrete is poured, moulded, cast and hardened off site in a factory environment.	• Durable. • Controlled manufacture gives greater accuracy (use of CAD) and improved quality control. • The moulds are reusable so repetition can be achieved. • 'Made-to-measure' fabrication can mean less waste. • Off-site factory-based production means can avoid weather variances / interruptions. • Controlled dust and noise pollution.	• Weight. • Very small margin for error. • Connections may be difficult. • Somewhat limited building design flexibility. • Because panel size is limited, precast concrete cannot be used for two-way structural systems. • Need for repetition of forms will affect building design. • Joints between panels are often expensive and complicated. • Skilled workmanship is required in the application of the panel on site. • Cranes are required to lift panels.	• Interfaces between precast units and in-situ construction. • Quality testing should be approved using appropriate standards. • Care should be taken in loading and unloading precast concrete forms to avoid damage. Precast elements require proper supports, frames, cushioning and tie downs. Particular care should be taken of the edges of the precast elements.

Relevant standards

Approved Document A	Structure.
BS EN 13369:2018	Common rules for precast concrete products.
ASTM C1675 - 18	Standard Practice for Installation of Precast Reinforced Concrete Monolithic Box Sections for Culverts, Storm Drains, and Sewers.
ASTM C858 - 18	Standard Specification for Underground Precast Concrete Utility Structures.
ASTM C1433M - 18	Standard Specification for Precast Reinforced Concrete Monolithic Box Sections for Culverts, Storm Drains, and Sewers (Metric).
ASTM C1786 - 18	Standard Specification for Segmental Precast Reinforced Concrete Box Sections for Culverts, Storm Drains, and Sewers Designed According to AASHTO LRFD.
BS 8297:2017	Design, manufacture and installation of architectural precast concrete cladding. Code of practice.
ASTM C1719 - 11(2017)	Standard Test Method for Installed Precast Concrete Tanks and Accessories by the Negative Air Pressure (Vacuum) Test Prior to Backfill.
ASTM C969M - 17	Standard Practice for Infiltration and Exfiltration Acceptance Testing of Installed Precast Concrete Pipe Sewer Lines (Metric).
ASTM C969 - 17	Standard Practice for Infiltration and Exfiltration Acceptance Testing of Installed Precast Concrete Pipe Sewer Lines.
ASTM C1837 - 17	Standard Specification for Production of Dry Cast Concrete Used for Manufacturing Pipe, Box, and Precast Structures.
BS EN 15037-5:2013	Precast concrete products. Beam-and-block floor systems. Lightweight blocks for simple formwork.
BS EN 13225:2013	Precast concrete products. Linear structural elements.
BS EN 12839:2012	Precast concrete products. Elements for fences.
BS EN 13224:2011	Precast concrete products. Ribbed floor elements.
BS 8103-1:2011	Structural design of low-rise buildings. Code of practice for stability, site investigation, foundations, precast concrete floors and ground floor slabs for housing.
BS EN 15191:2009	Precast concrete products. Classification of glass fibre reinforced concrete performance.
BS EN 15037-4:2010+A1:2013	Precast concrete products. Beam-and-block floor systems. Expanded polystyrene blocks.
BS EN 15258:2008	Precast concrete products. Retaining wall elements.
BS EN 15037-3:2009+A1:2011	Precast concrete products. Beam-and-block floor systems. Clay blocks.
BS 6073-2:2008	Precast concrete masonry units. Guide for specifying precast concrete masonry units.
BS EN 15435:2008	Precast concrete products. Normal weight and lightweight concrete shuttering blocks. Product properties and performance.
BS EN 15037-1:2008	Precast concrete products. Beam-and-block floor systems. Beams.
BS EN 15498:2008	Precast concrete products. Wood-chip concrete shuttering blocks. Product properties and performance.
BS EN 15050:2007+A1:2012	Precast concrete products. Bridge elements.
BS EN 14843:2007	Precast concrete products. Stairs.

BS EN 14844:2006+A2:2011	Precast concrete products. Box culverts.
BS EN 14992:2007+A1:2012	Precast concrete products. Wall elements.
BS EN 14991:2007	Precast concrete products. Foundation elements.
BS EN 13747:2005+A2:2010	Precast concrete products. Floor plates for floor systems.
BS 7533-3:2005+A1:2009	Pavements constructed with clay, natural stone or concrete pavers. Code of practice for laying precast concrete paving blocks and clay pavers for flexible pavements.
BS EN 1168:2005+A3:2011	Precast concrete products. Hollow core slabs.
BS EN 12629-6:2004+A1:2010	Machines for the manufacture of constructional products from concrete and calcium-silicate. Safety. Stationary and mobile equipment for the manufacture of precast reinforced products.
BS EN 12794:2005	Precast concrete products. Foundation piles.
BS EN 14649:2005	Precast concrete products. Test method for strength retention of glass fibres in cement and concrete (SIC test).
BS EN 14474:2004	Precast concrete products. Concrete with wood-chips as aggregate. Requirements and test methods.
BS EN 12843:2004	Precast concrete products. Masts and poles.
BS EN 13693:2004+A1:2009	Precast concrete products. Special roof elements.
BS EN 12737:2004+A1:2007	Precast concrete products. Floor slats for livestock.
BS EN 13198:2003	Precast concrete products. Street furniture and garden products.
BS 7533-8:2003	Pavements constructed with clay, natural stone or concrete pavers. Guide for the structural design of lightly trafficked pavements of precast concrete flags and natural stone flags.
BS 7533-2:2001	Pavements constructed with clay, natural stone or concrete pavers. Guide for the structural design of lightly trafficked pavements of clay pavers or precast concrete paving blocks.
BS 7533-1:2001	Pavements constructed with clay, natural stone or concrete pavers. Guide for the structural design of heavy duty pavements constructed of clay pavers or precast concrete paving blocks.
BS 7533-6:1999	Pavements constructed with clay, natural stone or concrete pavers. Code of practice for laying natural stone, precast concrete and clay kerb units.
BS EN 1169:1999	Precast concrete products. General rules for factory production control of glass-fibre reinforced cement.
BS EN 1170-2:1998	Precast concrete products. Test method for glass-fibre reinforced cement. Measuring the fibre content in fresh GRC, 'Wash out test'.
BS EN 1170-1:1998	Precast concrete products. Test method for glass-fibre reinforced cement. Measuring the consistency of the matrix. 'Slump test' method.
BS EN 1170-3:1998	Precast concrete products. Test method for glass-fibre reinforced cement. Measuring the fibre content of sprayed GRC.
BS EN 1170-4:1998	Precast concrete products. Test method for glass-fibre reinforced cement. Measuring bending strength. 'Simplified bending test' method.
BS EN 1170-5:1998	Precast concrete products. Test method for glass-fibre reinforced cement. Measuring bending strength, "complete bending test" method.
BS EN 1170-6:1998	Precast concrete products. Test method for glass-fibre reinforced cement. Determination of the absorption of water by immersion and determination of the dry density.

BS EN 1170-7:1998	Precast concrete products. Test method for glass-fibre reinforced cement. Measurement of extremes of dimensional variations due to moisture content.
ISO 9883:1993	Performance standards in building. Performance test for precast concrete floors. Behaviour under concentrated load.
ISO 9882:1993	Performance standards in building. Performance test for precast concrete floors. Behaviour under non-concentrated load.
BS 8000-2.2:1990	Workmanship on building sites. Code of practice for concrete work. Site work with in-situ and precast concrete.
BS 5642-2:1983+A1:2014	Sills, copings and cappings. Specification for copings and cappings of precast concrete, cast stone, clayware, slate and natural stone.
BS 5642-1:1978+A1:2014	Sills, copings and cappings. Specification for window sills of precast concrete, cast stone, clayware, slate and natural stone.
BS ISO 13270:2013	Steel fibres for concrete. Definitions and specifications.
BS 8298-3:2010	Code of practice for the design and installation of natural stone cladding and lining. Stone-faced pre-cast concrete cladding systems.
BS EN 1857:2010	Chimneys. Components. Concrete flue liners.
BS EN 1858:2008+A1:2011	Chimneys. Components. Concrete flue blocks.
BS EN 1739:2007	Determination of shear strength for in-plane forces of joints between prefabricated components of autoclaved aerated concrete or lightweight aggregate concrete with open structure.
BS EN 13791:2007	Assessment of in-situ compressive strength in structures and precast concrete components.
BS EN 1992-1-1:2004+A1:2014	Eurocode 2: Design of concrete structures. General rules and rules for buildings.
BS 5911-6:2004+A1:2010	Concrete pipes and ancillary concrete products. Specification for road gullies and gully cover slabs.
BS EN 13295:2004	Products and systems for the protection and repair of concrete structures. Test methods. Determination of resistance to carbonation.
BS 7533-11:2003	Pavements constructed with clay, natural stone or concrete pavers. Code of practice for the opening, maintenance and reinstatement of pavements of concrete, clay and natural stone.
BS EN 1339:2003	Concrete paving flags. Requirements and test methods.
BS EN 1338:2003	Concrete paving blocks. Requirements and test methods.
BS EN 1340:2003	Concrete kerb units. Requirements and test methods.
BS EN 1917:2002	Concrete manholes and inspection chambers, unreinforced, steel fibre and reinforced.
BS EN 1916:2002	Concrete pipes and fittings, unreinforced, steel fibre and reinforced.
BS 5911-4:2002+A2:2010	Concrete pipes and ancillary concrete products. Specification for unreinforced and reinforced concrete inspection chambers (complementary to BS EN 1917:2002).
BS EN 1740:1998	Performance test for prefabricated reinforced components made of autoclaved aerated concrete or lightweight aggregate concrete with open structure under predominantly longitudinal load (vertical components).

