**Digital Quality Management in Construction**

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**1. Introduction**

Managing the quality of design and construction has been a skill set for millennia, dating back to the earliest structures, when accepting and rejecting the quality of stone and timber based on deep experience, was vital for the successful building of a house, burial place or citadel. Over thousands of years, quality control knowledge and experience acquired, informed all levels of construction workers and ‘managers’ and was imbued into their training and supervision. That knowledge and experience was communicated in order to provide instruction, enable collaboration with others and ultimately build what was required.

As quality control steadily gave way to a more strategic approach through first quality assurance and then quality management, so the influence of quality professionals grew until around the turn of the 21st century when it seems that ‘quality’ was merely a fad to be shunted sideways to make way for six sigma, business improvement and business excellence. The fundamentals of managing the quality of the built environment are sound but need to be brought into the digital world.

**2. Quality Information Model**

The lifeblood of quality management processes is information. Without unique, accurate, timely, complete, accessible, valid and reliable information then these processes will fail to fully demonstrate performance i.e. that the as-built product conforms with the design specification and it is ‘fit for purpose’. The **right information** must be collated and supplied to the quality professional (and to all those colleagues who also need quality management information), at the **right time** to allow judgements to be made that empowers decision makers in business to act.

Digital Quality Management is fundamentally about ‘*facilitating the performance guarantee*’ of the built structure and is broken down into the four information management elements required for construction; people, processes, machines and materials (see *Figure 1.1*). We should enough conviction in our quality management principles, to state unequivocally that the outcomes of the built asset have a guarantee of performance. If we cannot facilitate such a guarantee, then what is the point of quality management in construction?



*Figure 1.1 – Quality Information Model*

The quality management profession in construction has typically fallen into a rut of assuming that quality audits, inspections, test reports, non-conformances and other random reports will magically supply the right information on whether the construction outputs are meeting the client requirements. Instead, the quality professional needs a business intelligence dashboard to show all real time information and data that has been summarised and prioritised within an information management process.

This raises the capability standard of quality professionals who need to understand the underlying principles of information management. This may not require specialist qualifications but does require a close working relationship with Information Technology (IT) and Information Systems (IS) professionals, to learn their jargon and firmly keep asking the ‘dumb’ questions’ to translate IT speak into business or quality speak. It also requires quality professionals to clearly map out their quality information requirements for both the wider business and specific projects. It still may not mean that the quality professional comes to the best decisions or makes the best recommendations (that depends on their capability and specific circumstances), but it increases the probability that they will provide better information to decision makers.

Information Management becomes a fundamental requirement in the duties of the quality professional. As digital information is not only collated but the collection process can be automated so the time needed to develop the collection process can be reduced.

Quality professionals have more time to analyse and drive continual improvement rather than engage in quality control and fire-fighting. That doesn’t mean the quality roles will be easier but rather they will require different skills. It is likely that this information analysis and continual improvement drive will add much more value to the business and allow measurable improvements to be reported.

There may be concerns that the quality professional will be stuck behind a desk poring over business intelligence dashboards all day but that should not happen. The quality professional will have more time to travel around, talk to colleagues, people in the supply chain, research best practices and propose initiatives that make a difference in the design office and construction site. Intelligent, smart information and better people skills will be the predominant capabilities in future.

Getting alongside designers, engineers, quantity surveyors, commercial managers, project managers will remove much of the quality control clipboard stigma surrounding audits. Likewise, it will demand relationship building skills to a higher standard to influence decision makers in the business and ensure that quality management tasks are embedded and understood within other business processes.

Examples of information that could be evidenced for each performance attribute is shown in *Table 1.1*. Ideally the information in the table will be priority scored but this may be challenging, as for example, pouring one concrete slab may be different from another slab (eg housebuilding to nuclear power plants). In this case, such scoring and prioritisation can still be undertaken for each component within each project management phase.

