Lean Six Sigma

Black Belt Skill Set

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Content

1 Introduction ........................................................................................................................................ 4
  1.1 LSSA - Lean Six Sigma Academy ................................................................................................. 4
  1.2 ECQA – European Certification and Qualification Association................................................ 4
2 Skill Definition Model .......................................................................................................................... 5
  2.1 Skill Set Strategy .......................................................................................................................... 5
  2.2 Definitions .................................................................................................................................... 5
  2.3 Skill Set Structure ......................................................................................................................... 6
3 Black Belt Skill Set ............................................................................................................................... 7
  3.1 U1 – Enterprise-Wide Deployment ............................................................................................... 7
    3.1.1 E1 – World Class Performance .............................................................................................. 7
    3.1.2 E2 – Leadership ..................................................................................................................... 7
    3.1.3 E3 – Organisational Process Management ........................................................................... 8
  3.2 U2 – Project Management ............................................................................................................. 9
    3.2.1 E1 – Project Management Tools .......................................................................................... 9
    3.2.2 E2 – Team Formation .......................................................................................................... 10
    3.2.3 E3 – Team Facilitation ......................................................................................................... 10
    3.2.4 E4 – Communication .......................................................................................................... 11
  3.3 U3 – Define .................................................................................................................................. 11
    3.3.1 E1 – Voice of the Customer (VOC) ....................................................................................... 11
    3.3.2 E2 – Project Charter ............................................................................................................ 12
  3.4 U4 – Measure ............................................................................................................................... 12
    3.4.1 E1 – Process Mapping & Data Collection ............................................................................. 12
    3.4.2 E2 – Statistics ....................................................................................................................... 13
    3.4.3 E3 – Measurement Systems ................................................................................................... 14
    3.4.4 E4 – Process Capability and Performance ............................................................................ 15
  3.5 U5 – Analyse ............................................................................................................................... 16
    3.5.1 E1 – Exploratory Data Analysis ............................................................................................ 16
    3.5.2 E2 – Hypothesis Testing ........................................................................................................ 16
    3.5.3 E3 – Analytical Methods ...................................................................................................... 17
  3.6 U6 – Improve ............................................................................................................................... 18
    3.6.1 E1 – Process Improvement Methods .................................................................................... 18
    3.6.2 E2 – Waste Elimination ........................................................................................................ 19
    3.6.3 E3 – Design of Experiments (DOE) ...................................................................................... 19
1 Introduction

1.1 LSSA - Lean Six Sigma Academy

It is important for businesses and organisations to continuously focus on customer satisfaction by supplying products or services with outstanding quality, cost efficiently and within the agreed lead time. Improving quality and efficiency is the domain of ‘Process Improvement’.

Realising these objectives is effectively achieved by applying Lean Six Sigma: a combination of Lean Manufacturing and Six Sigma approaches. Both management strategies are well established with proven success and are among the most applied process improvement methods in the world. Lean Six Sigma is a clear, practical and structured method to reduce lead times, production losses, quality complaints and operational expenses.

Within Lean Six Sigma, individuals can be trained at various ‘Belt levels’. These levels are called Black Belt, Green Belt, Orange Belt and Yellow Belt.

<table>
<thead>
<tr>
<th>Belt level</th>
<th>Vocational Education Training</th>
<th>Adult Education – Job roles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yellow Belt</td>
<td>Initial VET secondary level</td>
<td>Team members, Operators</td>
</tr>
<tr>
<td>Orange Belt</td>
<td>-</td>
<td>Team members, Lean Facilitators, Supervisors</td>
</tr>
<tr>
<td>Green Belt</td>
<td>Higher Education</td>
<td>Engineers, Process owners</td>
</tr>
<tr>
<td>Black Belt</td>
<td>-</td>
<td>Senior Engineers, Project Managers, Management, Consultants</td>
</tr>
</tbody>
</table>

The LSSA – Lean Six Sigma Academy – was established in September 2009 with the main objective to determine a common certification standard for Lean Six Sigma job roles. This has been realised by developing four skill sets with clear criteria and an online exam portal.

1.2 ECQA – European Certification and Qualification Association

A European certificate is also available for the above mentioned levels with the exam portal managed by the ECQA - European Certification and Qualification Association. The ECQA is a not-for-profit association which was created as a result of a number of EU-supported initiatives over the past ten years within which educational establishments decided to follow a joint process for the certification of individuals working within industry as part of the European Union’s Lifelong Learning Program.

The ECQA/LSSA exam guide can be downloaded at [www.ecqa.org](http://www.ecqa.org) and at [www.lssa.eu](http://www.lssa.eu)
2 Skill Definition Model

2.1 Skill Set Strategy

A skill set is a group of specific Learning Element that one should be able to apply within a certain job role. A standard group of skill sets within Europe is necessary due to the free mobility of workers. European countries such as the UK, The Netherlands, and France already have well-established open learning courses which support APL (Accreditation of Prior Learning). Within APL the skills of students are assessed, existing skills are recognised, and a learning plan is developed to cover any skill gaps. The skill assessment is based on defined skill units and a skill profile which indicates how many skill units have been covered.

LSSA has developed four skill sets that specify which of the overall Lean Six Sigma tools are expected to be included within a certain Belt level. A skill set is a group of ‘Learning Elements’ within eight ‘Skill Units’. ASQ (American Society for Quality) Body of Knowledge [5], [6] documents were used as a baseline, and have been updated according the latest insights. Each of the ‘Learning Elements’ contains several ‘Performance Criteria’. Each ‘Performance Criteria’ has an explanation and a cognitive level according to Bloom [8] which should be applied. The skill sets are used by the Examination Development Committee and to help candidates prepare for the exam.

