Unit 33: Six Sigma Quality

Unit code: K/600/0295

QCF Level 3: BTEC Nationals

Credit value: 10

Guided learning hours: 60

Aim and purpose

This unit aims to give learners a broad understanding of Six Sigma methodologies, which are used to reduce variation and therefore frees an organisation to focus on improving process capability. It looks at the principles, infrastructure, metrics and how it is implemented within an organisation.

Unit introduction

Most organisations are continually striving to improve quality and reduce both costs and time. Six Sigma is a proven methodology for delivering consistent incremental improvement. The term Six Sigma derives from the mathematical use of sigma in statistics as a standard deviation – the measure of variability. By reducing process variation, Six Sigma frees the organisation to focus on improving process capability. The Six Sigma process encompasses all aspects of a business, including management, service delivery, design, production and customer satisfaction.

This unit aims to give learners a broad understanding of Six Sigma methodologies. It looks at the principles, infrastructure, metrics and how it is implemented within an organisation. It then focuses on the DMAIC project model, the foundation of all Six Sigma projects. DMAIC is an acronym for five interconnected phases: define, measure, analyse, improve and control. This structured methodology is used by improvement teams to root out and eliminate the causes of problems, such as products or processes not meeting customer specification or otherwise performing inadequately.

The unit then goes on to cover Six Sigma process mapping. This is a diagrammatical tool used to show the interrelationship between processes and enables teams to understand where and how improvements might be made.

The unit finally covers the competences required for carrying out a quality function deployment (QFD). It is widely recognised that customer focus is the key to business success. QFD is a process used for carrying the 'voice of the customer' throughout an organisation. Achieving customer focus in a product, process or service helps to minimise changes, improves communication, dramatically increases customer satisfaction and reduces the development cycle. Identifying priorities based on the customer's requirements also enables the most effective use of limited resources.

Learning outcomes

On completion of this unit a learner should:

1 Understand Six Sigma methodologies

2 Be able to apply the DMAIC model to a project

3 Be able to carry out a Six Sigma detailed process mapping activity

4 Know about quality function deployment (QFD).

Unit content

1 Understand Six Sigma methodologies

Principles: definition; concepts; vision; strategy; philosophy; goals; metrics; benchmarking

Infrastructure: leadership team; executive leader; champion/sponsor; master black belts (mentors); black belts (experts); green and yellow belts; roles and responsibilities

Implementation plan (road map): appoint champion; select cross-functional team; develop quantifiable goals; establish training programme; address data collection requirements and issues; develop change control programme; coordinate road map

Metrics: eg sigma level, voice of the customer (VOC) (such as meeting delivery date or functioning product), critical to quality (CTQ) criteria (such as delivery schedule achievement or non functioning product), opportunity for defects (such as one per delivery or number of components within a product), defects per unit (DPU), defect per opportunity (DPO), defects per million opportunities (DPMO), sigma scale

Tools: tools to define eg quality function deployment, process mapping, flow diagrams; tools to measure eg characteristic selection matrix, metric graphs, measurement system evaluation, check sheets, histograms/tally charts, capability studies, statistical process control; tools to analyse eg brainstorming, cause and effect diagram, affinity diagrams, Pareto analysis, scatter diagrams, potential failure modes and effects analysis, multi-variance studies; improvement tools eg mean shifting, variability reduction, poka yoke, value analysis, benchmarking, kaizen/kaizen blitz; tools for control eg standard operating procedures, workplace organisation, visual management, audits

DMAIC phases: define, measure, analyse, improve, control

2 Be able to apply the DMAIC model to a project

Define: eg team charter, project launch, define project objectives and outcomes, identify sponsor/key stakeholders, prepare communication plan, define gateways

Measure: eg create high level process map, obtain critical to quality (CTQ) criteria, characteristic selection matrix, gather primary and secondary metrics with metric graph, determine current process sigma level, make go/no-go decisions

Analyse: eg interpret collected data, define benchmarks, define cause and effect relationships, validate, quantify and prioritise root causes of current performance

Improve: eg activities using Six Sigma tools and techniques, prioritise, implement, interpret and learn from results, develop control methods, manage change

Control: eg continuously improve by monitoring process using dashboard and scorecard data, create feedback loops, process meeting customer requirements

3 Be able to carry out a Six Sigma process mapping activity

Theory: type eg top-level process map, detailed process map, key process input variables (KPIVs) and key process output variables (KPOVs) (such as big X or process/input parameters, little x or in-process parameters, big Y or end product/output parameters, little y or in-process product parameters); functional relationship $Y = \mathrm{f}(x)$; classification of data eg controllable, critical, noise, standard operating procedures

