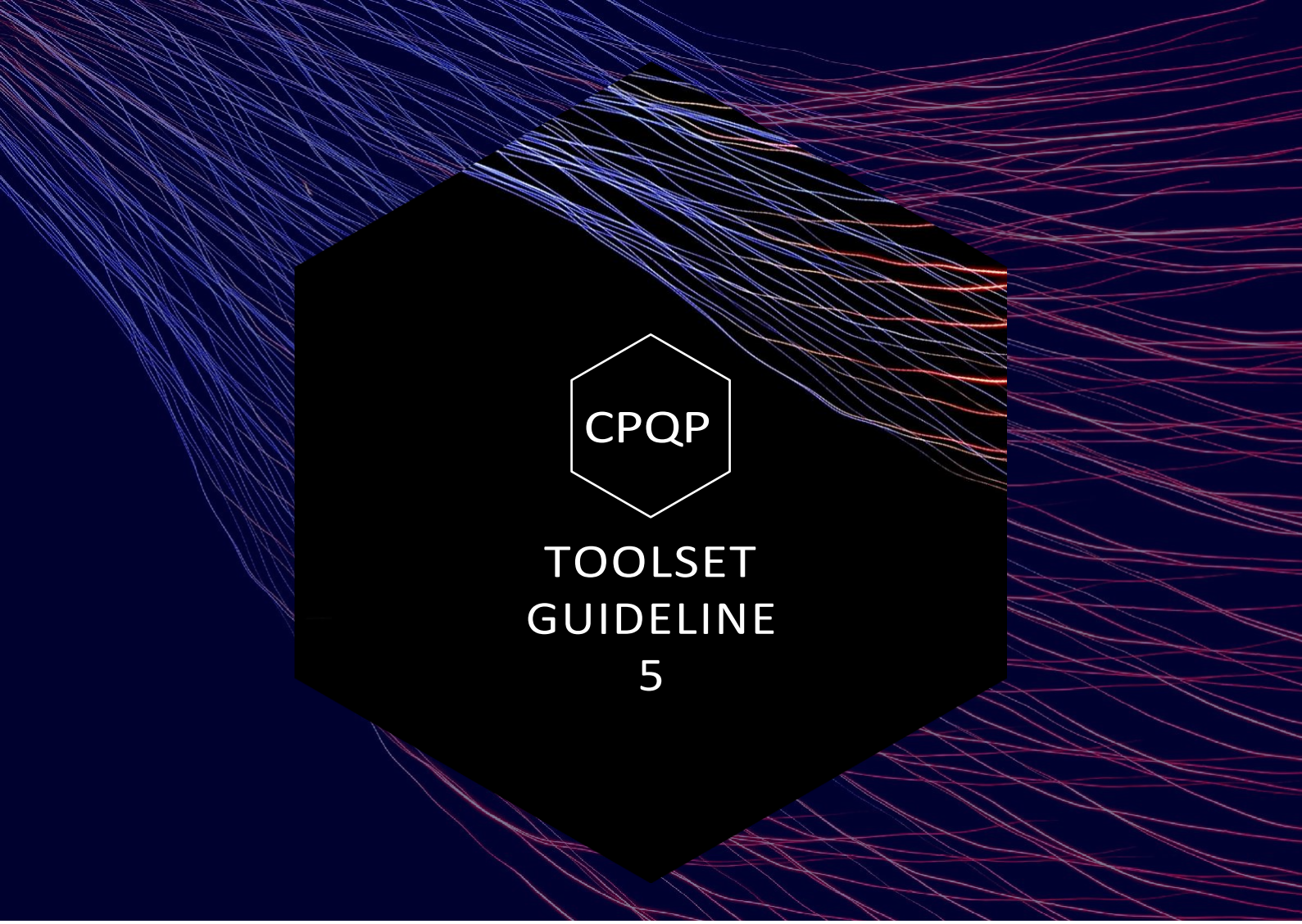

Process Failure Mode and Effects Analysis Guideline

Version 1.0

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CONSTRUCTION INNOVATION HUB

UK Research and Innovation

Contents

List of figures

List of tables

Use of this Guide

The Process Failure Mode and Effects Analysis (PFMEA) guideline is part of the Construction Product Quality Planning (CPQP) process and should be used in conjunction with the CPQP Guide and its toolset, published by the Construction Innovation Hub.

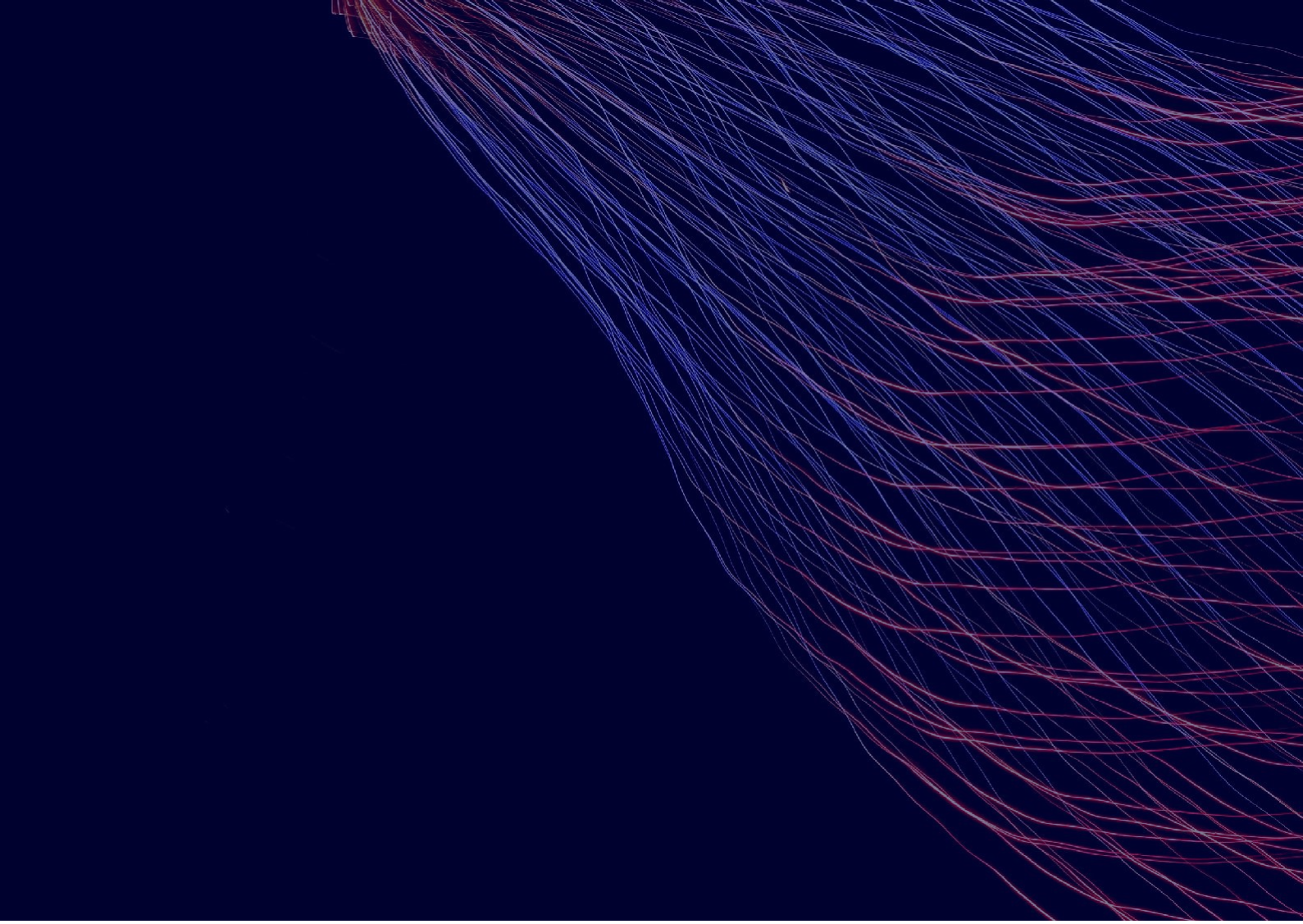
This document is intended to be a guideline to aid the process of creating a Process Failure Mode and Effects Analysis (PFMEA), providing the basic principles and a suggested methodology. The templates provided can be changed and modified to suit individual companies.

