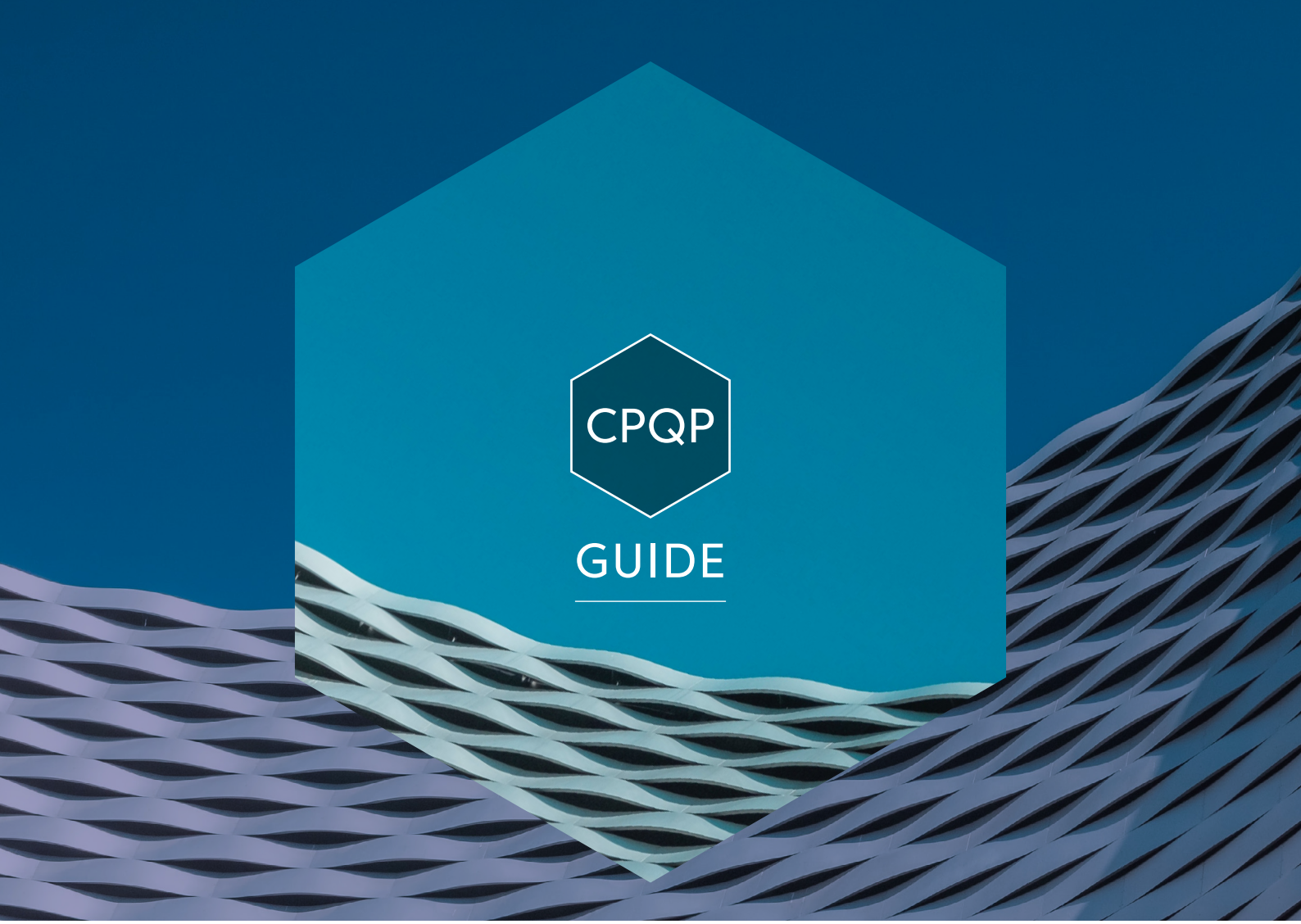

Construction Product Quality Planning Guide

Version 1.0

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CONSTRUCTION INNOVATION HUB

UK Research and Innovation

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Use of this Guide

The Construction Product Quality Planning (CPQP) process is a structured methodology aimed at supporting the development and introduction of new construction products. This CPQP guide is intended to aid the understanding of the CPQP process, providing the basic principles and describing the methodology.

It aims to provide enough knowledge to enable teams to complete the CPQP process, particularly where this subject is new to them. This document should be used in conjunction with the Construction Product Approval Process (CPAP) handbook and the nine supporting CPQP tools, published by the Construction Innovation Hub.

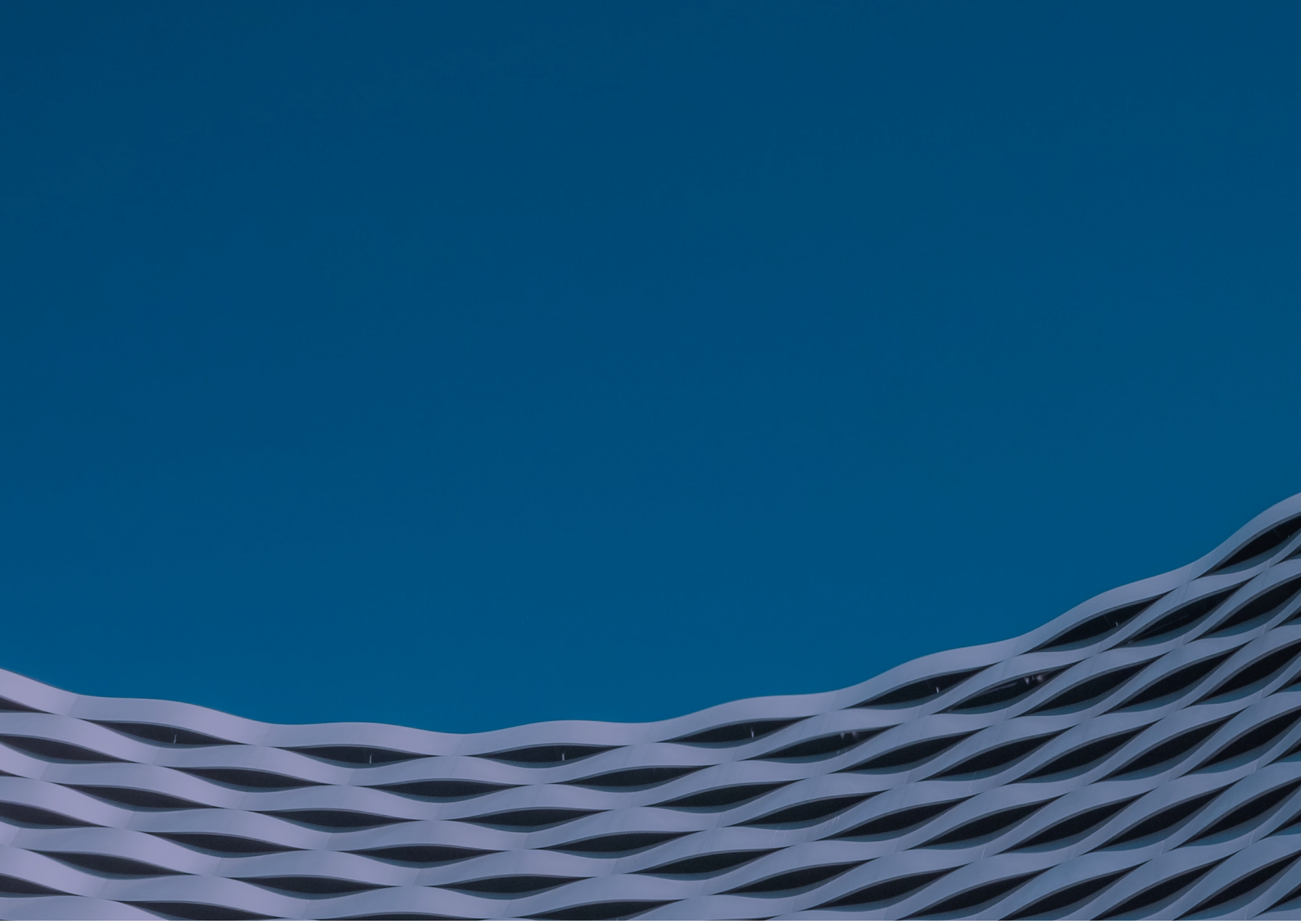
This guide is intended to aid the understanding of the CPQP process, providing the basic principles and describing the methodology. It aims to provide enough knowledge to enable teams to complete the CPQP process, particularly where this subject is new to them.

It is envisaged that over time companies will develop their own expertise, methods and standards through training and practice. The experience from early adopters will contribute to improve this guide so that it addresses the particularities of the construction industry.

The target audience for the CPQP Guide and its toolset are companies manufacturing offsite construction products, suppliers for those products and companies using offsite construction products in their projects.

Within this document there will be a blend of terminology from both the construction industry and the manufacturing industry; therefore it is recommended that readers and users of this guide familiarise themselves with the acronyms, abbreviations and glossary of terms provided within Appendix A and B.

For further information about the CPQP Guide and its toolset please contact: **cpqp@constructioninnovationhub.org.uk.**



Introduction

Background

Construction Product Quality Planning (CPQP) is a quality planning process aimed at those enterprises that design and manufacture construction products through manufacturing-led approaches. CPQP sits within a wider family of quality management tools and processes being developed as part of the Construction Innovation Hub's transformative programme. Together, these tools will help to deliver both quality and safe buildings by strengthening the oversight throughout the entire life cycle.

CPQP supports the New Product Introduction (NPI) process for the development and introduction of new products on the market through a structured process. The NPI process encompasses all new product development activities within an organisation ranging from product definition, through development to production launch.

CPQP is an adaptation of Advanced Product Quality Planning (APQP), which is employed throughout the manufacturing sector on a global scale to effectively 'build in' quality when developing new products. APQP ensures that quality is factored into the entire product development cycle, from concept design through to the full-scale implementation of a manufacturing strategy [1]. The APQP process is then validated through a Production Part Approval Process (PPAP). For the purpose of providing a standardised approach to APQP and PPAP for the construction sector, the Construction Innovation Hub has developed this guide and uses analogous terminology: Construction Product Quality Planning (CPQP) and Construction Production Approval Process (CPAP).

An important development seen in the growth of quality assurance has been the emergence and adoption of risk management. CPQP is a very good example of up-front planning and risk management tools used within product development and manufacturing processes. By using CPQP, products are de-risked which in turn will lead to de-risking the entire construction project.

In the construction industry, there is a new emphasis on the golden thread of information following the recommendations of the Hackitt Review. CPQP will ensure that clear and accurate records about product development, manufacturing and production monitoring are kept and made accessible, ensuring that information persists throughout the whole building life-cycle. Product information and design records will enable higher levels of control that go beyond simple traceability. Moreover, that information will also support the transformational change that digital technologies are bringing into the construction sector.

The Product Platform Rulebook enables clients who specify platform solutions and the consultants and contractors who design and install them, to create high quality, safe and better performing buildings. All these stakeholders will require assurance that the manufactured products used meet exacting quality, safety and performance criteria through a Construction Product Approval Process (CPAP). The CPQP process and the associated tools enable manufacturers to create products and solutions that meet this requirement.

Purpose

The main aim of CPQP is to increase product quality by emphasizing up-front planning and ensuring that parts and products conform to the fit, form, and function needed by the industry and uphold the quality standards that construction will require in order to get parts through productionised supply chains.

Achieving higher quality should not always lead to sacrifice speed or cost. Quality, Cost and Delivery (QCD) are closely tied together, as shown in Figure 1. CPQP aims to support companies in a highly competitive market in the development of high-quality and safe products that meet customer demands at the required cost and within the expected time.

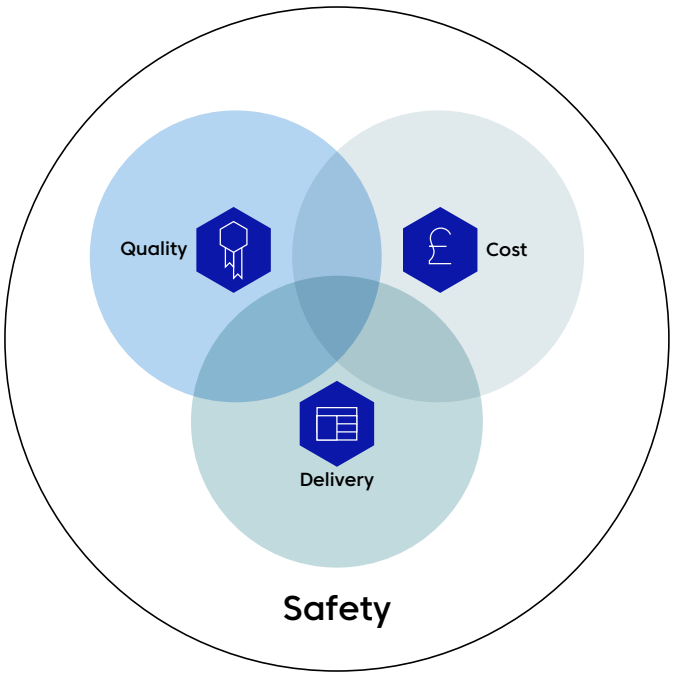


Figure 1. Quality, cost and delivery (QCD) goals

Benefits

The main benefit of CPQP is an industry-wide shift in focus from quality control and defect checking to quality assurance and defect prevention. CPQP, and the quality assurance toolset included within the methodology, applies continuous improvement at every phase of the product development cycle.

Several key areas for improvement in offsite construction have been identified, for example, design, standardisation for interfaces, connections, accuracies and tolerances, and documenting lessons learnt [2]. The implementation of CPQP within the construction sector for off-site and manufacturing-led approaches will contribute to:

- Drive towards 'zero defects' culture within the sector;
- Improve quality of products while also helping to address bottlenecks for the sector;
- Streamline the design and development processes;
- Promote a proactive approach that enables early identification of required changes;
- Enable organisations to easily communicate product quality planning requirements to manufacturers and suppliers;
- Foster the standardisation of products, interfaces, connections, accuracies and tolerances;
- Document lessons learnt in the different product development processes; and
- Improve quality management systems and tools already deployed in the organisations.

The Process

The CPQP process depicted in Figure 2 has been created to support the development of new construction products for manufacturing-led approaches. The process covers the entire product development cycle, from concept design through to product launch.

The CPQP guide defines the process and outlines the five phases to be completed. It details the required inputs, activities, outputs, deliverables and milestones for each phase. It also provides background into the tools to be used to achieve those deliverables and milestones, as well as a breakdown of the gated approval process that represents the transitions between the phases.

This CPQP guide should be used in conjunction with the CPAP handbook which provides a pathway to achieve a formal approval for the outputs of the CPQP activities. The CPAP handbook provides an overview of the roles and responsibilities in the supply chain to ensure that the flow of requirements and corresponding submissions defined in the CPQP process are maintained throughout the product development process.

Supporting guideline documents have been created for the main CPQP tools and should be used in conjunction with this guide. The guidelines include:

- Quality Function Deployment (QFD);
- Design for Manufacture and Assembly (DfMA);
- Design Failure Mode and Effects Analysis (DFMEA);
- Process Failure Mode and Effects Analysis (PFMEA);
- Process Flow;
- Control Plans;
- Measurement System Analysis (MSA);
- Process Control; and
- Eight Disciplines of Problem Solving (8D).

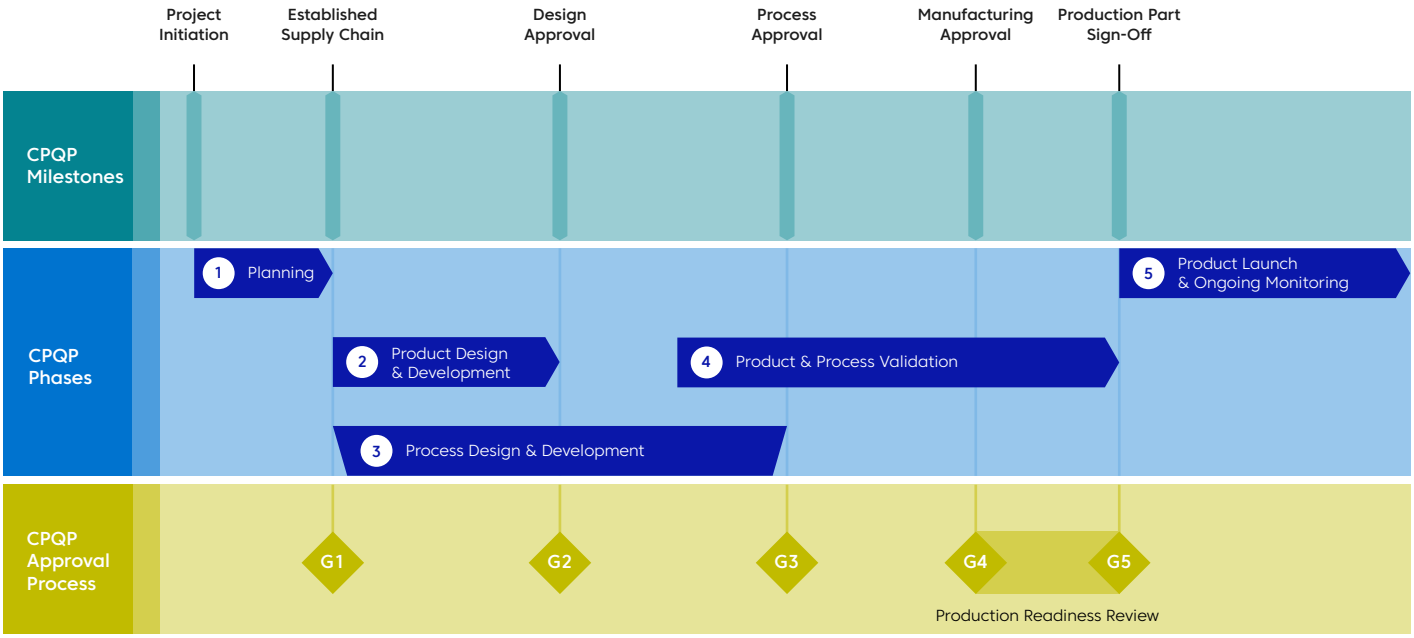


Figure 2. Construction Product Quality Planning Process

The feedback and problem-solving mechanisms provided within CPQP assist in identifying corrective and preventative actions as well as documenting lessons learnt. This ensures that new construction products, significant or critical to the overall build quality, are introduced through a standardised process and validated at the required production rate. Figure 3 illustrates the scope of the different tools of the CPQP toolset.