Procedures: pre-mapping eg select suitable process, define problem statement and specify goal; mapping process eg walk the process, observe and ask questions, identify process key stages, identify process input variables, identify process output variables; mapping outputs eg classify the input and output data, contribute to the process mapping of the current state, identify the value added and non-value added steps of the process, identify improvement opportunities

4 Know about quality function deployment (QFD)

Principles: customer dissatisfaction; causes of design problems; definition of QFD; purpose of QFD; benefits of QFD; QFD requirements; house of quality (HoQ); QFD phases

Procedures: pre-QFD activity eg define customers, identify customer needs and expectations, define importance of requirements (wants); applying QFD eg determine how to satisfy customer wants, complete inter-relationship matrix (wants versus hows), prioritise the hows, analyse how well competitors meet customer wants, complete technical attributes and evaluate, define target values

Grading criteria

In order to pass this unit, the evidence that the learner presents for assessment needs to demonstrate that they can meet all the learning outcomes for the unit. The criteria for a pass grade describe the level of achievement required to pass this unit.

Assessment and grading criteria		
To achieve a pass grade the evidence must show that the learner is able to:	**To achieve a merit grade the evidence must show that, in addition to the pass criteria, the learner is able to:**	**To achieve a distinction grade the evidence must show that, in addition to the pass and merit criteria, the learner is able to:**
P1 describe the principles of Six Sigma including an outline of its infrastructure	**M1** develop Six Sigma metrics for a project and analyse the resultant metric graph to identify improvement tools	**D1** describe the issues encountered when executing a Six Sigma implementation plan
P2 explain how to implement a Six Sigma programme	**M2** construct a characteristic selection matrix for a project and use this information to identify improvement activities	**D2** use and evaluate the QFD procedure and HoQ to evaluate a product and its processes.
P3 calculate a range of Six Sigma metrics [IE1]	**M3** evaluate a detailed process map and develop a future state process map.	
P4 use one of the Six Sigma tools in each of the DMAIC phases		
P5 define a suitable Six Sigma project within an organisation		
P6 carry out measurement and analysis phases of a given DMAIC project [IE1, IE4]		
P7 carry out improvement and control phases of a given DMAIC project [RL3, SM3, SM6]		
P8 use the theory and procedures of Six Sigma process mapping to develop a current state map of a selected process		
P9 describe the principles and procedures of quality function deployment.		

PLTS: This summary references where applicable, in the square brackets, the elements of the personal, learning and thinking skills applicable in the pass criteria. It identifies opportunities for learners to demonstrate effective application of the referenced elements of the skills.

Key	IE – independent enquirers	RL – reflective learners	SM – self-managers
	CT – creative thinkers	TW – team workers	EP – effective participators

Essential guidance for tutors

Delivery

Delivery of this unit could concentrate on a particular manufacturing sector and work area only, eg automotive and assembly. However, a generic approach covering a range of sectors and work areas is more likely. Centres should determine their approach through an analysis of their learners' needs and, in particular, through consideration of the range of industries that the centre is working with or preparing their learners for. Whichever approach is taken should provide learners with the underpinning knowledge and skills needed to fully understand the principles of Six Sigma and effectively apply the relevant tools and techniques in their area of work.

The learning outcomes are ordered logically and could be delivered sequentially. In this way, learners will begin to recognise the range of tools and techniques, their function and use during a DMAIC project. It is recommended that a variety of delivery methods are used including group discussions, team/group and individual activities, research, industrial visits, presentations and tutor-led learning. This approach will help give a more practical approach, rather than spending too much time on theory. For example, a short introduction to Six Sigma process mapping could be followed by an industrial visit for learners to walk a process, observe and ask questions, and identify process key stages, process input variables and process output variables.

A blend of learning materials should be used to stimulate learners and place the unit in context. These should include CD ROMs, internet research, specific study packs on Six Sigma topics, worksheets, industrial case studies, videos/DVDs and textbooks for extended study where appropriate.

Formative assessment will play an important part in learners' general development, especially their achievement at merit and distinction grades. Evaluative skills are required at distinction level; formative work in the delivery phase will encourage learners to consider how the tools and techniques being applied can be improved.

Note that the use of 'eg' in the content is to give an indication and illustration of the breadth and depth of the area or topic. As such, not all content that follows an 'eg' needs to be taught or assessed.

Outline learning plan

The outline learning plan has been included in this unit as guidance and can be used in conjunction with the programme of suggested assignments.

The outline learning plan demonstrates one way in planning the delivery and assessment of this unit.