2.2 Definitions

The skill sets are based on the skills definition proposed by the DTI (Department of Trade and Industry) in the UK for NVQ (National Vocational Qualification) standards [2] and revised skill cards from other countries. It contains the following items:

- **Domain**: An occupational category. E.g. Domain = Process Improvement.
- **Job role**: A certain profession that covers part of the domain knowledge. E.g. Job role = Yellow Belt, Orange Belt, Green Belt or Black Belt.
- **Unit**: A list of certain activities that have to be carried out in the workplace. It is the top-level skill in the qualification standard hierarchy. Each unit consists of a number of elements.
- **Learning element**: Description of one distinct aspect of the work performed by a worker, either a specific task that the worker has to do or a specific way of working. Each element consists of a number of performance criteria.
- **Performance criteria**: Description of the minimum level of performance a participant must demonstrate in order to be assessed as competent.
- **Level of cognition**: For each performance criteria there is an intended level of cognition. At the same time this describes the complexity level of the test questions for each performance criteria, according Bloom’s Taxonomy – Rev. 2001.
2.3 Skill Set Structure

A skills hierarchy for the job role ‘Lean Six Sigma Black Belt’ has been designed using the terminology outlined in the skills definition model and includes the skills identified during the demand analysis performed at the beginning of the project.

In the graph below you will find an example of the first four Skill Units and their Learning Elements. The first Learning Element of the first Skill Unit has three Performance Criteria, which are listed in the lower box. In total, the Lean Six Sigma skill set for the ‘Black Belt’ job role is composed of 8 Units; 23 Learning Element and 117 Performance Criteria.

<table>
<thead>
<tr>
<th>Domain</th>
<th>Job Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process Improvement</td>
<td>LSS Black Belt</td>
</tr>
</tbody>
</table>

**U1 - Skill Unit 1:** Enterprise-Wide Deployment

**Learning Elements:**
- E1 - World Class Performance
- E2 - Leadership
- E3 - Organizational Process Management

**U2 - Skill Unit 2:** Project Management

**Learning Elements:**
- E1 - Project mgmt tools
- E2 - Team formation
- E3 - Team facilitation
- E4 - Communication

**U3 - Skill Unit 3:** Define

**Learning Elements:**
- E1 - Voice of the customer
- E2 - Project Charter

**U4 - Skill Unit 4:** Measure

**Learning Elements:**
- E1 - Process Mapping & Data Collection
- E2 - Measurement systems
- E3 - Statistics
- E4 - Process capability and performance

**Performance Criteria:**

<table>
<thead>
<tr>
<th>Bloom Cognition Level</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>U1.E1.PC1</td>
<td>History of continuous improvement Describe the origins of continuous improvement and its impact on other improvement models.</td>
</tr>
<tr>
<td>U1.E1.PC2</td>
<td>Value and foundations of Lean and Six Sigma Describe the value of Six Sigma, its philosophy, history and goals. Describe the relationship between Lean and Six Sigma.</td>
</tr>
<tr>
<td>U1.E1.PC3</td>
<td>Six Sigma and Lean applications Know that Lean and Six Sigma can be applied to processes in different types of enterprises (e.g. manufacturing, service, transactional, product and process design, innovation, construction)</td>
</tr>
<tr>
<td>U1.E1.PC4</td>
<td>Lean principles in the organization Know the Toyota philosophy, the 14 principles and understand the impact of the Toyota Production System (TPS) on strategy, quality and production.</td>
</tr>
</tbody>
</table>
3 Black Belt Skill Set

3.1 U1 – Enterprise-Wide Deployment

The Unit ‘Enterprise Wide Deployment’ discusses the general philosophy of Process Improvement. It handles the overview of different process improvement methods and the history of the most important methods: Lean and Six Sigma. It also explains why process improvement is needed, how it is organised and the different roles and responsibilities involved.

3.1.1 E1 – World Class Performance

The Learning Element ‘World Class Performance’ explains the history, value and principles of Lean and Six Sigma. Similarities and differences to other improvement methods are also reviewed.

<table>
<thead>
<tr>
<th>U1.E1.PC1</th>
<th>History of continuous improvement</th>
<th>Remember</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Describe the origins of continuous improvement and its impact on other improvement models.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>U1.E1.PC2</th>
<th>Value and foundations of Lean and Six Sigma</th>
<th>Understand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Describe the value of Six Sigma, its philosophy, history and goals. Describe the value of Lean, its philosophy and goals. Describe the relationship between Lean and Six Sigma.</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>U1.E1.PC3</th>
<th>Six Sigma and Lean applications</th>
<th>Understand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Describe how Lean and Six Sigma can be applied to processes in different types of enterprises (e.g. manufacturing, service, transactional, product and process design, innovation, construction)</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>U1.E1.PC4</th>
<th>Lean principles in the organisation</th>
<th>Apply</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Describe the Toyota philosophy, the 14 principles and understand the impact of the Toyota Production System (TPS) on strategy, quality and production.</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>U1.E1.PC5</th>
<th>Business processes and systems</th>
<th>Understand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Describe the relationship among various business processes (design, production, purchasing, accounting, sales, etc.) and the impact these relationships can have on business systems. Distinguish between different types of production environment (e.g. Job shop, Batch production and Line or Flow production).</td>
<td></td>
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</tbody>
</table>

3.1.2 E2 – Leadership

The Learning Element ‘Leadership’ explains the roles and responsibilities of the people involved in process improvement. The different Belt-levels and roles of management, team leaders and team members are also reviewed.