The Construction Innovation Hub is also developing the Quality Assurance Digital tool that will provide a single digital interface to a family of quality management tools and processes to support the uptake of manufacturing-led construction approaches. The tool will contribute to streamlining the implementation of CPQP and therefore build stakeholder confidence in the underlying advanced quality approach.

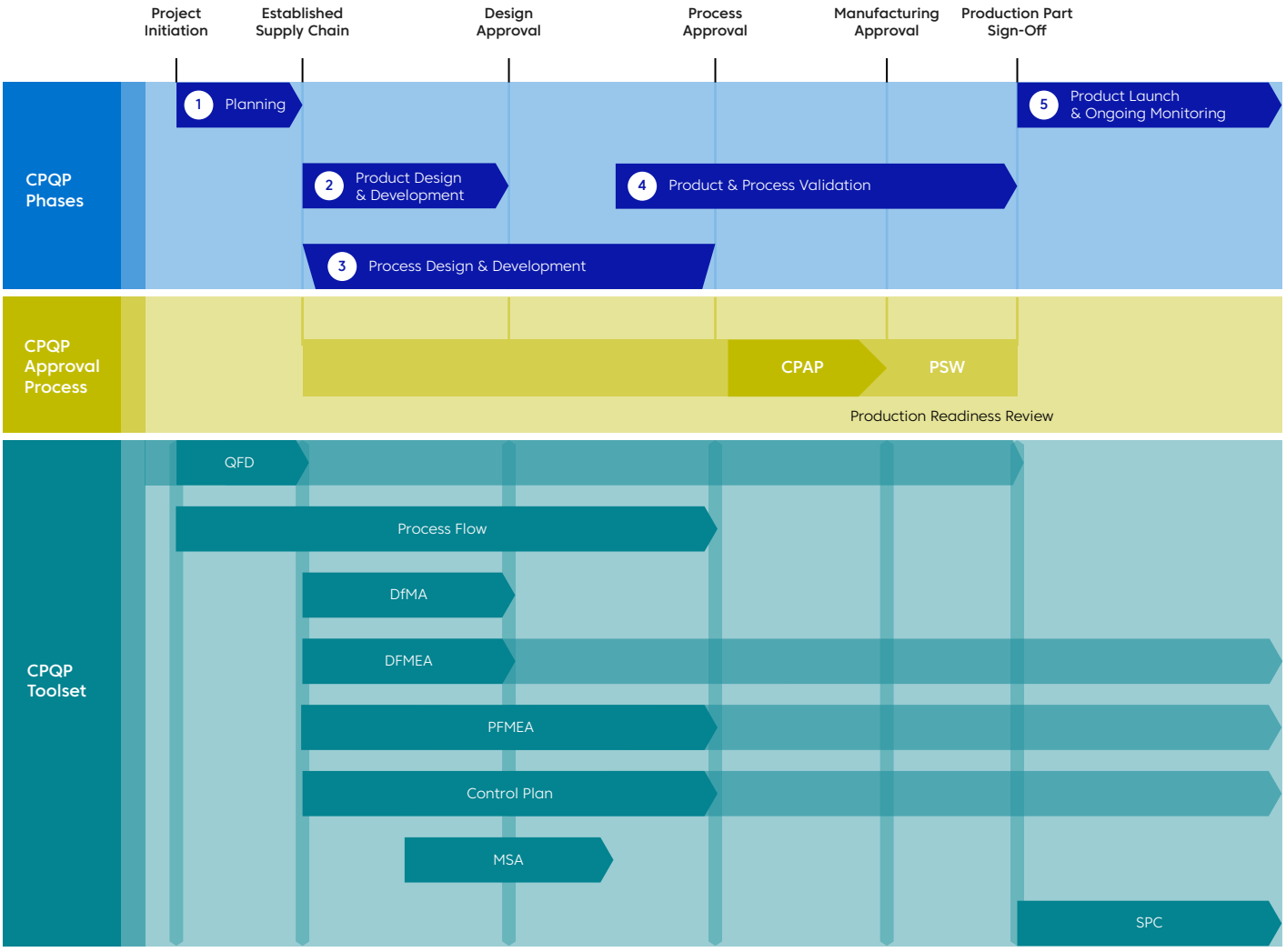


Figure 3. CPQP toolset

Fundamentals of CPQP

Fundamentals of CPQP

The Construction Product Quality Planning (CPQP) process is a structured methodology aimed at supporting the development and introduction of new construction products. The gateways ensure quality is factored into the entire product development cycle, from concept design through to the full-scale implementation of a manufacturing strategy. The CPQP aims at delivering new products on time, at the right cost and at the highest level of quality.

CPQP supports the New Product Introduction (NPI) journey. The proposed methodology is based on the following considerations:

- The CPQP process covers the entire product development cycle from planning and concept design through to product launch;
- CPQP applies to construction products being manufactured and delivered at scale (large production volumes) using manufacturing-led construction approaches such as offsite, Modern Methods of Construction (MMC), platform and DfMA approaches;
- CPQP is applicable to products which are critical or significant to the fit, form or function and overall quality of the building asset (see 'Product Classification and Applicability' section for more details);
- CPQP does not directly cover any site-based assembly processes but it ensures designers and manufacturers consider the final assembly of the design solution, error proofing the assembly and define Key Characteristics (KCs) which could be critical to 'fit, form or function'. For the CPQP process to be successful and complete, an indication of successful installation of the first production batch is required from the onsite construction team or through validation on a relevant operational environment;
- Any specific quality assurance and quality management processes applying to onsite assembly and installation activities, transportation, logistics and storage are out of scope of the current CPQP document. These topics are addressed as part of the overarching quality assurance framework for off-site construction in development by the Hub;
- The CPQP team focuses on monitoring the product quality rather than the built asset quality or whole life performance of different projects using the same product. Any further ongoing monitoring is limited to the factory environment and the production process. However, any rejects from customer site are dealt with a thorough problem solving and root cause analysis process; and
- CPQP promotes continuous improvement and any issues or feedback encountered throughout the product lifecycle are referred to the production team.

The Five Phases

The Construction Product Quality Planning (CPQP) process consists of five phases with five key milestones referred to as gates, as illustrated in Figure 4. These phases and gates ensure that quality is 'built-in' to the manufacturing process and final product.

The five phases of the CPQP process are:

1. **Planning:** CPQP Phase 1 refers to building the Voice of Customer (VoC) into easy-to-interpret requirements and using the Voice of the Organisation to establish deliverables and a feasible concept. Organisations should set their high-level Key Performance Indicators (KPIs) and targets during this phase. Another key task in the planning phase is to understand and capture any relevant regulations. At this point, the initial procurement route shall be established;

2. **Product Design and Development**: CPQP Phase 2 ensures that the product, as designed, is verified and validated against the requirements laid out in the planning phase. Design validation at this phase typically takes the form of prototype testing (not necessarily following a fully productionised process), to ensure that it meets customer requirements;

3. **Process Design and Development:** CPQP Phase 3 is a key step in the manufacturing supply chain and runs concurrent with both product design and overall validation. The aim of this phase is to establish a manufacturing process that can consistently produce conforming product at the customer demand rate;

4. **Product and Process Validation:** CPQP Phase 4 validates the product quality and manufacturing process at a productionised demand rate. The key differentiator being that product quality shall be met in a full production environment. In the construction industry, Phase 4 will provide a clear path for all production validation activities; and

5. **Production Launch and Ongoing Monitoring:** CPQP Phase 5 hands over the New Product Introduction (NPI) project from the CPQP team to the Production Operations team and ramps up to full volumes. Ongoing monitoring ensures that the verified and validated production process remains in control.

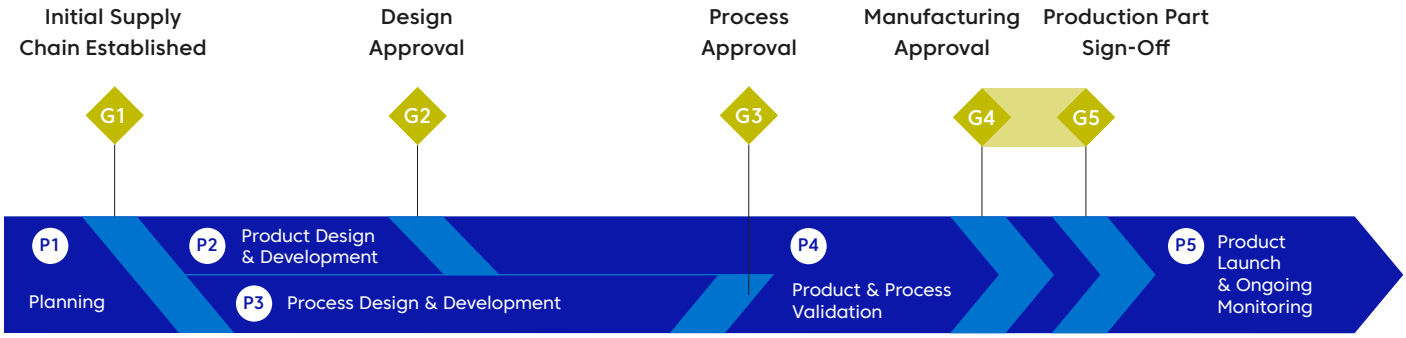


Figure 4. CPQP Process Overview

Team Approach

CPQP requires a team approach utilising all functions of the construction industry. A cross-functional CPQP team must be formed as early as possible so that all functions and disciplines can input into the planning and design phases. This will ensure that valuable input is received early in the process and that a 'Simultaneous Engineering' approach applies.

A multi-disciplined approach will allow a broader set of views and skills to contribute to the success of the product development process. This approach ensures a balance between competing project demands rather than individual disciplines pushing forward with a narrow focus. The team should include representatives from different disciplines such as engineering, design, quality, marketing, purchasing, sales, as well as representatives from suppliers, installers, and customers. The aim is for team representatives to showcase their experience and knowledge in their respective fields to be able to identify risks and offer resolutions.

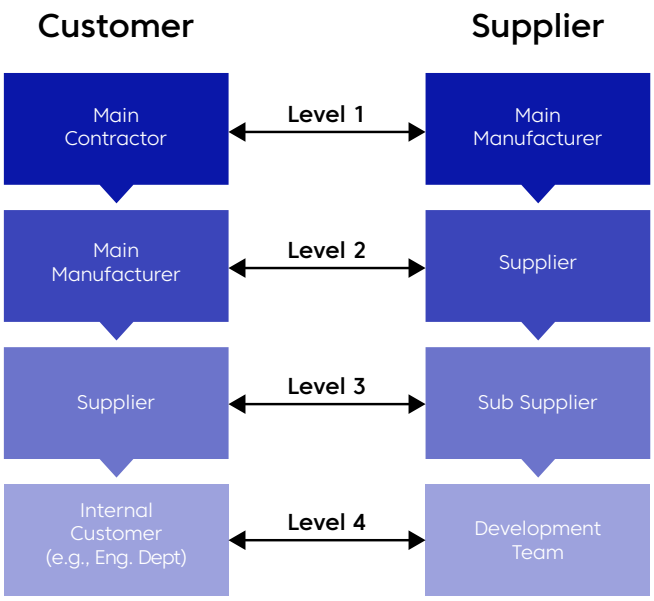


Figure 5. Customer-supplier relationships

Given the different nature of the CPQP activities and phases as well as the specific expertise required to complete them, the composition CPQP team is likely to vary during the process. This will allow representatives from relevant areas to participate and contribute when their expertise is more valuable. However, there should be always an accountable person assigned from the customer and the supplier organisations to ensure successful implementation of the process.

Customer and Supplier Relationships

The CPQP approach should be adopted in collaboration with both internal or external customers and suppliers. In the context of this CPQP guide, the customer is the organisation or department (in the case of internal customers) that leads the implementation of the CPQP process and therefore responsible for the overall quality aspects of the project. The customer defines the initial requirements and signs off the outputs at the end of each phase. Therefore, depending on the product delivery strategy, the customer could sit within an organisation representing the client (e.g. main contractors, contract management organisations, etc) or an internal representative acting as product owner for internal product development processes.

The supplier or manufacturer is the organisation that manufactures and delivers the actual product to meet the customer requirements. The manufacturer shall engage with its supply chain and ask the major suppliers to follow the CPQP process to ensure quality planning of their products.

Figure 5 illustrates different potential customer-supplier relationship levels that can further clarify the scope of this guide. The customer-supplier levels may extend beyond the four illustrated levels to consider the different sub-tier suppliers.

Client Representative (CRe) and Product Approval Coordinator (PAC)

The CPAP handbook provides further details on the key roles, and the general approval process. The CPQP activities require the outline of at least two main roles within the organisations, namely Client Representative (CRe) and Product Approval Coordinator (PAC).

Client Representative (CRe)

The CRe is the responsible and accountable person for monitoring the overall progress associated with the CPQP process and the submission of the CPAP. This role sits within the organisation that is responsible for the overall quality requirements of the project, i.e., is accountable to the client. The CRe provides the final sign-off to approve the supply chain as production ready for the project or future projects.

The CRe ensures that the CPQP Project Plan has been kicked off and the supply chain is on track to complete the CPQP process. It would also be the CRe's responsibility to ensure that any risks encountered by the cross-functional project team are alleviated or mitigated.

The CRe also ensures that the delivery of the CPQP milestones and gates are as per the original plan and proactively communicates any bottlenecks to the client. If any design, manufacturing or validation issues are encountered during the later phases of CPQP, the CRe would ensure that the relevant technical authorities are involved in additional risk analysis.

Product Approval Co-ordinator (PAC)

The Product Approval Co-ordinator (PAC) is responsible for coordinating the delivery of the CPQP activities and the submission of the CPAP pack. The PAC is a role defined for a competent person within the organisation to ensure the communication and completion of the different CPQP activities.

The CRe sets out the initial requirements for the different CPQP elements and customer specific requirements. It is then the responsibility of the PAC to flow down the relevant requirements internally to the designers, manufacturers and sub-tier suppliers.

Simultaneous Engineering

The use of the phased approach supports Simultaneous Engineering principles. Tasks traditionally carried out in sequence by separate teams are now carried out simultaneously by cross-functional teams. The phases therefore overlap, are iterative and are carried out simultaneously. The team works across the whole product development project rather than on individual specialisms or parts of the project timeline.

When results from tasks become available, they can become inputs to other phases and the CPQP team should not necessarily wait for a gate sign off. This should expedite the tasks of the product development project, and help identify risks and issues early.

It should be noted that the timeframe for completing the entire CPQP process or individual phases is mainly dependent upon the complexity of the product, the detail of the client requirements, and the experience of the development team. However, the adoption of the CPQP process is not expected to significantly increase the product development time when compared to other adopted approaches. It certainly requires up-front planning and an early effort that however would offset the time and cost associated with resolving issues and addressing quality defects later in the development and production processes.

Product Classification and Applicability

A construction product is defined as "any product or kit which is produced and placed on the market for incorporation in a permanent manner in construction works or parts thereof and the performance of which has an effect on the performance of the construction works with respect to the basic requirements for construction works" [3]. Products can be defined as assemblies, sub-assemblies and individual components where assemblies and sub-assemblies are systems of products and components; see Table 1 for further details.

CPQP adopts a risk-based methodology to classify features and products. This approach ensures that appropriate quality tools can be deployed as a part of the CPQP process when the identified product risks are higher than acceptable.