Topic and suggested assignments/activities and/assessment
Whole class teaching: • introduction to unit content, outline scheme of work and assignments • introduce and define the principles of six sigma • explain six sigma infrastructure • describe the use of implementation plans • explain and demonstrate how to calculate six sigma metrics • explain six sigma tools and their use in each of the DMAIC phases. *Small group activity:* • research six sigma methodologies using case studies of local or regional manufacturers.

Topic and suggested assignments/activities and/assessment
Preparation for and carrying out **Assignment 1: Six Sigma Methodologies** (P1, P2, P3, D1)
Whole class teaching: • explain the application of the DMAIC model to a project. *Practical learner activities:* • define a project and carry out measurement, analysis, improvement and control phases.
Preparation for and carrying out **Assignment 2: The DMAIC Model** (P4, P5, P6, P7, M1, M2)
Whole class teaching: • describe the different types of process mapping • describe the functional relationship and classification of data • explain and demonstrate pre-mapping procedures • explain and demonstrate the mapping process • explain mapping outputs. *Industrial visit:* • walk a process and view key stages process variables.
Preparation for and carrying out **Assignment 3: Process Mapping** (P8, M3)
Whole class teaching: • explain principles of quality function deployment • explain pre-QFD procedures and means of applying QFD.
Preparation for and carrying out **Assignment 4: Quality Function Deployment** (P9, D2)
Feedback on assessment and unit evaluation.

Assessment

Evidence of meeting criteria can be collected from the learners' involvement in Six Sigma activities in their workplace and through case studies, assignments and projects. This should enable learners to demonstrate knowledge and understanding of the principles of Six Sigma in a manufacturing environment.

To achieve P1 learners will need to describe the principles of Six Sigma. This could be done through the use of a written task, or tutors could allocate different areas to individual learners or groups of learners and ask them to feed back to the class in the form of a presentation or annotated poster. In these cases it must, however, be remembered that the presentation skills or poster design skills are not being assessed.

P2 requires learners to explain how to implement a Six Sigma programme. An assignment could be developed on the overall approach and then linked to D1 by asking learners to describe in more detail the issues encountered when executing a Six Sigma implementation plan.

For P3, learners have to calculate a range of Six Sigma metrics. The range will depend on the Six Sigma programme or project under consideration. To determine the correct metrics, learners must properly define and quantify the unit, defects and opportunity for defects. The voice of the customer (VOC) is the method of gathering such information and must be taken into consideration. The critical to quality criteria (CTQs) can then be translated from these comments, issues and specifications. The quality characteristics become opportunities for defects when the specification is set. The total number of opportunities indicates the complexity of the product, process or service. These can then be converted to defects per million opportunities (DPMO) and a Sigma value determined for a benchmark. The evidence for this criterion could be generated by a short written assessment.

P4, P5, P6 and P7 call for the demonstration of practical skills required in a Six Sigma programme. Evidence for these criteria could be provided from the learners' involvement in Six Sigma activities in the workplace or through a work placement. If assessed directly by the tutor, suitable evidence would be standard documentation and observation records completed by the learner and tutor. If assessed during a placement, witness statements should be provided by a suitable representative and verified by the tutor. Guidance on the use of observation records and witness statements is provided on the Edexcel website. Where learners do not have access to this form of 'real' activity, simulation could be used.

Learners will need to keep an activity log showing evidence of achievement and witness statements/ observation records should be used to verify achievement.

Learners could expand on P7 and generate evidence for M1 by developing Six Sigma metrics for a project and analysing the resultant metric graph to identify improvement tools. M1 can be linked to M2 by asking learners to construct a characteristic selection matrix for a project and use this information to identify improvement activities.

P8 requires learners to use the theory and procedures of Six Sigma detailed process mapping to develop a current state map of a selected process. Again, evidence of this could be provided from the learners' involvement in Six Sigma activities in the workplace or through simulation. P8 could then be linked to M3 by asking learners to evaluate the detailed process map and develop a future state process map.

P9 requires learners to describe the principles and procedures of quality function deployment. This could be achieved through oral questioning or a short written assignment. P9 could be linked to D2, where learners are requested to evaluate the use of the QFD procedure and HoQ to evaluate a product and its processes. This may be best achieved through a simulated activity.

To achieve M1, learners need to develop Six Sigma metrics for a project and analyse the resultant metric graph to identify improvement tools. M2 requires learners to construct a characteristic selection matrix for a project and use this information to identify improvement activities. For M3 learners need to evaluate a detailed process map and develop a future state process map.

To achieve a distinction grade, D1 and D2 could be linked to the tasks or activities carried out when addressing criteria P2 and P9. For D1 learners are required to describe the issues encountered when executing a Six Sigma implementation plan. This could be achieved by linking and expanding on the evidence associated with P2. D2 could be linked to P9 by asking learners to use the QFD procedure and HoQ to evaluate a simulated product and its processes.