This guideline is aimed at companies that manufacture offsite construction products and use the CPQP process with their customers and suppliers. It is intended to provide enough knowledge to enable the CPQP team to complete a PFMEA, particularly where this subject is new to them, as well as to provide an ongoing aid. Over time, companies will develop their own expertise, methods and standards through training and practice.

For a list of the acronyms and abbreviations used in this document, refer to Appendix B – List of Abbreviations.

For the various terms used in this document, refer to Appendix C – Glossary of Terms.

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



Introduction

Introduction

Process Failure Mode and Effects Analysis (PFMEA) is used by engineers to identify potential failures that could occur in a manufacturing process.

PFMEA is a risk evaluation tool that seeks to:

1. Identify operational steps and requirements;
2. Identify the possible failure modes of the process;
3. Identify the causes of the failure modes and their occurrence, by looking at how the process could be wrong and how likely it is to cause the failure. The team can check what process control exists in the operational step;
4. Identify the effects of those failures and their severity;
5. Identify the likelihood to prevent and detect the failures. Prevention controls stop or reduce the likelihood of the failure mode from occurring. Detection controls can be used to detect the existence of the cause or the failure mode before the product is released to the downstream manufacturing process;
6. Identify actions and their priorities. PFMEA uses a scoring system for occurrence, severity, prevention and detection to get a Risk Priority Number (RPN), which helps to prioritise actions to reduce the risks; and
7. Review RPN scores before and after any improvement actions have been carried out.

PFMEA should be carried out using cross-functional teams to identify and assess risks.

A PFMEA is a live document that captures the key functions of a manufacturing process and analyses the potential causes of failure modes and associated risk. It defines what could go wrong with the process, how bad the effect might be, and how to prevent or control it.

Purpose

PFMEA is designed to reduce the risk of a manufacturing process failure and does this by:

- Evaluating the initial process, identifying and quantifying process failure risk;
- Increasing the likelihood of capturing potential failure modes;
- Developing a prioritised list of potential failure modes and effects;
- Identifying, assessing and justifying control measures in the manufacturing process;
- Supporting development of control plans;
- Providing a methodical approach for the development of the manufacturing process; and
- Providing a platform for continuous process improvement and source for future reference in a form of a traceable document.

Benefits

Performing a PFMEA on a new or existing process enables:

- Improved quality, reliability and safety of the process;
- Increased customer satisfaction;

- Reduced Cost of Poor Quality (CoPQ) in production; and
- Reduced cost and time of new product development.

Performing a PFMEA is good, cost-effective practice to identify risks associated with product and process design as early in the design and development stages as possible. Early identification of risk gives a greater ability to impact the process. Additionally, the longer it takes to identify a problem, the costlier it is to correct it, as shown in Figure 1. The typical increase in costs associated with failing to identify a design issue early in the process is illustrated in Table 1.

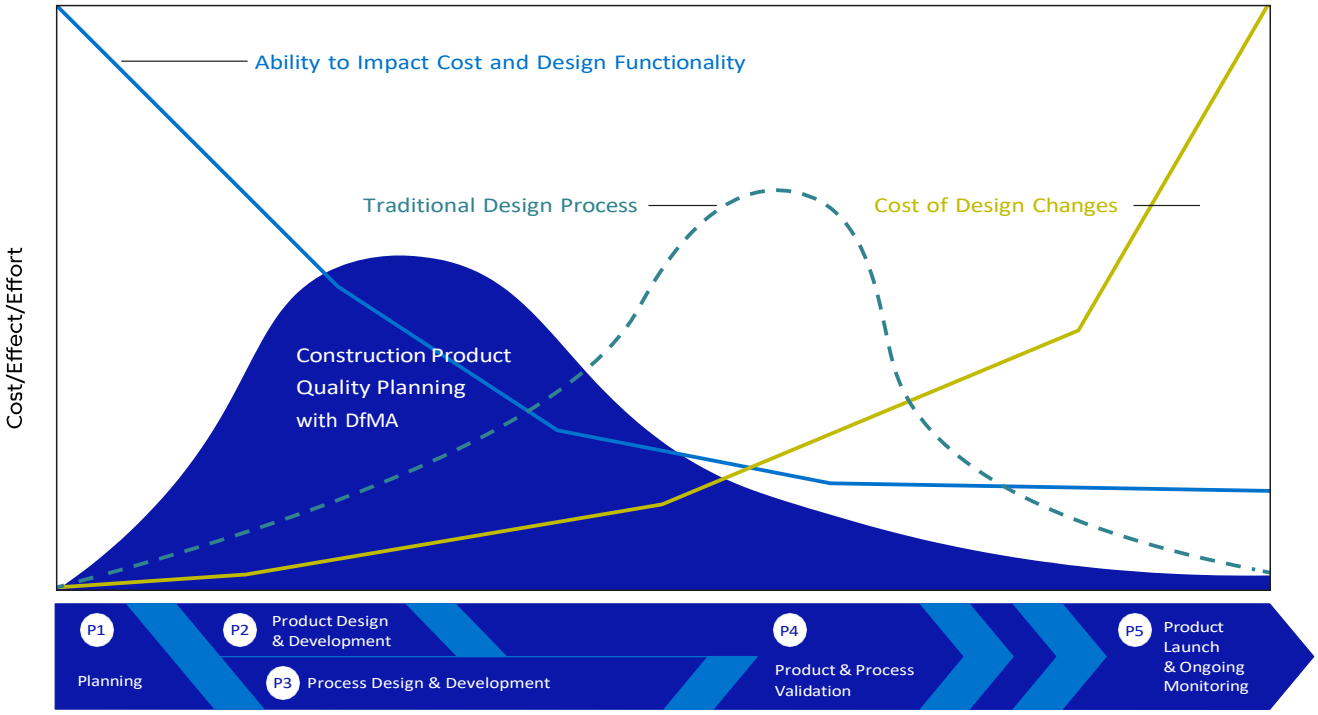


Figure 1. Cost/Effect/Effort diagram – CPQP design process versus traditional design process

Stage	Cost to Identify & Solve Issue
Feasibility	0 X
Design	10 X
Development	100 X
Testing	1000 X
Manufacturing	10,000 X
At Customer	100,000 X

Table 1. Typical increase in costs associated with failing to identify a design issue at the earliest possible stage

How does PFMEA fit in with Construction Product Quality Planning?

A PFMEA should be completed or reviewed:

- As part of the New Product Introduction (NPI) process;
- If a new application of a currently existing process is developed (source of lessons learnt);
- As part of a regular process improvement/ risk reduction workshops;
- If any changes are made to product design or the process itself; and
- For non-conformance recording, accompanied by the root cause and corrective action plan.

A PFMEA is developed in Phase 3 of the CPQP process, as shown in Figure 2. It utilises outputs from previous phases, e.g., Process Flow, the Design Failure Mode and Effects Analysis (DFMEA), identified Key Characteristics (KCs). In order to complete a PFMEA, which should be done as early as possible to maximise benefits, it is required that the design team have finalised severity scoring for the product features and that the manufacturing process flow has been established. The PFMEA is one of the documents signed-off during final process review at the end of Phase 3, after which, any further changes would have to go through a controlled change process. The PFMEA needs to be maintained as long as the process is being used to manufacture the product.

