



V Creating World Class products

IV Creating capable processes

III Creating stable & efficient processes

II Creating a Continuous Improvement culture

I Creating a solid foundation

LEAN SIX SIGMA BLACK BELT SKILL SET

A GUIDELINE FOR LEAN SIX SIGMA
BLACK BELT TRAINING AND CERTIFICATION

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VERSION 2.5

Lean Six Sigma Academy®

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The structure of this document is based on the 'Continuous Improvement Maturity Model' - CIMM™. You have the permission to share and distribute this model in its original form by referencing the publisher and author, (LSSA®, Theisens et. al., 2014).

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INTRODUCTION

Within the domain of 'Continuous Improvement' individuals can be trained at four different levels. These levels are called Yellow Belt, Orange Belt, Green Belt and Black Belt.

Table 1. *Overview of Belt levels*

Belt level	Level
Yellow Belt	Awareness
Orange Belt	Foundation
Green Belt	Practitioner
Black Belt	Expert

The LSSA - Lean Six Sigma Academy® was established in September 2009 with the objective to develop an international recognized certification scheme for all Lean Six Sigma Belt levels. The LSSA Exam Board has developed four skill sets with clear criteria for skills and competences. These skill sets specify which of the overall Lean Six Sigma tools and techniques are expected to be included within certain Belt level competencies. Lean Six Sigma training is provided by a global network of 'Accredited Training Organizations' (ATOs). These ATOs provide training programs that are aligned to the LSSA skill sets.

Examinations are provided through a number of 'Examination Institutes' (EIs), which use the skill sets to develop exams. The exams are open to all. Individuals can apply directly to the EIs or sign up via one of the ATOs. It is recommended that candidates receive training through an ATO to prepare for certification. Alternatively, candidates who wish to self-study have the option to apply directly to an EI for certification.

Examinations are provided through the following three Examination Institutes (EIs):

- **APMG** APM Group Limited www.apmg-international.com
- **iSQI** International Software Quality Institute www.isqi.org
- **UT** University of Twente www.utwente.nl

The LSSA Black Belt skill set describes the assessment criteria for the theoretical and practical exams. Candidates are required to pass both elements to be recognized as a 'Certified Lean Six Sigma Black Belt'. Passing the theoretical exam is a pre-requisite to subscribe for the practical exam. The Black Belt certification can be achieved independently. There are no pre-requisites for Black Belt certification and therefore does not require any prior completion of any other Belt(s).

THEORETICAL ASSESSMENT CRITERIA

The assessment criteria for the theoretical exam are as follows:

- The theoretical exams consists of 60 multiple choice questions.
- The pass mark for the exams is set at 63% (38 marks or more required to pass).
- The duration of the exams is 180 minutes.
- The exams are Open book exams, where a maximum of 2 books are allowed. (eBook or Pdf's are not allowed)
- A calculator is allowed. Check with your ATO or exam institute if Minitab is allowed.
- You must be able to identify yourself with photographic ID.

If you pass you will receive a 'Partial LSSA certificate' from your EI that states you passed the theoretical exam. You will receive the 'Full LSSA certificate' if you also pass the practical assessment within a maximum period of three years after passing the theoretical exam.

PRACTICAL ASSESSMENT CRITERIA

Lean Six Sigma Black Belts have to submit two practical projects that meet the following criteria:

- Two successful projects at Level-III or higher. One of the projects needs to be Level-IV or higher.
- Each project has resulted in significant savings (e.g. € 50,000.- on a yearly basis).
- Projects follow the DMAIC, DMADV or IDOV roadmap, and consists of a maximum of 25 pages. The LSSA review template can be downloaded at the LSSA website (www.lssa.eu).
- The candidate should complete the self-assessment criterion that are listed in the LSSA review template prior to submission. A detailed overview of the assessment criteria are described in Appendix A.
- Each project has been signed by the Champion and Financial controller, thereby declaring that the project is carried out professionally and that the savings have been achieved.
- Projects must be submitted no later than three years after theoretical examination.

Both projects will be assessed by Master Black Belts assigned by the LSSA. The criterion listed in Appendix A will be applied. It is advisable to use these criterion during your project. It is additionally strongly advised that the submission is also checked by an internal Master Black Belt or coach.