BS EN 1737:1998	Determination of shear strength of welded joints of reinforcement mats or cages for prefabricated components made of autoclaved aerated concrete or lightweight aggregate concrete with open structure.
BS EN 1742:1998	Determination of shear strength between different layers of multilayer components made of autoclaved aerated concrete or lightweight aggregate concrete with open structure.
BS EN 1741:1998	Determination of shear strength for out-of-plane forces of joints between prefabricated components made of autoclaved aerated concrete or lightweight aggregate concrete with open structure.
BS 1881-208:1996	Testing concrete. Recommendations for the determination of the initial surface absorption of concrete.
BS 8000-2.1:1990	Workmanship on building sites. Code of practice for concrete work. Mixing and transporting concrete.
BS 6579-8:1987	Safety fences and barriers for highways. Specification for concrete safety barriers.

8.3.3 Precast/composite concrete

The term composite is used when concrete and one or more other materials are used in its fabrication, e.g. steel, timber and plastic. Using these other materials makes use of different characteristics. For example, steel, which, unlike concrete, is very strong in tension; thus the combined characteristics of compression and resistance to tension.

	Description	Advantages	Disadvantages	Quality Issues
Precast composite concrete	• A combination of concrete and other components to provide different characteristics to concrete-only components.	• Can be lightweight. • Ideal for decking – concrete with reinforced steel bars. • In columns it provides high strength for a relatively small cross-sectional area.	• Very small margin for error. • Connections may be difficult. • Need for repetition of forms will affect building design. • Joints between panels are often expensive and complicated. • Skilled workmanship is required in the application of the panel on site. • Cranes may be required to lift panels.	• Interfaces between precast units and in-situ construction. • Quality testing should be approved using appropriate standards. • Care should be taken in loading and unloading precast concrete forms to avoid damage. Precast elements require proper supports, frames, cushioning and tie downs. Particular care should be taken of the edges of the precast elements.

Relevant standards

Approved Document A	Structure.
BS EN 1994-2:2005	Eurocode 4. Design of composite steel and concrete structures. General rules and rules for bridges.
BS EN 1994-1-1:2004	Eurocode 4. Design of composite steel and concrete structures. General rules and rules for buildings.
ASTM D8173 - 18	Standard Guide for Site Preparation, Layout, Installation, and Hydration of Geosynthetic Cementitious Composite Mats.
ISO 19044:2016	Test methods for fibre-reinforced cementitious composites. Load-displacement curve using notched specimen.
ISO 10406-1:2015	Fibre-reinforced polymer (FRP) reinforcement of concrete. Test methods. FRP bars and grids.
ISO 10406-2:2015	Fibre-reinforced polymer (FRP) reinforcement of concrete. Test methods. FRP sheets.
BS EN 15037-5:2013	Precast concrete products. Beam-and-block floor systems. Lightweight blocks for simple formwork.
ISO 14484:2013	Performance guidelines for design of concrete structures using fibre-reinforced polymer (FRP) materials.

8.3.4 Masonry

Masonry is bricks or pieces of stone which have been stuck together with cement as part of a wall or building.

	Description	Advantages	Disadvantages	Quality Issues
Masonry	• Brickwork. • Blockwork. • Natural stone. • Masonry systems: external leaf system; internal leaf system; partition system; freestanding wall leaf system.	• Durability and strength. • High thermal mass and good acoustic insulation. • Cavity acts as insulation and a vapour barrier. • Does not require finishing / decorating. • Inexpensive to maintain and repair. • Fire resistant.	• Less effective in the resistance of lateral loading and / or tension forces. • Heavy, requiring strong foundations. • May be prone to frost damage, joint disintegration and discolouration.	• Where strength is an issue, piers / buttresses should be used. • The mortar mix needs to be appropriate, meeting the relevant standards. • Frequent inspections to ensure quality standards are met. • Brickwork reference panels can provide quality guidelines. • Ensure consistent pointing. • Ensure consistent quality, colour and strength.

				• Only specified admixtures (BS EN 934 3:2009+A1:2012) should be used in the mortar. • Rusting / failure of ties. • Length of wall ties meet specifications in Approved Document A of the Building Regulations (Table 5).

Relevant standards

Approved Document A	Structure.
Eurocode 6	Structure Part 1–1, General rules for reinforced and unreinforced masonry structures; Part 1–2, Structural fire design; Part 2, Design considerations, selection of materials and execution of masonry; Part 3, Simplified calculation methods for unreinforced masonry structures. There are a very large number of standards related to masonry; these can be found in Appendix One.

8.3.5 Carpentry

This is a skilled trade which involves cutting, shaping and installation of building materials during the construction of buildings, timber bridges, concrete formwork etc.

	Description	Advantages	Disadvantages	Quality Issues
Carpentry	• Types of carpentry: rough; framing; formwork; roofing, joister, trim, cabinet maker. • Timber structures: panels; panel diaphragms.	• Less embodied energy. • Strength of panels built up of sheets. • Compared to steel: more flexible; more energy efficient.	• Wood studs may warp, rot, shrink, crack or split. • Wastage due to imperfections. • Compared to steel: will burn.	• Adequate storage facilities to prevent warping. • Inspection of timber before use and once constructed. • Ensure that timber meets quality and strength specifications. • Lateral loads should be clearly stated for a panel roof-deck system or any other timber diaphragm wall.

Relevant standards

BS 8000-5:1990	Workmanship on building sites. Code of practice for carpentry, joinery and general fixings.
BS 6100-8:2007	Building and civil engineering. Vocabulary. Work with timber and wood-based panels.
BS 3087-13:1991	Pliers and nippers. Specification for dimensions and test values of carpenter's pincers.

8.3.6 Cladding and covering

Cladding is any material used to cover a structure's exterior. It is mainly used to stop wind and rain from entering the building. Cladding can also provide sound and thermal insulation as well as fire resistance. It can make a building's exterior more attractive.

	Description	Advantages	Disadvantages	Quality Issues
Cladding	• Attached to a building's framework or an intermediate layer of battens or spacers. • It can be made of: Wood, metal, brick, vinyl, composite materials that can include aluminium, wood, blends of cement and recycled polystyrene, straw fibres. • Types: Curtain walling; sandwich panels; patent glazing; rainscreen; timber cladding; metal profile cladding; tensile fabric coverings; brick slips; tile hanging; shakes and shingle; uPVC.	• Aesthetic. • Weather proof. • Insulation. • Fire resistance.	• Constructed incorrectly can create a fire hazard. • Cost. • Construction time. • Repair costs.	• Check warranty policies / schedules. • Compliance with manufacturer's installation specifications. • Regular inspections required, including spot checks of structure, brackets and other components. • Contractor's skill and experience.

Relevant standards

Approved Document A	Structure.
Approved Document B	Fire safety.
BS 8297:2017	Design, manufacture and installation of architectural precast concrete cladding. Code of practice.
BS 5427:2016+A1:2017	Code of practice for the use of profiled sheet for roof and wall cladding on buildings.
BS 5534:2014+A2:2018	Slating and tiling for pitched roofs and vertical cladding. Code of practice.
BS EN 12326-1:2014	Slate and stone for discontinuous roofing and external cladding. Specifications for slate and carbonate slate.
BS EN 14783:2013	Fully supported metal sheet and strip for roofing, external cladding and internal lining. Product specification and requirements.
BS EN 491:2011	Concrete roofing tiles and fittings for roof covering and wall cladding. Test methods.
BS EN 490:2011+A1:2017	Concrete roofing tiles and fittings for roof covering and wall cladding. Product specifications.
BS 8298-3:2010	Code of practice for the design and installation of natural stone cladding and lining. Stone-faced pre-cast concrete cladding systems.
BS 8410:2007	Code of practice for lightweight temporary cladding for weather protection and containment on construction works.
BS EN 14782:2006	Self-supporting metal sheet for roofing, external cladding and internal lining. Product specification and requirements.
BS 8298:1994	Code of practice for design and installation of natural stone cladding and lining.
ISO 14:1982	Asbestos-cement products. Asbestos-cement-cellulose corrugated sheets and fittings for roofing and cladding.
ISO 14:1982	Asbestos-cement products. Trapezoidal section sheets for roofing and cladding.
BS 4904:1978	Specification for external cladding colours for building purposes.
BS EN ISO 12631:2017	Thermal performance of curtain walling. Calculation of thermal transmittance.
BS EN 1364-5:2017	Fire resistance tests for non-loadbearing elements. Air transfer grilles.
BS ISO 17738-1:2017	Thermal insulation products. Exterior insulation and finish systems. Materials and systems.
ASTM C1729 - 17	Standard Specification for Aluminium Jacketing for Insulation.
ASTM C1729M - 17	Standard Specification for Aluminium Jacketing for Insulation.
BS EN 16758:2016	Curtain walling. Determination of the strength of sheared connections. Test method and requirements.
BS EN 14019:2016	Curtain Walling. Impact resistance. Performance requirements.
BS EN 14509:2013	Self-supporting double skin metal faced insulating panels. Factory made products. Specifications.
BS 8000-6:2013	Workmanship on building sites. Code of practice for slating and tiling of roofs and claddings.
BS EN 1304:2013	Clay roofing tiles and fittings. Product definitions and specifications.