The CPQP team shall identify and classify the product into one of three categories as defined below:

Critical: Products with features that if non-conforming could result in loss of primary function of the product resulting in catastrophic or hazardous failures without any warning. These are failures that could potentially lead to loss of lives and/or irreparable damage. Products with any critical features are automatically classified as critical products. This could be the case for instance of loadbearing elements such as the structural frame, or products with features that could lead to hazardous situations such as facades systems, heating systems, fire doors, etc.

Significant: Products with features that if non-conforming could result in loss of primary function of the product resulting in major failures. These are failures that cause significant disruption and costs to the client. Products with any significant features and no critical features are classified as significant products. This category could include products such as lifts, roof systems, building management systems, prefabricated pods, etc.

Unclassified: Products with features that if non-conforming could result in loss of a functionality that causes only minor disruption to the end user of the building. These are failures that can be repaired with relative ease and cause only minor disruptions for example, a lift switch, window panels and standard building products. Products with all unclassified features are unclassified products.

CPQP is applicable to products which are critical or significant to the fit, form or function and overall quality of the building asset. **CPQP does not apply to products that are unclassified** and, therefore, any unclassified Commercial Off-The-Shelf (COTS) material or unclassified product is not part of this process.

Some examples of unclassified materials and products include standard building and commodity products such that if they were to fail in service, they would only result in minor failures and may be replaced with relative ease. These may be products that are widely available from multiple manufactures, manufactured to known industry standards and supplied in volume (e.g. paint, adhesive, sheet material, standard systems and

Product Type	Definition	Example
Assemblies	Large systems that will be manufactured off-site and supplied and fitted as units making-up the building onsite.	3D Volumetric Modules Kitchen/bathroom pods Roof plant stillages
Sub-Assemblies	Sub systems that will be manufactured off-site and either fitted to assembles off-site (in a factory) or fitted into assemblies onsite.	2D panel systems Lighting rafts MEP systems
Components	Single components manufactured off-site that are fitted into assemblies or sub-assemblies off-site or fitted as part of the building on-site.	Columns and beams Doors Connectors

Table 1. Product Type Breakdown

other products such as electrical fittings and window/door frames).

However, assemblies and sub-assemblies incorporating unclassified materials or products can be classified as critical and significant depending on the risk and the impact that the failure can have on the overall system (e.g., standard doors and window systems part of volumetric modules).

Further details for the risk-based classification and the risk analysis can be found in the Design Failure Mode and Effects Analysis (DFMEA) guideline.

CPQP applies not only for the introduction of new construction products but also when changes in the product design, the manufacturing process or the supply chain increase the risk of delivering non-conformance products. Table 2 details the different scenarios where the CPQP is applicable.

Applicable	Non Applicable
The introduction of significant and critical products on new or existing projects.	The introduction of unclassified products.
Re-introduction of an outdated significant or critical product with no continuity of supply for more than 2 years.	Purchase of unclassified COTS products.
Change to the production process for an existing significant or critical product (only certain elements of CPQP apply).	Products purchased only for supporting the construction process but those that will not be included in the final built asset.
A modification to an existing significant or critical product being procured through the same supplier (only certain elements of CPQP apply).	Modification considered low risk by CRe or customer.
Change of supply source, change of facility within existing source or change to production process (only certain elements of CPQP apply).	Only volume ramp up within existing source without any change to the production process. (In this instance, a simple load and capacity report should be sufficient).

Table 2. CPQP Applicability Matrix

CPQP Approval Process

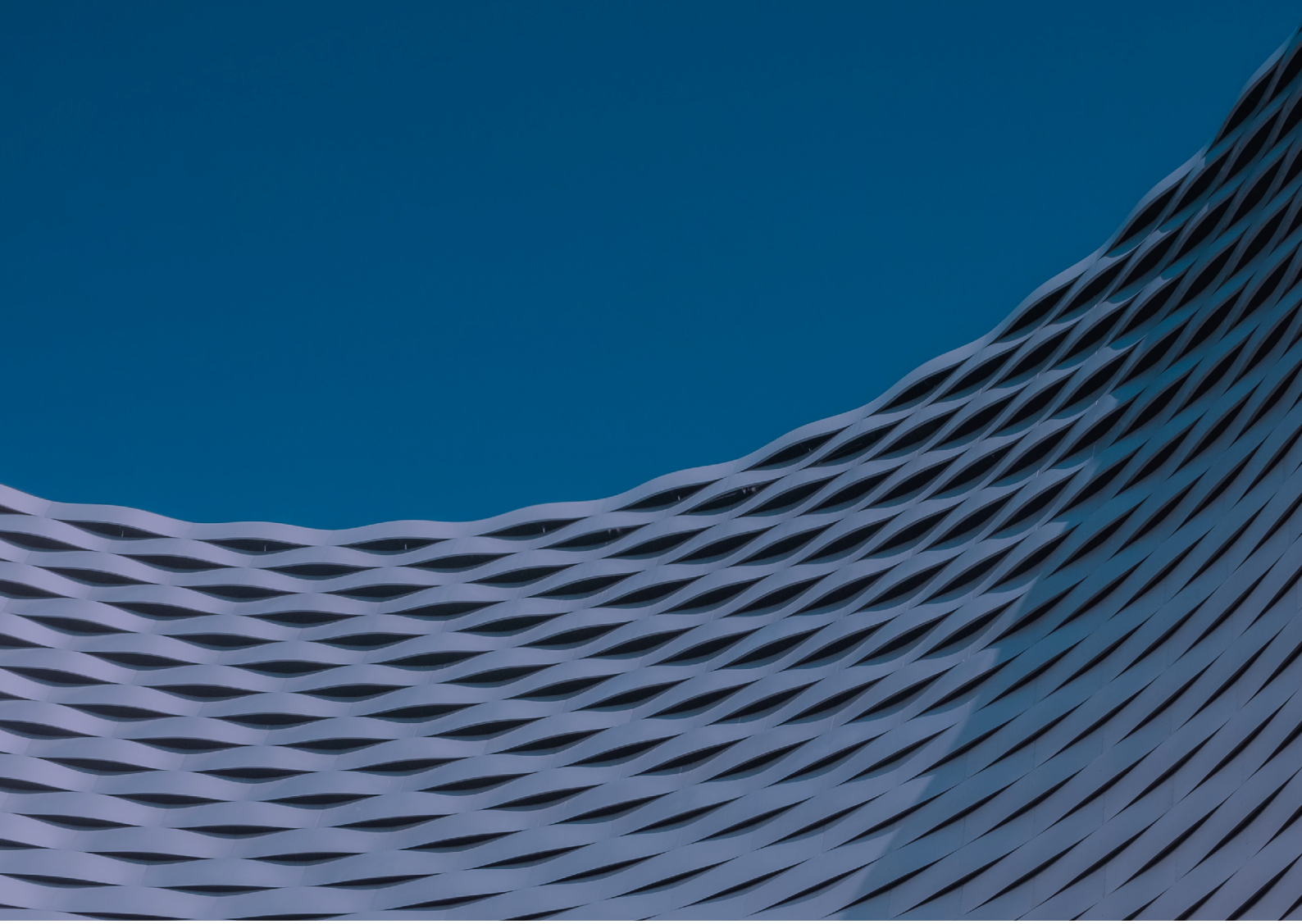
The approval process for the CPQP is discussed in detail in the CPAP handbook and the reader should refer to it for specific guidance. An overview of the process is described in this section.

Each phase of the CPQP process is subjected to a gate review. This ensures that the CPQP process is controlled, its objectives are met, and issues are resolved as early as possible. At each gate, the deliverables of the phase must comply to satisfactory level. If not, actions must be taken to resolve issues before the CPQP process can progress. The aim of the gate reviews is to detect and solve issues proactively to prevent them from being carried forward. This will avoid incurring additional expenses at later stages.

The gate review is an internal review by the CPQP team and the appropriate internal stakeholders and authorisers (e.g. senior managers, project managers). Regular reviews with both the customer and suppliers should also take place and as part of the CPAP process the CPQP checklist should be completed. The CPQP Checklist tracks the progress and completion of the CPQP deliverables and it documents the progress of the approval process. A template for the CPQP checklist can be found in the CPAP handbook.

CPQP is a process for a cross-functional project team (the CPQP team) to follow up with their customer or CRe. The CPQP process should be led and initiated by the customer (or CRe) and should engage the entire development team from designers and manufactures to suppliers. The 'product' is approved by the 'customer' or a Client Representative (CRe) at the end of the Product and Process Validation Phase and the Part Submission Warrant (PSW) is sign-off. This confirms that the product can be produced according to the requirements of the customer and that the process is capable of delivering the product consistently at the required rate.

The manufacturer should initiate the CPQP activity with their supply chain as applicable (i.e. if it will receive a critical or significant product from their sub-tier suppliers for the new product they are developing). The manufacturer shall flow down the customer's requirements and will be accountable for the sub-tier supplier's CPQP process.



Phase 1. Planning

Phase 1. Planning

The first phase of CPQP, as highlighted in Figure 6, is concerned with capturing customer requirements and translating them into a planned quality program with defined objectives for the product and NPI project. Inputs to this stage will come from the customer, the CPQP team's experience, available data on similar past or existing products and previous lessons learnt. The timeline and key milestones set against customer expectations should be identified at an early stage and defined in a plan.

An initial step of the quality planning is to ensure that customer needs and expectations are understood. The Voice of Customer (VoC) must be translated into easy-to-interpret design requirements, considering the Voice of the Organisation as well. A key task in the planning phase is also to understand and capture any relevant regulations that are necessary in addition to the customer requirements. The Product Design Requirements (PDR) document is derived from these and other inputs. The Quality Function Deployment (QFD) tool provides a structured method to capture the VoC and as part of the CPQP toolset a separate guideline is available for the usage of this tool.

The product concept shall also be developed within the PDR with a high-level Product Breakdown Structure (PBS) showing how top-level systems, sub systems and components are defined and structured. This shall be turned into a preliminary Bill of Materials (BOM) against which manufacturing solutions, suppliers and the supply chain can be identified. This would include defining the preliminary process flow, reviewing manufacturing, processing technologies as well as the evaluation and selection of suppliers. These initial product requirements will mature into a complete product design in Phase 2.

The CPQP team should at this phase discuss the information management and exchange strategy and align it with the requirements set up in the BS EN ISO 19650 to facilitate the adoption of the Building Information Modelling (BIM) methodology for buildings and civil engineering works. The team should also ensure that the initial supply chain has the capability and capacity to deliver the documentation for the final CPAP submission.

When the CPQP process is implemented to deliver products and assemblies for construction projects adopting BIM, the CPQP team should at this stage tie in with the Exchange Information Requirements (EIR) document and align the required CPQP documents for inclusion in the Common Data Environment (CDE).

The benefit of completing the Planning stage is to ensure that the customer needs and expectations are captured. Once captured and understood the CPQP team is able to plan out the new product introduction project and establish the Supply Chain.

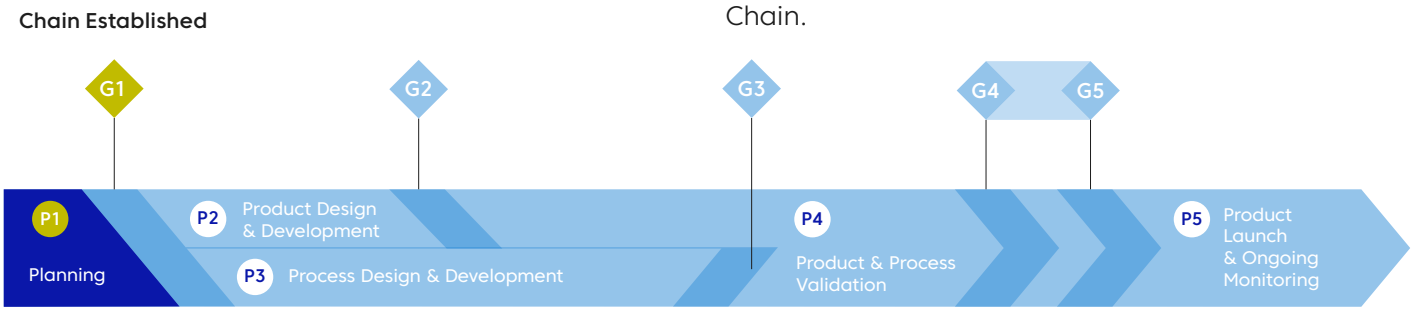


Figure 6: CPQP Phase 1 Overview

1.1 Activities and Deliverables

The activities and deliverables required for CPQP Phase 1 are outlined in Table 3.

Inputs	Process/Activities	Outputs/Deliverables
• VoC including Market Research, Historical Warranty and Quality data. • Previous and or similar product Performance data. • Lessons learnt on previous products and projects. • Benchmark data for products and process. • Product and Process Assumptions. • Customer Inputs (on above) with their needs, wants, expectations and timings. • Current supply chain and known suppliers – performance, technologies and capability. • Internal manufacturing capability and performance.	• Define the timeline and key milestones with the customer. • Collect all product and project information and define associated targets (i.e. tolerance and specification limits, interfaces). • Develop the product breakdown structure (i.e., high-level BOM) to support source selection. • Review the supply chain, both current and future, for potential suppliers. • Review manufacturing capability and technologies.	• D1.1 Product Development - Project Plan. • D1.2 PDR. • D1.3 Preliminary Bill of Materials. • D1.4 Preliminary Sourcing Plan. • D1.5 Preliminary Process Flow Diagram. • D1.6 Preliminary Critical Items (CIs) and Key Characteristics (KCs).
Key Milestones		
M1 Program established. **M2 Finalised product concept with pre-design available.**		
Gateway		
G1 Initial supply chain established.		

Table 3. CPQP Phase 1 Activities and Deliverables

D1.1 – Product development - Project Plan

The CPQP Project team shall identify a project timing plan at the outset of the product development project to show how the product will be developed. The timing should cover the 5 Phases of CPQP from initial concept to production. The timing should include product development, delivery to site, supplying the building projects and any ongoing manufacture. The plan needs to be aligned to the customer timing plan and milestones while taking into account their needs and expectations. The plan should show:

- Customer milestones;
- CPQP milestones (5 phases and gates);
- Tasks with start and end dates, responsibilities and assigned resources;
- Tasks that are linked and dependant on each other;
- Critical path; and
- Deliverables.

The plan shall be signed off by all those involved including the customer and communicated to the supply base. It should be used during the product development project to track progress and report against predefined KPIs.

D1.2 – Product Design Requirements

The CPQP team shall establish a set of PDR, translated from the customer wants, expectations, requirements and Design Goals for the building asset into a measurable set of Engineering and Quality targets for the product. The design specification should consider among other aspects:

- Safety;
- Quality;
- Maintainability and servicing;
- Aesthetics;
- User experience requirements;
- Reliability;
- Durability;
- Target costs (Ex Works);
- Whole life costs;
- Environmental outcomes and Sustainability;
- Re-use and recyclability;
- Assembly error proofing for onsite assembly;
- Interfaces and system requirements; and
- Time to assemble Validation Criteria.

Figure 7 illustrates main inputs and the information flow for the development of the PDR. During the development of the PDR, an initial set of process and product assumptions are created. The product and process assumptions are based on the analysis of customer needs and expectations and a preliminary list is developed from customer meetings, surveys, market research, and the identification of key process characteristics from the anticipated manufacturing process. The team should use among others:

- Voice of the Customer (VoC);
- Market research;
- Benchmarking data (e.g. costs, construction time, production capability;
- Past performance data of similar products and building;
- Competitor product analysis; and
- Appropriate engineering and or construction standards, legislation, and regulations.

The PDR outlines the initial design concept and likely manufacturing processes and set the high-level KPIs. Targets and requirements should be stated such that they can be measured and verified if they have been achieved.