<table>
<thead>
<tr>
<th>U1.E2.PC1</th>
<th>Roles and responsibilities</th>
<th>Apply</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Describe Six Sigma level of expertise: Master Black Belt, Black Belt, Green Belt, Orange Belt and Yellow Belt. Describe various team roles and responsibilities: Champion, Project leader, Supplier, User, Coach and Team member.</td>
<td></td>
</tr>
</tbody>
</table>
U1.E2PC2 Change management Apply
Describe and use various techniques for facilitating and managing organisational and technical changes. Able to manage resistance to change.

U1.E2PC3 Team performance, evaluation and reward Apply
Measure team progress in relation to goals, objectives and other metrics that support team success and reward and recognise the team for its accomplishments.

U1.E2PC4 Organisational roadblocks Apply
Describe the impact an organisation’s culture and inherent structure can have on the success of Lean Six Sigma and how deployment failure can result from the lack of resources or management support. Apply techniques to overcome these barriers.

U1.E2PC5 Enterprise leadership responsibilities Understand
Describe the responsibilities of executive leaders and how they affect the deployment of Lean Six Sigma in terms of providing resources, managing change, communicating ideas, etc.

3.1.3 E3 – Organisational Process Management
The Learning Element ‘Organisational Process Management’ explains the business perspective of process improvement such as business performance and financial measures, benchmarking and customer survey’s. Project selection based on the above measures and project tracking is also reviewed.

U1.E3PC1 Financial measures Apply
Define and use financial measures, including revenue growth, market share, margin, cost of poor quality (COPQ), net present value (NPV), return on investment (ROI) and cost-benefit analysis.

U1.E3PC2 Business performance measures Apply
Define and describe various business performance measures, including balanced scorecard, key performance indicators (KPIs), and the financial impact of customer loyalty.

U1.E3PC3 Market segmentation Apply
Define the criteria for market segmentation and segment the market in line with the strategic short and long term goals.

U1.E3PC4 Customer survey Apply
Identify and select the appropriate data collection method (e.g. surveys, focus groups, interviews and observation) to gather customer feedback to better understand customer needs, expectations requirements and desires. Ensure that the instruments used are reviewed for validity and reliability to avoid introducing bias or ambiguity in the responses.

U1.E3PC5 Benchmarking Apply
Define and distinguish between various types of benchmarking, including best practices, competitive and collaborative.
U1.E3.PC6  Project selection  
Understand project selection criteria. Able to select process improvement opportunities that meet these criteria best. Realise how individual projects meet higher level business goals and strategy.

U1.E3.PC7  Process elements  
Define and describe process components and boundaries. Recognise how processes cross various functional areas and the challenges that result for process improvement efforts.

U1.E3.PC8  Project tracking  
Understand how projects fit together with other projects. Able to follow multiple projects timing and progress.

3.2  U2 – Project Management

The Unit ‘Project Management’ outlines the way improvement projects should be executed. It covers the most common project management tools, the DMAIC improvement roadmap and team facilitation.

3.2.1  E1 – Project Management Tools
The Learning Element ‘Project Management Tools’ sets out the main elements that have to be taken into account during project execution, such as differing interests of stakeholders and project execution within time and budget.

U2.E1.PC1  Stakeholder analysis  
Evaluate a stakeholder analysis. Describe the impact Lean Six Sigma projects can have on process owners, internal and external customers and other stakeholders in a project.

U2.E1.PC2  DMAIC roadmap  
Analyse and follow the Process Improvement DMAIC roadmap. Identify and select the proper tools to use during the Process Improvement project.

U2.E1.PC3  Time management  
Evaluate time management techniques, such as Gantt Charts, Critical Path Management (CPM), Program Evaluation and Review Techniques (PERT) charts and Tollgates to track progress. Set up team meetings, publishing agendas and ensure that the right people and resources are available.

U2.E1.PC4  Project risk analysis and mitigation  
Analyse a team meeting that puts together a risk analysis (including resources, finance, customer impact, quality etc). Define proper mitigation actions.
U2.E1.PC5  Project documentation  Evaluate
Provide input and select the proper vehicle for presenting project documentation
(e.g., spreadsheet output and storyboards) at phase reviews, tollgate reviews or
management reviews. Set up a structure to store project documentation properly.

3.2.2  E2 – Team Formation
The Learning Element ‘Team Formation’ discusses the various types of teams and the process for
selecting team members.

U2.E2.PC1  Team member selection  Apply
Define and describe various factors that influence team member selection, including
required skills sets, subject matter expertise, and availability. Able to collect the
proper resources so that a team is staffed for success.

U2.E2.PC2  Team types and constraints  Understand
Describe various types of teams (e.g., formal, informal, virtual, cross-functional and
self-directed) and determine what team model will work best for a given situation.
Identify constraining factors including geography, technology, schedules, etc.

U2.E2.PC3  Launching teams  Apply
Identify and describe elements required for launching a team, including having
management support, establishing clear goals, ground rules and timelines and how
these elements can affect the team’s success.

3.2.3  E3 – Team Facilitation
The Learning Element ‘Team Facilitation’ discusses the dynamics that can occur during a project such
as cooperation, resistance, escalation of problems and solving roadblocks.

U2.E3.PC1  Team dynamics and performance  Evaluate
Identify and use various techniques (e.g., coaching, mentoring and intervention) to
overcome various challenges within group dynamics, including
overbearing/dominant or reluctant participants, feuding and other forms of
unproductive disagreements, unquestioned acceptance of opinions as facts,
groupthink, floundering, rushing to accomplish or finish, digressions and tangents.

U2.E3.PC2  Team stages  Apply
Facilitate the team through the classic stages of development: forming, storming,
norming, performing, adjourning and recognition.