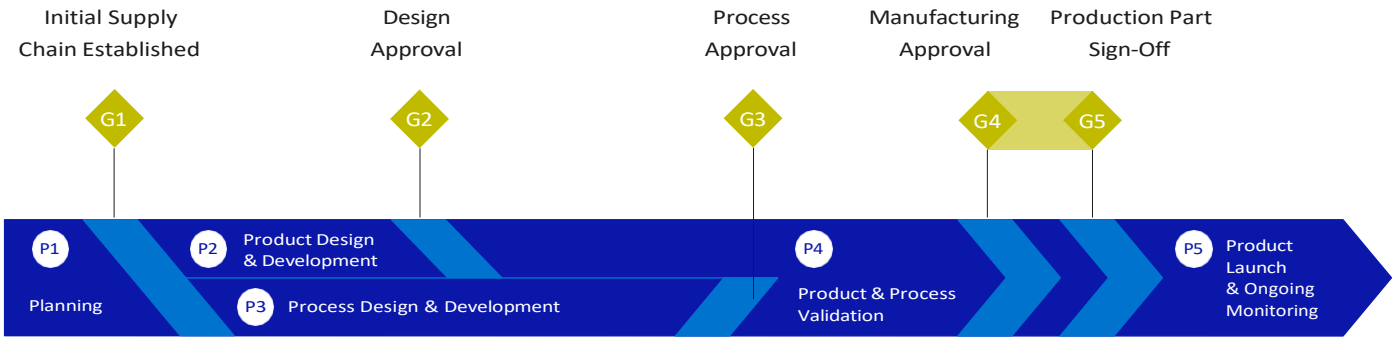
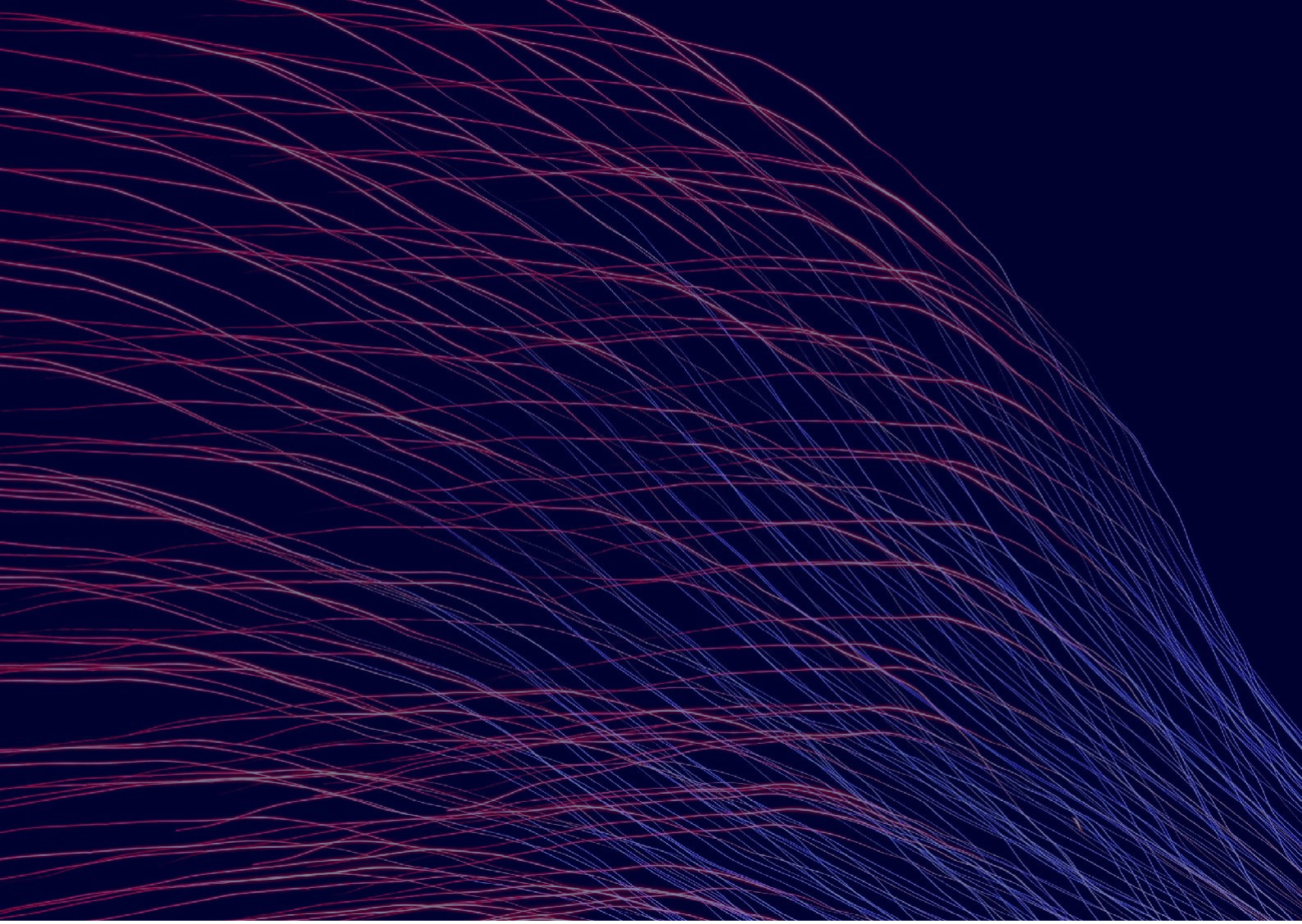


Figure 2. New product introduction stages [1]



Methodology

Methodology

Key steps in performing a PFMEA

In order to complete a PFMEA, 11 steps must be followed, as per Figure 3.

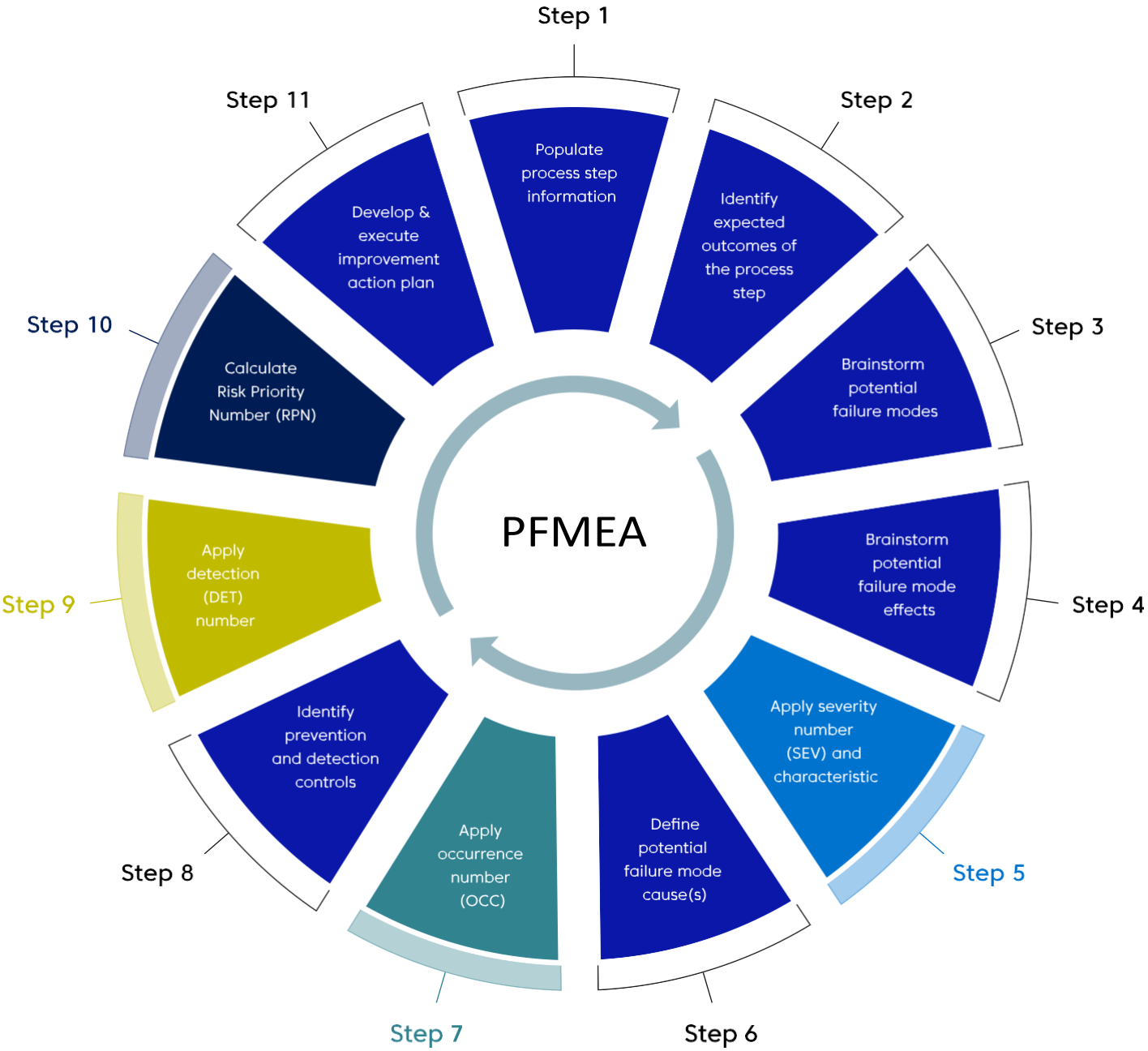


Figure 3. PFMEA key process steps

Planning for the PFMEA

To perform a successful PFMEA, a cross-functional team, trained in use and development of the tool, should be deployed. This will reduce the risk of over-sights by ensuring a diversity of views are taken into account and providing multi-disciplinary expertise and input.