BS EN 505:2013	Roofing products from metal sheet. Specification for fully supported roofing products of steel sheet.
BS EN 16301:2013	Natural stone test methods. Determination of sensitivity to accidental staining.
BS EN 12467:2012+A2:2018	Fibre-cement flat sheets. Product specification and test methods.
BS EN 13381-6:2012	Test methods for determining the contribution to the fire resistance of structural members. Applied protection to concrete filled hollow steel columns.
BS EN 14617-12:2012	Agglomerate stone. Test methods. Determination of dimensional stability.
BS EN 771-3:2011+A1:2015	Specification for masonry units. Aggregate concrete masonry units (Dense and lightweight aggregates).
BS EN 771-5:2011+A1:2015	Specification for masonry units. Manufactured stone masonry units.
BS EN 544:2011	Bitumen shingles with mineral and/or synthetic reinforcements. Product specification and test methods.
BS EN 13050:2011	Curtain Walling. Water tightness. Laboratory test under dynamic condition of air pressure and water spray.
BS 6100-6:2008	Building and civil engineering. Vocabulary. Construction parts.
BS EN 14992:2007+A1:2012	Precast concrete products. Wall elements.
NA to BS EN 1991-1-5:2003	UK National Annex to Eurocode 1. Actions on structures. General actions.
BS 6093:2006+A1:2013	Design of joints and jointing in building construction. Guide.
BS EN 1991-1-5:2003	Eurocode 1. Actions on structures. General actions.
BS EN 12152:2002	Curtain walling. Air permeability. Performance requirements and classification.
BS EN 13364:2002	Natural stone test methods. Determination of the breaking load at dowel hole.
BS 8219:2001+A1:2013	Installation of sheet roof and wall coverings. Profiled fibre cement. Code of practice.
BS 6915:2001+A1:2014	Design and construction of fully supported lead sheet roof and wall coverings. Code of practice.
BS EN 13051:2001	Curtain walling. Water tightness. Site test.
BS EN 13116:2001	Curtain walling. Resistance to wind load. Performance requirements.
BS EN 12179:2000	Curtain walling. Resistance to wind load. Test method.
BS EN 12153:2000	Curtain walling. Air permeability. Test method.
BS EN 12155:2000	Curtain walling. Water tightness. Laboratory test under static pressure.
BS EN 12154:2000	Curtain walling. Water tightness. Performance requirements and classification.
BS 5493:1977	Code of practice for protective coating of iron and steel structures against corrosion.
CP 143-10:1973	Code of practice for sheet roof and wall coverings. Galvanized corrugated steel.
CP 143-15:1973	Code of practice for sheet roof and wall coverings. Aluminium. Metric units.
CP 143-12:1970	Code of practice for sheet roof and wall coverings. Copper. Metric units.

8.3.7 Roof coverings

Constructions which may consist of one or more layers of material, but does not refer to the roof structure as a whole. Roof size and shape often dictate material and system selection.

	Description	Advantages	Disadvantages	Quality Issues
Tiles	• Roof tiles are either plain or interlocking. • Roof tiles are traditionally made from clay and commonly measure 256mm x 165mm. They need to be double-lapped. • Single-lapped tiles are interlocking with a tongue and groove joint.	• Small tiles are easy to handle and transport. • Interlocking tiles reduce the weight of the roof (compared to double lapping).	• Double-lapped tiles can make the roof heavy, slow to lay and therefore relatively expensive. • Single-lapped tiles require a larger baton size and to be fixed by a clip or nail.	• Incorrect or inadequate flashing put in place. • Ensure adequate nailing / fixing is taking place. • Poor cutting around roof vents or other protuberances. • Integration with the rest of the building or neighbouring property. • Drainage criteria associated with roof type.
Slates	• Slate is a natural material that is dense, strong, acid resistant and non-absorptive. • Artificial slates are also available.	• Impervious to freeze/thaw cycles. • Fire resistant. • Aesthetically pleasing. • Can be laid on roofs with a pitch as low as 30˚.	• It is necessary to nail every slate which increases time and cost. • Double lapping requirement means that slate roofs are heavier. • Artificial slate is cheaper but does not last as long as real slate.	
Wood shingles and shakes	• Shingles are sawn; shakes split. • Although they are naturally durable, timber preservative treatment is usually applied.	• Renewable source and therefore sustainable.	• Fire retardant treatment may also be required. • Fixings should be stainless steel and care should be taken with acidic run–off from cedar shingles.	

Sheet coverings	• These are used for flat roofs. • Materials used include bituminous felt, asphalt and metal (e.g. lead or copper).	• Metal sheets are mould and fungus resistant. • Easier to fit than tiles.	• Poor longevity of flat roofs. • Prone to weakness when the sheets are bent or penetrated by ducts, flues etc. • Possible weakness at joints or seams. • Large unit sizes requiring adequate manpower.	

Relevant standards

BS EN 12691:2018	Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Determination of resistance to impact.
ASTM E1592 - 05(2017)	Standard Test Method for Structural Performance of Sheet Metal Roof and Siding Systems by Uniform Static Air Pressure Difference.
ASTM D5636/D5636M (2017)	Standard Test Method for Low Temperature Unrolling of Felt or Sheet Roofing and Waterproofing Materials.
BS EN 12039:2016	Flexible sheets for waterproofing. Bitumen sheets for roof waterproofing. Determination of adhesion of granules.
BS 5427:2016+A1:2017	Code of practice for the use of profiled sheet for roof and wall cladding on buildings.
BS EN 13859-1:2014	Flexible sheets for waterproofing. Definitions and characteristics of underlays. Underlays for discontinuous roofing.
BS EN 16240:2013	Light transmitting flat solid polycarbonate (PC) sheets for internal and external use in roofs, walls and ceilings. Requirements and test methods.
BS EN 13707:2013	Flexible sheets for waterproofing. Reinforced bitumen sheets for roof waterproofing. Definitions and characteristics.
BS EN 1844:2013	Flexible sheets for waterproofing. Determination of resistance to ozone. Plastic and rubber sheets for roof waterproofing.
BS EN 12311-2:2013	Flexible sheets for waterproofing. Determination of tensile properties. Plastic and rubber sheets for roof waterproofing.
BS EN 12316-2:2013	Flexible sheets for waterproofing. Determination of peel resistance of joints. Plastic and rubber sheets for roof waterproofing.
BS EN 495-5:2013	Flexible sheets for waterproofing. Determination of foldability at low temperature. Plastic and rubber sheets for roof waterproofing.
BS EN 14783:2013	Fully supported metal sheet and strip for roofing, external cladding and internal lining. Product specification and requirements.
BS EN 1109:2013	Flexible sheets for waterproofing. Bitumen sheets for roof waterproofing. Determination of flexibility at low temperature.
BS EN 505:2013	Roofing products from metal sheet. Specification for fully supported roofing products of steel sheet.
BS EN 502:2013	Roofing products from metal sheet. Specification for fully supported roofing products of stainless steel sheet.