CONTINUOUS IMPROVEMENT MATURITY MODEL (CIMM)

The LSSA skill sets are based on the ‘Continuous Improvement Maturity Model’ (CIMM). This is a framework that guides an evolutionary staged approach for process improvement from a very early stage till delivering world class products. CIMM summarizes all best practices elements of many different improvement methods in one framework, along two axes.

CIMM Axis 1 - Organization Development

The first axis focuses on the developing the employees and the organization. Organizational development can relate to the development of products and services, improvement of efficiency, market development, and so forth. CIMM describes the development of leadership, the development of employee’s competencies, the development of organizational culture and the way in which the organization is managed.



Figure 1 - CIMM Organizational Development (LSSA, 2017)

CIMM Axis 2 - Process Improvement

The second axis focuses on improving processes. In order to implement the strategy, the organization must continuously simplify, align and improve its processes. CIMM describes the creation of a solid foundation, an improvement culture, stable and predictable processes, capable processes and future-proof processes.

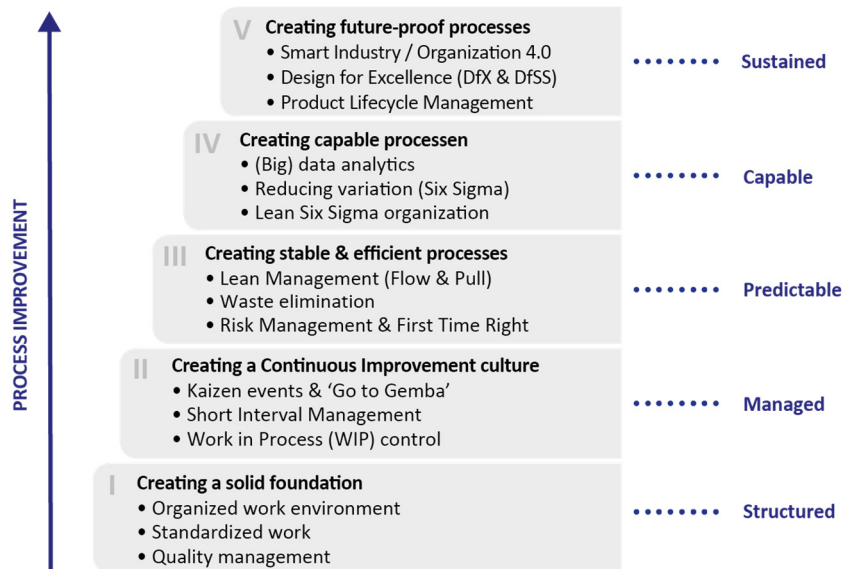


Figure 2 – CIMM Process Improvement (LSSA, 2017)

The following chapters describe the theoretical skill set elements. The structure consists of a number of 'Units', 'Elements' and 'Performance Criteria'.

- **Unit:** The skill set is presented by skill set areas; each called a 'Unit'. The chapters in the book 'Climbing the Mountain' reflect the 'Units' described in this skill set.
- **Element:** Each 'Unit' consists of a number of 'Elements'. The paragraphs in each chapter of the book 'Climbing the Mountain' reflect the 'Elements' in this skill set.
- **Performance Criteria:** Each 'Element' consists of a number of 'Performance Criteria' and each 'Performance Criteria' has an explanation. These describe the tools, techniques and competencies that are required to be achieved by the Black Belt.
- **Level of Cognition:** A 'Cognitive Level' has been assigned to each 'Performance Criteria'-description according to Bloom's Taxonomy [Appendix A]. This defines at which level the Black Belt is expected to apply the respective tool, technique or skill. This is the minimum level the Black Belt must be able to demonstrate in order to be assessed as competent.

U1. WORLD CLASS PERFORMANCE

The Unit 'World Class Performance' reviews the general philosophy of Process Improvement. It discusses the overview of different process improvement methods and the history of the most important methods. It also explains why process improvement is needed.

E1. COMPETITIVE STRATEGIES

The Learning Element 'Competitive strategies' explains Operational Excellence, Customer Intimacy and Product Leadership. It also explains how Operational Excellence can be applied to processes in different types of enterprises.