U2.E3.PC3  Team motivation  Apply
Describe and apply techniques that motivate team members and support and sustain
their participation and commitment.
3.2.4 E4 – Communication
The Learning Element ‘Communication’ reviews the communication and decision making process within a team. The presentation of project progress is also reviewed.

U2.E4.PC1 Effective communication Apply
Identify and use appropriate communication methods (both within the team and from the team to various stakeholders) to report progress, conduct milestone reviews and support the overall success of the project.

U2.E4.PC2 Project Progress and presentation skills Apply
Organising Tollgate reviews. Prepare presentation and present project results to the project board. Describe objectives achieved and apply lessons learned to identify additional opportunities.

U2.E4.PC3 Decision making Apply
Select and apply brainstorming tools, nominal group technique and multi-voting.

3.3 U3 – Define
Define is the first phase within the DMAIC roadmap. The Unit ‘Define’ discusses the elements that have to be taken into account during the first phase of a process improvement project such as the project charter and customer requirement.

3.3.1 E1 – Voice of the Customer (VOC)
The Learning Element ‘Voice of the Customer’ reviews customer requirements (internal/external) and the flow down of these requirements to measurable criteria for the product and/or process.

U3.E1.PC1 Customer identification Apply
Segment customers for each project and show how the project will impact both internal and external customers.

U3.E1.PC2 Customer requirements Apply
Translation of customer statements into customer needs with focus on latent and non-addressed needs. Understand the experience of customers linked to product features described in the range from dissatisfied, expected, satisfied and desired quality levels (e.g. new KANO model).

U3.E1.PC3 Customer demand Evaluate
Calculate customer takt time. Distinguish between takt time and cycle time.
U3.E1.PC4  Critical requirements (CTx)  Apply
Define and describe various CTx requirements (critical to quality (CTQ), cost (CTC),
process (CTP), safety (CTS) and delivery (CTD)) and the importance of aligning
projects with those requirements.

U3.E1.PC5  CTx Flowdown  Apply
Translate Voice of the customer (VOC) requirements into project goals and
objectives. Translate objectives into CTx targets and specifications.

3.3.2  E2 – Project Charter
The Element ‘Project Charter’ covers the description of the project such as problem description,
objectives, scope, timing and benefits.

U3.E2.PC1  Problem statement  Create
Develop and evaluate the problem statement in relation to customer requirements
and business goals.

U3.E2.PC2  Project scope and goal  Evaluate
Develop and review project boundaries to ensure that the project has value to the
customer (scope). Develop the objectives and measurable targets for the project
based on the problem statement and scope (goal).

U3.E2.PC3  Project performance measures  Analyse
Identify and evaluate performance measurements (Cost, Quality and Delivery) and
establish key project metrics that relate to the voice of the customer.

U3.E2.PC4  Project benefits calculation  Analyse
Define and calculate the hard benefits of the project and describe the soft benefits of
the project.

3.4  U4 – Measure
Measure is the second phase within the DMAIC roadmap. The Unit ‘Measure’ describes the
measurability of the process/product responses and factors of influence. The Unit also reviews
several process mapping methods, types of data and the reliability of the measurement method. This
Unit also discusses statistics and visualisation of data.

3.4.1  E1 – Process Mapping & Data Collection
The Learning Element ‘Process Mapping & Data Collection’ sets out the different ways of process
mapping to visualise the process. This Element also covers types of data and the accuracy and
integrity of data.

U4.E1.PC1  Input and output variables (SIPOC)  Evaluate
Identify input and output process variables and evaluate their relationships using
PFM (Process Flow Mapping), SIPOC or Cause & Effect matrix.
<table>
<thead>
<tr>
<th>U4.E1.PC2</th>
<th>Process flow modelling and metrics</th>
<th>Evaluate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Evaluate process flow and utilisation to identify waste and constraints by analysing work in progress (WIP), work in queue (WIQ), touch time, takt time, cycle time and throughput.</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>U4.E1.PC3</th>
<th>Types of data</th>
<th>Evaluate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Define, classify and evaluate qualitative and quantitative data, continuous (variable) and discrete (attribute) data and convert attribute data to variable measures when appropriate. Convert ordinal data in discrete or continuous data.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>U4.E1.PC4</th>
<th>Sampling methods for ensuring data accuracy and integrity</th>
<th>Evaluate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Define and apply the concepts related to sampling (e.g., representative selection, homogeneity and bias). Select and use appropriate sampling methods (e.g., random sampling, stratified sampling and systematic sampling) that ensure the integrity of data.</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>U4.E1.PC5</th>
<th>Measurement scales</th>
<th>Analyse</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Apply, analyse and evaluate measurements with nominal, ordinal, interval and ratio scales.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>3.4.2 E2 – Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Learning Element ‘Statistics’ reviews the basics of statistics such as mean, deviation and probability. This Learning Element reviews a range of graphs that can be used to visualise data as well.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>U4.E2.PC1</th>
<th>Basic terms</th>
<th>Apply</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Define and distinguish between population parameters and sample statistics (proportion, mean and standard deviation)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>U4.E2.PC2</th>
<th>Visualisation of data</th>
<th>Evaluate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Construct and interpret diagrams and charts, including Pareto, Bar Chart, Pie Chart, Time Series Plot, Scatter Plot, Histogram, Box plot. Probability plot and Probability Distribution plot.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>U4.E2.PC3</th>
<th>Commonly used distributions</th>
<th>Evaluate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Describe, apply and interpret the following distributions: Normal, Poisson, Binomial, Chi square, Student’s t and F distributions. Apply normality test (Anderson-Darling; Skewness and Kurtosis).</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>U4.E2.PC4</th>
<th>Other distributions</th>
<th>Apply</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Describe when and how to use the following distributions: hypergeometric, bivariate, exponential, lognormal and Weibull.</td>
<td></td>
</tr>
</tbody>
</table>
U4.E2.PC5  **Descriptive statistics**  
Evaluate  
Calculate and interpret measures of dispersion and central tendency, and construct and interpret frequency distributions and cumulative frequency distributions.