| *Table 1.1* - Evidence of conformance to performance attributes |
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| **Performance attribute** | **Details** | **Information required - examples** |
| **People capability - the extent of some’s ability to achieve an intended result** | Evidence of capability to undertake and supervise work | * Competency Assessments
* Appointment based on qualifications, training and experience
* CSCS Operator card
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| **Processes - a set of inter-related activities that use inputs to deliver an intended result** | Documented approach to how the work is carried out for end-to-end processes (not just procedures) | * Management Systems UKAS approved certification to ISO9001
* Process map for concrete pours
* Method statement on excavation and setting up the formwork
* Risk assessment
* Inspection & Test Plans and records
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| **Materials - physical matter and utilities needed to make a structure** | Standards of how materials are produced for safety, sustainable use etc | * Contract Specification
* British Standards certification
* CE Marking certificate
 |
| **Machines - construction plant, equipment, tools** | Evidence of maintenance from detailed inspections under PUWER down to daily check before use. | * Certificate of inspection
* HGV annual test eg mobile cranes & engineering plant
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The Quality Plan (or Design Quality Plan or other Project Quality Plan) should set out the contract specific quality requirements for the information management and there must be clear communications with H&S professionals over the contents of the Construction Phase Plan (CPP) and Environmental Management professionals over the Environmental Management Plan (EMP). It is best practice to co-ordinate all information requirements with the design team compiled into the BIM Execution Plan (BEP) to ensure that there aren’t quality management information gaps or duplicate information.

The information could be reviewed as part of a quality audit, but quality auditors tend to focus on just the process management and develop checklists and questions that take process documents such as procedures and assess them for conformance of completion of referenced records rather than any meaningful assessment of the content of the records. A green rated audit may be worth little if the technical side of the work is not understood by the audit team. A multiple discipline audit team, depending upon resources, will add greater value and use individual auditors who have full SHEQ multi-capability.

The challenge of relying on just audits is that they may not take place for some time. The audit schedule may be prepared in the December for the following year and although it can be adapted and changed, it is no more than a modest tool in assessing compliance. The evidence unearthed by a year of quality audits tend to be the ‘tip of the iceberg’ of what information has actually been recorded across the business.

Unless a business embraces a full Master Data Management (MDM) strategy, aligned to its business vision, then the naturally fragmented IT will fail to optimise the potential of information management. Traditional data and information were waste products from a final product or service. No one cared what happened to data unless the auditors came sniffing around and then it would need to be dusted off. In contrast, a data strategy places data at the prized heart of a business so that it is efficient to access, share and learn lessons. Agreed protocols means that everyone knows how to manage data in a standardised way. There is a single source of truth for each piece of data rather than multiple copies across the business. Which is the true version if there are multiple copies? Even with old fashioned version control imprinted on the bottom of documents these can be amended or mistakes can be made. The only way is to be certain is for the true data to be labelled and stored uniquely and then recalled or shared from a fixed location in a database.

Think about Netflix. Customers all access the same version of the film, Jaws and it comes from one source. It can be downloaded and viewed offline but it can’t be altered (unless perhaps by some tenacious and technological whizz kids but regardless they can’t upload the amended version back to Netflix).

For quality professionals, having copies of data scattered across different applications undermines the ability to interrogate and identify trends and patterns. Demands should be made to package quality management data in logical ways, so that audit report fields relate to benchmarking reports and inspection and test plans. If company names are tagged as ‘Business name’ in an audit report, ‘Organisation’ in an external benchmarking report and ‘Company’ in the ITP then the data user isn’t interested in excuses by application developers that such data isn’t relatable and the app developers conventions needs to be remembered by users to find the company in question. It is a failure of internal customer satisfaction to understand that a quality professional needs to assess the company performance across a range of data sources and IT needs to solve these challenges through a data strategy.

Digital Quality Management will create a framework for these records to be captured electronically in a database so that each piece of information on an electronic form is unique and cannot be amended without leaving a digital fingerprint. As an Inspection and Test Plan (ITP) for a concrete slab is completed online using a tablet rather than a printed form, drop down menus and refilled information such as project name, specification reference, pass/fail tolerances etc. invoke ‘poka yoke’ best practice by making it error proof, or at least reduce the risk of errors being entered onto the form.

As information is uploaded to a database so a picture is being created that should comply with rules and protocols. For example, a process map for pouring concrete will stipulate a rule that an ITP must be completed at a fixed stage in the process. Rules will check automatically that not only has an ITP been created but that the data and information within it complies with other rules. This allows real time reporting. Instead of it taking days, weeks or even years to discover a key piece of quality management information is missing or just plain wrong, it can be reported immediately or once other interdependent information is added to the database.