U1.E1.PC1 **Operational Excellence, Customer Intimacy & Product Leadership** **Understand**
Understand the three competitive strategies. Understand how Operational Excellence can be applied in different types of enterprises e.g. manufacturing, service, transactional, product and process design and innovation.

U1.E1.PC2 **Physical vs. Transactional processes** **Apply**
Describe the similarities and differences between physical processes and transactional processes.

E2. HISTORY OF CONTINUOUS IMPROVEMENT

The Learning Element 'History of Continuous Improvement' explains the history of process improvement and quality management.

U1.E2.PC1 **History of TQM, Lean and Six Sigma** **Understand**
Understand the origins of TQM, Lean and Six Sigma.

E3. PHILOSOPHY & PRINCIPLES

The Learning Element 'Philosophy & Principles' explains the values and principles of Lean and Six Sigma. Similarities and differences to other improvement methods are also reviewed.

U1.E3.PC1 **Value and foundations of Lean and Six Sigma** **Apply**
Propagate the value of Lean and Six Sigma, its philosophy, history and goals. Describe the relationship between Lean and Six Sigma.

U1.E3.PC2 **Lean principles** **Apply**
Describe the Toyota philosophy, the 14 principles and the House of Quality. Understand the impact of the Toyota Production System (TPS) on strategy, quality and production.

U1.E3.PC3 **Six Sigma principles** **Apply**
Use the Six Sigma philosophy to realize breakthroughs in process performance. Describe the meaning of Six Sigma level.

E4. ORGANIZATIONAL PROCESS MANAGEMENT

The Learning Element 'Organizational Process Management' explains the cohesion between business strategy, systems, processes and performance.

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| U1.E4.PC1 | Business process management
Define the relationship among various business processes e.g. design, production, purchasing, accounting, sales. Describe the impact these relationships can have on business systems. | Apply |
| U1.E4.PC2 | Business processes performance
Define and implement various business performance measurement systems, including balanced scorecard, key performance indicators (KPIs), and the financial impact of customer loyalty. Understand how these can be applied in different functional areas. | Apply |
| U1.E4.PC3 | Process improvement planning
Define the right process improvement strategy, based on the current maturity level of the organization. Define breakthrough opportunities and select process improvement methods and techniques to achieve business objectives. | Apply |

E5. PROJECT SELECTION PROCESS

The Learning Element 'Project Selection Process' explains how projects are selected based on the strategy of the organization and financial measures.

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|------------------|---|-------------------|
| U1.E5.PC1 | Financial measures
Define and use financial measures e.g. cost of poor quality (COPQ), net present value (NPV), return on investment (ROI) and working capital (WC). | Apply |
| U1.E5.PC2 | Project selection
Define project selection criteria. Identify process improvement opportunities. Apply project selection techniques to select the projects that contribute to the strategy of the organization. | Apply |
| U1.E5.PC3 | Strategic deployment
Understand the strategic planning process of Hoshin Kanri and how it forms the link between strategic mission and vision, tactical project plans and individual action plans. | Understand |

U2. PROCESS IMPROVEMENT DEPLOYMENT

The Unit 'Process Improvement Deployment' reviews how process improvement programs should be deployed across the organization. It explains the role and responsibilities of Leadership in its efforts to coach and inspire improvement teams. Also team development and change management aspects will be reviewed.

E1. MANAGEMENT OF CHANGE

The Learning Element 'Management of Change' reviews the dynamics that can occur during a project such as cooperation, resistance, escalation of problems and solving roadblocks.

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| U2.E1.PC1 | Organizational Culture
Describe and use various techniques for facilitating and management of change.
Describe the impact an organization's culture and inherent structure can have on the success of Lean Six Sigma. | Apply |
| U2.E1.PC2 | Change Management approaches
Describe how deployment failure can result from the lack of resources or management support. Organize a Top-Down approach and facilitate a Bottom-Up approach. | Apply |
| U2.E1.PC3 | Stakeholder analysis
Prepare 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. | Apply |

E2. LEADERSHIP

The Learning Element 'Leadership' explains the roles and responsibilities of executive leaders. This includes effective communication, motivating, coaching and rewarding improvement teams.