U4.E2.PC6  **Central limit theorem**  
Apply  
Describe and use the central limit theorem and apply the sampling distribution of the mean to inferential statistics for confidence intervals and control charts.

U4.E2.PC7  **Basic probability concepts**  
Apply  
Describe and apply probability concepts such as independence, mutually exclusive events, multiplication rules, complementary probability and joint occurrence of events.

U4.E2.PC8  **Drawing valid statistical conclusions**  
Evaluate  
Analyse and evaluate enumerative (descriptive) and analytic (inferential) statistical studies and evaluate their results to draw statistical significant conclusions.

### 3.4.3  E3 – Measurement Systems

The Learning Element ‘Measurement Systems’ examines the reliability of the measurement system.

U4.E3.PC1  **Measurement methods**  
Apply  
Define and describe measurement methods for both continuous and discrete data.

U4.E3.PC2  **Measurement systems analysis**  
Evaluate  
Use various analytical methods (repeatability and reproducibility (R&R), correlation, bias, linearity, precision to tolerance, percent agreement and number of distinct categories) to analyse and interpret measurement system capability for variables and attributes measurement systems.

U4.E3.PC3  **Metrology**  
Apply  
Define and describe elements of metrology, including calibration systems, traceability to reference standards, the control and integrity of standards and measurement devices.

U4.E3.PC4  **Measurement systems in the enterprise**  
Apply  
Identify how measurement systems can be applied in marketing, sales, engineering, research and development (R&D), supply chain management, customer satisfaction and other functional areas.
3.4.4 E4 – Process Capability and Performance


U4.E4.PC1 Process performance metrics Evaluate
Distinguish between natural process limits and specification limits and calculate process performance metrics such as percent defective, parts per million (PPM), defects per million opportunities (DPMO), defects per unit (DPU) and rolled throughput yield (RTY). Know the difference between a defect and a defective.

U4.E4.PC2 Process capability studies Evaluate
Describe and apply elements of designing and conducting process capability studies, including identifying characteristics and specifications, developing sampling plans and verifying stability.

U4.E4.PC3 Short-term and long-term capability Evaluate
Describe and use appropriate assumptions and conventions when only short-term data or attributes data are available and when long-term data is available. Interpret the relationship between long-term and short-term capability.

U4.E4.PC4 Process capability indices Evaluate
Define, select and calculate Cp and Cpk to assess process capability.

U4.E4.PC5 Process performance indices Evaluate
Define, select and calculate Pp, Ppk and Cpm to assess process performance.

U4.E4.PC6 Process capability for attributes data Apply
Calculate the process capability and process sigma level for attributes data.

U4.E4.PC7 Process capability for non-normal data Apply
Identify non-normal data and determine when it is appropriate to use Box-Cox or Johnson transformation.
3.5 U5 – Analyse

Analyse is the third phase within the DMAIC roadmap. The Unit ‘Analyse’ reviews the analysis of current process performance. The different elements will review Risk Analysis, Root Cause Analysis, Waste Identification, Regression Analysis and Analysis of Variance.

3.5.1 E1 – Exploratory Data Analysis

The Learning Element ‘Exploratory Data Analysis’ describes the predictive models using regression techniques to determine the relation between factors on a response. This Learning Element also covers process performance metrics and the method for determining the capability of a process to meet specifications.

**U5.E1.PC1 Regression analysis**: Evaluate
Calculate and interpret linear regression analysis and apply and interpret hypothesis tests for regression statistics. Use the regression model for estimation and prediction, analyse the uncertainty in the estimate and perform a residual analysis to validate the model.

**U5.E1.PC2 Correlation coefficient**: Analyse
Calculate and interpret the correlation coefficient. Determine its statistical significance (p-value) and recognise the difference between correlation and causation.

**U5.E1.PC3 Analysis of variance (ANOVA)**: Evaluate
Define terms related to ANOVA and interpret their results and data plots.

**U5.E1.PC4 Multi-variate studies**: Evaluate
Create and interpret multivariate studies such as principal components, factor analysis, discriminant analysis, multiple analysis of variance (MANOVA) to investigate sources of variation.

**U5.E1.PC5 Attributes data analysis**: Analyse
Analyse attributes data using logit, probit, and logistic regression to investigate sources of variation.

3.5.2 E2 – Hypothesis Testing

The Learning Element ‘Hypothesis testing’ reviews test methods that are used to test a hypothesis. This Learning Element also discusses Confidence Intervals that indicate the reliability of test conclusions.