BS EN 13956:2012	Flexible sheets for waterproofing. Plastic and rubber sheets for roof waterproofing. Definitions and characteristics.
BS EN 13583:2012	Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Determination of hail resistance.
BS EN 508-2:2008	Roofing products from metal sheet. Specification for self-supporting products of steel, aluminium or stainless steel sheet. Aluminium.
BS EN 1548:2007	Flexible sheets for waterproofing. Plastic and rubber sheets for roof waterproofing. Method for exposure to bitumen.
BS EN 14782:2006	Self-supporting metal sheet for roofing, external cladding and internal lining. Product specification and requirements.
BS 8219:2001+A1:2013	Installation of sheet roof and wall coverings. Profiled fibre cement. Code of practice.
BS 6915:2001+A1:2014	Design and construction of fully supported lead sheet roof and wall coverings. Code of practice.
BS EN 13416:2001	Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Rules for sampling.
BS EN 1848-2:2001	Flexible sheets for waterproofing. Determination of length, width and straightness. Plastic and rubber sheets for roof waterproofing.
BS EN 1850-2:2001	Flexible sheets for waterproofing. Determination of visible defects. Plastic and rubber sheets for roof waterproofing.
BS EN 1107-2:2001	Flexible sheets for waterproofing. Determination of dimensional stability. Plastic and rubber sheets for roof waterproofing.
BS EN 1296:2001	Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roofing. Method of artificial ageing by long term exposure to elevated temperature.
BS EN 12310-2:2000	Flexible sheets for waterproofing. Determination of resistance to tearing (nail shank). Plastic and rubber sheets for roof waterproofing.
BS EN 1931:2000	Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Determination of water vapour transmission properties.
BS EN 1928:2000	Flexible sheets for waterproofing. Bitumen, plastic and rubber sheets for roof waterproofing. Determination of water tightness.
BS EN 12316-1:2000	Flexible sheets for waterproofing. Determination of peel resistance of joints. Bitumen sheets for roof waterproofing.
BS EN 12311-1:2000	Flexible sheets for waterproofing. Determination of tensile properties. Bitumen sheets for roof waterproofing.
BS EN 12310-1:2000	Flexible sheets for waterproofing. Determination of resistance to tearing (nail shank). Bitumen sheets for roof waterproofing.
BS EN 12317-1:2000	Flexible sheets for waterproofing. Bitumen sheets for roof waterproofing. Determination of shear resistance of joints.
BS EN 1108:2000	Flexible sheets for waterproofing. Bitumen sheets for roof waterproofing. Determination of form stability under cyclical temperature changes.
BS EN 1850-1:2000	Flexible sheets for waterproofing. Determination of visible defects. Bitumen sheets for roof waterproofing.
BS EN 1107-1:2000	Flexible sheets for waterproofing. Determination of dimensional stability. Bitumen sheets for roof waterproofing.
BS EN 1848-1:2000	Flexible sheets for waterproofing. Determination of length, width and straightness. Bitumen sheets for roof waterproofing.

BS EN 1849-1:2000	Flexible sheets for waterproofing. Determination of thickness and mass per unit area. Bitumen sheets for roof waterproofing.
BS EN 507:2000	Roofing products from metal sheet. Specification for fully supported roofing products of aluminium sheet.
BS EN 504:2000	Roofing products from metal sheet. Specification for fully supported roofing products of copper sheet.
BS EN 501:1994	Roofing products from metal sheet. Specifications for fully supported roofing products of zinc sheet.
ISO 14:1982	Asbestos-cement products. Short corrugated and asymmetrical section sheets and fittings for roofing.
ISO 14:1982	Asbestos-cement products. Asbestos-cement-cellulose corrugated sheets and fittings for roofing and cladding.
ISO 14:1982	Asbestos-cement products. Trapezoidal section sheets for roofing and cladding.
ISO 14:1982	Directives for fixing asbestos-cement corrugated and asymmetrical section sheets and fittings for roofing.
CP 143-10:1973	Code of practice for sheet roof and wall coverings. Code of practice for sheet roof and wall coverings. Galvanized corrugated steel. Metric units.
CP 143-15:1973	Code of practice for sheet roof and wall coverings. Code of practice for sheet roof and wall coverings. Aluminium. Metric units.
CP 143-12:1970	Code of practice for sheet roof and wall coverings. Code of practice for sheet roof and wall coverings. Copper. Metric units.
CP 143-5:1964	Code of practice for sheet roof and wall coverings. Code of practice for sheet roof and wall coverings. Zinc.
ASTM D6380/D6380M - 03(2018)	Standard Specification for Asphalt Roll Roofing (Organic Felt).
ASTM D8154 - 17	Standard Test Methods for 1H-NMR Determination of Ketone-Ethylene-Ester and Polyvinyl Chloride Contents in KEE-PVC Roofing Fabrics.
ASTM D7505/D7505M - 17	Standard Specification for Self-Adhesive Polyester Fabric Reinforced Polymer Modified Asphalt Steep Slope Roll Roofing Surfaced with Mineral Granules.
ASTM D7530/D7530M - 17	Standard Specification for Self-Adhesive Glass Fibre Fabric Reinforced Polymer Modified Asphalt Steep Slope Roll Roofing Surfaced with Mineral Granules.
BS EN 494:2012+A1:2015	Fibre-cement profiled sheets and fittings. Product specification and test methods.
BS EN 12467:2012+A2:2018	Fibre-cement flat sheets. Product specification and test methods.
BS EN 15976:2011	Flexible sheets for waterproofing. Determination of emissivity.
BS EN 1849-2:2009	Flexible sheets for waterproofing. Determination of thickness and mass per unit area. Plastic and rubber sheets.
BS EN 14964:2006	Rigid underlays for discontinuous roofing. Definitions and characteristics.
BS EN 15057:2006	Fibre cement profiled sheets. Impact resistance test method.
BS EN 534:2006+A1:2010	Corrugated bitumen sheets. Product specification and test methods.
BS EN 612:2005	Eaves gutters with bead stiffened fronts and rainwater pipes with seamed joints made of metal sheet.
BS 5803-5:1985	Thermal insulation for use in pitched roof spaces in dwellings. Specification for installation of man-made mineral fibre and cellulose fibre insulation.

BS EN 544:2011	Bitumen shingles with mineral and/or synthetic reinforcements. Product specification and test methods.
BS 8000-6:2013	Workmanship on building sites. Code of practice for slating and tiling of roofs and claddings.
BS EN 1304:2013	Clay roofing tiles and fittings. Product definitions and specifications.

8.3.8 Doors, shutters and hatches

A hinged, sliding, or revolving barrier at the entrance to a building, room, or vehicle, or in the framework of a cupboard.

	Description	Requirements	Quality Issues
Doors	• Door types: Automatic; batwing; bi-fold; false; fire; flush; french; half; ledge and brace; louvered; pivot; revolving; rolling shutter; saloon; security; single-leaf; sliding; wicket.	• Minimum fire resistance according to BS 476-22:1987. • Flashing for exterior doors is critical for shedding rainwater. • Doors in public spaces, corridors, stairwells etc. should open in the direction of escape. • Good energy rating of door glazing.	• Inadequate / incorrectly installed flashing on exterior doors. • Damage to doors by other trades. • Inconsistent alignment. • Joints and gaps. • Poor dimensional quality.
Roller shutters	• Typically made of steel, this type of door is usually found in warehouses, garages, shops, and so on.		
Hatches	• A hatch is an opening which is usually flush with the surface of a floor, roof or ceiling.		

Relevant standards

There are over 200 standards relating to doors. A selected few are shown here.

BS EN ISO 10077-2:2017	Thermal performance of windows, doors and shutters. Calculation of thermal transmittance. Numerical method for frames.
BS 8214:2016	Timber-based fire door assemblies. Code of practice.
BS 8213-4:2016	Windows and doors. Code of practice for the survey and installation of windows and external doorsets.
ASTM E2112 - 18	Standard Practice for Installation of Exterior Windows, Doors and Skylights.
BS EN 1109:2013	Flexible sheets for waterproofing. Bitumen sheets for roof waterproofing. Determination of flexibility at low temperature.
BS EN 505:2013	Roofing products from metal sheet. Specification for fully supported roofing products of steel sheet.
BS EN 502:2013	Roofing products from metal sheet. Specification for fully supported roofing products of stainless steel sheet.

8.3.9 Windows, screens and lights

	Description	Requirements	Quality Issues
Windows	• Window types: Fixed light; vertical slider / sash; casement; tilt and turn; pivot; bi-fold; louvre. • Made of timber, metal or PVC.	• Suitable materials that have good thermal and sound properties, are easily maintained, provide safety and security and are capable of resisting wind and rain. • The efficiency of windows is improved by double glazing, treble glazing, low-e coatings, the construction of the frame, the type of glass, the gas used to fill the sealed unit and so on. • If required, suitable egress from windows in the event of a fire.	• Poor installation leaving gaps, unsafe operation etc. • Safety glass not used where specified. • Poor dimensional quality. • Weatherproofing / waterproofing.
Screens	• Screen types: Sliding; pocket; hinged; pivot or bi-folding.		
Lights	• Skylights. • Rooflights. • Roof windows.		

Relevant standards

There are over 200 standards relating to doors. A selected few are shown here.

BS EN ISO 10077-2:2017	Thermal performance of windows, doors and shutters. Calculation of thermal transmittance. Numerical method for frames.
BS 8213-4:2016	Windows and doors. Code of practice for the survey and installation of windows and external doorsets.
ASTM E2112 - 18	Standard Practice for Installation of Exterior Windows, Doors and Skylights.

8.3.10 Insulation, fire stopping and fire protection

Board, sheet, quilt, sprayed, loose fill or foamed insulation and fire protection.

	Description	Requirements	Quality Issues
Insulation	• Insulation types: Mineral fibre; plastic beads; cellulose fibre; hemp fibre, cork, wood fibre boards, sheep's wool; expanding foam; other type of blown or injected material.	• Scientific calculations to insulation selection but other peripheral factors that will affect installation need to be considered. • Requirement to adhere to manufacturers' instructions and general best practice / workmanship. • To recognise that laboratory-based performance tests may not relate well to the installation of insulation on site.	• Facility / building may not be suitable for certain types of insulation. • Wet insulation can encourage mould growth. • Compliance with manufacturer's installation specifications. • Contractor's skill and experience. • Risk of cold bridging and thermal bypass, or of other insulation materials.
Fire stops	• Fire stop types: Horizontal; vertical; raking; stepped; curved.		