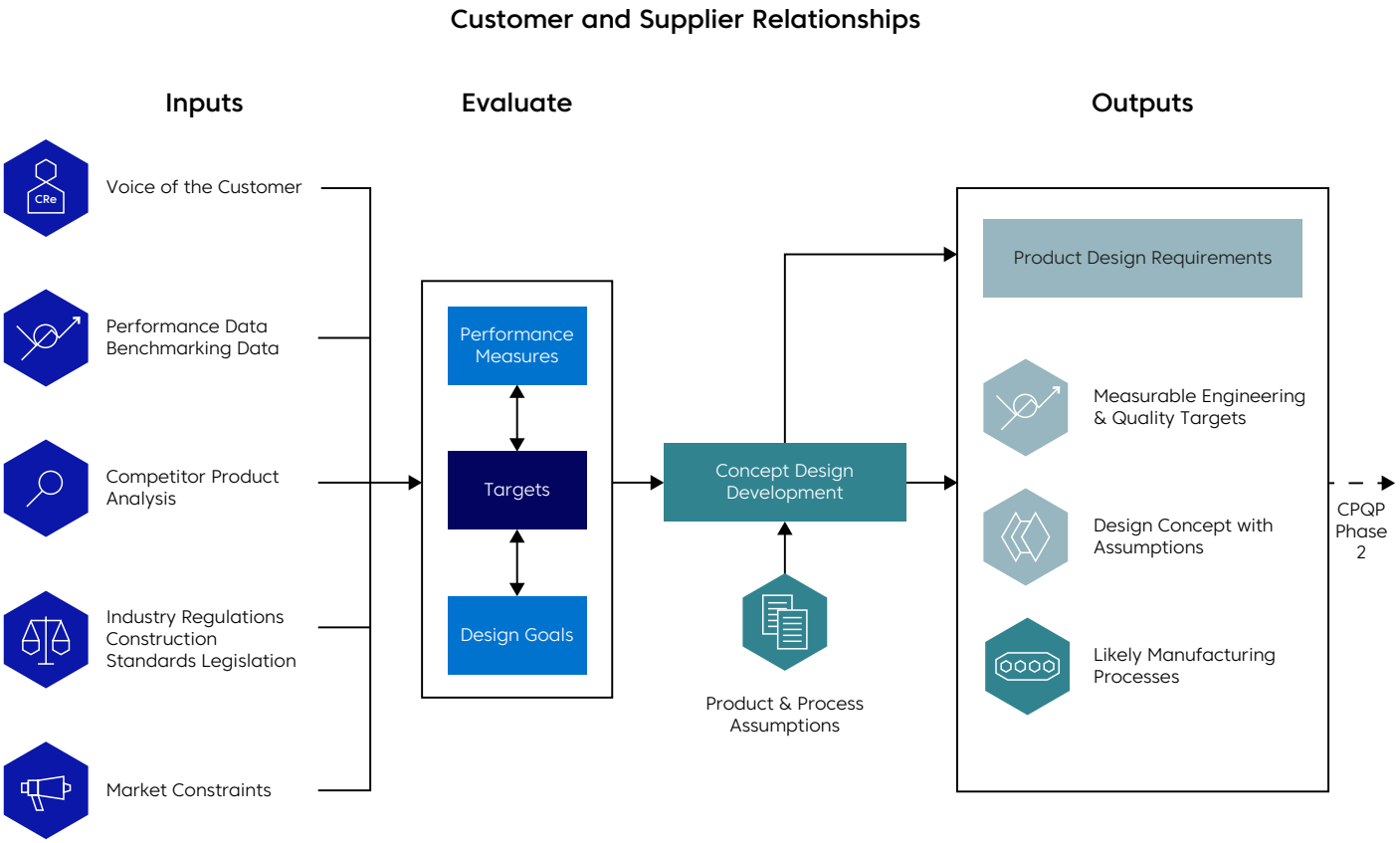


Figure 7. Product Requirements Development Information Flow

D1.3 – Preliminary Bill of Materials

Based on a product breakdown structure, initial process and product assumptions, the CPQP team shall create a structured preliminary BOM for the manufactured product. This should be broken down in a hierarchy from system level into assemblies, sub-assemblies, components, materials and consumable items with quantities and usage figures assigned when possible.

While considering the BOM, the team should classify each level of product in the PBS as significant, critical or unclassified. This will help the CPQP team identify where CPQP and CPAP need to be applied along its supply chain.

D1.4 – Preliminary Sourcing Plan

Driven from the preliminary BOM and based on past and current product history, existing manufacturing, supplier agreements and relationships, the team shall identify an initial list of suppliers for each of the product items in the PBS. This will include make vs. buy decisions (identifying if the product will be outsourced or manufacturing internally).

D1.5 – Preliminary Process Flow Diagram

A preliminary process flow diagram shall be created by the CPQP team showing and describing the intended manufacturing steps and sequence for the product. This shall be based on the preliminary BOM and the initial process and product assumptions. The Process Flow Diagram is expected to be developed in Phase 3, however a preliminary discussion of the potential process flow will provide insights during the planning phase to identify barriers or constrains to address early in the process.

D1.6 – Preliminary Critical Items and Key Characteristics

An initial list of KCs for both product and processes as well as CIs within the preliminary BOM shall be identified by the CPQP team. These should be identified using the customer and CPQP team knowledge and experience. Inputs to the development of the list could come from:

- The customer;
- Product assumptions and initial design derived from the customer needs and expectations;
- Identification of reliability, durability, maintainability, whole-life costs goals and requirements;
- Past and similar products;
- Past and similar buildings, projects and performance data;
- Existing Failure Mode and Effects Analysis (FMEA); and
- Preliminary process flow diagram.

1.2 Gate 1 – Established Supply Chain

At the conclusion of Phase 1 a gate review shall be held. During this review the deliverables and milestones achieved throughout the phase shall be approved. All actions needed to transition to the next phase should be initiated.

Milestones

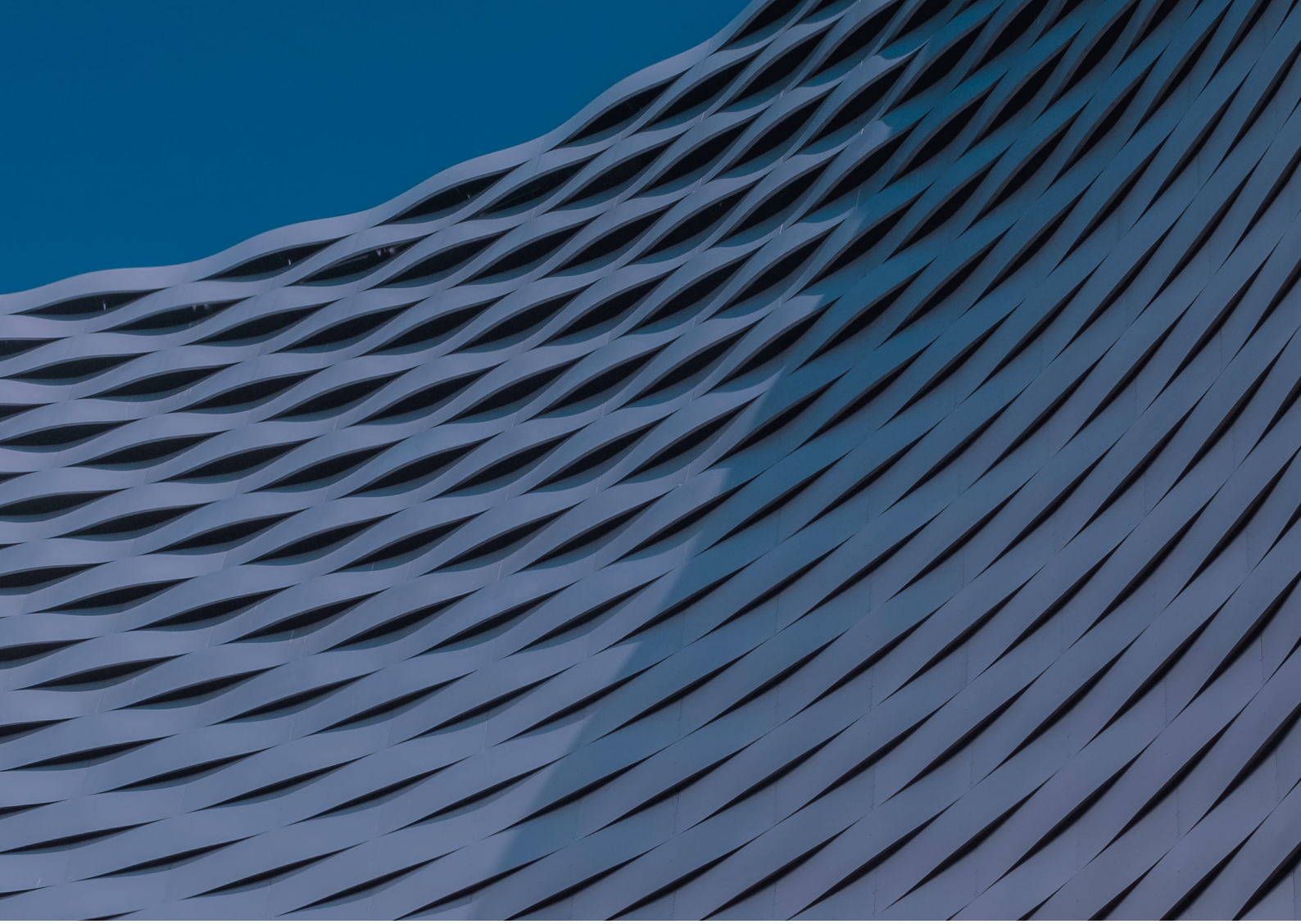
- The quality program has been established; ensure a plan is in place for product development and *Quality, Cost and Delivery (QCD)* targets are set;
- An initial design concept is clear, and the design requirements have been captured, understood and translated in to engineering and quality requirements and targets; and
- The initial supply chain has been established.

Elements and Actions

The elements and actions required for Gate 1 are outline in Table 4.

CPQP Element	Action	Sign Off Criteria
Product Development - Project Plan	 SIGN OFF	• The plan is up to date with key milestones aligned to the customer milestones. • All tasks are defined with start and end dates, ownership has been assigned and the plan is resourced. • The team has put in place a method of reviewing progress and dealing with issues.
Product Design Requirements (PDR)	 SIGN OFF	• The PDR has been completed. It is up to date and represents the design requirements. • The PDR Checklist has been completed with no outstanding issues.
Bill of Materials (BOM)	 KICK OFF	• The preliminary BOM has been raised based on the PDR, assumptions and likely design. • The major systems, assemblies, sub-assemblies and components are identified with initial quantities. • Significant/critical products set in a hierarchy with initial quantities.
Preliminary Sourcing Plan	 SIGN OFF	• The main potential suppliers for the components in the BOM have been identified. • Make vs. buy decisions have been made.
Process Flow Chart	 KICK OFF	• An initial top-level process flow has been raised showing major steps from end to end based on initial design assumptions.
Preliminary Listing of CIs and KCs	 KICK OFF	• An initial listing has been documented based on the PDR, initial BOM, and preliminary process flow.
Design Review	 KICK OFF	• A cross-functional Design review has been undertaken using the design review document at the early stage of the Design. • Any actions have been identified and documented.

Table 4. CPQP Gate 1 Elements and Actions



Phase 2. Product Design and Development

Phase 2. Product Design and Development

The second Phase of CPQP, depicted in Figure 8, is concerned with developing the product design and confirming the key features and characteristics for the product. During this phase, the CPQP team ensures that the product, as designed, meets the engineering requirements. The team also ensures that the product meets the quality, reliability, sustainability, cost and timing objectives laid out during the planning process.

Inputs to Phase 2 come from Phase 1. The PDR document is an essential input for phase 2 which drives the design based on a measurable set of engineering and quality targets for the product. As part of the design process all technical information, regulations and specifications are reviewed, design risk analysis is undertaken, and products are developed through DfMA techniques.

Design verification and validation in this phase typically take the form of Computer Aided Design (CAD) modelling or mature prototype testing (not necessarily following a fully productionised process). The verification and validation aim to confirm that the product meets the requirements and it delivers to the Voice of the Customer. Error proofing tools and periodic design reviews are used at this stage to ensure a defect free product.

The digital information management and exchange strategy for the product design activities should align with the requirement set up in the BS EN ISO 19650 to facilitate the adoption of the BIM methodology for buildings and civil engineering works. The use of a Common Data Environment (CDE) as a single source of information allows customer to collect, manage, disseminate documentation and data relevant for the design activities. It also provides a single resource location for the entire product lifecycle with non-graphical data, engineering and graphical models.

In the case of products being developed within the framework of a construction project adopting BIM, all information exchanges for any CAD models, engineering models, and engineering records should be done as per the defined in the Exchange Information Requirements (EIR) of the project.

The first approved design is released at the end of this phase. Any further changes to the design after Gate 2 approval will be subject to design Change Control procedures.

Completing the Product Design and Development phase will benefit the NPI project by ensuring the product has been developed to the meet the customer and engineering requirements. This also allows for preliminary assessment of manufacturing issues early in the process.

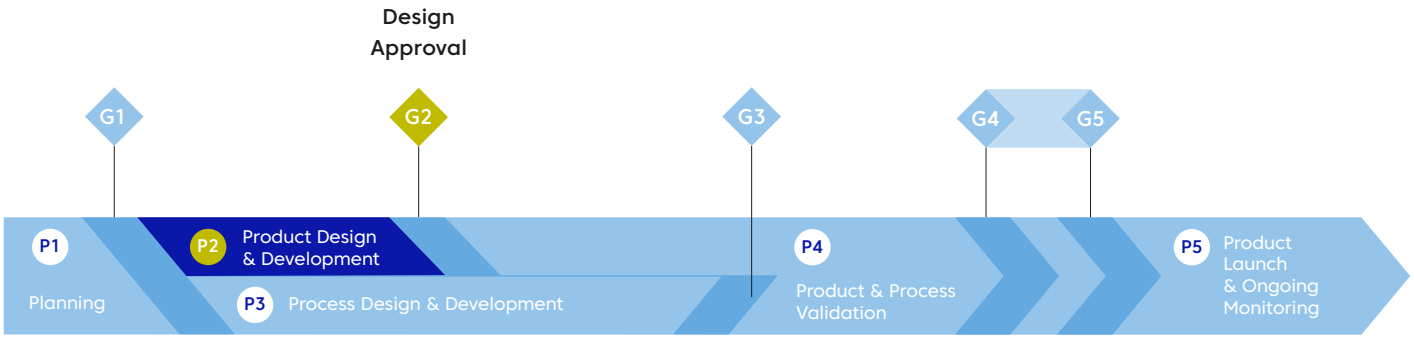


Figure 8. CPQP Phase 2 Overview

2.1 Activities and Deliverables

The activities and deliverables required for CPQP Phase 2 are outline in Table 5.

Inputs	Activities	Deliverables
D1.1 Product Development - Project Plan. **D1.2 Product Design Requirements (PDR).** **D1.3 Preliminary BOM.** **D1.4 Preliminary Sourcing Plan.** **D1.5 Preliminary Process Flow Diagram.** **D1.6 Preliminary CIs and KCs.**	• Design the product systems. • Review product regulations and design requirements. • Prepare engineering data and records (e.g., engineering and graphical models as well as non-graphical data). • Design risk analysis. • Identification of Product KCs. • DfMA. • Design for Maintenance. • Product error proofing. • Verify and validate product design. • Initial logistics and shipping planning.	D2.1 Design records and BOM(s). D2.2 DFMEA. D2.3 DfMA. D2.4 Design Verification & Validation Plan. D2.5 Special Requirements for KCs and CIs. D2.6 Packaging System Design. D2.7 Design Reviews.
Key Milestones		
M3 Design record and BOM. **M4 Design verification and validation plans.** **M5 Design sign-off and release.**		
Gateway		
G2 Final design review.		

Table 5. CPQP Phase 2 Activities and Deliverables

D2.1 – Design Records and BOM

As the design progresses, the team shall ensure the appropriate design records are maintained and the creation of CAD, engineering models and BOM data are undertaken. The team shall ensure that there are:

- **Engineering Models:** A review of design models and calculations is conducted to ensure reliable engineering and product data have been provided to allow the design of the product. 3D model-based design allows for streamlined product data management throughout the manufacturing and supply chain. The use of these tools will allow efficient process planning, requirements, engineering and design management;
- **Engineering/Construction Specifications:** A review of all the appropriate controlling specifications for the product is completed to determine functional, durability and acceptance criteria for the system, assembly or sub-assembly. The team should ensure that product and manufacturing process are designed to meet these specifications during the design process. The team can use several tools to validate these designs; physical testing, simulation and other CAD application. Additionally, the customer can use records that already exist to confirm these actions; and
- **Material Specifications:** A review of material specifications is carried out to identify, review and check any KCs relating to physical properties, performance, sustainability, handling and storage.

The design records should show the design of the product, define the BOM and verify that the design process has been carried out with all supporting data and calculations.

D2.2 – Design Failure Mode Effects Analysis

The team shall carry out a DFMEA on the design of the product as a method of assessing the risk of failures, the effect of such failure and what action to take to deal with those risks. The DFMEA is a live document and should be updated throughout the product development project. During this process, the team shall update and/or confirm the Preliminary listing of CIs and KCs.

Further details to complete a DFMEA can be found in The Design Failure Mode and Effect Analysis Guideline.

D2.3 – Design for Manufacture and Assembly

A DfMA activity should be undertaken with actions identified to feed into the design process to ensure the product is designed to meet its functional requirements whilst making it easy to manufacture and assemble. This approach should also contribute to 'design-out' waste and improve the quality of products during design, manufacturing and assembly. The activity should include a review of:

- Number of lower level components (with a view to reducing);
- Number of materials;
- Operation steps and process steps;
- Tolerance stack ups and avoiding clash conditions;
- Complexity of manufacturing or assembly steps (and how to reduce);
- Ease of assembly and error proofing; and
- Sensitivity of design to manufacturing variability.