**U5.E2.PC1 Terminology**: Evaluate
Define and interpret the significance level, power, type I and type II errors in statistical tests.
<table>
<thead>
<tr>
<th>U5.E2.PC2</th>
<th>Statistical vs. practical significance</th>
<th>Evaluate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Define, compare and interpret statistical and practical significance.</td>
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<table>
<thead>
<tr>
<th>U5.E2.PC3</th>
<th>Sample size</th>
<th>Apply</th>
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<tbody>
<tr>
<td></td>
<td>Calculate sample size for common hypothesis tests (equality of means and equality of proportions).</td>
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<table>
<thead>
<tr>
<th>U5.E2.PC4</th>
<th>Point and interval estimates/Confidence Intervals</th>
<th>Evaluate</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Define and distinguish between confidence and prediction intervals. Define and interpret the efficiency and bias of estimators. Calculate tolerance and confidence intervals.</td>
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</table>

<table>
<thead>
<tr>
<th>U5.E2.PC5</th>
<th>Tests for means, variances and proportions</th>
<th>Evaluate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Use and interpret the results of hypothesis tests for means, variances and proportions.</td>
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</table>

<table>
<thead>
<tr>
<th>U5.E2.PC6</th>
<th>Paired-comparison tests</th>
<th>Evaluate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Define and describe paired-comparison parametric hypothesis tests.</td>
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<table>
<thead>
<tr>
<th>U5.E2.PC7</th>
<th>Goodness-of-fit (Chi square) tests</th>
<th>Evaluate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Define, select and interpret chi square and use it to determine statistical significance.</td>
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<thead>
<tr>
<th>U5.E2.PC8</th>
<th>Contingency tables</th>
<th>Evaluate</th>
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<tbody>
<tr>
<td></td>
<td>Select, develop and use contingency tables to determine statistical significance.</td>
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</table>

<table>
<thead>
<tr>
<th>U5.E2.PC9</th>
<th>Non-parametric tests</th>
<th>Evaluate</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Select, develop and use various non-parametric tests, including Mood’s Median, Levene’s test, Kruskal-Wallis and Mann-Whitney.</td>
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</table>

### 3.5.3 E3 - Analytical Methods

The Learning Element ‘Analytical Methods’ describes the tools that can be used for risk analysis, root cause analysis and waste identification.

<table>
<thead>
<tr>
<th>U5.E3.PC1</th>
<th>Failure mode and effects analysis (FMEA)</th>
<th>Evaluate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Describe the purpose and elements of FMEA, including the risk priority number (RPN) and evaluate FMEA results for processes, products and services. Distinguish between design FMEA (DFMEA) and process FMEA (PFMEA) and interpret results from each.</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>U5.E3.PC2</th>
<th>Root cause analysis</th>
<th>Evaluate</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Define and apply root cause analysis, recognise the issues involved in identifying a root cause. Apply problem solving process and tools (5-Why and Cause and Effect diagrams / Ishikawa) for analysing problems.</td>
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</tr>
</tbody>
</table>
U5.E3.PC3 Waste identification Evaluate Identify and interpret the 8 types of waste (Overproduction, Waiting, Transport, Over-processing, Inventory, Movement, Defects, Unused expertise).

U5.E3.PC4 Value Stream Mapping (Current State) Evaluate Distinguish value added from non value added activities. Apply Value Stream Mapping to construct a Current State Map of the process to identify waste and non value added activities.

U5.E3.PC5 Gap analysis Analyse Use various tools and techniques (e.g. gap analysis and scenario planning) to compare the current and future state in terms of pre-defined metrics.

3.6 U6 – Improve

Improve is the fourth phase within the DMAIC roadmap. The Unit ‘Improve’ discusses the identification, implementation and verification of improvements that solve a problem, eliminate waste or improve quality or process performance.

3.6.1 E1 – Process Improvement Methods
The Learning Element ‘Process Improvement Methods’ sets out a series of methods and tools that can be used for process improvement, such as 5S, Kaizen, 8D, Theory of Constraints and Total Productive Maintenance.


U6.E1.PC2 Improvement teams (Kaizen) Apply Able to empower and facilitate improvement teams such as Kaizen or Small Group Activities.

U6.E1.PC3 Basic Problem Solving (8D) Apply Apply the eight disciplines problem solving process which is used to approach and resolve problems.

U6.E1.PC4 Theory of constraints (TOC) Apply Define and describe this concept and its uses. Identify bottle necks in the organisation and apply basic concepts to release or eliminate the bottle neck.
U6.E1.PC5  Total Productive Maintenance (TPM)  Apply
Describe the eight pillars of TPM and describe how it can be used for process improvement. Identify and apply elements of TPM to control the improved process.

3.6.2  E2 – Waste Elimination
The Learning Element ‘Waste Elimination’ discusses improving the organisation of a production line or process. This Learning Element also explains line balancing, Flow, Pull, quick change-overs and doing things right the first time.

U6.E2.PC1  Value Stream Mapping (Future State)  Evaluate
Define a Future state map using Value Stream Mapping to eliminate waste and reduce cycle time.

Calculate and distinguish between takt time and cycle time. Create a balanced process flow by levelling both volume and product mix. Implement Pull systems to avoid overproduction and calculate Kanban levels.

U6.E2.PC3  Quick Change Over (SMED)  Evaluate
Support work and line balancing by reducing change over times by applying Single Minute Exchange of Dies (SMED). Reduce materials, skilled resources and time necessary to equipment setup and product change over.

U6.E2.PC4  First Time Right (FTR)  Evaluate
Build a culture of stopping to fix problems to get quality right the first time. Understand the line has to be stopped when there is a quality problem. Apply tools such as Poka Yoke to avoid quality problems.

3.6.3  E3 – Design of Experiments (DOE)
The Learning Element ‘Design of Experiments’ reviews the design and evaluation of Full Factorial and Fractional experiments. These efficient experiments examine the influence of factors and interactions on a process.

U6.E3.PC1  Design principles and terminology  Analyse
Define and apply DOE principles and terms: Power & Sample size, Responses, Variables, Factors, Levels, Interactions, Balanced designs, Resolution, Run Order, Randomisation, Centerpoints, Blocking, Curvature, Confounding, Alias Table, Folding over, Covariates, Significance, Error and Residual analysis.

