Unit 32: Production System Design

Unit code: J/600/0286
QCF Level 3: BTEC Nationals
Credit value: 10
Guided learning hours: 60

Aim and purpose

This unit aims to develop learners' understanding of the issues and dynamics associated with the design and management of modern production systems.

Unit introduction

Industry professionals within engineering companies understand that manufacturing must be seen as a holistic and dynamic system that integrates people, business processes and technology. This unit aims to develop learners' understanding of the issues and dynamics associated with the design and management of modern production systems.

The unit specifically focuses on lean manufacturing – a management philosophy that focuses on the identification and elimination of waste in manufactured products. Lean thinking principles have emerged as a method to improve the flexibility, reliability and profitability of engineering enterprises worldwide. It is being used to reduce inventory, batch size and set-up times. As enterprises have reduced costs and improved quality, the primary competitive measure is the ability to respond to the customer.

This unit first introduces the basic principles of lean (value, value stream, flow, pull, and continuous improvement). The unit will develop these concepts and give learners a full understanding of the skills and competencies required by someone working in a lean manufacturing environment. It then covers lean manufacturing methods and tools designed to put these concepts into practice in a manufacturing environment. Topics explored include flow process analysis, production levelling, kanban systems, set-up reduction, standard operations, total productive maintenance and autonomous maintenance.

Learning outcomes

On completion of this unit a learner should:

1 Know the principles of lean manufacturing

2 Know how to create a flexible production system

3 Be able to apply the single minute exchange of die (SMED) method to a production system

4 Know how to implement a total productive maintenance system.

Unit content

1 Know the principles of lean manufacturing

Minimising waste: definition of waste; areas of waste eg operator motion, waiting time, over production, process time, defects, inventory, transportation, definition of value/non-value added activities; streamline flow eg goal of streamline flow, impact of smoothing production, assumptions of the economic batch quantity, hidden costs of inventory

Group technology techniques: use of classification system; cluster analysis; cell design; exploiting similarities of products within families eg reduced set-ups, smaller batch sizes, improved productivity, reduced inventory, easier handling, standardisation of tasks and equipment, reduced tooling, jigs, fixtures and pallets, simplified production planning and control, improved quality, identification and solving recurring problems, employee job satisfaction

Continuous improvement principles: small incremental improvement steps; benefits over large step-changes eg sustainable reduction/elimination of the 'seven wastes' and the 'six big losses' of production, reduced cost, improved safety, quality, working practices and procedures

Visual management: local visual management systems; visual display techniques; visual control methods; benefits of visual management

Pull production systems principle: demand-driven production; advantages of pull production eg reduced inventory, reduced lead time, improved part synchronisation, elimination of queues, improved defect detection rate

Workplace organisation: correct location for machines, tools, equipment and inventory; point-of-use stock; sort out/clear out; straighten/configure; shine/clean; standardise/conformity; self-discipline/custom and practice; 5S/5Cs audits

2 Know how to create a flexible production system

Flow process analysis: analysis charts eg flow diagrams, multiple-activity charts, man/machine charts, two-handed charts, payback matrix, lead-time analysis, lead time profiles, frequency diagrams; basic mapping procedure eg identify area, map current state, examine, develop future state map, implement and repeat

Production levelling: documentation eg precedence charts, collecting manual, production schedule; line balancing procedure eg walk and machine times, determining customer demand, determining batch size, calculating system cycle time, calculating takt time, calculating number of work stations, assigning tasks; analysis eg line balance ratio, line balance efficiency

Kanban systems: types of kanban eg production, withdrawal, special, combined, single card system, dual card system; kanban rules eg determining the batch quantity, determining the number of kanban; further kanban systems eg express production kanban, offline kanban, raw material kanban, supplier kanban, footprint kanban, max/min buffers, two bin systems

Standard operating procedure (SOP): rules of the standardised job; documentation (standard combination sheets and standardised work charts); key quality and safety points; work elements; element times eg manual, walking, machine, cycle, takt; equipment and machine layout