The Design for Manufacture and Assembly Guideline provides guidance for carrying out DfMA analysis.

D2.4 – Design Verification Plan

The design, engineering, material specifications and outputs of the DFMEA allow the team to identify all the engineering tests required to verify the design. These tests may be requested by the customer and/or required due to regulations.

The management of the test required is key to ensuring the process is not delayed. The following steps are just a few required to execute these tests:

- Identify the appropriate test (e.g. physical tests, computer simulations, etc);
- Plan when tests should be conducted;
- Identify a test house or facilities provider; and
- Identify what parts are required and plan when to make the parts available.

Physical tests include testing of prototypes through to pre-production of parts. These may include destructive or non-destructive testing, fire testing, and environmental testing.

The Design Verification Plan and Report (DVP&R) documents the plan that will be implemented to confirm that a product, system or component meets the design specifications and the performance requirements. This report should be created and used to log results and completion dates.

D2.5 – Special Requirements for Critical Items and Key Characteristics

Building on the preliminary list created in Phase 1 and as more technical information is fed from the development of the design and the DFMEA, the team should begin to finalise the list and agree on the KCs and CIs. This list will form the basis of the Control Plan detailed in Phase 3.

The CPQP team shall classify the features and products as shown in Figure 9. The classification assesses the risk of a product or a certain design feature failure that could lead to the loss of functionalities and which result in major, hazardous or catastrophic situations. Therefore, the classification does not consider features or products in isolation but assess their risk of failure when interacting with other building parts and as part of the overall building system.

Critical	**Loss of primary function resulting in catastrophic or hazardous failures without any warning.** These are failures that could potentially lead to loss of life and/or irreparable damage.
Significant	**Loss of primary function resulting in major failures.** These are failures that could cause significant disruption and costs to the client.
Unclassified	**Loss of functionality that causes only minor disruption to the end user.** These are failures that can be repaired with relative ease and cause only minor disruptions.

Figure 9. Classification of Products and Features

For products being identified as Critical or Significant, the CPQP team should identify and manage Critical Items (CI) and Key Characteristics (KCs). CIs are those items that have a significant effect and a major impact on the safety, performance, form, fit, function, producibility or service life of a product and therefore must be managed (e.g. parts, functions, key characteristics, parts, processes, software). KCs are features or attributes that have a significant impact on the performance, form, fit, function, producibility or service life of a product when they vary and therefore they must be controlled (e.g. dimensional aspects, material/component properties, surface properties and finishes).

The CPQP team identifies those specific requirements that present challenges for the realisation of the product with the aim to monitor and control them.

The Design Failure Mode and Effects Analysis (DFMEA) Guideline released as part of the supporting documentation provides additional guidance for identifying Critical items (CIs) and Key Characteristics (KCs).

D2.6 – Packaging System Design

As part of the product design process, the CPQP team shall develop an initial packaging specification for the product(s). In relation to large systems and assemblies that need to be transported and delivered to a construction site, the specification shall address how the product can be transported to site assuring that its performance and characteristics will remain unchanged. If required, the product design should incorporate features to aid its transport or packing, such as lifting points and additional support structures, as well as the design of any specific packaging and transport equipment such as cradles and jigs should be undertaken.

D2.7 – Design Reviews and Design Sign Off

During the development of the design, the team (ideally with both the customer and any suppliers) shall regularly review the design and activities to verify progress as well as resolve any current issues. The design review allows regular monitoring and progression updates facilitating customer engagement and approval when required.

These reviews should discuss the following:

- Design requirements and any changes to them;
- Objectives and targets set out;
- Engineering models and CAD;
- Design Verification Plan and Report (DVP&R);
- Latest test results and failures;
- Updates to DFMEAs;
- Updated to DfMA;
- Budget and overall production and delivery cost; and
- Manufacturing targets and process design inputs.

A final design review will act as the design sign-off at the end of the phase with the team confirming the feasibility of design. After this point, any further design changes would need to go through a controlled design change process.

2.2 Gate 2 – Design Approval

At the conclusion of Phase 2 a gate review should be held. During this review the deliverables and milestones achieved throughout the phase shall be approved. All actions needed to transition to the next phase should be initiated.

Objectives

- Ensure that the Design meet the requirements and has been agreed by a cross-functional team; and
- Initial Process has been designed.

Elements and Actions

The elements and actions required for Gate 2 are outlined in Table 6.

CPQP Element	Action	Sign Off Criteria
Product Development - Project Plan	 UPDATE	• The plan is reviewed and updated, issues are logged and actioned.
Bill of Materials (BOM)	 SIGN OFF	• The full BOM based on the design has a structured hierarchy of finished product of assemblies, sub-assemblies, components, consumables and materials with significant/critical products identified. • Part numbers, quantities, usage figures and suppliers must all be stated. • Ensure there is alignment with engineering models and other required engineering data.
Process Flow Chart	 UPDATE	• The process flow has been updated following the development of the design.
Preliminary listing of CIs and KCs	 UPDATE	• The listing has been updated following completion of the DFMEA and development of the Design. • The KCs are classified as critical or significant products and process characteristics. • All product KCs that have been identified as Critical and Significant need to be included in the list.
Design Records	 SIGN OFF	• Engineering models, CADs and engineering date have been submitted, reviewed and signed off. • The latest revision includes correct Change Control notes and processes. • The latest revision corresponds to the Design at the Design Sign-off stage. • All relevant engineering, construction and material specifications are referenced and detailed at the correct level. • Part numbers, names and description are correctly linked.
Design Failure Mode and Effect Analysis (DFMEA)	 SIGN OFF	• The DFMEA has been completed, it is up to date, and it represents the Design at Design Sign-off stage. • The DFMEA Checklist been completed with no outstanding issues.

CPQP Element	Action	Sign Off Criteria
Design for Manufacturing and Assembly (DfMA)	SIGN OFF	• The DfMA has been completed, it is up to date and it represents the Design at Design Sign-off stage. • The DfMA Checklist been completed with no outstanding issues.
Design Verification Plan and Report (DVP&R)	SIGN OFF	• A DVP&R plan for all design testing and verification has been raised, it is up to date, and it represents the design at Design Sign-Off stage. • The DVP&R Checklist been completed with no outstanding issues.
Packaging System Design	SIGN OFF	• A shipment packaging system design has been completed and documented with drawings, requirements and instruction that will ensure that its performance and characteristics will remain unchanged when moved to site. • There is a plan to create and test this shipment packaging. • The part labelling and identification has been defined, documented and a standard set has been agreed with the customer.
Design Reviews	SIGN OFF	• A cross-functional Design review has been undertaken using the Design Review document to review the final Design. • All previous actions have been closed and the Design is signed off.
Production Readiness Review (PRR) and Process Sign Off	KICK OFF	• A cross-functional review has been undertaken at the early stage of the Process and Product Design with any actions identified and documented.

Table 6. CPQP Gate 2 Elements and Actions

Phase 3. Process Design and Development

Phase 3. Process Design and Development

CPQP Phase 3, shown in Figure 10, is a key step in the manufacturing supply chain and runs concurrent with both product design and overall validation. The aim of this phase is to establish a manufacturing process that can consistently produce conforming product at the customer demand rate.

The main inputs for Phase 3 will come from Phase 2 but the CPQP team should not wait for Phase 2 to be complete, in line with simultaneous engineering principles.

During this phase the full manufacturing process will be designed and the detailed flow of the process finalised. Process risk will be assessed, and the process KCs will be established.
The development of production equipment and early testing of the process will begin, and the team shall ensure that the process being designed will meet the production targets and provide the required capacity.

Process instructions and material handling requirements shall be written and designed.
In developing the process, the CPQP team may wish to take advantage of process modelling and simulation techniques to validate the flow, sequence and physical layout.

This phase also includes having capable measurement systems that will validate the product during full production.

As in the previous phases, the information management and exchange for the product and process design activities should align with the requirement set up in the BS EN ISO 19650 to facilitate the adoption of the BIM methodology for buildings and civil engineering works.

Completing the third phase will benefit the NPI project by ensuring the process has been developed to manufacture the product as defined in Phase 2. Development of an effective manufacturing system relatively early in the process allows issues to be resolved with minimal impact.

At the end of the phase the process is ready for Product and Process Validation.

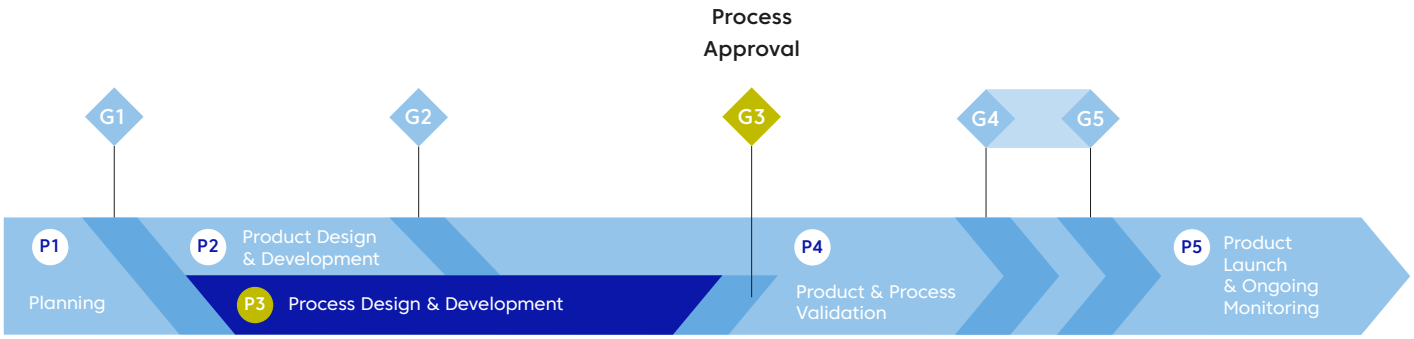


Figure 10. CPQP Phase 3 Overview

3.1 Activities and Deliverables

The activities and deliverables required for CPQP Phase 3 are outlined in Table 7.

Inputs	Activities	Deliverables
D2.1 Design Records and BOM(s). **D2.2 DFMEA.** **D2.3 DfMA.** **D2.4 Design Verification & Validation Plan.** **D2.5 Special Requirements for KCs and CIs.** **D2.6 Packaging System Design.** **D1.4 Preliminary Sourcing Plan.** **D1.5 Preliminary Process Flow Diagram.**	• Develop process flow diagram with known or estimated process data. • Review material movement requirements within the process flow. • Conduct PFMEA on the proposed process(es) and identify process KCs. • Update the process flow based on the PFMEA risk mitigation plans, focusing on Process KCs. • Create the control plan including results of the PFMEA and KC identification. • Plan and develop a measurement system. • Create process manufacturing instructions and documentation. • Evaluate production readiness.	D3.1 Process Flow Chart. D3.2 Process Failure Mode Effects Analysis. D3.3 Process KCs Parameters. D3.4 Control Plan. D3.5 MSA Plan. D3.6 Preliminary Capacity Assessment. D3.7 Process Instructions. D3.8 Material Handling and Part Labelling. D3.9 PRR and Process sign-off.
Key Milestones		
M6 Production process defined and deployed. **M7 Process sign off and released process.**		
Gateway		
G3 Final manufacturing process approval.		

Table 7. CPQP Phase 3 Activities and Deliverables

D3.1 – Process Flow Chart

A final process flow diagram should be created by the CPQP team showing in a diagrammatic form the intended manufacturing process with the steps shown in sequence for the product. The flow chart allows the assessment of the entire process rather than individual steps in the process. Data for how long the step will take (process cycle time) should be included based on actual known data or estimates.

The flow chart shall be updated based on the frozen design, BOM(s), PFMEA updates, DfMA actions, the developed process and product assumptions. If relevant, handling, loading and unloading steps should be considered as it is commonly done for precast concrete and structural steel work.

The supplier could use Supplier, Inputs, Process, Outputs and Customers (SIPOC) as a framework for developing process flow.

Further guidance to develop a process flow chart can be found in the Process Flow Chart Guideline.

D3.2 – Process Failure Mode Effects Analysis

The CPQP team shall perform a PFMEA using input from the Process Flow, the DFMEA and any identified KCs (Critical and Significant Process Characteristics). The PFMEA is a comprehensive analysis of a new or revised process to anticipate, resolve or monitor any potential issues in the proposed manufacturing system. It characterises failure modes of the process depending on the severity of the effect, occurrence and detection criteria. It determines the risk of failure in the process and what action to take to deal with those risks.

The PFMEA is a live document and shall be updated throughout the product development project.

In order to complete a PFMEA, it is required that the design team have completed severity scoring for the product features and the manufacturing process flow has been established.

Any future non-conformances are fed back to the document and will be recorded after a root cause analysis.

The Process Failure Mode and Effects Analysis (PFMEA) Guideline released as part of the supporting CPQP documentation provides additional guidance for identifying Critical Items (CI) and Key Characteristics (KCs).

D3.3 – Process Key Characteristic Parameters

The team shall identify and set the parameters of the process for high risk failure modes determined from the PFMEA and for all process KCs that have been identified as Critical and Significant. These will be fed into the Control Plan and monitored on an ongoing basis during production in order to control the correct output from the manufacturing process

D3.4 – Control plan

The control plan allows for monitoring of high-risk features/process parameters (or Process KCs) through established error-proofing techniques or advanced inspection. For any risks identified in the PFMEA, a control plan is put in place on the shop floor.

In situations where the control might fail, a reaction plan is put in place. A good practice on a manufacturing shop floor is to have some key reaction plans as laminated numbered documents (e.g. reaction plan 1, reaction plan 2, etc.) which can be quickly referred to during intense situations.

The Control Plan Guideline released as part of the supporting CPQP documentation provides additional guidance to create and maintain control plans.

D3.5 – Measurement Systems Analysis Plan

The CPQP team shall create an MSA plan. The plan shall show how the CPQP team aims to have capable gauges for measurement prior to final checks being carried out on the shop floor for production parts. The measurement systems used should be driven by the control plan. The actual measurement system shall be developed, tested and validated for repeatability and reproducibility during early prototype or pre-production parts as a part of the plan.

Following or during the production trial runs, the design measurement system should be used to check the identified characteristics and engineering specifications as defined in the control plan. The system should be evaluated to check that it works and can be used in a production environment. Any further validation requirements should be discussed with the CRe and if products would be undergoing reduced and sample frequency inspection, this shall be specified in the plan and approved as a part of the final MSA in Phase 4.

Further information of MSA can be found in the Measurement System Analysis Guideline released as part of the CPQP supporting documentation.

D3.6 – Preliminary Capacity Assessment

The team shall carry out an initial capacity study based on the process assumptions and process flow using synthetic, estimated or actual process times. The characteristics identified in the control plan will serve as a basis for the capacity analysis and capacity report to be completed in Phase 4.

The capacity assessment involves looking at the following metrics:

- Length of a single production shift (hours);
- Planned downtime per shift (hours);
- Number of production shifts per week (used if the customer demand rate is in required number of parts per week);
- Is the capacity dedicated or shared?; and
- If the capacity is shared then, number of planned hours for all other products on shared capacity per week.

The team shall ensure that the planned process will meet the required capacity at this stage and take action if the capacity falls short.

D3.7 – Process Instructions

For each operation of the process the team shall prepare Work Instructions (WI) standard operations for how to perform each process and process step. This ensures that the best method is established including points for safety, quality and ease of operation. The WI should cover:

- Processing equipment and machines;
- Setting up processes;
- Setting process parameters; and
- Tooling.

The WI should also link and cross-reference to other production control documents such as Route Cards. The WI should be only accessible to operators, supervisors and personnel directly involved and competent to complete the tasks.

D3.8 – Material Handling and Part Labelling

The CPQP team shall define how parts will be handled throughout the process and onto final shipping based on their design, the process flow and any risks identified in the PFMEA, assuring that the parts performance and characteristics will remain unchanged. Any specialist handling equipment should be identified and designed.

The marking of the products at component and finished assembly shall be determined. The method of marking should be set, and the information required on the marking listed based on:

- Batch/lot control;
- Traceability;
- Internal/external identification;
- Customer specific requirements; and
- Regulation.

D3.9 – Production Readiness Review and Process Sign-Off

During the development of the process the team should regularly review the process design activities (ideally with the customer and suppliers) checking progress and resolving issues as they occur.

The review should cover:

- Process Flow Chart;
- PFMEAs;
- Process KCs;
- Control Plan;
- MSA;
- Capacity Assessment;
- Process Instructions;
- Material Handling and Part Labelling;
- Issue lists from any prototype or pre-production builds; and
- Issues from previous reviews have been closed off.

A final Production Readiness Review (PRR) will act as the process sign-off at the end of the phase with the team confirming the feasibility of the process and confirming readiness to begin pre-production runs.

The team should be satisfied that the process can produce the parts in volume and delivered to construction sites at the required QCD targets whilst maintaining its engineering integrity and function.

Through the use of production reviews, the team will have built an understanding of this and identified issues early in the process.