All evidence must be generated in a form suitable for inclusion in the learners' portfolio. This could include standard forms (eg process maps, flow diagrams, check sheets etc), images (eg photographs, scanned images, completed charts, diagrams, plans and engineering drawings), presentation slides, written reports, witness statements and solutions to problems set in assignments.

Programme of suggested assignments

The table below shows a programme of suggested assignments that cover the pass, merit and distinction criteria in the assessment and grading grid. This is for guidance and it is recommended that centres either write their own assignments or adapt any Edexcel assignments to meet local needs and resources.

Criteria covered	Assignment title	Scenario	Assessment method
P1, P2, P3, D1	Six Sigma Methodologies	Learners need to show a new member of staff the use of six sigma methodologies in relation to a project or programme.	A written report outlining six sigma principles and describing how to implement a six sigma programme, including a range of metrics calculated for the programme.
P4, P5, P6, P7, M1, M2	The DMAIC Model	Learners have to implement a DMAIC project.	A practical assignment, evidenced through learners' logbook and observation records.
P8, M3	Process Mapping	Learners need to develop a current state map of a selected process.	A practical assignment evidenced through learners' logbook.
P9, D2	Quality Function Deployment	Learners need to produce a report explaining QFD.	A written report or presentation describing procedures of quality function deployment.

Links to National Occupational Standards, other BTEC units, other BTEC qualifications and other relevant units and qualifications

This unit forms part of the BTEC Engineering sector suite. This unit has particular links with:

Level 1	Level 2	Level 3
	Applying Continuous Improvement and Problem Solving Techniques	Production System Design
	Workplace Organisation and Standard Operating Procedures	Quality and Business Improvement Techniques
		Teamwork in a Continuous Improvement Environment

This unit supports the Level 3 NVQ in Business Improvement Techniques, particularly:

- Unit 18: Applying the Six Sigma Methodology to a Project
- Unit 19: Carrying out Six Sigma Process Mapping
- Unit 22: Applying Six Sigma Metrics to a Project
- Unit 23: Producing a Characteristic Selection Matrix.

Essential resources

To deliver this unit centres will need to have an up-to-date reference library with computer aided learning resources and appropriate journals.

Employer engagement and vocational contexts

Most of the work required for this unit can be set in the context of learners' work placements or be based on case studies of local employers. There are a range of organisations that may be able help centres engage and involve local employers in the delivery of this unit, for example:

- Work Experience/Workplace learning frameworks – Centre for Education and Industry (CEI, University of Warwick) – www.warwick.ac.uk/wie/cei
- Learning and Skills Network – www.vocationallearning.org.uk
- Network for Science, Technology, Engineering and Maths Network Ambassadors Scheme – www.stemnet.org.uk
- National Education and Business Partnership Network – www.nebpn.org
- Local, regional Business links – www.businesslink.gov.uk
- Work-based learning guidance – www.aimhighersw.ac.uk/wbl.htm

Indicative reading for learners

Textbooks

Bicheno J – *Cause and Effect Lean: Lean Operations, Six Sigma and Supply Chains* (Picsie Press, 2000) ISBN 0951383019

Bicheno J – *The New Lean Toolbox* (Picsie Press, 2004) ISBN 0954124413

Chen C and Roth H – *Big Book of Six Sigma Training* (McGraw-Hill Education, 2005) ISBN 0071443851

Gygi C, DeCarlo N and Williams B – *Six Sigma for Dummies* (Hungry Minds Inc, 2005) ISBN 0764567985

Journal

International Journal of Operations and Production Management

Magazines

Engineering Technology

Manufacturing Engineer

Delivery of personal, learning and thinking skills

The table below identifies the opportunities for personal, learning and thinking skills (PLTS) that have been included within the pass assessment criteria of this unit.

Skill	When learners are ...
Independent enquirers	identifying questions to answer and problems to solve when calculating Six Sigma metrics identifying problems to solve and analysing and evaluating information when carrying out measurement and analysis phases of a DMAIC project
Reflective learners	carrying out the improvement phase of a DMAIC project reviewing progress and acting on the outcomes
Self-managers	organising time and resources when implementing the control phase of a DMAIC project, managing and responding positively to change.

Although PLTS are identified within this unit as an inherent part of the assessment criteria, there are further opportunities to develop a range of PLTS through various approaches to teaching and learning.

Skill	When learners are ...
Independent enquirers	analysing and evaluating information relating to a Six Sigma programme.

Functional Skills – Level 2

Skill	When learners are ...
English	
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	researching and analysing information relating to Six Sigma
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	describing the principles of Six Sigma quality and explaining how to implement a Six Sigma programme.