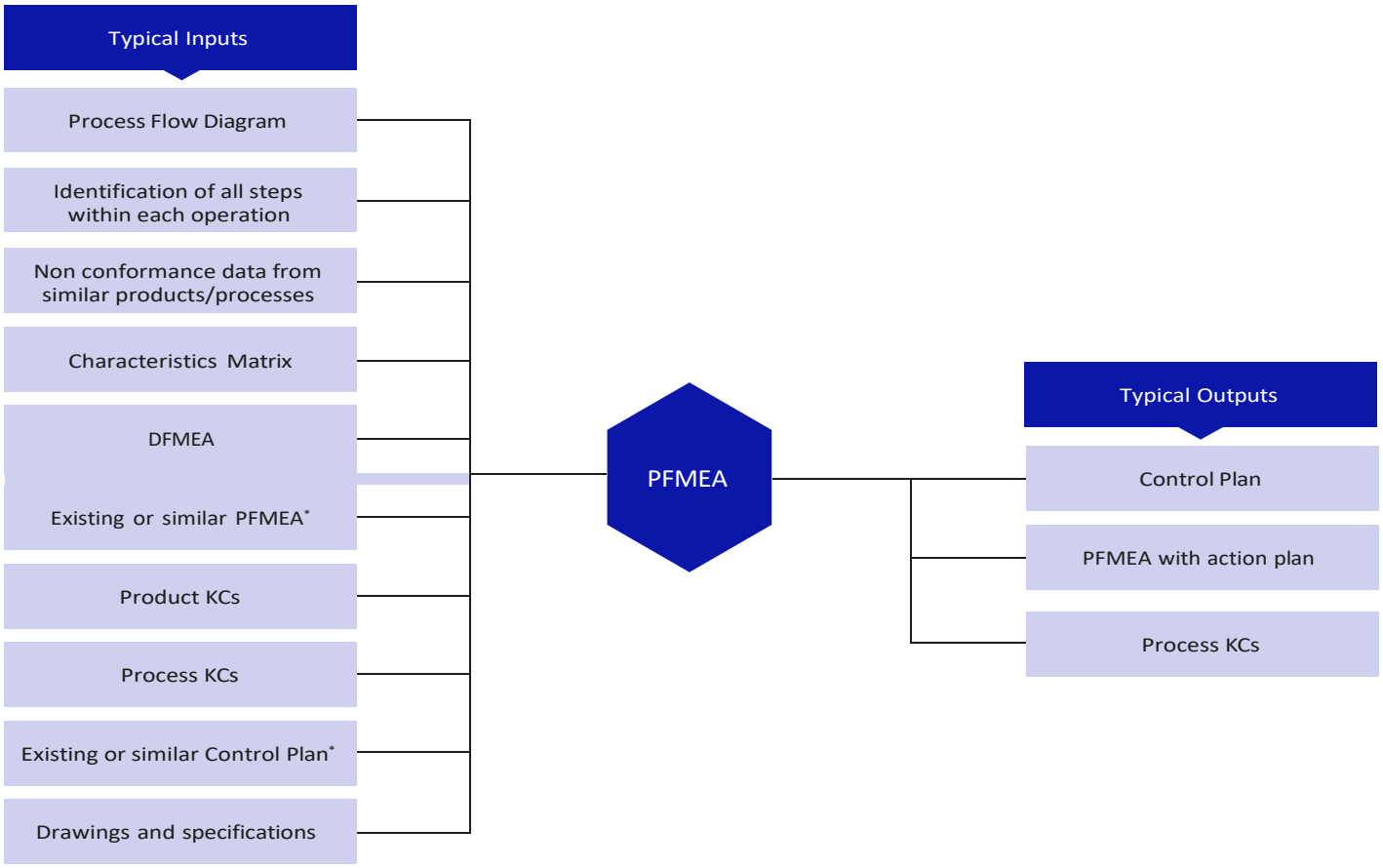
A well-defined, cross-functional team should include representatives from, but not limited to:

- Experienced facilitator;
- Manufacturing engineers;
- Process planners;
- Design engineers;
- Quality engineers;
- Process operators;
- Inspectors;
- HSE specialists; and
- Maintenance engineers.

In some cases, inputs form client's representative could be beneficial. Other functions worth consulting with are project management, logistics, and packaging specialists.

Inputs and Outputs

There are a number of key inputs required to complete the PFMEA and a number of key outputs generated from it, as illustrated in Figure 4.



*If an existing PFMEA or Control Plan is used partially or in full, it is crucial that its content is checked before any work will commence. Reference to the original document must be recorded.

Figure 4. PFMEA typical inputs and outputs

PFMEA Data

A standard template is used to create the PFMEA. Table 2 shows the headings of the PFMEA template and details the sources of the data.

PFMEA Heading	Description	Typical data source
Op no. (Operation number)	The sequential number for the operation step	Process Flow Chart
Operation/process step	A description of the process step, taken from the Process Flow Chart	Process Flow Chart, characteristics matrix
Requirements/expected outcome	The requirement for that function	Process Flow Chart, drawings, specifications, characteristics matrix
Potential failure mode	The way the part produced may fail to meet a design requirement, it is not a process failure (those are picked up in potential causes)	Team knowledge or past PFMEA examples
Potential failure mode effect	The effects of the failure mode to the customer, end user or internal process	Design, DFMEA, team knowledge or past PFMEA examples
SEV (Severity)	The severity of the failure effect on the product to the end user, customer or process.	DFMEA, team knowledge or past PFMEA examples
Classification	The product feature Key Classifications (Critical Characteristic (CC) or Significant Characteristic (SC) as determined by the DFMEA and design	DFMEA, KCs for product and process
Potential failure mode cause	The 'processes', i.e. manufacturing or assembly failures, which could cause the potential failure mode	Process Flow Chart, team knowledge or past PFMEA examples
OCC (Occurrence)	The likelihood (potential) for the failure to occur i.e. how often it will happen?	Past quality data, team knowledge or past PFMEA examples, ref. tables
Prevention of potential failure mode cause	The controls that exist in the process that stop the failure mode from occurring due to that particular cause	Process Flow Chart, team knowledge or past PFMEA examples
Detection of potential failure mode occurrence	The controls that exist in the design process that detect the failure mode if it occurred in the design	Process Flow Chart, team knowledge or past PFMEA examples.
DET (Detection)	The likelihood (potential) for the failure to be detected	Process Flow Chart, team knowledge or past PFMEA examples
RPN	The RPN is calculated as SEV x OCC x DET	This is an output of the PFMEA
Recommended improvements/ corrective actions	The corrective actions for items with high RPNs or high severity	This is an output of the PFMEA

Table 2. PFMEA standard headings and data sources

PFMEA Tools

There are two main tools that can be used during PFMEA to aid the work:

- Process Flow Chart; and
- Characteristics Matrix.

As each tool brings its own unique contribution to a PFMEA, it is important to know when to use it.

Process Flow Chart

Refer to the Process Flow Chart Guideline, which is part of the CPQP toolset. The flow chart defines the sequence of the manufacturing or assembly process steps and provides information about the expected outcomes and requirements of those steps.

Characteristics Matrix

The Characteristics Matrix documents all operations and all features as well as sequence in which they are created, making it an important PFMEA input document.