3.2 Gate 3 – Process Approval

A gate review shall be held at the conclusion of Phase 3. During this review the deliverables and milestones achieved throughout the phase shall be approved. All actions needed to transition to the next phase should be initiated.

Objective

- To ensure the process meets the requirements of producing the product to the design and has been agreed by a cross-functional team.

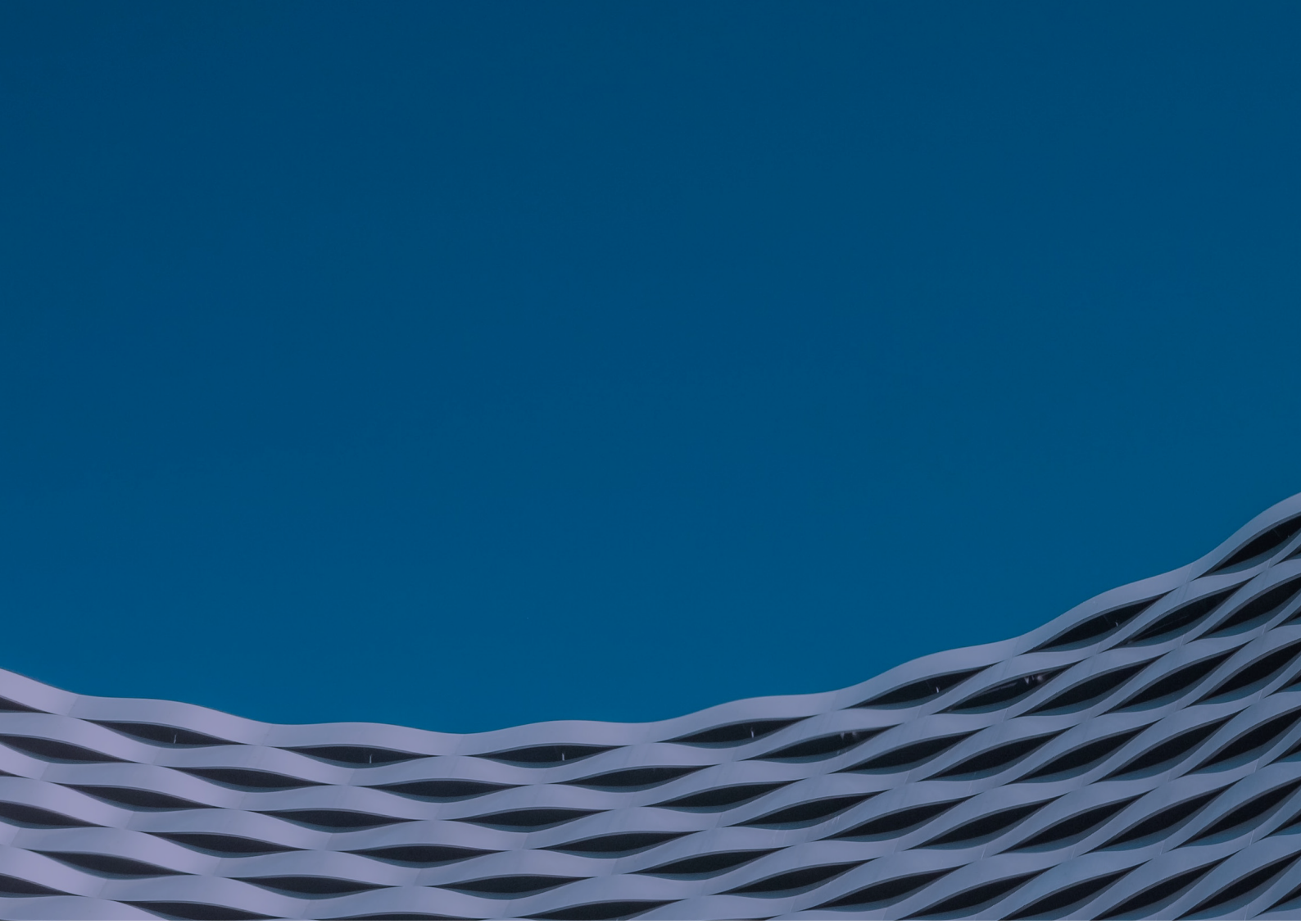
Elements and Actions

The elements and actions required for Gate 3 are outline in Table 8.

CPQP Element	Action	Sign Off Criteria
Product Development - Project Plan	 UPDATE	• The plan is reviewed and updated, issues are logged and actioned.
Process Flow Chart	 SIGN OFF	• The Process Flow been documented, it is up to date and represents the Process at Process Sign-off stage. • The Process Flow Checklist has been completed with no outstanding issues.
Listing of CIs and KCs	 SIGN OFF	• The listing has been updated following completion of the PFMEA and development of the Design and process. • All Process KCs have been identified as Critical and Significant.
Process Failure Mode and Effects Analysis (PFMEA)	 SIGN OFF	• The PFMEA has been completed, it is up to date and represents the process at Process Sign-off stage. • The PFMEA Checklist has been completed with no outstanding issues.
Control Plan	 KICK OFF	• The Control plan has been raised reflecting the latest Process Flow. • The control plan covers the Design intent process from end to end. • The outputs from the PFMEA have been included. • The KCs have been identified in the control plan.
Measurement System Analysis (MSA) Plan	 KICK OFF	• The MSA Plan has been completed, is it up to date, and it represents the Process as intended at the Process Design Sign-off stage. • The MSA Plan has been completed with no outstanding issues. • All actions should be closed.

CPQP Element	Action	Sign Off Criteria
Capacity Report	KICK OFF	• The capacity of the process been calculated using synthetic, best estimates, known process or benchmark processing cycle time, uptime, and changeover times and shift patterns. • The capacity of the process calculated shows that the Design intent of the process will meet customer demand. • Actions to address any issue in shortfall of capacity have been actioned or are in place.
Process Instructions	KICK OFF	• Initial Operator Instructions have been created based on the process design intent for people operating the process to follow, understand and be trained to. • Initial Operator Instructions have been developed considering the outputs of the FMEA's Control Plans, Flow Charts, KCs Process parameter and machine settings, Health and Safety, process layout, machine operating manuals and engineering drawings.
Material Handling and Part Labelling	SIGN OFF	• The Material and Part Labelling specification has been completed, it is up to date, and it represents the Process at Process Sign-off stage. • The Material and Part Labelling Checklist has been completed with no outstanding issues.
PRR and Process Sign Off	SIGN OFF	• A cross-functional review has been undertaken using the PRR document to review the final Processes and Product Design. • All previous actions have been closed and it the Process signed-off.
Change Control Review	SIGN OFF	• Design or Process changes have been managed through the Change Control process. • Changes have been also applied to the BOM, Design Records, DFMEA, DfMA, DVP&R, and Packaging System Design, as required.

Table 8. CPQP Gate 3 Elements and Actions



Phase 4. Product and Process Validation

Phase 4. Product and Process Validation

The aim of CPQP Phase 4, depicted in Figure 11, is to validate the product quality and manufacturing process at a productionised demand rate. This phase should ensure that product quality is met in a full production environment.

The inputs to the phase will come from Phase 3 with the focus being on trial production runs where the product is manufactured using the designed production processes. Depending on the complexity of the product it may be necessary to run smaller trials before a full production trial. The full production trial validates that the designed process meets the customer demand rate and delivers products at the accepted quality level.

The trial runs give the CPQP team the ability to confirm capacity using real data, to test and validate the MSA and finalise the product testing validation using production parts. It also tests all the production equipment, process instructions, process layouts, flows and operators.

The completion of Phase 4 has the benefit of allowing the CPQP team to identify and resolve any additional concerns prior to full production. It allows them to validate the output in real production conditions without the risk of doing so when the customer requires product for ongoing supply.

At the end of this phase all parties can be assured that all requirements have been met and the process is fully productionised. The result of Phase 4 is the approval from the customer and or CRe to move into full production and delivery.

Phase 4 of the CPQP process has two gates due to the nature of offsite manufacturing:

- Gate 4 is for Manufacturing Approval whereby the CPQP team and CRe have verified that the production facility can manufacture repeatable parts as required; and
- Gate 5 is for onsite construction whereby the CPQP team and CRe verify that the product goes together correctly as part of a building system as required by the customer.

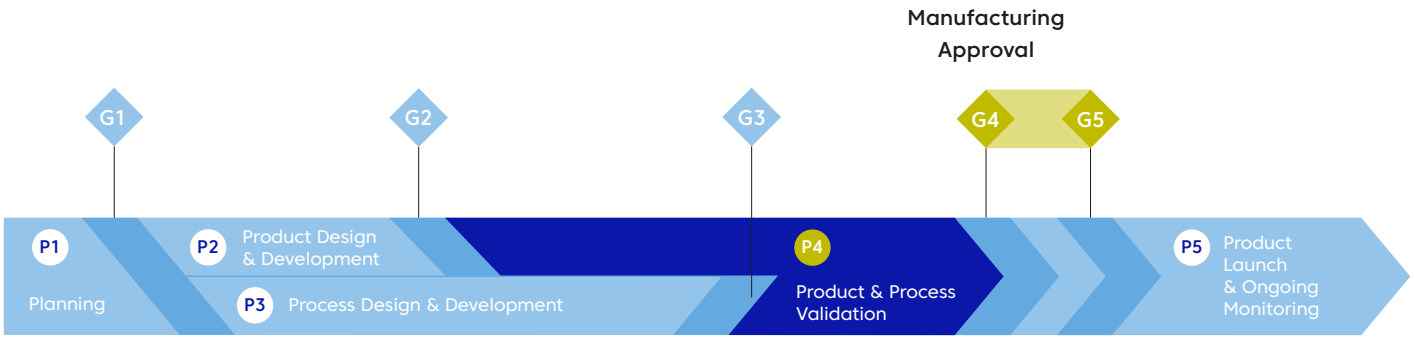


Figure 11. CPQP Phase 4 Overview

4.1 Activities and Deliverables

The activities and deliverables required for CPQP Phase 4 are outline in Table 9.

Inputs	Activities	Deliverables
D3.1 Process Flow Chart. **D3.2 PFMEA.** **D3.3 Process KCs Parameters.** **D3.4 Control Plan.** **D3.5 MSA Plan.** **D3.6 Preliminary Capacity Assessment.** **D3.7 Process Instructions.** **D3.8 Material Handling and Part Labelling.**	• Approval Process (CPAP) file. • Completion of a production product run(s). • Conduct a capacity analysis. • Review the results of production process runs and determine corrective actions, as needed conduct product testing with sub-contractors.	D4.1 Product from production process run(s). D4.2 MSA Validation. D4.3 Capacity Analysis & Report. D4.4 Production Validation Testing. D4.5 Customer Specific Requirements. D4.6 Master Production Part and Validation of First-Off Onsite Installation. D4.7 Construction Part Approval Process and Part Submission Warrant.
Key Milestones		
M8 Validation that intended manufacturing process and the associated product conforms to specified requirements. **M9 Product supply approval.**		
Gateway		
G4 Manufacturing Approval (Approved CPAP). **G5 Validation of Onsite installation.**		

Table 9. CPQP Phase 4 Activities and Deliverables

D4.1 – Completion of a Trial Production Process run(s)

The trial production runs must be completed in a production environment (i.e. facility, operators, production rates) using production tooling and equipment. A trial production process run implies manufacturing a minimum quantity of products that is usually set by the customer.

The trial runs are monitored as a part of the Construction Product Approval Process (CPAP). At this stage the manufacturer monitors whether the identified KCs are within an acceptable level of control. The outputs of the trial runs are also used for assessing process efficiency, production and labour readiness.

D4.2 – MSA Validation

The MSA validation exercise is performed to go through the reports for the gauges used as a part of the production process. The gauge report needs to indicate satisfactory values for repeatability & reproducibility, bias and in case of subjective binary measurements (i.e. 'good/bad' type results). The Measurement System Analysis (MSA) Guideline provides further details to complete a MSA.

The information can be used to assess if the quality of the data output being received from the supply chain is satisfactory. All in-process check, such as poka-yoke devices, need to be confirmed and ensure that they work properly. Gauges or measurement systems deemed unsatisfactory should be put into quarantine to limit access by personnel on the shop floor.

D4.3 – Capacity Analysis and Capacity Report

During the production trial run the CPQP team should collect data that will allow the capacity to be analysed. This is then verified that it will meet customer demand. This should be compiled into the Quality, Load and Capacity (QLC) Report.

The following metrics should be collated to become a part of the QLC report which forms part of the CPAP submission:

- Length of a single production shift (hours);
- Planned downtime per shift (hours);
- Number of production shifts per week (used if the customer demand rate is in required number of parts per week);
- Capacity dedicated or shared;
- If the capacity is shared then, number of planned hours for all other products on shared capacity per week;
- Actual duration of the whole production process trial run (total hours used);
- Actual unplanned downtime during production process trial run (hours);
- Actual set up time used during production process trial run (hours); and
- Total number of non-conforming products produced during production process run

Using these metrics, the following results can then be evaluated for each manufacturing process:

- Right First Time (%);
- Average Cycle Time;
- Availability of Equipment; and
- Actual capacity of the process (for this product).

The capacity of the process(es) to meet customer demand can now be determined and validated against the customer demand required. If using shared equipment for multiple customers or products, the process will need to demonstrate it can run at the required rate of manufacture (process cycle time) that delivers the required capacity.

The customer can now look at all the process steps and be assured that the potential to satisfy the customer demand rate is over 100% for each individual process step.

The capacity analysis (QLC) can be then signed off to warrant a further Part Submission Warrant (PSW) submission once the CPAP file is complete.

D4.4 – Production Validation Testing

In line with the DVP&R the testing shall be carried out on parts made from the production process. This validates that the process can make the parts to the required design and engineering standards. The testing also validates the customer needs as specified in the earlier phases.

D4.5 – Validation of Customer Specific Requirements

At this stage, customer specific requirements shall be validated before submitting the CPAP. Customer specific requirements are identified at the outset of CPQP. These requirements are almost always over and above the accepted minimum standards.

D4.6 – Master Production Part and First-Off Onsite Installation

At this stage, a Master Production part made using the approved production process will be submitted by the supplier for the onsite sign-off.

The Master (first-off) production part can consist of assemblies, sub-assemblies or components. The installation of the 'first-off' production product onto the construction site or in a representative operational environment should be reviewed with the CRe. The installation should be reviewed with the CRe for fit, form, function and inspected to confirm acceptable levels of quality. If the CRe is not a site-based representative, the indication of successful installation should be documented by a competent site-based person.

Any issues arising from first off assembly should be addressed and any corrective actions completed to customer satisfaction before further production and supply is undertaken. Updates to Control Plans, WIs and other documents should be carried out as required.

D4.7 – Construction Part Approval Process and Part Submission Warrant

A CPAP file forms the final submission of the 'product' by the supplier to the customer to demonstrate production readiness for their supply chain. CPAP is approved using the PSW which is signed off by the CRe to formalise the acceptance that the quality requirements have been met and the product can be manufactured at the required demand rate.

In order to complete CPAP, the elements outlined in this guide shall be completed and the CRe shall monitor the overall progress. Ideally, progress towards achieving CPAP approval, should be audited with the customer throughout the CPQP process using the CPQP elements check list. By doing so, issues will be identified pro-actively and the CPQP team can ensure they remain aligned with the customer requirements.

Approval to continue with further production and supply with necessary concessions or corrective actions in place should be sought. The CPAP might be approved on an interim basis if there are issues with first off-site installation depending on the nature of the non-conformance identified.

The PSW shall be signed off by the CRe to signify the final sign off and give authority to launch full production and supply of the product when all quality requirements have been met.

The CPAP process is further outlined in the accompanying guideline document.

4.2 Gate 4 – Manufacturing Approval

Objectives

- Ensure that the process has been validated as having met the requirements to produce the product to the required standard. This has been agreed to by a cross-functional team; and
- All activity has been completed. Ready to commence full production.

Elements and Actions

The elements and actions required for Gate 4 are outline in Table 10.

CPQP Element	Action	Sign Off Criteria
Product Development - Project Plan	 UPDATE	• The plan is reviewed and updated, issues are logged and actioned.
MSA Validation	 SIGN OFF	• The MSA Validation has been completed, it is up to date, and represents the Process as intended at the Process Validation Sign-off stage. • The MSA Validation has been completed with no outstanding issues. • All actions should be closed.
Control Plan	 SIGN OFF	• The Control Plan has been completed, it is up to date and represents the Process at the Process Validation Sign-off stage. • The Control Plan Checklist has been completed with no outstanding issues. • All actions should be closed.
Capacity Verification	 SIGN OFF	• Capacity has been confirmed using real data from the production trials. • Actions to address any issue in shortfall of capacity have been actioned.
Process Instructions	 SIGN OFF	• The process instructions have been finalised with operator input following their use during the pre-production trials.
Product from Production Process Run(s)	 SIGN OFF	• The product has been manufactured from the production intent process at the production intended rate using trained operators and using the associated production documentation. • All issues have been captured, documented and actioned during or following the trial runs. • The required cycle times, outputs and quality targets were met. • The required number of parts were made. • Any non-conformance have been documented.