This standardisation of quality management starts to bring discipline and order to an otherwise chaotic world of paper forms being completed that may be inappropriate for the process being undertaken, with fields not fully completed or with data that has ‘10cm’ being written instead of ‘10mm’. A dumb PDF being scanned does little to improve the situation other than provide a back-up copy rather than just a single paper copy liable to misplacement, loss or damage.

By creating such rules once, they can be reapplied over and over to similar work activities with minimal amendments and from project to project. At the beginning it will take patience to identify each piece of quality management information required in an activity or process and then create the rules for checking. Mistakes will be made, information missed and results not perfect. But that logical approach is far better than the traditional quality assurance approach that fails miserably to provide unique, accurate, timely, complete, accessible, valid and reliable information.

In time, artificial intelligence and machine learning will be able to map out the rules for typical processes, understand interdependencies and even propose changes according to situations. That may still take a few years; not because it can’t be done but rather who will provide the investment in a notoriously conservative industry? As automation increases so the need for traditional quality audits will change from a slow, inefficient and ineffective process into one that can report in near real time.

The Quality Information Model is compatible with the 2015 edition of the international standard, ISO9001 - Quality Management Systems. Section 7.5 Documented Information sets out the requirements for information management to be in compliance with the standard, after replacing ‘documents’ and ‘records’ from the 2008 version. This requires an organisation to have a holistic view of information rather than simply seeing and thinking in a document-centric world, which is utterly out of date.

Hence, this book echos the 2015 edition’s importance of ‘information’ and highlights the need to think about it in quality management planning. Given the need for ISO 9001 to cover all industries and reflect a multitude of different business scenarios then it is hard to envisage this particular standard detailing how information management should be practically implemented for quality management in construction.

**3. Digital quality professionals in 2030**

Over time the document centric world of quality management will erode and almost vanish. Over the coming years, quality professionals need to prepare for the transformation of their duties towards an information-centric world. A side by side comparison of generic duties shown in *Table 1.2* (not specific to any particular quality role) between now and around 2030, shows the dramatic changes coming in quality management duties.

| *Table 1.2 - Typical Quality Management duties* |
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| **Responsibility** | **Current - document centric** | **Future - AI centric** |
| Quality Management System | QMS maintenance - Quality Manual, procedures, work instructions, forms, templates | Full Integrated Management System with 90% of quality management activities embedded into business processes (rather than stand alone) |
| Project Quality Plans production and maintenance based on traditional, generic template | PQPs will be built from the BIM model that highlights prioritised quality risks. |
| Auditing | Internal Quality Audits - preparation, audit and issue reports | Audits will be automated to review all digital information in accordance with contract/works information to report on BI dashboard on graded issues found in real time. Remote quality control inspections at suppliers and contractors using AR headsets to walk through premises to assess onsite issues/non-conformances |
| Training | Quality Management training - tool box talks, classroom courses | E-learning packages in quality management customised to individuals based on baseline capabilities when they are inducted. Any tool box talks or classroom live training will be through holograms and online interactive gamification presentations |
| Communications & awareness | Communications - Emailed Quality Alerts, newsletter contributions, Intranet articles and web page updates, Yammer updates | Standardised messaging will be linked to AI assessments of topical quality issues that automatically draft suggested communications. These will be reviewed, fine-tuned, approved and published by the quality professional. One message will be published instantly on multiple platforms. |
| Inspection & Testing | Inspection and Testing - plans production/approval, create/approve I&T records,  | Generic ITP’s for specific processes and materials will be tailored to each design package by AI and reviewed by quality manager.Equipment calibration data automatically streamed and assessed by AI and included in Daily Update.Laser scanning will replace most inspections of as-built vs design measurements. Videoing by robots and drones will replace witness and hold points.Material inspections and tests will be automated using sensors and results supplied in real time to a BI dashboard. |
| Equipment calibration - review and approve records |
| Materials - Review and approve material schedules, inspect and surveil site material deliveries and storage |
| Information Management | Document Control duties to ensure controlled documents follow version control rules. | Skills needed to add a quality management layer of information to BIM models and feed into BEP’s. Quality professional responsible for assessing the quality assurance of data flowing through processes. |
| Project reviews and approvals | Sub-contractor PQPs and method statements’ approvals as part of a process of project document approvals. | Automated process that ties completed work to payment through block chains. The quality professional may be one person in a chain (eg H&S, Env, business continuity etc) whose quality control approvals of work completed will collectively trigger payment. |
| Problem solving expertise | Creation of Handbook of Quality Tools such as 8D, 5S, FMEA, Pareto etc. | Comprehensive digital Quality Tool kit accessible through Knowledge Management system linked to IMS. Facilitating crowdsourcing using quality tools will assist with problem solving. |
| Continual Improvement | Non-Conformances register - create NCs, maintain NC register, analyse for root causes | Software will collate design clashes by type and severity. Defects and re-work will be reported online. BI dashboards will collate NC results, identify root causes and offer suggested corrective/preventive actions. |