For each operation, it indicates where the features are:

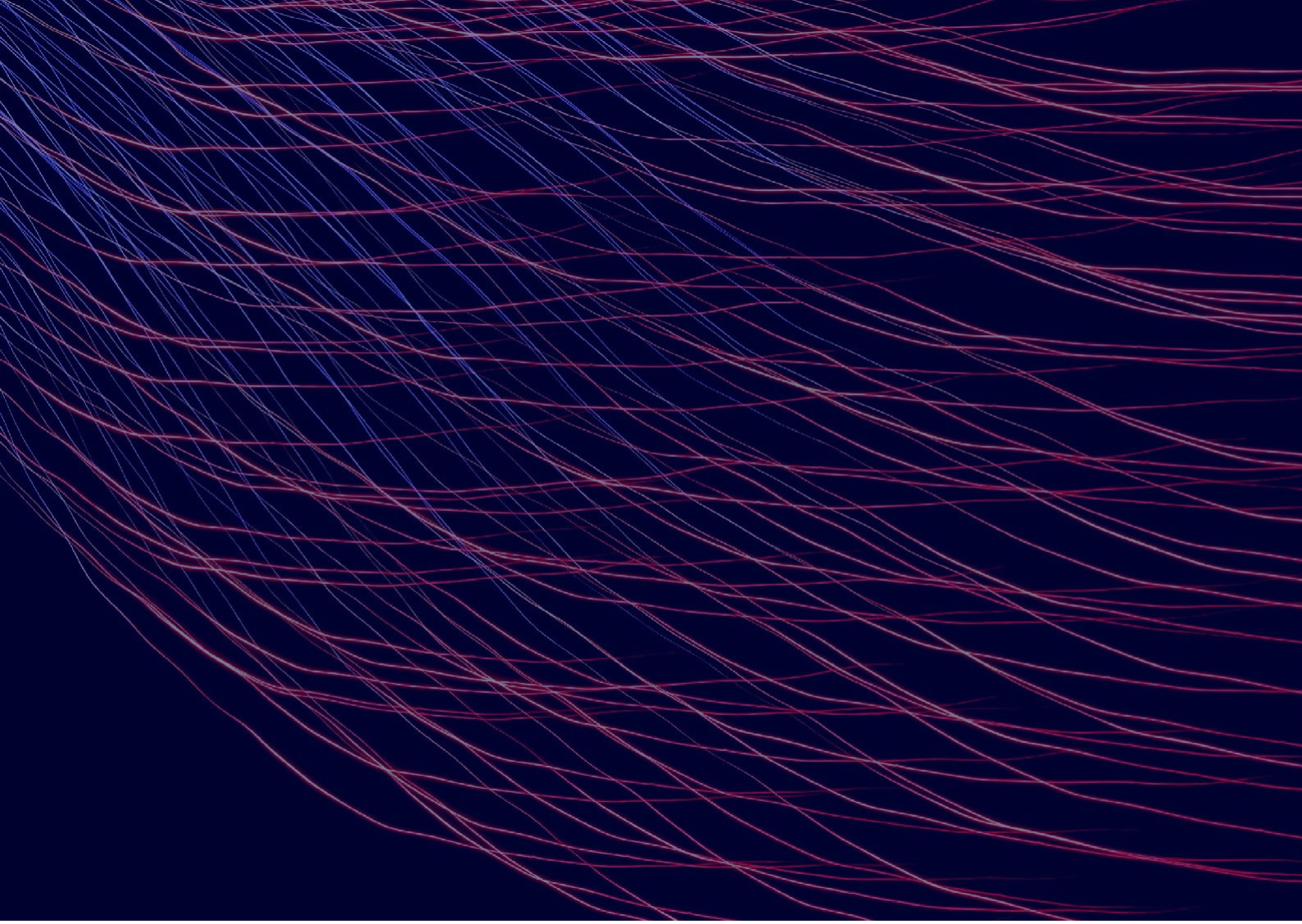
- Created;
- Transformed; and
- Inspected.

The relationship between the operations and the features created (including specification details) is clearly visible. Activities that can affect them at an earlier stage should also be listed, e.g., heat treatment, coating, welding, etc.

The Characteristics Matrix ensures that all features are included in the process and assesses the potential for minimising inspection operations, problems with transformations, etc. Table 3 shows a extract from the Characteristic Matrix.

Feature Details			Operation Sequence				
Feature Number	Description	Specification	OP100 Drill	OP110 Deburr	OP120 Clean	OP300 CMM	Etc.
1	Retaining Screw #1 Hole Diameter	M20	X	A		I	
2	Retaining Screw #1 Hole Location	1500 (x), 790 (y), 1000 (z)	X				
3	Retaining Screw #2 Hole Diameter	M20	X	A		I	
4	Retaining Screw #2 Hole Location	1500 (x), 790 (y), 500 (z)	X				
Key: X – Feature created. A – Feature affected, I – Inspected							

Table 3. Extract from the Characteristics Matrix example



Guideline

Guideline

Complete a PFMEA by following the 11 steps outlined in Figure 3 using the PFMEA template.

When filling in the template it is important to describe each element in sufficient detail whilst keeping it concise. Additionally, for traceability, references to any already existing PFMEAs used in the process should be noted.

The key PFMEA steps are described herein using a simple example. Further details and a link to the complete worked example can be found in Appendix A

Step 1: Populate process step information

From the Process Flow Chart, populate the operation number and the process step information as it is shown in Figure 5.

It is important to include all the process steps where material or product is transformed or has a potential to be transformed, e.g., damage during handling. There is no need for prioritisation of operations as all steps should be covered.

Op. No.	Operation/Process Step
20.70	Insert Insulation

Figure 5. PFMEA step 1 outcome example – populate process step information

Step 2: Identify expected outcomes of the process step

Confirm and fill in key requirements for the process step based on the Characteristics Matrix, Process Flow Chart, drawings and specifications. Figure 6 illustrates an example of the information to add.

Op. No.	Operation/Process Step	Requirements/ Expected Outcome
20.70	Insert insulation	3 x 349875 insulation panels located to the central panel in the locations and orientation as per assembly drawing (AS453213), with max 1mm gaps

Figure 6. PFMEA step 2 outcome example - identify expected outcomes

Step 3: Brainstorm potential failure modes

Brainstorm and list all the ways in which process might fail.

Do not list potential failure modes based on a requirement that is not mentioned on any drawing or specification, and therefore is not part of the operation scope, e.g., if deburring is not mentioned, sharp edges are not a failure mode of the process.

The few general examples of failure modes include:

- Feature too small;
- Feature too big;
- Feature missing;
- Feature in the wrong position/orientation;
- Wrong part/item used;
- Surface finish too rough;
- Surface finish too smooth; and
- Feature in the incorrect quantity.

Op. No.	Operation/Process Step	Requirements/Expected Outcome	Potential Failure Mode
20.70	Insert insulation	3 x 349875 insulation panels located to the central panel in the locations and orientation as per assembly drawing (AS453213), with max 1mm gaps	Less than three sections fitted
			Fitted with gaps larger than 1mm
			Sections fitted in the wrong orientation

Figure 7. PFMEA step 3 outcome example - brainstorm potential failure modes

Step 4: Brainstorm potential failure mode effects

Describe the potential effects of the failure mode on the downstream process, product, business or the customer. Add the relevant information in the template as illustrated in Figure 8. Which events described in potential failure mode are worrisome and why?

A design team representative and a DFMEA for the product are necessary for this stage.

Usually, a good starting point is to consider the internal and external impact in terms of:

- Quality;
- Cost;
- Delivery; and
- Environment, Health and Safety.

Op. No.	Operation/Process Step	Requirements/Expected Outcome	Potential Failure Mode	Potential Failure Mode Effect
20.70	Insert insulation	3 x 349875 insulation panels located to the central panel in the locations and orientation as per assembly drawing (AS453213), with max 1mm gaps	Less than three sections fitted	Significant reduction in insulation performance
			Fitted with gaps larger than 1mm	Reduced insulation performance
			Sections fitted in the wrong orientation	Reduced insulation performance
				Scrap due to interference with other wall panels when assembled

Figure 8. PFMEA step 4 outcome example - brainstorm potential failure mode effects

Step 5: Apply severity number (SEV) and characteristic

Severity Number

Assign a severity number to the failure mode, based on the severity of the consequences of that failure, using Table 4. Impacts on the customer and other sub-systems should be considered as illustrated in Figure 9.