3 Be able to apply the single minute exchange of die method to a production system

Single minute exchange of die (SMED): methodology (identify elements, separate internal and external activities, convert internal activities to external, standardisation, reduce internal times, reduce external times, implementation plan); aids (conversion matrix, use of pre-set tooling, special fasteners, manifolds, parallel activities); set-up elements eg preparation, mounting and extraction, establishing control settings, first run capability

4 Know how to implement a total productive maintenance system

Total productive maintenance: major causes of machine breakdowns; the traditional approach to maintenance; elements of a breakdown eg mean time between breakdowns, mean time to repair, availability, activities during machine downtime; principles of total productive maintenance; 5C/5S foundations; prioritisation and elimination of the 'six big losses' to production eg unexpected breakdowns, set-up and adjustments, minor stoppages, actual operating speed, defects, start up yield, role of operator and maintenance engineer during 1st and 2nd line maintenance

Steps to autonomous and planned maintenance: establish autonomous maintenance; establish planned maintenance programme; conduct operator and maintenance engineer training; maintain equipment in optimum condition; set up early equipment management programme

Overall equipment effectiveness (OEE): performance metric and improvement cycle; definition of availability; performance; quality; calculating OEE

Assessment and 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 assessment 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 minimising waste and the techniques of group technology	**M1** explain the benefits of applying group technology to a production system	**D1** compare and contrast the incremental approach to continuous improvement with that of large step changes
P2 describe the principles of continuous improvement and the use of visual management systems	**M2** describe the advantages of smoothing production	**D2** evaluate the issues encountered when applying lean principles to create a flexible production system from a traditional production system.
P3 describe the principles of a pull production system and the use of workplace organisation	**M3** explain the importance of set-up reduction to the performance of a production system.	
P4 use suitable flow process analysis charts and mapping procedures to determine the current state of a production system		
P5 perform a production levelling exercise to determine a future state map of a production system [IE2, CT1, SM3]		
P6 describe a type of kanban system and a further kanban system, including kanban rules		
P7 compile a SOP for one element of a production system		
P8 apply the SMED to reduce the change over time of one element of a production system [IE2, CT1, SM3]		

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:**
P9	describe total productive maintenance and the steps required for autonomous and planned maintenance		
P10	gather production data and calculate the overall equipment effectiveness (OEE) of a production system. [IE4]		

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 enable learners to fully understand the principles of lean manufacture and apply relevant tools and techniques to aid production system design in most industrial settings.

The learning outcomes are logically ordered and could be delivered sequentially. Learners will begin to recognise the range of tools and techniques and their function and use during the design of a flexible production system. It is recommended that a variety of delivery methods be used including group discussions, team/group and individual activities, research, industrial visits, presentations and tutor-led learning. This approach will help give a practical approach, rather than spending too much time on theory. For example, a short introduction to lean manufacture and areas of waste found in a production system – followed by an industrial visit for learners to see real examples of waste at first hand.

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

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, scheme of work and method of assessment • define waste and explain the areas where waste occurs • explain streamline flow • describe the use of group technology techniques • explain continuous improvement principles and the benefits of small incremental changes • describe the use and benefits of visual management systems and control methods • explain the principle and advantages of pull production systems • describe the best means of workplace organisation including 5S/5C methodology. *Small group/individual activity*: • using case studies, research the use of lean manufacturing principles in industry and compare its use to a company that has yet to implement lean methodologies.
Preparation for and carrying **Assignment 1: Principles of Lean Manufacturing** (P1, P2, P3, M1, D1)