Whilst there will still be a requirement for sound quality management technical knowledge; will it reside primarily with future quality professionals? Given the rapid developments in AI, much of the quality management technical knowledge may be subsumed into AI making it easier to access by other construction professionals. Whilst then the time spent on educating others on problem solving tools such as 8D, 5Whys, SPC and so on, may be reduced, it will free up time for other duties such as quality risk management, developing new process and performance metrics. Or we may find that there are opportunities for genuinely multi-skilled SHEQ professionals with the business assurance and improvement functions coming together.

It will depend on how much AI can automate and intelligently analyse and understand health and safety, environmental management and quality management. If much of the drudgery of the traditional quality professional role disappears then arguably the common SHEQ duties can open up a wider technical capacity for individuals to learn not only SHEQ but information security, business continuity and other risk management associated capabilities. Time will tell but quality professionals need to understand that no role in the future can avoid the impact of AI and it is better to shape that future than be swept aside by it.

**4. Quality knowledge management**

What have we learnt over the past few thousands of years about quality management in construction? The Great Pyramid of Giza’s architect, Hemiunu, the Acropolis’ Phidias, the Hagia Sophia’s engineer/architects Anthemius and Isidore, the Anji Bridge stonemason Li Chun to name but a few brilliant individuals that we know of, didn’t just design their creations and issue instructions they were fully fledged hands on construction managers who knew the materials, building techniques, the importance of accurate information and effective communication and the people skills needed to achieve the quality results they required. They would have walked the construction sites and known the men and women working there. They would have listened and learnt from the generational expertise gathered from the workers and slaves to further enhance their own construction understanding and enlisted them to help solve the day to day problems. They would instinctively have known what the client wanted from listening and knowing their patrons desires (and possibly an additional incentive of facing the client’s wrath if they got it wrong).

Quality control was an inherent and noble skill base essential to building. The knowledge acquired over many, many generations and passed on to young apprentices and trainees established tried and trusted methods of working to assess the quality of raw and manufactured materials and components. QC was even more important given the circumstances of the past. Identifying materials from local sources would save time and money and locating areas for quarrying, tree felling, smelting and building kilns and lime burners required labourers who had knowledge of identifying the best seams of sandstone or the right size oak to minimise wasting time on imperfect specimens. Stone masons in India, were adept at using a metal hammer for testing the sound of a stone for suitability in construction.

There has been a repeated synergy through all cultures of careful thought in creating a built environment in harmony with the built environment. The Hindu temple building was based upon the rules of the *Vastu Shastras* embracing the *prana* or universal life-force energy, captured in over 30 books written between 3000 BCE and 600 CE in Sanskrit. The I Ching book from Chinese Confucian culture has influenced Feng Shui, which seeks to bring humans and nature close together and creating a positive effect in living spaces. In the Japanese writing system if you take the pictogram (Kanji) for "house" and the pictogram for "garden," it gives you "home."

The ancient supervising material managers had to know how logistics for transporting and best methods for handling and storage of the materials. The issue is not that the ancient cultures had perfect management skills in construction materials since they no doubt also wasted materials and ordered inadequate types but rather we should notice that they developed an acute sense of the need for understanding the strength, texture, colour and durability of the material. We now need a better trained workforce and a higher level of practical quality management knowledge within project decision makers of construction businesses.