U6.E3.PC2  Planning experiments  Evaluate
Plan, organise and evaluate experiments by determining the objective, selecting factors, responses and measurement methods and choosing the appropriate design.

U6.E3.PC3  Full factorial experiments  Evaluate
Design, analyse and interpret full factorial experiments.
**U6.E3.PC4**  
Two-level fractional factorial experiments  
Evaluate  
Design, analyse and interpret fractional factorial experiments and describe how confounding affects their use.

**U6.E3.PC5**  
Response Surface Modelling  
Evaluate  
Design, conduct and analyse Response Surface Models (RSM) such as Box Behnken and Central Composite Designs. Optimise responses.

**U6.E3.PC6**  
One-factor experiments  
Evaluate  
Design and conduct completely randomised, randomised block and Latin square designs and evaluate their results.

### 3.7 U7 – Control

Control is the fifth phase within the DMAIC roadmap. The Unit ‘Control’ is about sustaining achievements and discusses the tools and procedures that ensure good quality. The elements that are reviewed include Statistical Process Control, Visual Management, Standardisation and Documentation.

#### 3.7.1 E1 – Statistical Process Control (SPC)

The Learning Element ‘Statistical Process Control’ explains the controls methods used to identify out-of-control situations and deviations over time. Different types of SPC charts are reviewed.

**U7.E1.PC1**  
Objectives and benefits  
Analyse  
Define and describe the objectives of SPC, including monitoring and controlling process performance and tracking trends. Apply SPC for reducing variation in a process.

**U7.E1.PC2**  
Selection and application of control charts  
Apply  
Identify, select, construct and apply the following types of control charts: Xbar-R, Xbar-S, individuals and moving range (ImR/XmR), median, p, np, c, u, short-run SPC and moving average.

**U7.E1.PC3**  
Control chart analysis  
Analyse  
Interpret control charts and distinguish between common and special cause variation using rules for determining statistical control.

**U7.E1.PC4**  
Selection of variables  
Apply  
Identify and select critical characteristics for control chart monitoring.

**U7.E1.PC5**  
Rational sub grouping  
Apply  
Define and describe how rational sub grouping is used.
3.7.2   E2 – Quality Assurance
The Learning Element ‘Quality Assurance’ establishes a series of tools and procedures that can be used to measure, communicate and ensure quality such as visual management and controls.

**U7.E2.PC1 Visual Management**  Evaluate
Define the elements of Visual Management and describe how they can help to control the improved process.

**U7.E2.PC2 Control plan**  Evaluate
Develop a control plan to document and hold gains. Define controls and monitoring systems. Transfer of responsibility from the project team to the process owner.

**U7.E2.PC3 Measurement system re-analysis**  Evaluate
Review and evaluate measurement system capability as process capability improves and ensure that measurement capability is sufficient for its intended use.

3.7.3   E3 – Sustain Improvements
The ‘Sustain Improvements’ Learning Element discusses methods for maintaining achievements, becoming a learning organisation, standardisation and documentation.

**U7.E3.PC1 Lessons learned**  Apply
Document the lessons learned from all phases of a project and identify how improvements can be replicated and applied to other processes in the organisation.

**U7.E3.PC2 Standardised work and Documentation**  Apply
Standardise tasks and processes to establish the foundation for continuous improvement and employee empowerment. Develop or modify documents and standard operating procedures (SOPs) and work instructions to ensure that the improvements are sustained over time.

**U7.E3.PC3 Training deployment**  Apply
Develop and implement training plans to ensure continued support of the improved process.

**U7.E3.PC4 On-going evaluation and auditing**  Evaluate
Identify and apply tools for the on-going evaluation of the improved process, including auditing (internal/external), monitoring for new constraints and identification of additional opportunities for improvement.
3.8 U8 – Design for Six Sigma (DfSS)

The Unit ‘Design for Six Sigma’ is about applying Six Sigma tools in the product development process with the objective to design products and processes that will perform on a Six Sigma level from the earliest phase.

3.8.1 E1 – DfSS methodologies & Roadmap

The Learning Element ‘DfSS methodologies & Roadmap’ handles about the DMADV and IDOV roadmaps for product development. Additional tools are reviewed such as Quality Function Deployment, Reliability engineering and Tolerance analysis.

U8.E1.PC1 Road maps for DfSS
Apply
Describe and distinguish between DfSS roadmaps: DMADV (define, measure, analyse, design, verify) and IDOV (identify, design, optimise, verify). Identify how they relate to DMAIC and how they help close the loop on improving the end product/process during the design (DFSS) phase.

U8.E1.PC2 Quality function deployment (QFD)
Understand
Know QFD can be used into the DfSS process to translate customer requirements into performance measures.

U8.E1.PC3 Design failure mode and effects analysis (DFMEA)
Analyse
Define and document the key functions of a design, the primary potential failure modes relative to each function and the potential causes of each failure mode. Distinguish between DFMEA and PFMEA.

U8.E1.PC4 Design for X (DFX)
Apply
Describe design constraints, including design for cost, design for manufacturability and producibility, design for test and design for maintainability.

U8.E1.PC5 Tolerance Analysis
Apply
Construct tolerance intervals using worst case, RSS, Monte Carlo and empirical methods.

U8.E1.PC6 Reliability
Apply
Define reliability specifications and design tests to demonstrate these reliability specifications. Analyse failure data of life time tests.
Appendix A – Bloom’s Taxonomy for Performance Criteria

In addition to specifying content, each performance criteria in this skill set also indicates the intended complexity level of the test questions for each topic. These levels are based on “Levels of Cognition” (from Bloom’s Taxonomy – Revised, 2001), and can be used to create learning outcomes for students [7].