Relevant standards

Approved Document Part C Site preparation and resistance to contaminates and moisture.

Energy Efficiency and Historic Buildings	Application of Part L of the Building Regulations to Historic and Traditionally Constructed Buildings.
ASTM C1859 - 17a	Standard Practice for Determination of Thermal Resistance of Loose-Fill Building Insulation in Side Wall Applications.
BS 7457:1994	Specification for polyurethane (PUR) foam systems suitable for stabilization and thermal insulation of cavity walls with masonry or concrete inner and outer leaves.
BS 7456:1991	Code of practice for stabilization and thermal insulation of cavity walls (with masonry or concrete inner and outer leaves) by filling with polyurethane (PUR) foam systems.
BS 5617:1985	Specification for urea-formaldehyde (UF) foam systems suitable for thermal insulation of cavity walls with masonry or concrete inner and outer leaves.
BS 5618:1985	Code of practice for thermal insulation of cavity walls (with masonry or concrete inner and outer leaves) by filling with urea-formaldehyde (UF) foam systems.
BS ISO 17738-1:2017	Thermal insulation products. Exterior insulation and finish systems. Materials and systems.
BS EN ISO 10140-1:2016	Acoustics. Laboratory measurement of sound insulation of building elements. Application rules for specific products.
BS EN 14064-1:2010	Thermal insulation products for buildings. In-situ formed loose-fill mineral wool (MW) products. Specification for the loose-fill products before installation.
BS EN 14316-2:2007	Thermal insulation products for buildings. In-situ thermal insulation formed from expanded perlite (EP) products. Specification for the installed products.
BS EN 14317-2:2007	Thermal insulation products for buildings. In-situ thermal insulation formed from exfoliated vermiculite (EV) products. Specification for the installed products.
BS EN 14317-1:2004	Thermal insulation products for buildings. In-situ thermal insulation formed from exfoliated vermiculite (EV) products. Specification for bonded and loose-fill products before installation.
BS EN 13499:2003	Thermal insulation products for buildings. External thermal insulation composite systems (ETICS) based on expanded polystyrene. Specification.
BS EN 13500:2003	Thermal insulation products for buildings. External thermal insulation composite systems (ETICS) based on mineral wool. Specification.
BS EN 14318-1:2013	Thermal insulating products for buildings. In-situ formed dispensed rigid polyurethane (PUR) and polyisocyanurate (PIR) foam products. Specification for the rigid foam dispensed system before installation.
BS EN 14315-1:2013	Thermal insulating products for buildings. In-situ formed sprayed rigid polyurethane (PUR) and polyisocyanurate (PIR) foam products. Specification for the rigid foam spray system before installation.
BS EN 16883:2017	Conservation of cultural heritage – Guidelines for improving the energy performance of historic buildings.

Interal Finishes

8.4.1 Proprietary linings and partitions

Metal framed systems to walls and ceilings and drylining and partitioning systems to walls and ceilings.

	Description	Requirements	Quality Issues
Plasterboard	• Used in dry lining / Drywall. • Good fire-resistant characteristics. • Easy to install. • It is durable and is relatively easy to maintain.	• Needs to be cut to size unless a standard size is specified. • Cavity barriers in a stud wall or partition, or provided around openings may be formed of gypsum-based boards at least 12mm thick. • Should be stored in dry conditions.	• Badly finished joints. • Installed against damp walls / ceilings. • Check a vapour barrier has been fitted where necessary.
Studwork	• Specialised forms of Drywall: Fire-rated; moisture resistant; sound board; lead-lined; flexible; blue.	• A load bearing stud wall should be no higher than 2.25m. • Cavity barriers in a stud wall or partition, or provided around openings may be formed of: a) steel at least 0.5mm thick; or b) timber at least 38mm thick; or c) polythene-sleeved mineral wool, or mineral wool slab, in either case under compression when installed in the cavity; or d) calcium silicate, cement-based or gypsum-based boards at least 12mm thick.	• Poor dimensional quality.

Relevant standards

Approved Document A	Structure.
Approved Document B	Fire safety.
BS EN 14209:2017	Preformed plasterboard cornices. Definitions, requirements and test methods.
BS EN 14353:2017	Metal beads and feature profiles for use with gypsum plasterboards. Definitions, requirements and test methods.
BS EN 13915:2017	Prefabricated gypsum plasterboard panels with a cellular paperboard core. Definitions, requirements and test methods.
BS EN 14566:2008+A1:2009	Mechanical fasteners for gypsum plasterboard systems. Definitions, requirements and test methods.
BS EN 520:2004+A1:2009	Gypsum plasterboards. Definitions, requirements and test methods.
BS 8212:1995	Code of practice for dry lining and partitioning using gypsum plasterboard.
BS 8000-8:1994	Workmanship on building sites. Code of practice for plasterboard partitions and dry linings.

BS EN 14496:2017	Gypsum based adhesives for thermal/acoustic insulation composite panels and gypsum boards. Definitions, requirements and test methods.
BS EN 14195:2014	Metal framing components for gypsum board systems. Definitions, requirements and test methods.
BS EN 14190:2014	Gypsum board products from reprocessing. Definitions, requirements and test methods.
BS EN 13963:2014	Jointing materials for gypsum boards. Definitions, requirements and test methods.
BS EN 13950:2014	Gypsum board thermal/acoustic insulation composite panels. Definitions, requirements and test methods.

8.4.2 Floor, wall, ceiling and roof finishing

	Description	Requirements	Quality Issues
Finishes	• Finishes can protect a component / system from impact, water, frost, corrosion, abrasion, and so on, and / or can be decorative. • Calcium sulphate based levelling screeds. • Cement based levelling / wearing screeds. • Decorative papers / fabrics. • Edge fixed carpeting. • Insulation with rendered finish. • Intumescent coatings for fire protection of steelwork. • Mastic asphalt flooring / floor underlays. • Metal lathing / anchored mesh reinforcement for plastered / rendered coatings. • Painting / clear finishing. • Plastered / rendered / roughcast coatings. • Resin flooring.	• Should be applied to suitable substrates. • Flooring - the floor must be fit for purpose and should have adequate stiffness to support the tiles and adhesive or other covering. • Where building services pass through the screed, allowance should be made for thermal movement between the screed and the service, and so that service pipes can resist chemical attack from the screed. • The paint and stain systems specified should be compatible with any timber preservatives and timber species used. • Bond and moisture protection are important considerations.	• Uneven substrate / finish. • Poor joints. • Integration with other components / systems. • Integrity of covering existing services. • Quality of materials used.

CONT.	Description	Requirements	Quality Issues
Finishes (cont)	• Rubber / plastics / cork / lino / carpet tiling / sheeting. • Sprayed monolithic coatings. • Stone / concrete / quarry / ceramic tiling / mosaic. • Terrazzo tiling / in-situ terrazzo. • Wood block / composition block / mosaic parquet flooring.		

Relevant standards

NHBC Standards Part 8	Services and internal finishing.
ASTM C1516 - 05(2017)	Standard Practice for Application of Direct-Applied Exterior Finish Systems.
BS EN 15286:2013	Agglomerated stone. Slabs and tiles for wall finishes (internal and external).
ASTM C1528/C1528M - 18	Standard Guide for Selection of Dimension Stone.
ASTM F2419 - 11(2017)	Standard Practice for Installation of Thick Poured Gypsum Concrete Underlayments and Preparation of the Surface for Resilient Flooring.
ASTM E2404 - 17	Standard Practice for Specimen Preparation and Mounting of Textile, Paper or Polymeric (Including Vinyl) and Wood Wall or Ceiling Coverings, Facings and Veneers, to Assess Surface Burning Characteristics.
ASTM C1288 - 17	Standard Specification for Fibre-Cement Interior Substrate Sheets.
BS 8203:2017	Code of practice for installation of resilient floor coverings.
PD CEN/TR 17024:2017	Natural stones. Guidance for use of natural stones.
BS EN 13914-1:2016	Design, preparation and application of external rendering and internal plastering. External rendering.
BS EN 1468:2012	Natural stone. Rough slabs. Requirements.
BS EN 15388:2008	Agglomerated stone. Slabs and cut-to-size products for vanity and kitchen tops.
BS 8481:2006	Design, preparation and application of internal gypsum, cement, cement and lime plastering systems. Specification.
BS 6150:2006+A1:2014	Painting of buildings. Code of practice.
BS 8204-4:2004+A1:2011	Screeds, bases and in-situ floorings. Cementitious terrazzo wearing surfaces. Code of practice.
BS 8204-5:2004+A1:2011	Screeds, bases and in-situ floorings. Mastic asphalt underlays and wearing surfaces. Code of practice.
BS 8425:2003	Code of practice for installation of laminate floor coverings.
BS EN 235:2002	Wallcoverings. Vocabulary and symbols.
BS 5325:2001	Installation of textile floor coverings. Code of practice.
BS EN 259-1:2001	Wallcoverings in roll form. Heavy duty wallcoverings. Specifications.