Effect	Criteria: Severity of effect on product (customer effect)	Rank	Effect	Criteria: Severity of effect on process (manufacturing/ assembly effect)
Failure to meet safety and/or regulatory requirements	Potential failure mode affects safe building operation/function and/or involves non-compliance with government regulation without warning	10	Failure to meet safety and/or regulatory requirements	May endanger operator (machine or assembly) without warning
	Potential failure mode affects safe building operation/function and/ or involves noncompliance with government regulation with warning	9		May endanger operator (machine or assembly) with warning
Loss or degradation of primary function	Loss of primary function (building inoperable or function not delivered, does not affect safety)	8	Major disruption	100% of product may have to be scrapped. Line shutdown
	Degradation of primary function (building operable, but at a reduced level of performance). Customer very dissatisfied	7	Significant disruption	A portion of the production run may have to be scrapped. Deviation from primary process including decreased line speed or added manpower
Loss or degradation of secondary function	Building or product functions, but comfort/ convenience reduced. Customer dissatisfied	6	Moderate disruption	100% of production run may have to be reworked off line and accepted
	Building or product functions, but comfort/ convenience at a reduced level of performance. Customer somewhat dissatisfied	5		A portion of the production run may have to be reworked off line and accepted
Annoyance	Fit and finish of product does not conform. Defect noticed by most customers (greater than 75%)	4	Moderate disruption	100% of production run may have to be reworked in station before it is processed
	Fit and finish of product does not conform. Defect noticed by 50% customers	3		A portion of the production run may have to be reworked in station before it is processed
	Fit and finish of product does not conform. Defect noticed by discerning customers (less than 25%)	2	Minor disruption	Slight inconvenience to process, operation or operator
No effect	No discernible effect	1	No effect	No discernible effect

Table 4. PFMEA severity evaluation criteria

Op. No.	Operation/ Process Step	Requirements/Expected Outcome	Potential Failure Mode	Potential Failure Mode Effect	SEV	Classification
20.70	Insert insulation	3 x 349875 insulation panels located to the central panel in the locations and orientation as per assembly drawing (AS453213), with max 1mm gaps	Less than three sections fitted	Significant reduction in insulation performance	6	SC
			Fitted with gaps larger than 1mm	Reduced insulation performance	5	
			Sections fitted in the wrong orientation	Reduced insulation performance	5	
				Scrap due to interference with other wall panels when assembled	8	

Figure 9. PFMEA step 5 outcome example - apply SEV number, characteristics

Key Characteristics

Key Characteristics (KCs) are identified in the DFMEA and should be referenced in appropriate column in the PFMEA. As part of PFMEA, additional process KCs are recognised and noted. KCs are defined in the DFMEA as described in Table 5.

Critical	Non-conformance would result in loss of primary function of the product resulting in catastrophic or hazardous failures without any warning. These are failures that would potentially lead to loss of lives and/or irreparable damage. Products with any critical features are automatically classified as critical products. On the DFMEA, critical features are those with potential failure modes having severity effects scored 9 or 10 on the severity scale.
Significant	Non-conformance would result in loss of primary function of the product resulting in major failures without any warning. These are failures that cause significant disruption and costs to the client. Products with any significant features are automatically classified as significant products. On the DFMEA, significant features are those with potential failure modes having severity effects scored 5 to 8 on the severity scale.
Unclassified	Non-conformance would result in loss of a 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. Products with all unclassified features are unclassified products. On the DFMEA, unclassified features are those with potential failure modes having severity effects scored less than 5 on the severity scale.

Table 5. Key Characteristics definition

Step 6: Define potential failure mode cause(s)

Identify and populate the likely cause(s) for each failure mode in question as illustrated in Figure 10. The failure mode cause is an underlying cause (or causes) leading to failure.

It might be helpful to ask the question: What initiated mechanism leading to failure? How could it happen?

Op. No.	Operation/ Process Step	Requirements/ Expected Outcome	Potential Failure Mode	Potential Failure Mode Effect	SEV	Classification	Potential Failure Mode Cause
20.70	Insert insulation	3 x 349875 insulation panels located to the central panel in the locations and orientation as per assembly drawing (AS453213), with max 1mm gaps	Less than three sections fitted	Significant reduction in insulation performance	6	SC	Incorrect kit of parts used
			Fitted with gaps larger than 1mm	Reduced insulation performance	5		Current measurement instruments susceptible to reproducibility error leading to part not having correct clearance
			Sections fitted in the wrong orientation	Reduced insulation performance	5		Incorrect fixture used
				Scrap due to interference with other wall panels when assembled	8		Incorrect fixture used

Figure 10. PFMEA step 6 outcome example - define potential failure mode cause(s)

Step 7: Apply occurrence number (OCC)

Assign an occurrence number to the failure mode cause using the guidelines in Table 6. The occurrence evaluates the likelihood of the failure mode being caused by the potential cause identified in the PFMEA. It is a relative ranking, which can be based on real data, if available, or the team's judgement as illustrated in Figure 11.

Likelihood	Incidents Per Product	Rank
Very High	≥ 100 per 1,000 ≥ 1 in 10	10
	50 per 1,000 1 in 20	9
High	20 per 1,000 1 in 50	8
	10 per 1,000 1 in 100	7
Moderate	2 per 1,000 1 in 500	6
	0.5 per 1,000 1 in 2,000	5
	0.1 per 1,000 1 in 10,000	4
Low	0.01 per 1,000 1 in 100,000	3
	≤0.001 per 1,000 1 in 1,000,000	2
Very Low	Failure is eliminated through preventive control.	1

Table 6. PFMEA occurrence evaluation criteria.

Op. No.	Operation/ Process Step	Requirements/ Expected Outcome	Potential Failure Mode	Potential Failure Mode Effect	SEV	Classification	Potential Failure Mode Cause	OCC
20.70	Insert insulation	3 x 349875 insulation panels located to the central panel in the locations and orientation as per assembly drawing (AS453213), with max 1mm gaps	Less than three sections fitted	Significant reduction in insulation performance	6	SC	Incorrect kit of parts used	4
			Fitted with gaps larger than 1mm	Reduced insulation performance	5		Current measurement instruments susceptible to reproducibility error leading to part not having correct clearance	6
			Sections fitted in the wrong orientation	Reduced insulation performance	5		Incorrect fixture used	3
				Scrap due to interference with other wall panels when assembled	8		Incorrect fixture used	3

Figure 11. PFMEA step 7 outcome example - apply an OCC number

Step 8: Identify prevention and detection controls

Populate the current prevention and detection controls for the process failure noting that prevention is a preferred option to detection, as it stops error from occuring. Figure 12 provides an example.

Process prevention controls include but are not limited to:

- Mistake-proofing; and
- Additional control equipment, e.g., bar code scanners reading tool information to ensure correct tool is used.

Detection controls detect the failure mode after the failure has occurred but before the product is released to the downstream process. These include:

- Inspection;
- Operator checks; and
- Automated control.

Op. No.	Operation/ Process Step	Requirements/ Expected Outcome	Potential Failure Mode	Potential Failure Mode Effect	SEV	Classification	Potential Failure Mode Cause	OCC	Prevention of Potential Failure Mode Cause	Detection of Potential Failure Mode Occurrence
20.70	Insert insulation	3 x 349875 insulation panels located to the central panel in the locations and orientation as per assembly drawing (AS453213), with max 1mm gaps	Less than three sections fitted	Significant reduction in insulation performance	6	SC	Incorrect kit of parts used	4	Not in place	Visual inspection by operator in station
			Fitted with gaps larger than 1mm	Reduced insulation performance	5		Current measurement instruments susceptible to reproducibility error leading to part not having correct clearance	6	Not in place	Gauge inspection by operator in station
			Sections fitted in the wrong orientation	Reduced insulation performance	5		Incorrect fixture used	3	Not in place	Visual inspection by operator in station
				Scrap due to interference with other wall panels when assembled	8		Incorrect fixture used	3	Not in place	Visual inspection by operator in station

Figure 12. PFMEA step 8 outcome example - identify prevention and detection controls

Step 9: Apply detection (DET) number

Assign a detection number to represent the likelihood of the failure mode being prevented or detected using Table 7. An illustrative example is shown in Figure 13