Topic and suggested assignments/activities and/assessment
Whole class teaching: • describe flow process analysis, the use of analysis charts and basic mapping procedures • describe the documentation used in production levelling • explain time balancing procedures and analysis • explain the different types of kanban and the use of kanban rules and systems • describe the production and use of standard operating procedures. *Small group/individual activity*: • using case studies, research and compare the use of different types of flexible production systems.
Preparation for and carrying **Assignment 2: Flexible Production Systems** (P4, P5, P6, P7, M2, D2)
Whole class teaching: • explain and demonstrate the use of SMED methodology, aids and set-up elements. *Small group/individual activity*: • using case studies, research the use of SMED methods in industry • use SMED methods and aids to identify elements and reduce times in a production system.
Preparation for and carrying **Assignment 3: Single Minute Exchange of Die** (P8, M3)
Whole class teaching: • explain the major causes and elements of breakdown • describe and compare traditional approaches to maintenance and the principles of total productive maintenance • describe methods of establishing autonomous and planned maintenance programmes • describe performance metric and improvement cycle and means of calculating overall equipment effectiveness.
Preparation for and carrying **Assignment 4: Total Productive Maintenance** (P9, P10)
Feedback, unit evaluation and close.

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, M1, D1	Principles of Lean Manufacturing	Learners have been asked to produce a report on the benefits of lean manufacturing systems.	A written report or an information poster.
P4, P5, P6, P7, M2, D2	Flexible Production Systems	Learners have been asked to look at ways of improving an existing production system.	A written report supported by a logbook and observation records.
P8, M3	Single Minute Exchange of Die	Learners must apply SMED approach to a production system.	A practical activity evidenced by supporting documentation and observation records. An additional written report explaining the importance of set-up reduction.
P9, P10	Total Productive Maintenance	Learners have been asked to explain total productive maintenance to new apprentices.	A short written report or information poster plus equipment effectiveness calculations based on production data.

Assessment

Evidence of learning outcomes can be collected from the learners' workplace, case studies, assignments and projects. This should enable learners to demonstrate knowledge and understanding of the principles of lean manufacture and the design and analysis of flexible production systems in a manufacturing environment.

For P1 they will need to describe the areas of waste found in a production system when they are describing the principles of minimising waste. This may be achieved in a number of ways, eg a short written description of the type of waste or by using suitable annotated photographs. Learners are not expected to write lengthy descriptions to achieve this criterion. Learners must also briefly describe the techniques that can be used to identify part families. Ideally this can be expanded to explain the benefits of exploiting the similarities of products within families and used for evidence towards M1.

P2 requires learners to describe the principles of continuous improvement and explain how visual management systems can be applied to reinforce and sustain improvements. An assignment could be developed on the two approaches and then linked to D1 by asking learners to compare and contrast the incremental approach to continuous improvement with that of large step changes.

P3 requires learners to describe the principles of pull production and its essential prerequisite workplace organisation. This could be achieved via a presentation to the group, or as an annotated poster.

For P4 learners need to use suitable flow process analysis charts to map the current state of a given production system. They must then perform a production levelling exercise and determine a future state map of the production system (P5). Evidence for these criteria could be provided from the learners' involvement in continuous improvement activities in the workplace or through a work placement. If assessed directly by the tutor, suitable evidence from these activities would be standard documentation and observation records. If assessed during a placement, witness statements should be provided by a suitable representative and verified by the tutor. P5 can be expanded to include M2, where learners describe the advantages of smoothing production. Evidence for this could be gathered either in the form of a short report or by a short presentation.

P6 requires learners to describe one kanban and a further kanban systems including their rules. Tutors could allocate different kanban systems to individual learners or groups of learners and ask them to feed back to the class through presentations.

P7 requires learners to compile a standard operating procedure for one element of a production system. Ideally this should be linked to P4 and be done in the workplace, or possibly as part of a work placement. Assessment evidence for this criterion could take a similar format to that for P4.

For P8 learners are asked to apply the SMED approach to reduce the changeover time of an element of a production system. Standard documentation used to aid the analysis may be used as evidence for this criterion. As some learners may not have real access to this form of activity, simulation could be used. Again, learners' evidence could be in the form of a presentation. M3 could be linked to P8 through the use of a short report, with learners explaining the importance of set-up reduction to the performance of a production system.