The Taxonomy of Educational Objectives, often called Bloom’s Taxonomy, is a classification of the different objectives that educators set for students (learning objectives). The taxonomy was proposed in 1956 by Benjamin Bloom, an educational psychologist at the University of Chicago. During the nineties, Lorin Anderson a former student of Bloom revisited the cognitive domain in the learning taxonomy [8]. Bloom’s Taxonomy divides educational objectives into three “domains”: Affective, Psychomotor and Cognitive. This Skill only notice the Cognitive domain.

The ‘Levels of Cognition’ are in rank order - from least complex to most complex.

**Remember**
Recall or recognise terms, definitions, facts, ideas, materials, patterns, sequences, methods, principles, etc.

**Understand**
Read and understand descriptions, communications, reports, tables, diagrams, directions, regulations, etc.

**Apply**
Know when and how to use ideas, procedures, methods, formulas, principles, theories, etc.

**Analyse**
Break down information into its constituent parts and recognise their relationship to one another and how they are organised; identify sublevel factors or salient data from a complex scenario.

**Evaluate**
Make judgments about the value of proposed ideas, solutions, etc., by comparing the proposal to specific criteria or standards.

**Create**
Put parts or elements together in such a way as to reveal a pattern or structure not clearly there before; identify which data or information from a complex set is appropriate to examine further or from which supported conclusions can be drawn.
Appendix B – European Qualifications Framework (EQF) for Job roles

The European Qualifications Framework (EQF) acts as a translation device to make national qualifications more readable across Europe, promoting workers' and learners' mobility between countries and facilitating their lifelong learning.

The core of the EQF are 'learning outcomes' which are eight reference levels describing what a learner knows, understands and is able to do. [8]

<table>
<thead>
<tr>
<th>Level</th>
<th>Knowledge</th>
<th>Belt level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>Basic general knowledge</td>
<td>-</td>
</tr>
<tr>
<td>Level 2</td>
<td>Basic factual knowledge of a field of work or study</td>
<td>-</td>
</tr>
<tr>
<td>Level 3</td>
<td>Knowledge of facts, principles, processes and general concepts, in a field of work or study</td>
<td>-</td>
</tr>
<tr>
<td>Level 4</td>
<td>Factual and theoretical knowledge in broad contexts within a field of work or study</td>
<td>Lean Six Sigma Yellow Belt</td>
</tr>
<tr>
<td>Level 5</td>
<td>Comprehensive, specialised, factual and theoretical knowledge within a field of work or study and an awareness of the boundaries of that knowledge</td>
<td>Lean Six Sigma Orange Belt</td>
</tr>
<tr>
<td>Level 6</td>
<td>Advanced knowledge of a field of work or study, involving a critical understanding of theories and principles</td>
<td>Lean Six Sigma Green Belt</td>
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</tbody>
</table>
| Level 7 | • Highly specialised knowledge, some of which is at the forefront of knowledge in a field of work or study, as the basis for original thinking and/or research  
• Critical awareness of knowledge issues in a field and at the interface between different fields | Lean Six Sigma Black Belt       |
| Level 8 | Knowledge at the most advanced frontier of a field of work or study and at the interface between fields | Lean Six Sigma Master Black Belt |
## Appendix B – Acronyms

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>APL</td>
<td>Accreditation of Prior Learning</td>
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<tr>
<td>ASQ</td>
<td>American Society of Quality</td>
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<tr>
<td>CREDIT</td>
<td>Accreditation of Skills via the Internet</td>
</tr>
<tr>
<td>YB</td>
<td>Lean Six Sigma Yellow Belt</td>
</tr>
<tr>
<td>OB</td>
<td>Lean Six Sigma Orange Belt</td>
</tr>
<tr>
<td>GB</td>
<td>Lean Six Sigma Green Belt</td>
</tr>
<tr>
<td>BB</td>
<td>Lean Six Sigma Black Belt</td>
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<tr>
<td>LSSA</td>
<td>Lean Six Sigma Academy, <a href="http://www.lssa.eu">www.lssa.eu</a></td>
</tr>
<tr>
<td>NVQ</td>
<td>National Vocational Qualification standard of England, Wales and N. Ireland</td>
</tr>
<tr>
<td>EQF</td>
<td>European Qualifications Framework</td>
</tr>
<tr>
<td>ECQA</td>
<td>European Certification and Qualification Association, <a href="http://www.ecqa.org">www.ecqa.org</a></td>
</tr>
</tbody>
</table>

The LSSA has developed an abbreviation list with over 200 Lean Six Sigma terms and abbreviations. It is available online in five different languages at [www.lssa.eu](http://www.lssa.eu).
Appendix C – References

[1] CREDIT Project, Accreditation Model Definition, MM 1032 Project CREDIT, Version 2.0, University of Amsterdam, 15.2.99

[2] DTI - Department of Trade and Industry UK, British Standards for Occupational Qualification, National Vocational Qualification Standards and Levels


It is important for businesses and organisations to continuously focus on customer satisfaction by supplying products or services with outstanding quality, cost efficiently and within the agreed lead time. Improving quality and efficiency is the domain of ‘Process Improvement’.

Realising these objectives is effectively achieved by applying Lean Six Sigma: a combination of Lean Manufacturing and Six Sigma approaches. Within Lean Six Sigma, individuals can be trained at various ‘Belt levels’. These levels are called Black Belt, Green Belt, Orange Belt and Yellow Belt.

The LSSA – Lean Six Sigma Academy – was established in September 2009, with the main objective to determine a common certification standard for Lean Six Sigma job roles. This has been realised by developing four skill sets with clear criteria and an online exam portal. This document describes the Black Belt skill set.

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