These material management skills fall into the discipline of what we call quality management and yet studies indicate that defective materials cost the industry between 5 and 10% of the production cost[[1]](#endnote-2). With construction contractor profit margins at an average 1.5%[[2]](#endnote-3), it does not take a genius to question why so little attention is paid to material management quality and the wider scourge of waste in time and processes. We need as a profession to re-develop our appreciation for material management and re-discover a passion for hunting out waste in all its forms.

To embed this quality knowledge, a business knowledge management (KM) strategy should embrace the requirements of quality professionals. As described in the seminal book, *The Knowledge-Creating Company* by Nonaka & Takeuchi[[3]](#endnote-4), knowledge is the basic unit for analysis, setting out the difference between explicit knowledge and tacit knowledge in organisations. The explicit knowledge is codified in written format such as manuals, specifications, reports designs and procedures. Tacit knowledge is what happens at the water cooler, when colleagues compare notes verbally, swap ideas and make suggestions. This exchange is not necessarily written down and yet it is crucial to any organisation in how it will succeed.

Tacit knowledge can be facilitated through Communities of Practice (CoP’s) and Experience (CoE’s) and should be set up to connect quality professionals with others in the same organisation and externally to facilitate an easier exchange of knowledge and wisdom.

CoP’s and CoE’s can be created by identified individuals with specialist quality management knowledge eg inspection and testing, management systems, data quality, document control, configuration management and laboratory materials testing with a brief summary added to a profile page on the business Intranet or using knowledge management software. Those leading subject matter experts should proactively set up meetings, presentations, lunch & learn sessions, webinars and other accessible opportunities to both spread knowledge and encourage question and answer sessions.

Quality knowledge can be codified so that it is easier for colleagues to find authoritative texts on key quality subjects. Again a specialist KM software can be utilised or an Intranet webpage with links out. Such signposting should also be comprehensively linked to the Integrated Management System so that there is a ‘one stop shop’ for users in understanding how to find information. Examples of authoritative texts may include: British and international standards (which may be found through links to specialist databases such as IHS[[4]](#endnote-5)), trade journal articles, construction case studies, online academic libraries, internal reports and strategies, CQI member resources and books. All such sources of information should be accessed within copyright laws and permissions sought, where required.

The Quality Knowledge Management system may need to be maintained and updated and this may become the responsibility of the quality professional but this is a great opportunity to keep in touch with innovations and latest editions of standards.

The quality professional needs to develop the capability to teach, coach and mentor others with the goal of improving their colleagues and supply chain stakeholders to become self-sufficient in quality knowledge. ‘Quality proofing’ the project is an important way of embedding knowledge into day to day decision making when the quality professional is not available and reduces errors and waste by uplifting quality capability across the business.

Self-learning and formal training to become an effective Trainer is an attribute of an effective quality professional. Skills to be developed should include classroom style training, developing e-learning packages, one-to-one coaching and mentoring and delivering stand up Quality Tool Box Talks (TBT’s) on site and presentations to busy executives. The more you practice, the better you become but these communications are a critical part to winning hearts and minds in the business and gaining supporters and champions who will back additional resourcing for quality management.

Imbuing quality management knowledge into the culture and values of the business is a huge task, especially if the business only currently pays lip service to a basic ISO 9001 certification. However, it is worth developing a Quality KM plan and identifying individuals who are quality enthusiasts to help infect and spread, a customer service mentality, as well as harder skills in management systems and quality tools. Next, sounding out the sceptics and even the critics of quality management, can be a useful way to influence their followers and subordinates. Listening to those hard core staff who may typically have been in the business for many years about their problems, especially with information quality and establishing ways to improve the processes that affect them most, can be an eye opener. However, it will lead to (grudging) acceptance and later, support of other quality management initiatives.

Getting to the cultural heart of a business takes boundless energy and perseverance but the value to the business will reap tangible and measurable rewards of lower costs, reduced time and better quality in the built environment. The message is; ‘don’t give up’ and ‘keep the faith’!

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**Endnotes**

1. Josephson, P.-E., (1998) *Defects and Defect Costs in Construction – A study of seven building projects in Sweden,* Working Paper, Department of Management of Construction and Facilities, Chalmers University of Technology. Retrieved from <http://publications.lib.chalmers.se/records/fulltext/201455/local_201455.pdf> [↑](#endnote-ref-2)
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4. IHS Markit. Retrieved from <http://www.ihsti.com> [↑](#endnote-ref-5)