CPQP Element	Action	Sign Off Criteria
Production Validation Testing	SIGN OFF	• The DVP&R plan have been completed, and all test results documented. • Any issues or failures were recorded, and corrective actions were fed back into the team. • Design or Process changes were managed through a Change Control process actioned and implemented. • The DVP&R Checklist has been completed with no outstanding issue.
Construction Product Approval process (CPAP) and Part Submission Warrant (PSW)	SIGN OFF	• The master sample submission documents have been submitted for all assemblies, sub-assemblies and components. • The Mater Production Part has been signed off.
Customer Specific Requirements	SIGN OFF	• Additional customer specific requirements requested were met and it was recorded. • The customer has confirmed specific requirements have been met if required. • This should refer to the PDR and the start of the product development project.
Change Control Review	SIGN OFF	• Design or Process changes were managed through the Change Control process and have been applied to the: BOM, Process Flow Chart, Design Records, DFMEA, DfMA, DVP&R, Packaging System Design, PFMEA, and MSA, as required.

Table 10. CPQP Gate 4 Elements and Actions

4.3 Gate 5 – Production Part Sign-Off

Objectives

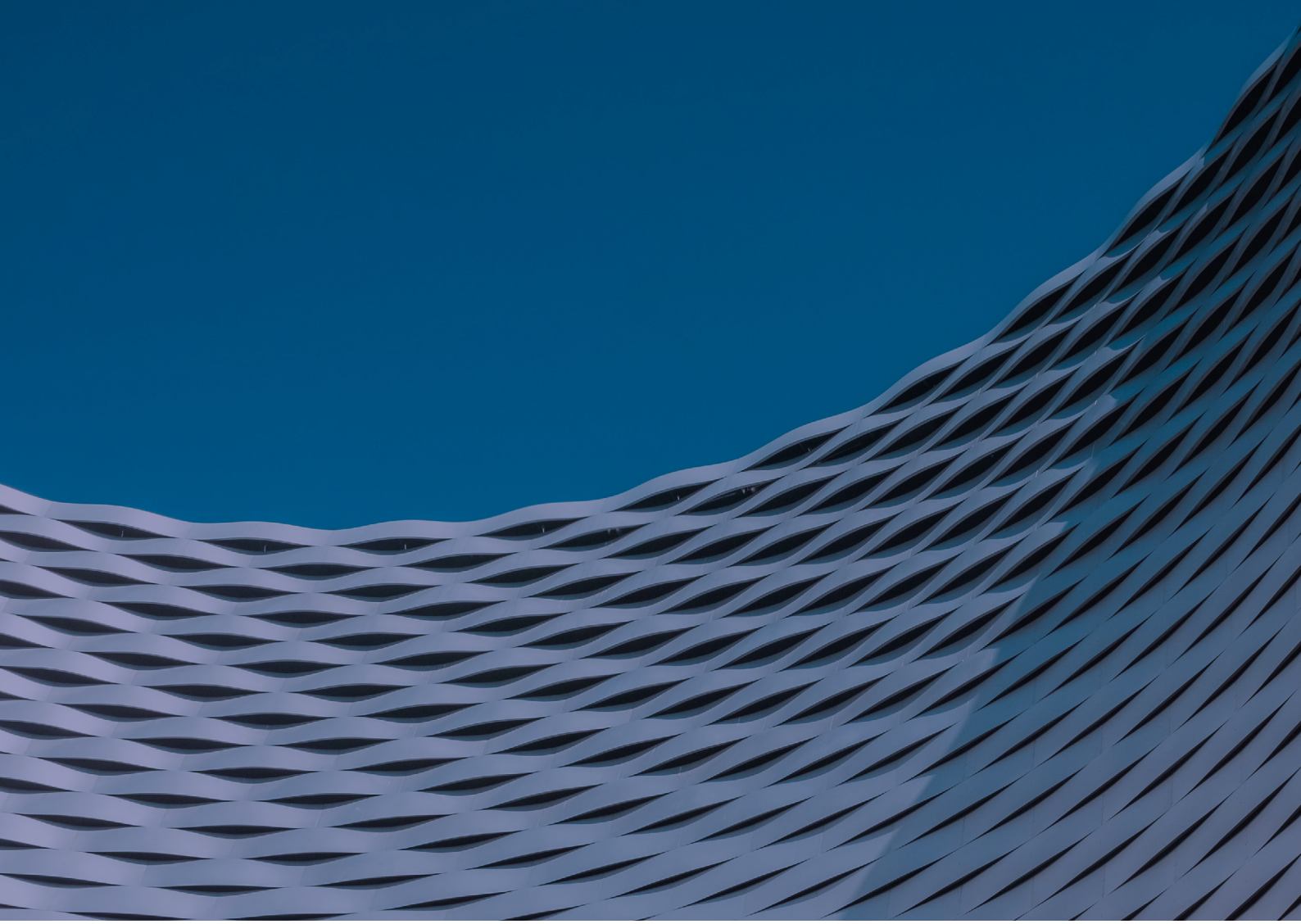
- Any ‘off process’ product can be supplied to the customer and assembled to the required standard onsite. That this has been validated with a cross-functional team as well as the customer;
- All issues are resolved; and
- Customer gives approval to start full production and supply via PSW.

Elements and Sign-Off

The elements required for Gate 5 are outlined in Table 11.

CPQP Element	Action	Sign Off Criteria
Product Development - Project Plan	 UPDATE	• The plan is reviewed and updated, issues are logged and actioned.
First-off Onsite Installation and Official production launch	 SIGN OFF	• Product has been supplied to the customer construction site, assembled and inspected through the production intent supply method. • The customer has verified that the assemblies, sub-assemblies and components all meet the required output and Design intent when assembled and that the specific specifications have been satisfied. • The supply method and delivery were acceptable. • All the required documentation met the required standard. • Any non-conformance was dealt with and corrective actions were set and fed back into the production process. • The Sign-off was report completed with all issues raised and actioned. • The Customer Signed Off the product for supply and authorised the start of production and supply in line with the required schedule.
Change Control Review	 SIGN OFF	• Design or Process changes were managed through the Change Control process and have been applied to the: BOM, Process Flow Chart, Design Records, DFMEA, DfMA, DVP&R, Packaging System Design, PFMEA, MSA, and Process Instructions as required.

Table 11. Gate 5 Elements and Actions



Phase 5. Production Launch and Ongoing Monitoring

Phase 5. Production Launch and Ongoing Monitoring

Phase 5 of CPQP, see Figure 12, starts the production and supply of the product. The initial aim is to ramp-up production to the demand levels required by the customer and then monitor the ongoing performance of the production process and product. Ongoing monitoring here is in relation to manufacturing and not onsite monitoring of the built asset.

Phase 5 takes inputs from Phase 4, building on the pre-production process trials. Phase 5 ensures that the validated production process remains in a state of statistical control. Production teams may want to employ Statistical Process Control (SPC) techniques to ensure that. Further information on the SPC application can be found in the Introduction to Process Control guideline.

Quality planning does not end with the process validation. As supply continues, the production operations team shall begin Continual Improvement activities. Improvement should be based on information gathered about the product and process performance, as well as feedback from the customer. All changes shall be implemented through a Change Control procedure.

Early in Phase 5 the CPQP team and Production Operations team should conduct a lessons-learnt review for the NPI project. This closes the Plan, Do, Check and Act (PDCA) cycle for the CPQP process itself.

Phase 5 is an ongoing phase with product being supplied. There is no formal gate in Phase 5 and the deliverables in this Phase are aligned with the Quality Management System of the organisation. The benefit of carrying out structured activities here will allow operational performance to be focused upon, targets met, and lessons learnt.

Product information as well as manufacturers' BIM objects and data are important factors in achieving success with BIM in construction projects. The digital information management and exchange strategy set at the early phases of the CPQP process should ensure that, at Phase 5, relevant information for the Asset Information Model (AIM) can be provided for construction projects implementing BIM. If any historic data for process capability is required at operation stage in the BIM lifecycle, then the supplier should be able to provide this as a part of on-going monitoring.

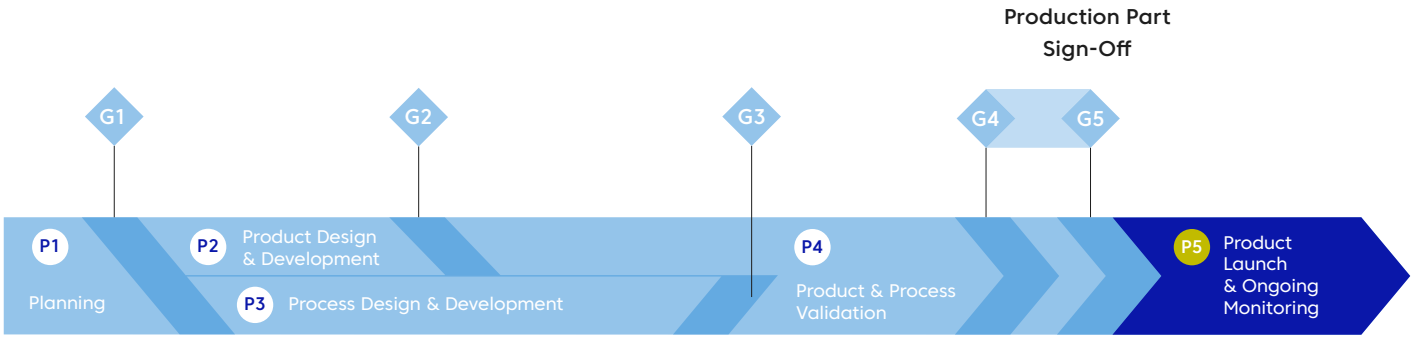


Figure 12. CPQP Phase 5 Overview

5.1 Activities and Deliverables

The activities and deliverables required for CPQP Phase 5 are outlined in Table 12.

Inputs	Activities	Deliverables
D4.1 Product from Production Process Run(s). **D4.2 MSA Validation.** **D4.3 Capacity Analysis & Capacity Verification.** **D4.4 Production Validation Testing.** **D4.5 Customer Specific Requirements.** **D4.6 Master Production Part and Validation of First-Off Onsite Installation.** **D4.7 Construction Part Approval Process and Part Submission Warrant.**	• Production and Supply. • Capture lessons learned. • Update Control plan PFMEAs. • Performance monitoring.	D5.1 Supply Ramp Up. D5.2 Lessons Learned. D5.3 Continual Improvement. D5.4 Design Change Control. D5.5 Production Handover.

Table 12. CPQP Phase 5 Activities and Deliverables

D5.1 – Supply Ramp Up to Target and Issue Resolution

Full supply of the product shall begin according to the required schedule with the CPQP team handing over to the manufacturing and operational team. The team shall ensure that the delivery and service targets and relevant manufacturing KPIs are being met and that the supply chain is performing to the QCD objectives set at the beginning of the product development project. The CPQP team should work with the operational team to resolve any issues.

D5.2 – Lessons Learnt

The CPQP Team shall review the product development project together with the production operations team, customers and suppliers to document any lessons learnt. The focus of the lessons learnt review is to assess how the CPQP process was applied and if it met the outputs and targets set out during the planning phase. Lesson learnt about the product can be included but the activity in itself is not a design review. The CRe must consider and protect customer or supplier IP if sharing the learnings on future products.

This activity should be done in context of Things-Gone-Right (TGR) and Things-Gone-Wrong (TGW) and should use supporting data relating to QCD versus the original objectives and targets of the product development project. Recommendations for future products, production processes, the company's application of CPQP processes and other quality management systems should be made with agreed plans for them to be implemented.

D5.3 – Continual Improvement Activities

Phase 5 focus on ramping up the production after Phase 4. It covers the ongoing production and supply element and will run until the product is discontinued. The continuous improvement strategy ensures that production performance is monitored for product, business and operational KPIs. This feedback comes from the customers and products out in the field. This can then be used to direct continual improvement opportunities and activities and/or address any QCD performance issues (i.e. product rejects, operational efficiency improvements, low adherence to the delivery schedule).

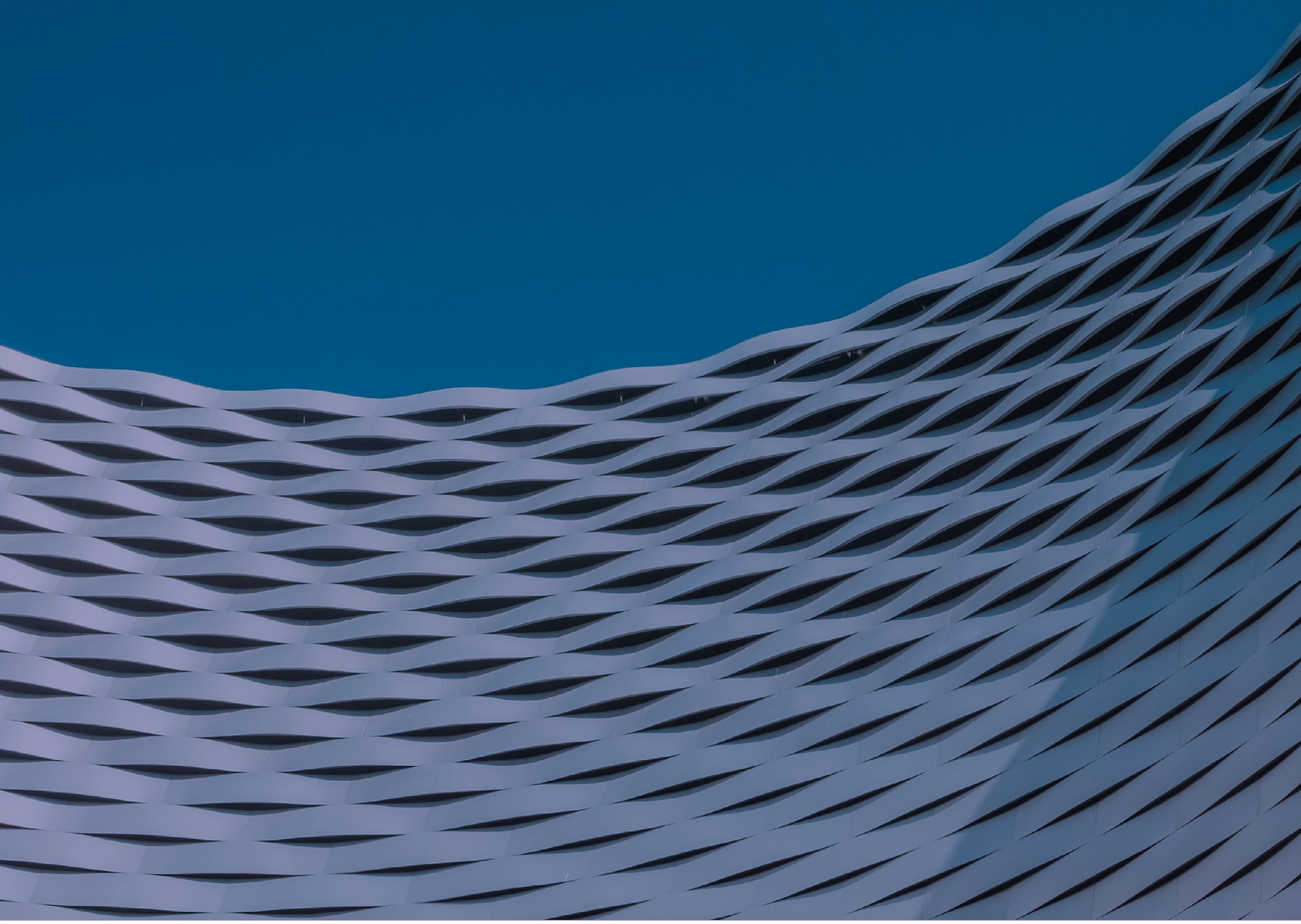
D5.4 – Design Change Control

During the products production life further design modifications may be required as a result of addressing issues arising from continual improvement activities or at the customer's request. Each design change shall be controlled through an Engineering Design Change process and implemented in a controlled way. It will be necessary to update the key documents created during the CPQP process such as the Engineering Information (drawings, BOMs, CAD), FMEAs, Control Plans, MSA, Process Flows and Process Instructions.

D5.5 – Production Handover

During Phase 4 and 5 the products and processes move from prototype to pre-production to production. This transition is also likely to occur between the teams involved, i.e. from the CPQP team to the Production Operations team (although they may be the same depending on a companies organisational size and structure). It is therefore good practice to ensure a smooth hand over and to do an internal review between the teams ensuring:

- The process and product are performing at the required levels set out in the project and achieving targets;
- The cross-functional CPQP team have resolved all outstanding issues and have agreed with the manufacturing operations team to hand the product over and close the product development project; and
- Lessons Learnt have been recorded and actions underway.