Opportunity for Detection	Criteria: Likelihood of Detection by Process Control	Rank	Likelihood of Detection
No detection opportunity	No current process control, cannot be detected or is not analysed	10	Almost impossible
Not likely to detect at any stage	Failure mode and/or error (cause) is not easily detected, e.g. random audits	9	Very remote
Problem detection post processing	Failure mode detection post-processing by operator through visual/tactile/audible means	8	Remote
Problem detection at source	Failure mode detection in-station by operator through visual/ tactile/audible means or post-processing through use of attribute gaging, e.g., go/no-go, manual torque check/clicker wrench, etc	7	Very Low
Problem detection post processing	Failure mode detection post-processing by operator through use of variable gaging or in-station by operator through use of attribute gaging, e.g., go/no-go, manual torque check/clicker wrench, etc	6	Low
Problem detection at source	Failure mode or error (cause) detection in-station by operator through use of variable gaging or by automated controls in-station that will detect discrepant part and notify operator, e.g., light, buzzer, etc. Gauging performed on setup and first piece check (for setup causes only)	5	Moderate
Problem detection post processing	Failure mode detection post-processing by automated controls that will detect discrepant part and lock part to prevent further processing	4	Moderately High
Problem detection at source	Failure mode detection in-station by automated controls that will detect discrepant part and automatically lock part in station to prevent further processing	3	High
Error detection and/or problem prevention	Error (cause) detection in-station by automated controls that will detect error and prevent discrepant part from being made	2	Very High
Detection not applicable; error prevention	Error (cause) prevention as a result of fixture design, machine design or part design. Discrepant parts cannot be made because component has been error-proofed by process/product design	1	Almost certain

Table 7. PFMEA detection evaluation criteria

Op. No.	Operation/ Process Step	Requirements/ Expected Outcome	Potential Failure Mode	Potential Failure Mode Effect	SEV	Classification	Potential Failure Mode Cause	OCC	Prevention of Potential Failure Mode Cause	Detection of Potential Failure Mode Occurrence	DET
20.70	Insert insulation	3 x 349875 insulation panels located to the central panel in the locations and orientation as per assembly drawing (AS453213), with max 1mm gaps	Less than three sections fitted	Significant reduction in insulation performance	6	SC	Incorrect kit of parts used	4	Not in place	Visual inspection by operator in station	7
			Fitted with gaps larger than 1mm	Reduced insulation performance	5		Current measurement instruments susceptible to reproducibility error leading to part not having correct clearance	6	Not in place	Gauge inspection by operator in station	6
			Sections fitted in the wrong orientation	Reduced insulation performance	5		Incorrect fixture used	3	Not in place	Visual inspection by operator in station	7
				Scrap due to interference with other wall panels when assembled	8		Incorrect fixture used	3	Not in place	Visual inspection by operator in station	7

Figure 13. PFMEA step 9 outcome example - apply a DET number

Step 10: Calculate Risk Priority Number (RPN)

Calculate the RPN for each identified failure mode and potential cause of failure using the following calculation:

Severity (SEV) x Occurrence (OCC) x Detection (DET), as per Figure 14.

- For the SEV score, use the highest number for the failure mode, i.e. the worst-case scenario;
- For the OCC score, use each potential failure mode and assign an RPN score for each potential failure cause identified for a particular failure mode; and
- For the DET score, use the lowest score identified for the failure mode and associated potential cause, i.e. the best-case scenario.

The RPN gives a risk number, from one to one thousand, with one being the lowest potential risk and one thousand the highest. Figure 15 illustrates the process.

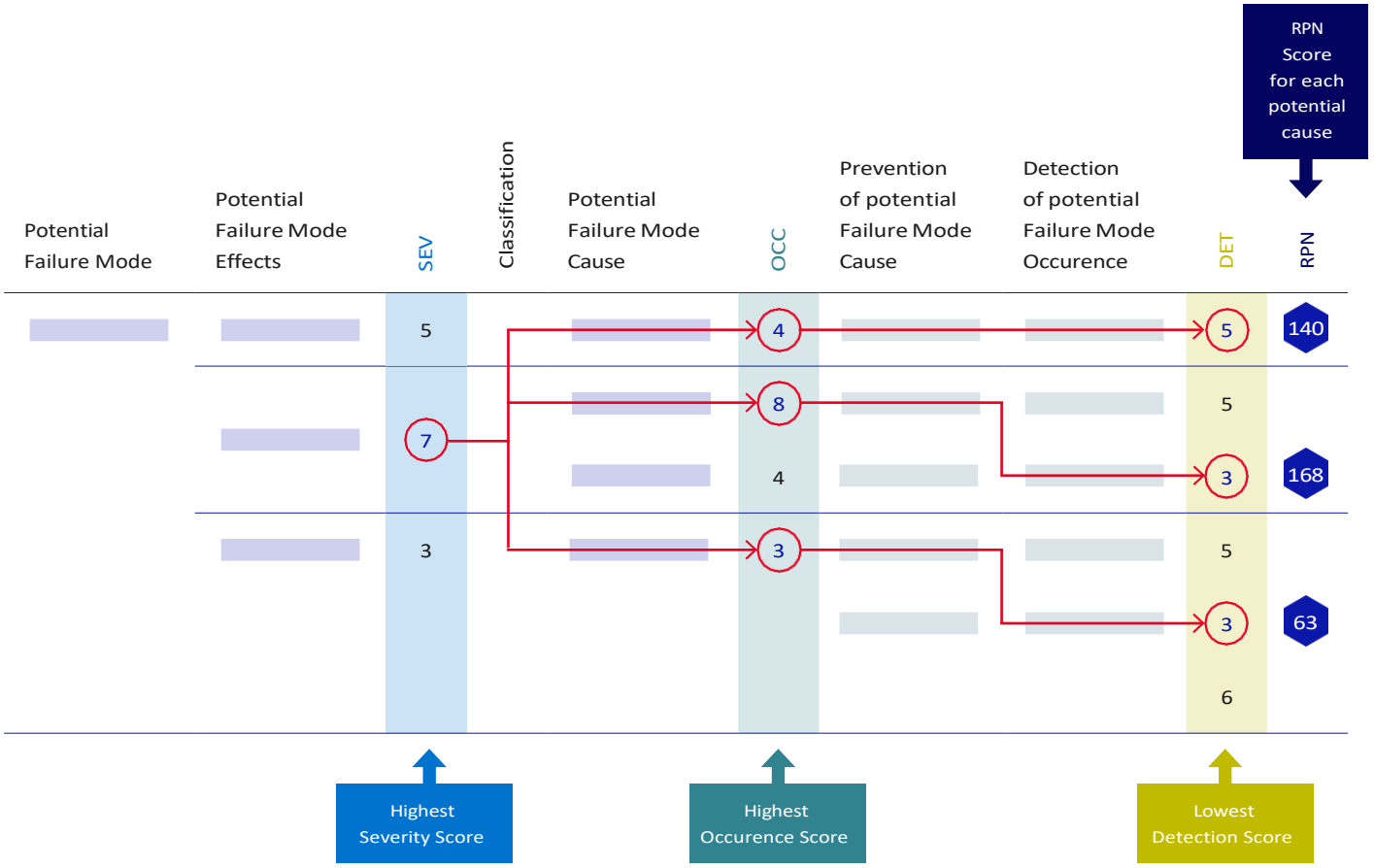


Figure 14. PFMEA RPN calculation guide

Op. No.	Operation/ Process Step	Requirements/ Expected Outcome	Potential Failure Mode	Potential Failure Mode Effect	SEV	Classification	Potential Failure Mode Cause	OCC	Prevention of Potential Failure Mode Cause	Detection of Potential Failure Mode Occurrence	DET	RPN
20.70	Insert insulation	3 x 349875 insulation panels located to the central panel in the locations and orientation as per assembly drawing (AS453213), with max 1mm gaps	Less than three sections fitted	Significant reduction in insulation performance	6	SC	Incorrect kit of parts used	4	Not in place	Visual inspection by operator in station	7	168
			Fitted with gaps larger than 1mm	Reduced insulation performance	5		Current measurement instruments susceptible to reproducibility error leading to part not having correct clearance	6	Not in place	Gauge inspection by operator in station	6	180
			Sections fitted in the wrong orientation	Reduced insulation performance	5		Incorrect fixture used	3	Not in place	Visual inspection by operator in station	7	105
				Scrap due to interference with other wall panels when assembled	8		Incorrect fixture used	3	Not in place	Visual inspection by operator in station	7	168