BS EN 259-2:2001	Wallcoverings in roll form. Heavy duty wallcoverings. Determination of impact resistance.
BS EN 12781:2001	Wallcoverings. Specification for cork panels.
BS EN 13085:2001	Wallcoverings. Specification for cork rolls.
BS EN 12956:1999	Wallcoverings in roll form. Determination of dimensions, straightness, spongeability and washability.
BS EN 12149:1998	Wallcoverings in roll form. Determination of migration of heavy metals and certain other elements, of vinyl chloride monomer and of formaldehyde release.
BS EN 234:1997	Wallcoverings in roll form. Specification for wallcoverings for subsequent decoration.
BS EN 266:1992	Specification for textile wallcoverings.

8.4.3 Suspended ceilings

	Description	Requirements	Quality Issues
Suspended ceiling (or dropped ceiling)	• A suspended ceiling can provide a clean, smooth finish to the internal ceiling of a room, whilst hiding electrical wires, pipework and other services. • Suspended ceilings are hung from a bracket fixed to the underside of the floor slab supporting a series of interlocking metal sections that form a grid into which panels such as ceiling tiles can be fitted. • Beam systems are also available, in which tiles are laid between parallel beams rather than a grid, and there are a wide range of different grid profiles and tile edge details that can be used to allow the grid to be exposed, flush, recessed or concealed. • A suspended ceiling can contribute to the overall fire resistance of a floor / ceiling assembly.	• Need to be carefully designed in order to integrate with partition systems; tiles, grids and partitions should intersect neatly. • Partitions may stop at the underside of the suspended ceiling to provide maximum ease of installation and flexibility, or may run through the ceiling to the underside of the floor slab. • Where partitions do not run through the ceiling void, care must be taken to ensure that a flanking path is not created for the transmission of sound between adjacent spaces or for the spread of fire. • Acoustic insulation or fire separation can be provided in the ceiling void if necessary.	• Integration with other components / systems. • Integrity of covering existing services. • Quality of materials used.

	• Acoustic-absorbing materials can be used. • The void can also be used as an air 'plenum', in which the void itself forms a pressurised 'duct' to supply air or extract it from the occupied space below.		

Relevant standards

ASTM C1858 - 17a	Standard Practice for Design, Construction, and Material Requirements for Direct Hung Suspended T-bar Type Ceiling Systems Intended to Receive Gypsum Panel Products in Areas Subject to Earthquake Ground Motions.
BS EN 14246:2006	Gypsum elements for suspended ceilings. Definitions, requirements and test methods.
ASTM E580/E580M - 17	Standard Practice for Installation of Ceiling Suspension Systems for Acoustical Tile and Lay-in Panels in Areas Subject to Earthquake Ground Motions.
ASTM C754 - 18	Standard Specification for Installation of Steel Framing Members to Receive Screw-Attached Gypsum Panel Products.
BS EN ISO 10848-2:2017	Acoustics. Laboratory and field measurement of flanking transmission for airborne, impact and building service equipment sound between adjoining rooms. Application to Type B elements when the junction has a small influence.

8.4.4 Glazing

Windows are one of the most important elements of a building's thermal envelope; providing aesthetics, letting in light, helping control sound, and serving as a means of natural ventilation.

	Description	Requirements	Quality Issues
Glazing	• Glass or transparent or translucent plastic sheet used in windows, doors, skylights, or curtain walls. • Glass can be tinted to reject sunlight, coated in a translucent film to increase energy efficiency, or be self-cleaning.	• Energy ratings of the glass based on an A+ to G scale. • Efficiency depends upon all the components: the frame; the glazing, and; the air tightness of the finished window. • Building Regulations have certain requirements for glazing in terms of safety, means of escape and ventilation.	• Professionalism / competency of installers. • Appropriate glazing type.

CONT.	Description	Requirements	Quality Issues
Glazing (cont.)	• There are many varied forms of glass: etched; textured; frosted; stained or tinted glass for privacy or aesthetic purposes. • There are a number of different ways to manufacture glass: float; annealed; heat-strengthened; fully-tempered; heat-soaked tempered; laminated; wired; low emissivity, and; self-cleaning.	• Part K of the Building Regulations require that where 'building work' is carried out in a critical location involving glass, safety glazing is used. Safety glazing is required. • In any glazed area within a window below 800 mm from floor level. • In any glazed area within a window that is 300 mm or less from a door and up to 1500 mm from floor level. • Within any glazed door up to 1500 mm from floor level.	

Relevant standards

Approved Document K	Protection from falling, collision and impact.
BS EN ISO 52022-3:2017	Energy performance of buildings. Thermal, solar and daylight properties of building components and elements. Detailed calculation method of the solar and daylight characteristics for solar protection devices combined with glazing.
BS EN ISO 52022-1:2017	Energy performance of buildings. Thermal, solar and daylight properties of building components and elements. Simplified calculation method of the solar and daylight characteristics for solar protection devices combined with glazing.
ASTM E2358 - 17	Standard Specification for Performance of Glazing in Permanent Railing Systems, Guards, and Balustrades.
BS EN 12758:2011	Glass in building. Glazing and airborne sound insulation. Product descriptions and determination of properties.
BS EN 15269-20:2009	Extended application of test results for fire resistance and/or smoke control for door, shutter and openable window assemblies, including their elements of building hardware. Smoke control for hinged and pivoted steel, timber and metal framed glazed doorsets.
BS 5516-1:2004	Patent glazing and sloping glazing for buildings. Code of practice for design and installation of sloping and vertical patent glazing.
BS 5516-2:2004	Patent glazing and sloping glazing for buildings. Code of practice for sloping glazing.
BS 8000-7:1990	Workmanship on building sites. Code of practice for glazing.
BS EN 1279-2:2018	Glass in building. Insulating glass units. Long term test method and requirements for moisture penetration.
BS EN ISO 10077-2:2017	Thermal performance of windows, doors and shutters. Calculation of thermal transmittance. Numerical method for frames.

BS EN ISO 12631:2017	Thermal performance of curtain walling. Calculation of thermal transmittance.
BS EN ISO 10077-1:2017	Thermal performance of windows, doors and shutters. Calculation of thermal transmittance. General.
BS EN 1634-1:2014+A1:2018	Fire resistance and smoke control tests for door and shutter assemblies, openable windows and elements of building hardware. Fire resistance test for door and shutter assemblies and openable windows.
BS ISO 18292:2011	Energy performance of fenestration systems for residential buildings. Calculation procedure.
BS 6375-3:2009+A1:2013	Performance of windows and doors. Classification for additional performance characteristics and guidance on selection and specification.
BS 7412:2007	Specification for windows and doorsets made from unplasticized polyvinyl chloride (PVC-U) extruded hollow profiles.
BS EN ISO 12567-2:2005	Thermal performance of windows and doors. Determination of thermal transmittance by hot box method. Roof windows and other projecting windows.
BS 8213-1:2004	Windows, doors and rooflights. Design for safety in use and during cleaning of windows, including door-height windows and roof windows. Code of practice.
BS EN ISO 14438:2002	Glass in building. Determination of energy balance value. Calculation method.
BS EN 12898:2001	Glass in building. Determination of the emissivity.
BS 6206:1981	Specification for impact performance requirements for flat safety glass and safety plastics for use in buildings.

8.4.5 Fittings, furnishings and equipment

Windows are one of the most important elements of a building's thermal envelope; providing aesthetics, letting in light, helping control sound, and serving as a means of natural ventilation.

	Description	Requirements	Quality Issues
Fittings, Furnishings and Equipment (FFE)	• The procurement of furniture, fixtures and equipment. • These might be procured separately to the main construction contract (or elements of them), especially by clients with procurement systems in place for procuring FFE, e.g. schools, universities, or hospitals.	• The building work or any services required for FFE needs to be identified in the contract. For example, fume cupboards or drinks stations that require M&E connections; built-in equipment not requiring services; stand-alone FFE that require power, air, water, drainage or telecommunication connections; stand-alone FFE that do not require services.	• Adequate maintenance plan in place. • Contractor's skill and experience. • Quality of materials. • M&E parts of the installation need to meet safety and quality standards.

CONT.	Description	Requirements	Quality Issues
Fittings, Furnishings and Equipment (FFE) (cont.)	• A fixture is defined as an asset that is installed or otherwise fixed in or to a building or land so as to become part of that building or land, in law.	• Programming and planning of the FFE procurement and installation is important. • Relevant manuals / instructions need to be available at handover. • Should meet codes and standards for properties such as flammability, toxicity, and slip resistance.	

Relevant standards

The Furniture and Furnishings (Fire Safety) Regulations 1988 (as amended in 1989, 1993 and 2010) set levels of fire resistance for domestic upholstered furniture, furnishings and other products containing upholstery.

Many of the standards under other headings in the above sections apply here, relating to individual materials.