P9 requires learners to describe total productive maintenance and the steps required to implement autonomous and planned maintenance. This could be achieved by a written description that should include areas identified in the unit content, from major causes of machine breakdowns, to 5C/5S foundations through to prioritisation and elimination of the '6 big losses' to production.

P10 builds on P9 and asks learners to gather production data and calculate the OEE of a production system. Assessment evidence could come from learners' involvement in continuous improvement activities in the workplace or through a work placement. Again, as some learners may not have real access to this form of activity, simulation could be used.

For M1, learners need to explain the benefits of applying group technology. Learners should be able to provide evidence of an understanding of how parts similarities (in terms of geometry, size, tolerances, material and method of production) can be exploited for the benefit of the production system. M2 requires learners to describe the advantages of smoothing production. To achieve M3 learners need to independently explain the importance of set-up reduction to production system performance. Evidence for all the merit criteria is likely to be through written reports.

To achieve D1, learners have to compare the incremental approach to continuous improvement with that of large step changes. Learners should consider both the business and human sides of managing change in terms of improved efficiencies, working practices, procedures, participation and sustainability of the improvement process.

D2 requires learners to evaluate the issues encountered when applying lean principles to develop a flexible production system from a traditional system. It is important that centres do not make this over-complex, otherwise learners will not have the time to achieve this. Learners can explain the issues they encountered during their practical exercises, evaluate their improvement methodology and suggest how this may alter their approach to future improvement activities. Learners should show an appreciation of the culture change required to create a modern production system and the practical, managerial and social challenges this presents.

The assessment of D1 and D2 may be linked and the evidence obtained via a written assessment or a pictorial presentation with notes (possibly using PowerPoint or OHTs) and an annotated poster.

All evidence must be generated in a form suitable for inclusion in learners' portfolios. This could include standard forms (eg PDCA forms, data gathering forms, analysis charts, minutes of team meetings etc), images (eg photographs, completed charts, diagrams, plans and engineering drawings), presentation slides, written reports, witness statements and solutions to group-set problems.

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 the following unit titles in the Engineering suite:

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

The unit supports the following units in the Level 3 NVQ in Business Improvement Techniques:

- Unit 4: Applying Workplace Organisation (5S/5C)
- Unit 6: Creating Flexible Production and Manpower Systems
- Unit 8: Carrying out Lead Time Analysis
- Unit 9: Creating Visual Management Systems
- Unit 11: Applying Set-up Reduction Techniques (SMED – Single Minute Exchange of Dies)
- Unit 12: Applying Total Productive Maintenance (TPM)
- Unit 15: Applying Flow Process Analysis.

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 and Holweg M – *The Lean Toolbox* (Picsie Press, 2008) ISBN 9780954124458

Wilson L – *How to Implement Lean Manufacturing* (McGraw Hill, 2009) ISBN 9780071625074

Womack J and Jones D – *Lean Thinking* (Free Press, 2003) ISBN 0743231643

Journal

International Journal of Operations and Production Management

Magazines

Engineering Technology

Manufacturing Engineer

Delivery of personal, learning and thinking skills (PLTS)

The following table identifies the PLTS that have been included within the assessment criteria of this unit:

Skill	When learners are ...
Independent enquirers	planning and carrying out research when performing a production levelling exercise and applying SMED techniques
Creative thinkers	generating ideas and exploring possibilities when performing a production levelling exercise and applying SMED techniques
Self managers	organising time and resources when carrying out production levelling and SMED and adapting to changing priorities.

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 ...
Team workers	collaborating with others when applying the SMED approach.

Functional Skills – Level 2

Skill	When learners are ...
Mathematics	
Identify the situation or problem and the mathematical methods needed to tackle it	gathering production data and calculating the OEE of a production system
English	
Reading – compare, select, read and understand texts and use them to gather information, ideas, arguments and opinions	researching and investigating production systems
Writing – write documents, including extended writing pieces, communicating information, ideas and opinions, effectively and persuasively	explaining and describing continuous improvement, kanban systems and total productive maintenance.