Figure 15. PFMEA step 10 outcome example – RPN calculation

Step 11: Develop an improvement action plan & execute

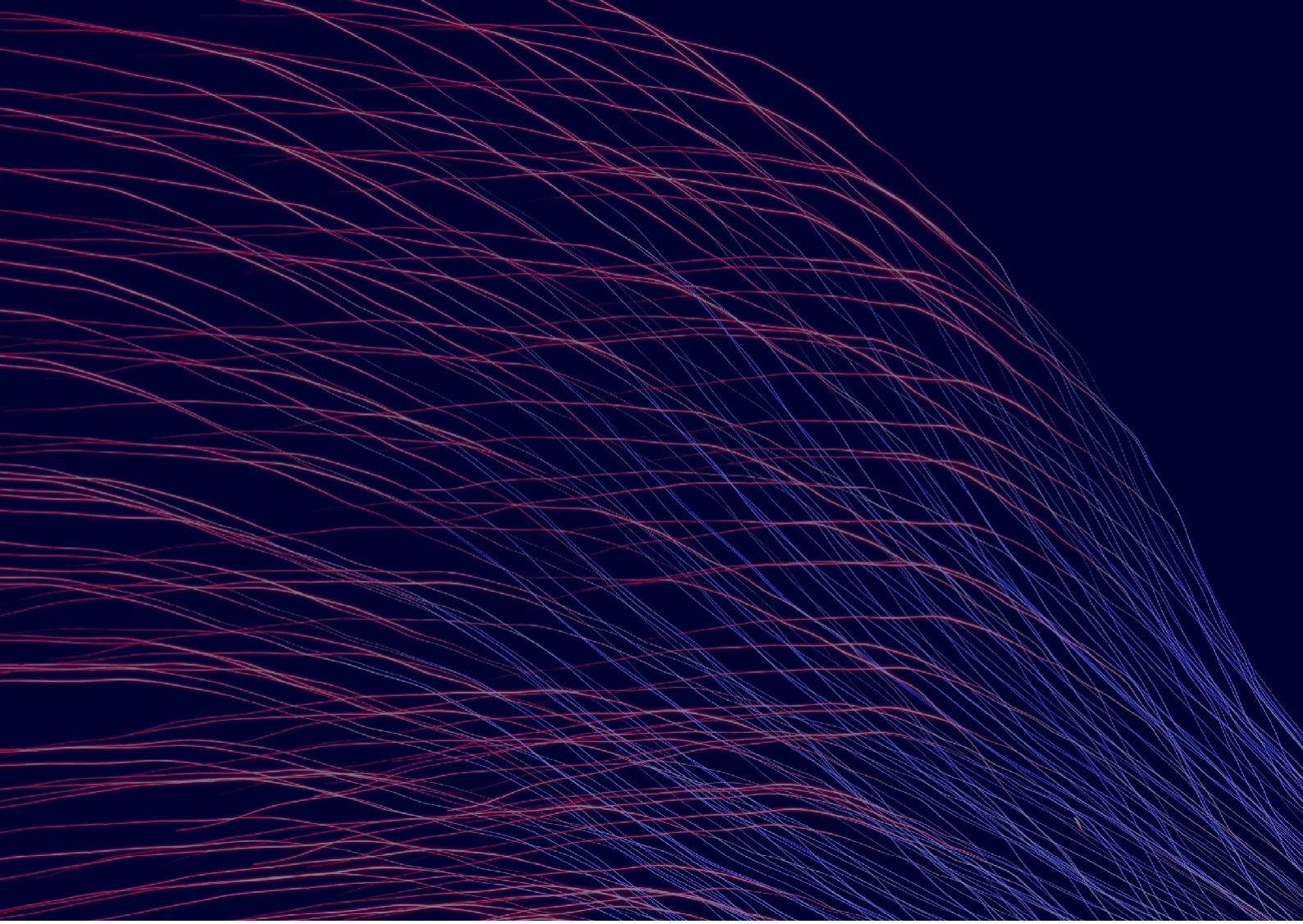
Use the calculated RPN to prioritise and define an action plan to reduce RPNs to an acceptable level. Actions should be taken for any failure mode effect with a severity greater than 7.

- Action owners and completion deadlines should be specified;
- Reduction in RPNs is usually achieved by lowering occurrence or detection independently or together. The reduction needs to be verified;
- Severity reductions cannot be achieved if the failure mode and its effect still exist;
- Occurrence reductions are achieved through prevention or control; and
- Detection reductions are achieved by improving prevention or detection controls.

During the design of the process, initial versions of the PFMEA may have very high RPNs. It is important to use the PFMEA tool to improve the design of the process. It should be updated and RPN recalculated in order to measure the effect of the improvement action. Figure 16 shows an example of a PFMEA improvement action list.

	Recommendations				Action Results					
RPN	Recommended Improvement/ Corrective Actions	Action Owner	Target Completion Date	Responsible Business/ Department	Actual improvement/ Corrective Actions Implemented	Actual Completion Date	SEV	OCC	DET	RPN
168 180	Add control to the machine/process station. Add part presence sensors into the jig to detect the insulation - lock into the station until three parts are seen.	J.Smith	29/11/2019	Manuf. Eng.	Presence sensors added to machine spec as described. Tested on development machine by manufacturer during trials.	27/01/2020	6	4	2	48
105 168	Add jig to load parts in correct spacing and orientation that swings over and places parts. Lock into machine with presence sensors above so can't swing into place until parts correct and locks station until fitted.	J.Smith	29/11/2019	Manuf. Eng.	Jig added. Tested on development machine by machine manufacturer during trials.	27/01/2020	8	1	7	56

Figure 16. PFMEA step 11 outcome example – sample improvement actions



References and Appendices

References

[1] Construction Innovation Hub. (2020). Construction Product Quality Planning Guide. UK.

[2] Automotive Industry Action Group (AIAG). (2008). Advanced Product Quality Planning (APQP) and control plan reference manual (2nd ed.). Southfield, MI: AIAG

[3] British Standards Institution. (2018). Aerospace Series – Requirements for advanced product quality planning and production part approval process. BS EN 9145. UK: BSI.

[4] Tanner, S. & Bailey, M. (2014). The business improvement handbook (4th ed.). London, UK: BSI Group.

Appendices

Appendix A – Tool Template

Templates to be used within the context of this guideline are available, please contact: cpqp@constructioninnovationhub.org.uk

Appendix B – List of Abbreviations

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

A	APQP	Advanced Product Quality Planning
C	CC	Critical Characteristic
	CI	Critical Item
	CoPQ	Cost of Poor Quality
	CPQP	Construction Product Quality Planning
D	DET	Detection (score)
	DFMEA	Design Failure Mode and Effects Analysis
F	FMEA	Failure Mode and Effects Analysis
K	KC	Key Characteristic
N	NPI	New Product Introduction
O	OCC	Occurrence (score)
P	PFMEA	Process Failure Mode and Effects Analysis
R	RPN	Risk Priority Number
S	SC	Significant Characteristic
	SEV	Severity (score)

Appendix C – 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 framework 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 [2].

C Construction Product Quality Planning (CPQP)

An adaptation of Advanced Product Quality Planning (APQP) that is aimed at those enterprises that will feed construction with new componentry for offsite builds.

Cost of Poor Quality (CoPQ)

Metric of all costs associated with quality incidents: this includes time spent on rework, doing quality investigations, additional materials used etc.

Critical Characteristic (CC)

An attribute or feature whose non-conformance would result in loss of primary function of the product resulting in catastrophic or hazardous failures without any warning. These are failures that would potentially lead to loss of life and/or irreparable damage.

Critical Item (CI)

BS EN 9145 [3]: '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.'

D Design Failure Mode and Effects Analysis (DFMEA)

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

F Failure Mode and 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 [4].' 'The FMEA assists in the identification of Critical Items (CIs) as well as key design and process characteristics, helps prioritize action plans for mitigating risk and serves as a repository for lessons learned [3].'

S Key Characteristics (KCs)

BS EN 9145 [3]: "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."

Process Mode Failure Effects Analysis (PFMEA)

An application of Failure Mode Effects Analysis (FMEA) for process design and implementation.

Significant Characteristic (SC)

An attribute or feature whose non-conformance would result in loss of primary function of the product resulting in major failures without any warning. These are failures that cause significant disruption and costs to the client.

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