8.5 Services

	Description	Requirements	Quality Issues
M&E	• Mechanical systems can include elements of infrastructure, plant and machinery, tool and components, heating and ventilation and so on. • Electrical systems might include, power supply and distribution, telecommunications, computing instrumentation, control systems and so on.	• M&E requirements need to be identified and planned for at an early stage to avoid clashes / rework. • Need to meet standards of energy efficiency, safety, emissions and sustainability. • Work on electrical equipment, machinery or installations should be: thoroughly planned and carried out by competent people using suitable equipment and work standards.	• Adequate maintenance plan in place. • Contractor's qualifications, skill and experience. • Inadequate detailing in specifications. • Conformance to safety / quality standards. • Poor understanding of interaction between components. • Not meeting predicted performance levels. • Miscalculation of power loads.

Relevant standards

Electrical Equipment (Safety) Regulations 1994

The Electricity at Work Act 1989.

BS 7671:2001	Requirements for electrical installations, IEE Wiring Regulations.
Building Regulations Part L	Conservation of fuel and power.

Many of the standards under other headings in the above sections apply here, relating to individual materials.

8.6 External works

All items outside the building footprint but inside the site boundary, encompassing wastewater and surface water drains, supply of utilities (e.g. gas, electricity and cabled services), footpaths, and access for vehicles including car parks and hard standings to be found in the vicinity of buildings.

	Description	Requirements	Quality Issues
Fencing and other external 'furniture'	• Fencing, railings and walls. • Bollards. • Street furniture. • Shelters.	• Security. • Aesthetics. • Boundary treatment. • To provide shelter.	• Poor quality materials. • Conformance to standards. • Appropriate maintenance plan.
Soft landscaping	• Plants, shrubs, trees, groundcover. • Irrigation systems.	• To provide a soft boundary, good visual appearance, ameliorate carbon emissions and provide a natural filtration system.	• Poor quality materials. • Appropriate maintenance plan. • Soil, geology and hydrology issues.
Drainage below ground (foul drainage)	• A system to carry foul (waste) water from appliances within a building to: a public sewer; a private sewer; a septic tank, or: a cesspool. • Subsoil water. • Surface water. • Foul and soil water.	• To provide a safe and effective way to transport foul and soil water into appropriate systems.	• Incorrect sizing of pipework. • Incorrect pipe gradient. • Incorrect backfill. • Cross-connections or Mis-connections. • Poor drainage design. • Poor construction.

Drainage above ground (sanitary pipework)	• Waste pipes and fittings connected to sanitary appliances (WCs, hand basins, kitchen sinks, baths and showers) and services equipment (dishwashers and industrial washing machines).	• To provide adequate drainage in accordance with requirements of water companies.	• Inadequate sealing of fire stopping at service penetrations. • Safety devices not provided on unvented hot water systems. • Incorrect pipework and couplings used and mismatched. • Lack of support throughout the full height of the soil stack. • Vertical stacks terminating into 92° junctions. • Pipework connections into soil stacks. • Opposed connections into the base of soil stacks. • Inadequate falls to horizontal pipework. • Missing sound insulation to pipework.
Site works	• Roads, paths, pavings and surfacing.	• To provide safe and appropriate works for workers, pedestrians and vehicles. • Cycle routes. • Sightlines, radii, gradients to meet standards. • Access for emergency services. • Dropped kerbs, tactile paving and facilities at signalled controlled crossings, lighting, signage as detailed in the Disability Rights Commission's Code of Practice - 'Rights of Access: Goods, Facilities, Services and Premises'.	• Uneven surfaces. • Poor/lack of maintenance plan. • Poor programme planning leading to untimely construction of road systems.

Relevant standards

Approved Document H	Drainage and waste disposal.

There are a huge number of relevant standards, for example just the paving-related ones are numerous:

BS EN 1338	Concrete Paving Blocks.
BS EN 1339	Concrete Paving Flags.

BS EN 1340	Concrete Kerb Units.
BS EN 1341	Natural Stone Flag Paving.
BS EN 1342	Natural Stone Setts.
BS EN 1343	Natural Stone Kerbs.
BS EN 1344	Clay Pavers.
BS 7533-1:2001	Guide for the structural design of heavy duty pavements constructed of clay or concrete pavers.
BS 7533-2:2001	Guide for the structural design of lightly trafficked pavements.
BS 7533-3:2005+A1:2009	Code of practice for laying precast concrete paving blocks and clay pavers for flexible pavements.
BS 7533-4:2006	Code of practice for the construction of pavements of precast concrete flags or natural stone slabs.
BS 7533-6:1999	Code of practice for laying natural stone, precast concrete and clay kerb units.
BS 7533-7:2010	Code of practice for the construction of pavements of natural stone paving units and cobbles, and rigid construction with concrete block paving.
BS 7533-8:2003	Guide for the structural design of lightly trafficked pavements of precast concrete flags and natural stone slabs.
BS 7533-9:2010	Code of practice for the construction of rigid pavements of clay pavers.
BS 7533-10:2010	Guide for the structural design of trafficked pavements constructed of natural stone setts and bound construction with concrete paving blocks.
BS 7533-11:2003	Code of practice for the opening, maintenance and reinstatement of pavements of concrete, clay and natural stone.
BS 7533-12:2006	Guide to the structural design of trafficked pavements constructed on a bound base using concrete paving flags and natural stone slabs.
BS 7533-13:2009	Guide for the design of permeable pavements constructed with concrete paving blocks and flags, natural stone slabs and setts and clay pavers.

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Section

9

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Section

10

Appendix One

Standards Relating to Masonry

ASTM C476 - 18	Standard Specification for Grout for Masonry.
ASTM C91/C91M - 18	Standard Specification for Masonry Cement.
ASTM C1660 - 10(2018)	Standard Specification for Thin-bed Mortar for Autoclaved Aerated Concrete (AAC) Masonry.
ASTM C140/C140M - 17b	Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units.
ASTM C144 - 17	Standard Specification for Aggregate for Masonry Mortar.
ASTM C404 - 11(2017)	Standard Specification for Aggregates for Masonry Grout.
ASTM C1691 - 11(2017)	Standard Specification for Unreinforced Autoclaved Aerated Concrete (AAC) Masonry Units.
ASTM C1384 - 17	Standard Specification for Admixtures for Masonry Mortars.
ASTM C62 - 17	Standard Specification for Building Brick (Solid Masonry Units Made From Clay or Shale).
ASTM C652 - 17a	Standard Specification for Hollow Brick (Hollow Masonry Units Made From Clay or Shale).
ASTM C216 - 17a	Standard Specification for Facing Brick (Solid Masonry Units Made from Clay or Shale).
ASTM E3121/E3121M - 17	Standard Test Methods for Field Testing of Anchors in Concrete or Masonry.
ASTM C1623 - 17a	Standard Specification for Manufactured Concrete Masonry Lintels.
ASTM C1670/C1670M - 17	Standard Specification for Adhered Manufactured Stone Masonry Veneer Units.
ASTM C331/C331M - 17	Standard Specification for Lightweight Aggregates for Concrete Masonry Units.
ASTM C1400 - 11(2017)	Standard Guide for Reduction of Efflorescence Potential in New Masonry Walls.
ASTM C279 - 17	Standard Specification for Chemical-Resistant Masonry Units.
ASTM C1780 - 17	Standard Practice for Installation Methods for Adhered Manufactured Stone Masonry Veneer.
ASTM C129 - 17	Standard Specification for Non-loadbearing Concrete Masonry Units.
ASTM C1713 - 17	Standard Specification for Mortars for the Repair of Historic Masonry.
ASTM C139 - 17	Standard Specification for Concrete Masonry Units for Construction of Catch Basins and Manholes.
ASTM C780 - 17	Standard Test Method for Preconstruction and Construction Evaluation of Mortars for Plain and Reinforced Unit Masonry.
ASTM E3069 - 17	Standard Guide for Evaluation and Rehabilitation of Mass Masonry Walls for Changes to Thermal and Moisture Properties of the Wall.
BS EN 459	Building lime.
BS EN 998-1:2016	Specification for mortar for masonry. Rendering and plastering mortar.
BS EN 998-2:2016	Specification for mortar for masonry. Masonry mortar.