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Appendices

Appendix A – List of Abbreviations

The following is a list of initialisations and acronyms used in this guideline.

0-9	2D	Two-Dimensional
	3D	Three-Dimensional
	8D	Eight (8) Disciplines of Problem Solving
A	APQP	Advanced Product Quality Planning
	AIM	Asset Information Model
B	BRE	Building Research Establishment
	BIM	Building Information Modelling
	BOM	Bill of Materials
C	CAD	Computer Aided Design
	CDE	Common Data Environment
	CI	Critical Item
	COTS	Commercial Off-The-Shelf
	CPAP	Construction Product Approval Process
	CPQP	Construction Product Quality Planning
	CRe	Client Representative
D	DfMA	Design for Manufacture and Assembly
	DFMEA	Design Failure Mode and Effects Analysis
	DVP&R	Design Verification Plan and Report
E	EIR	Exchange Information Requirement
F	FMEA	Failure Mode and Effects Analysis
K	KC	Key Characteristic
	KPI	Key Performance Indicator
M	MIDP	Master Information Delivery Plan
	MMC	Modern Methods of Construction
	MSA	Measurement Systems Analysis
	MTC	The Manufacturing Technology Centre
N	NPI	New Product Introduction
	NRFT	Not Right First Time
P	PBS	Product Breakdown Structure
	PDCA	Plan Do Check Act
	PDR	Product Design Specification
	PFMEA	Process Failure Mode and Effects Analysis
	PPAP	Production Part Approval Process
	PRR	Production Readiness Review
	PSW	Part Submission Warrant
Q	QCD	Quality Cost Delivery
	QFD	Quality Functional Deployment
	QLC	Quality, Load and Capacity Report
S	SIPOC	Supplier, Inputs, Process, Outputs and Customers
	SPC	Statistical Process Control
T	TGR	Things Gone Right
	TGW	Things Gone Wrong
	TIDP	Task Information Delivery Plan
V	VoC	Voice of the Customer
W	WI	Work Instruction

Appendices

Appendix B – Glossary of Terms

The following is a list of commonly utilised quality, manufacturing and construction specific terms and their definitions within this context used within this guideline.

A

Advanced Product Quality Planning (APQP)

A quality planning process used for developing new products. It was developed by the automotive industry but can be applied to any industry and is similar in many respects to the concept of design for six sigma; see AIAG Reference Manual [1].

Asset Information Model (AIM)

As defined by the BIMe Initiative: "A sub-type of Information Models supporting the maintenance, management and operation of an asset throughout its lifecycle. An Asset Information Model (AIM) is used (a) as a repository for all information about the asset; (b) as a means to access/ link to enterprise systems (e.g., CMMS and BMS); and (c) as a means to receive and centralize information from other parties throughout project stages [4].

B

Bill of Materials (BOM)

A hierarchical listing of the physical assemblies, subassemblies, and components needed to fabricate a product as well as the quantity of each material required [5].

Building Information Modelling (BIM)

BS EN ISO 19650-1: "Use of a shared digital representation of a built asset to facilitate design, construction and operation processes to form a reliable basis for decisions [6]."

C

Change Control

A process through which requests to change the baseline scope of a project or product are captured, evaluated and then approved, rejected or deferred [7].

Client Representative (CRe)

The CRe is the responsible and accountable person for monitoring the overall progress associated with the CPQP process. This role sits within the organisation that is responsible for the overall quality requirements for the product development project i.e., is accountable to the client. Depending on the nature of the procurement contract, different organisations may be delegated to have this responsibility. The CRe provides the final signature to approve the supply chain as production ready for the project or future projects. This term is synonymous to 'Client Representative'.

Commercial Off-The-Shelf (COTS)

BS EN 9145: "Commercially available products, defined by industry recognized specifications and standards, sold through public catalogue listings [8]."

Common Data Environment (CDE)

BS EN ISO 19650-1: "An agreed source of information for any given project or asset, for collecting, managing and disseminating each information container through a managed process [6]."

Computer Aided Design (CAD)

BS ISO 6707-2: "Use of a computer for design and drafting [9]."

Construction Product Approval Process (CPAP)

An adaptation of Production Part Approval Process (PPAP) that is aimed at those enterprises that will feed construction with new componentry and products.

Continual Improvement

As defined by ISO 9001: "To continually improve the suitability, adequacy and effectiveness of the quality management system" [10]. Formerly referred to as 'continuous' improvement within the ISO 9000/9001 lexicon, it was changed to 'continual' in 2000. ISO/Technical Committee 176 decided that 'continuous' implied duration without interruption while 'continual' indicated duration in over an extended period but with intervals of interruption and therefore, 'continual' was the more appropriate term [11].

Control plan

BS EN 9145 [8]: "Documented description linking manufacturing process steps to key inspection and control activities. The intent of a control plan is to control the design characteristics and the process variables to ensure product quality."

Critical Item (CI)

BS EN 9145 [8]: "Those items (e.g., functions, parts, software, characteristics, processes) having significant effect on the product realization and use of the product; including safety, performance, form, fit, function, producibility, service life, etc. that require specific actions to ensure they are adequately managed."

Customer

BS EN 9145 [8]: "Organization, legal entity, or person that receives a product or service (e.g. consumer, client, end-user, retailer, beneficiary, purchaser)."

Customer Demand Rate

in a given time frame, by one or many customers. It is likely that most construction projects will be delivered for one particular client, but most newly introduced products could have demand from multiple clients. In such cases, customer demand rate is derived as the sum total of the volume required in the given time frame and consequently any validation activities are carried out at peak demand. If additional customers come on board then the demand rate would just increase by adding the extra volume demand per unit time.

D Deliverables

Defined outputs to be completed within the CPQP process.

Demand rate

BS EN 9145 [8]: “Quantity of products required to be produced by the production organization over a specified period of time to fulfil the delivery schedule.”

Design Failure Mode Effects Analysis (DFMEA)

An application of Failure Mode Effects Analysis (FMEA) for product design.

Design for Manufacture and Assembly (DfMA)

Product design with design priority given to ease of both assembly and manufacture.

Design validation

Simply put, design validation implies: “Does the design provide the solution required by the customer?”

Design verification

Simply put, design verification implies: “Is the design error free?”

Design Verification Plan and Report (DVP&R)

A planning tool for the systematic determination that a product or process meets its design specifications and performance requirements. Closely tied to FMEA; FMEA determines the ‘what’ in anticipating potential failures while DVP&R focuses on the ‘how’.

E Eight Disciplines of Problem Solving (8D)

A problem-solving approach originally developed by the Ford Motor Company, now used throughout the automotive industry; it has also been successfully applied in other industries, e.g. manufacturing, healthcare, and finance. A useful tool in both product and process improvement, 8D is a methodology for identifying, correcting and eliminating recurring problems.

Exchange Information Requirements (EIR)

According to BSI, the EIR is a document that "determines the appointing party's information requirements in relation to an appointment (contract). It identifies what the appointing party expects to be delivered during both the delivery and handover. It includes responsibility, timescales, format, and level of information need of the project information. It also includes any other project-specific requirements, such as procedures to be adopted, the plan of work to be used, any format restrictions, and it should consider (amongst other things) the Project's information Standard, organisation information requirements and asset information requirements respectively".

F Failure Mode Effects Analysis (FMEA)

"A tool for facilitating the process of predicting failures, planning preventative measures, estimating the cost of the failure, and planning redundant systems or system responses to failures [12].” “The FMEA assists in the identification of CIs as well as key design and process characteristics, helps prioritize action plans for mitigating risk and serves as a repository for lessons learned[8].”

K Key Characteristic (KC)

BS EN 9145 [8]: “An attribute or feature whose variation has a significant influence on product fit, performance, service life or producibility; that requires specific action for the purpose of controlling variation.”

Key Performance Indicator (KPI)

A quantifiable or measurable value that reflects how successful a business is in accomplishing a strategic goal or objective [13].

L Lean Six Sigma

Lean and Six Sigma are two methodologies that were developed separately. “Lean is about the elimination of waste in a process, which can include defects and errors, whereas Six Sigma is about the reduction and control of variation within a process, which can include workflow and workplace management [12].” The combination of these two methodologies provides a disciplined approach to total business improvement.

M Master Information Delivery Plan (MIDP)

As defined by the BIMe Initiative: “A plan listing all the information deliverables of a project including models, drawings, specifications, equipment, schedules and Room Data Sheets. A Master Information Delivery Plan (MIDP) identifies when project information is to be prepared, by whom, and using what protocols and procedures. An MIDP incorporates all relevant Task Team Information Delivery Plans (TIDP)s and an updated/detailed Responsibility Matrix” [4].

Measurement Systems Analysis (MSA)

A tool that is used to validate measurement systems; this can range from subjective, manual measuring equipment to automated sensor equipment that outputs measured values. MSA looks not only at the equipment being used but also the human factors, environment, location and inspection process. A complete MSA study can provide confidence to all parties involved in the construction process that the data has been validated through a comprehensive process.

Modern Methods of Construction (MMC)

A wide term, embracing a range of offsite manufacturing and onsite techniques that provide alternatives to traditional building. MMC ranges from sub-assemblies to entire buildings being constructed from factory-built volumetric modules, through the use of innovative techniques for laying concrete blockwork onsite [14]. MMC results in a range of subtypes that includes volumetric construction, pods, panelised systems, sub-assemblies and components and site-based MMC [15].

N

New Product Introduction (NPI)

NPI programs aim to introduce new and usually complex products to markets through a standardised process. The phases typically covered are concept planning, design & manufacture, final validation & production launch. This is usually achieved in other sectors through application of process such as the APQP process [1].

Not Right First Time (NRFT)

The first measure under the QCD approach to improved production performance, it measures a product's ability to match a specification. It is typically expressed in 'number of defect parts per million' with a defective unit defined as one that does not conform to specification and may be scrapped or reworked [16].

O

Offsite

Not at the building works or construction site; often referring to the activities or processes physically taking place outside of the building works or construction site.

Onsite

At the building works or construction site; often referring to the activities or processes physically taking place at this location.

P

Plan, Do, Check, Act Cycle (PDCA)

Simply put, PDCA cycle providers a framework for continuous improvement and puts high emphasis on the planning phase.

Poka-yoke

Based on the Japanese term for "mistake proofing" it more broadly refers to any mechanism within a product or process designed to prevent errors.

Preliminary bill of materials

BS EN 9145 [8]: "An initial BOM completed, prior to design validation and release of design record, for production use."

Process validation

Simply put, process validation answers the question "Is the process capable to provide the solution required by the customer at the rate required by the customer?"

Process verification

Simply put, process verification answers the question, "Is the process error free?"

Product Breakdown Structure (PBS)

Simply put, PBS is the hierarchical breakdown of the main project/product into its constituent sub projects/products. Developing the PBS document is a key activity performed within the phase 1 of the CPQP process.

Product Design Requirements/Specification (PDR)

The Product Design Requirements document contains specification for overall functional aspects of the product and the concept being generated using the CPQP process (usually completed during phase 1). BS 7373 provides further information on how to develop the PDR document.

Product validation

Simply put, product validation answers the question, "Does the product meet the customer needs?"

Product verification

Simply put, product verification implies: "Is the product error free?"

Production Part Approval Process (PPAP)

A process, standardised by both the automotive and aerospace industries, that outlines the steps and requirements for approval of production designs and/or manufacturing processes throughout the product development cycle. It also ensures that the entire supply chain understands these steps when procuring externally manufactured parts.

Production Readiness Review (PRR)

BS EN 9145 [8]: "A review of the manufacturing process (e.g. equipment, operator training, manufacturing documentation, control plan, associated measurement tools) by a multi-disciplinary team to verify that the production processes are appropriately defined, documented and ready for production."

Part/Product Submission Warrant (PSW)

The PSW is the final approval form that the Customer Representative has to sign off indicating that all the requirements for the CPQP process have been completed and production readiness status has been achieved.

Q

Quality, Load and Capacity Report (QLC)

The Quality, Load and Capacity Report contains all relevant information regarding the quality of the production batch of components along with any constraints within capacity. The QLC report forms a key part of the overall CPQP submission.

Quality, Cost, and Delivery (QCD)

An umbrella term for seven key performance measures originally developed by the automotive industry but now used to improve production performance across a wide range of industries [16]. QCD includes the following, all of which use simple mathematical equations to analyse production performance: Not right first time (NRFT), delivery schedule achievement, people productivity, stock turns, overall equipment effectiveness, value added per person, and floor space utilisation.

Quality Functional Deployment (QFD)

A structured approach to defining customer needs and translating them into specific product development plans.

R

Route Card

A document that lists the manufacturing operations and the defined sequence It also indicates the equipment associated with each operation and the department in which the operation is carried out.

S Six Sigma

A disciplined methodology developed by the Motorola Company in the '80s for improving an organisation's process capability and now included within ISO 9001 quality toolsets. Six Sigma is based on rigorous data gathering and statistical analysis to identify the sources of variation and ways of reducing them [12].

Special characteristic

"Product and process characteristics designated by the customer, including governmental regulatory and safety, and/or selected by the organisation through knowledge of the product and process [1]."

Special requirements

BS EN 9145 [8]: "Those requirements identified by the customer or determined by the organization, which have high risks of not being achieved, thus requiring their inclusion in the risk management process; Factors used in the determination of special requirements include product or process complexity, past experience, and product or process maturity; Examples of special requirements include performance requirements imposed by the customer that are at the limit of the industry's capability, or requirements determined by the organization to be at the limit of its technical or process capabilities."

Statistical Process Control (SPC)

ISO 3534-2 [17]: "Activities focused on the use of statistical techniques to reduce variation, increase knowledge about the process, and steer the process in the desired way. SPC operates most efficiently by controlling variation of a process characteristic or an in-process product characteristic that is correlated with a final product characteristic and/or by increasing the robustness of the process against this variation. A supplier's final product characteristic can be a process characteristic to the next downstream supplier's process."

Supplier, Inputs, Process, Outputs and Customers (SIPOC)

A tool from six sigma that provides a tabular summary of the inputs to outputs of one or more processes, known as a SIPOC diagram. Some organisations refer to it as COPIS in order to put the emphasis on customer requirements.

T Task Information Delivery Plan (TIDP)

According to the BIMe Initiative, "This document sets out the information delivery responsibilities of each Task Team. TIDPs are submitted in accordance with the Master Information Delivery Plan (MIDP) and aggregate team information deliverables, project tasks, formats, dates and related responsibilities" [4].

Things-Gone-Right

A term with its roots in the automotive industry, originally used in interpreting and quantifying the positive results from customer satisfaction surveys. In CPQP TGR is used during Lessons Learnt in Phase 5 (although can be done at any time in relation to any process with outcomes). As part of the Lessons Learnt review the reviewing team would list out points (TGR) where they feel they had achieved the objectives of the project i.e., what the team felt was successful. The required objectives of the project and or key metrics (Quality Cost, Delivery, Product Performance, and Process Performance) can be used to assess this quantitatively but could also be qualitative based on the view of the teams. The review would then try to understand what it was that contributed to that success in relation to the process followed (i.e. CPQP), the tools used and how the team worked. The aim of the review is it then ensure that the contributing factors to TGR are actioned and rolled into the CPQP process, tools used, working behaviours and future products.

Things-Gone-Wrong

A term with its roots in the automotive industry, originally used in interpreting and quantifying the negative results/ complaints from customer satisfaction surveys. In CPQP TGW is used during Lessons Learnt in Phase 5 (although can be done at any time in relation to any process with outcomes). As part of the Lessons Learnt review the reviewing team would list out points (TGW) where they feel they hadn't achieved the objectives of the project, i.e., what the team felt was not successful. The required objectives of the project and or key metrics (Quality Cost, Delivery, Product Performance, and Process Performance) can be used to assess this quantitatively but could also be qualitative based on the view of the teams. The review would then try to understand what it was that contributed to the lack of success or issues encountered in relation to the process followed (i.e. CPQP), the tools used and how the team worked. The aim of the review is it then ensure that corrective actions to prevent the TGW happening again are actioned and rolled into the CPQP process, tools used, working behaviours and future products.

Three-Dimensional (3D)

BS ISO 6707-2: "Having or seeming to have length, width and depth [9]."

Two-Dimensional (2D)

BS ISO 6707-2: "Having or seeming to have two dimensions, such as width and height but no depth [9]."

V Validation

BS EN 9145 [8]: "Assurance that a product, service, or system fulfils the needs of the customer and other identified stakeholders. It often involves acceptance with external customers." Simply put, validation implies: "Are we building the right thing?"

Verification

BS EN 9145 [8]: "Confirmation by examination and provision of objective evidence that the specified requirements have been fulfilled." Simply put, verification implies: "Are we building it right?"

Voice of the Customer (VoC)

The stated and unstated customer needs or requirements. This includes customer feedback (both positive and negative) [1].

W Work Instruction (WI)

A detailed description of the steps required to perform particular tasks. Generally required, but not specifically defined in ISO 9001:2015 Section 8.5.1 [10].

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