BS EN 1015-12:2016	Methods of test for mortar for masonry. Determination of adhesive strength of hardened rendering and plastering mortars on substrates.
BS EN 1052-2:2016	Methods of test for masonry. Determination of flexural strength.
BS EN 772-5:2016	Methods of test for masonry units. Determination of the active soluble salts content of clay masonry units.
ASTM A951/A951M - 16e1	Standard Specification for Steel Wire for Masonry Joint Reinforcement.
ASTM C1713 - 15	Standard Specification for Mortars for the Repair of Historic Masonry.
BS EN 16572:2015	Conservation of cultural heritage. Glossary of technical terms concerning mortars for masonry, renders and plasters used in cultural heritage.
BS 8103-2:2013	Structural design of low-rise buildings. Code of practice for masonry walls for housing.
BS EN 845-1:2013+A1:2016	Specification for ancillary components for masonry. Wall ties, tension straps, hangers and brackets.
BS EN 845-2:2013+A1:2016	Specification for ancillary components for masonry. Lintels.
BS 8539:2012	Code of practice for the selection and installation of post-installed anchors in concrete and masonry.
BS EN 846-14:2012	Methods of test for ancillary components for masonry. Determination of the initial shear strength between the prefabricated part of a composite lintel and the masonry above it.
BS EN 846-5:2012	Methods of test for ancillary components for masonry. Determination of tensile and compressive load capacity and load displacement characteristics of wall ties (couplet test).
BS EN 846-6:2012	Methods of test for ancillary components for masonry. Determination of tensile and compressive load capacity and load displacement characteristics of wall ties (single end test).
BS EN 846-7:2012	Methods of test for ancillary components for masonry. Determination of shear load capacity and load displacement characteristics of shear ties and slip ties (couplet test for mortar joint connections).
BS EN 771-2:2011+A1:2015	Specification for masonry units. Calcium silicate masonry units.
BS EN 771-1:2011+A1:2015	Specification for masonry units. Clay masonry units.
BS EN 771-3:2011+A1:2015	Specification for masonry units. Aggregate concrete masonry units (Dense and lightweight aggregates).
BS EN 771-4:2011+A1:2015	Specification for masonry units. Autoclaved aerated concrete masonry units.
BS EN 771-5:2011+A1:2015	Specification for masonry units. Manufactured stone masonry units.
BS EN 771-6:2011+A1:2015	Specification for masonry units. Natural stone masonry units.
BS EN 413-1:2011	Masonry cement. Composition, specifications and conformity criteria.
BS EN 772-1:2011+A1:2015	Methods of test for masonry units. Determination of compressive strength.
BS EN 772-11:2011	Methods of test for masonry units. Determination of water absorption of aggregate concrete, autoclaved aerated concrete, manufactured stone and natural stone masonry units due to capillary action and the initial rate of water absorption of clay masonry units.

BS EN 772-16:2011	Methods of test for masonry units. Determination of dimensions.
BS EN 772-18:2011	Methods of test for masonry units. Determination of freeze-thaw resistance of calcium silicate masonry units.
BS EN 772-21:2011	Methods of test for masonry units. Determination of water absorption of clay and calcium silicate masonry units by cold water absorption.
ASTM C144 - 11	Standard Specification for Aggregate for Masonry Mortar.
BS EN 934-3:2009+A1:2012	Admixtures for concrete, mortar and grout. Admixtures for masonry mortar. Definitions, requirements, conformity and marking and labelling.
BS 6073-2:2008	Precast concrete masonry units. Guide for specifying precast concrete masonry units.
BS EN 1062-3:2008	Paints and varnishes. Coating materials and coating systems for exterior masonry and concrete. Determination of liquid water permeability.
NA to BS EN 1996-1-2:2005	UK National Annex to Eurocode 6. Design of masonry structures. General rules. Structural fire design.
NA to BS EN 1996-2:2006	UK National Annex to Eurocode 6. Design of masonry structures. Design considerations, selection of materials and execution of masonry.
NA to BS EN 1996-1-1:2005+A1:2012	UK National Annex to Eurocode 6. Design of masonry structures. General rules for reinforced and unreinforced masonry structures.
BS EN 1996-2:2006	Eurocode 6. Design of masonry structures. Design considerations, selection of materials and execution of masonry.
BS EN 1996-3:2006	Eurocode 6. Design of masonry structures. Simplified calculation methods for unreinforced masonry structures.
BS EN 1996-1-1:2005+A1:2012	Eurocode 6. Design of masonry structures. General rules for reinforced and unreinforced masonry structures.
BS EN 1052-5:2005	Methods of test for masonry. Determination of bond strength by the bond wrench method.
BS EN 1996-1-2:2005	Eurocode 6. Design of masonry structures. General rules. Structural fire design.
BS EN 1015-18:2002	Methods of test for mortar for masonry. Determination of water absorption coefficient due to capillary action of hardened mortar.
BS EN 1015-21:2002	Methods of test for mortar for masonry. Determination of the compatibility of one-coat rendering mortars with substrates.
BS EN 1052-3:2002	Methods of test for masonry. Determination of initial shear strength.
BS EN 1062-6:2002	Paints and varnishes. Coating materials and coating systems for exterior masonry and concrete. Determination of carbon dioxide permeability.
BS EN 772-14:2002	Methods of test for masonry units. Determination of moisture movement of aggregate concrete and manufactured stone masonry units.
BS EN 846-4:2002	Methods of test for ancillary components for masonry. Determination of load capacity and load-deflection characteristics of straps.

BS EN 846-13:2001	Methods of test for ancillary components for masonry. Determination of resistance to impact, abrasion and corrosion of organic coatings.
BS EN 772-6:2001	Methods of test for masonry units. Determination of bending tensile strength of aggregate concrete masonry units.
BS 8000-3:2001	Workmanship on building sites. Code of practice for masonry.
BS EN 772-15:2000	Methods of test for masonry units. Determination of water vapour permeability of autoclaved aerated concrete masonry units.
BS EN 1015-17:2000	Methods of test for mortar for masonry. Determination of water-soluble chloride content of fresh mortars.
BS EN 1052-4:2000	Methods of test for masonry. Determination of shear strength including damp proof course.
BS EN 12418:2000+A1:2009	Masonry and stone cutting-off machines for job site. Safety.
BS EN 772-13:2000	Methods of test for masonry units. Determination of net and gross dry density of masonry units (except for natural stone).
BS EN 772-19:2000	Methods of test for masonry units. Determination of moisture expansion of large horizontally perforated clay masonry units.
BS EN 772-20:2000	Methods of test for masonry units. Determination of flatness of faces of masonry units.
BS EN 846-10:2000	Methods of test for ancillary components for masonry. Determination of load capacity and load deflection characteristics of brackets.
BS EN 846-11:2000	Methods of test for ancillary components for masonry. Determination of dimensions and bow of lintels.
BS EN 846-2:2000	Methods of test for ancillary components for masonry. Determination of bond strength of prefabricated bed joint reinforcement in mortar joints.
BS EN 846-3:2000	Methods of test for ancillary components for masonry. Determination of shear load capacity of welds in prefabricated bed joint reinforcement.
BS EN 846-8:2000	Methods of test for ancillary components for masonry. Determination of load capacity and load-deflection characteristics of joist hangers.
ISO 9652-5:2000	Masonry. Vocabulary.
BS EN 1015-10:1999	Methods of test for mortar for masonry. Determination of dry bulk density of hardened mortar.
BS EN 1015-11:1999	Methods of test for mortar for masonry. Determination of flexural and compressive strength of hardened mortar.
BS EN 1015-9:1999	Methods of test for mortar for masonry. Determination of workable life and correction time of fresh mortar.
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BS EN 1015-3:1999	Methods of test for mortar for masonry. Determination of consistence of fresh mortar (by flow table).
BS EN 1015-1:1999	Methods of test for mortar for masonry. Determination of particle size distribution (by sieve analysis).
BS EN 1015-2:1999	Methods of test for mortar for masonry. Bulk sampling of mortars and preparation of test mortars.
BS EN 1015-4:1999	Methods of test for mortar for masonry. Determination of consistence of fresh mortar (by plunger penetration).
BS EN 1015-6:1999	Methods of test for mortar for masonry. Determination of bulk density of fresh mortar.
BS EN 1015-7:1999	Methods of test for mortar for masonry. Determination of air content of fresh mortar.
BS EN 1052-1:1999	Methods of test for masonry. Determination of compressive strength.
BS EN 1015-19:1999	Methods of test for mortar for masonry. Determination of water vapour permeability of hardened rendering and plastering mortars.
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BS EN 772-7:1998	Methods of test for masonry units. Determination of water absorption of clay masonry damp proof course units by boiling in water.
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BS 5080-1:1993	Structural fixings in concrete and masonry. Method of test for tensile loading.
BS 7456:1991	Code of practice for stabilization and thermal insulation of cavity walls (with masonry or concrete inner and outer leaves) by filling with polyurethane (PUR) foam systems.
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BS EN 14617-4:2012	Agglomerated stone. Test methods. Determination of the abrasion resistance.
BS EN 14617-5:2012	Agglomerated stone. Test methods. Determination of freeze and thaw resistance.

BS EN 14617-6:2012	Agglomerated stone. Test methods. Determination of thermal shock resistance.
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BS 8298-3:2010	Code of practice for the design and installation of natural stone cladding and lining. Stone-faced pre-cast concrete cladding systems.
BS EN 1998-3:2005	Eurocode 8. Design of structures for earthquake resistance. Assessment and retro-fitting of buildings.
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BS EN 14617-15:2005	Agglomerated stone. Test methods. Determination of compressive strength.
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BS 5977-1:1981	Lintels. Method for assessment of load.
BS 1199 and 1200:1976	Specifications for building sands from natural sources.

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Guide to Quality Management in Construction:

Site production & assembly

The aim of the Guide is to provide project stakeholders with a single point of information on construction quality management to improve construction quality by establishing best practice for the quality management process for site production and assembly.

The main focus is on how quality management is achieved during the site production process, including the requirements for ensuring quality is managed through the supply chain. A transformation and improvement challenge is needed to bring quality to the fore for the construction industry. Quality engineering should be an integral part of the construction industry. The focus is away from checking and remedying defects and towards defect prevention.

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Notes

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