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| U2.E2.PC1 | Enterprise leadership responsibilities
Demonstrate leadership in the deployment of process improvement in terms of providing resources, managing change, communicating ideas, etc. | Understand |
| U2.E2.PC2 | Effective communication
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. | Apply |

- U2.E2.PC3 Team performance and motivation Apply**
Demonstrate team progress in relation to goals, objectives and other metrics that support team success and reward and recognize the team for its accomplishments. Describe and apply techniques that motivate team members and support and sustain their participation and commitment.
- U2.E2.PC4 Coaching Apply**
Apply coaching of all employees involved in process improvement e.g. Toyota Kata.

E3. TEAM DEVELOPMENT

The Learning Element 'Team Development' reviews various types of teams, team stages, team dynamics and setting up a training plan.

- U2.E3.PC1 Team Stages Apply**
Facilitate the team through the classic stages of development: forming, storming, norming, performing, adjourning and recognition.
- U2.E3.PC2 Personality Types Understand**
Understand the four basic personality types (MBTI) and use appropriate communications.
- U2.E3.PC3 Team Roles Understand**
Understand the nine team roles (Belbin) and select team members with appropriate natural strengths.
-

U3. PROJECT MANAGEMENT

The Unit 'Project Management' outlines the way improvement projects should be executed. It starts with the identification of customers and its requirements. The Unit also covers a number of project management roadmaps, team formation, the project charter and a number of project management tools.

E1. TEAM FORMATION

The Learning Element 'Team Formation' reviews the different role and responsibilities within and around an improvement team. It also reviews how a team is formed.

U3.E1.PC1 **Roles and Responsibilities** **Apply**
Promote the Lean Six Sigma levels of expertise: Master Black Belt, Black Belt, Green Belt, Orange Belt and Yellow Belt. Describe various team roles and responsibilities: Deployment leader, Champion, Project leader, Coach, and Team member.

U3.E1.PC2 **Team member selection** **Apply**
Facilitate the team member selection process, which includes required competences, subject matter expertise and availability. Select the proper resources so that a team is staffed for success.

E2. PROCESS IMPROVEMENT ROADMAPS

The Learning Element 'Process Improvement Roadmaps' reviews a number of roadmaps, including Plan-Do-Check-Act (PDCA) and Define, Measure, Analyze, Improve and Control (DMAIC).

U3.E2.PC1 **Kaizen Roadmap** **Apply**
Apply project management methods that can be used in the work place for Kaizen initiatives e.g. PDCA, A3-report.

U3.E2.PC2 **Problem Solving Process (8D)** **Apply**
Apply the 'Eight Disciplines Problem Solving Method' which is used to approach and resolve problems.

U3.E2.PC3 **DMAIC Roadmap** **Apply**
Apply the DMAIC roadmap for Lean and Six Sigma breakthrough projects. Select the proper tools to use during the Process Improvement project.

E3. VOICE OF THE CUSTOMER (VOC)

The Learning Element 'Voice of the Customer' reviews customer identification (internal/external) and customer requirements.

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| U3.E3.PC1 | Customer identification
Define the customer segment for each project and demonstrate how the project will impact both internal and external customers. | Apply |
| U3.E3.PC2 | Customer requirements
Apply the 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). | Apply |
| U3.E3.PC3 | Customer survey
Identify and apply the appropriate survey method (e.g. Net Promotor Score, focus groups and observations) to gather customer feedback to better understand their 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. | Apply |
| U3.E3.PC4 | Customer segmentation
Divide the market into segments of customers with identical needs, resulting in the same service level expectations. | Apply |

E4. PROJECT CHARTER

The Element 'Project Charter' covers the description of the project such as problem description, objectives, scope, timing and benefits.

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| U3.E4.PC1 | Problem statement
Develop and analyze the problem statement in relation to customer requirements and business goals. | Analyze |
| U3.E4.PC2 | Project scope and goal
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). | Analyze |
| U3.E4.PC3 | Project performance measures
Select and analyze performance measurements (Cost, Quality and Delivery) and establish key project metrics that relate to the voice of the customer. | Analyze |

U3.E4.PC4 **Project benefits calculation** **Analyze**
Define and calculate the hard benefits of the project and describe the soft benefits of the project.

E5. PROJECT MANAGEMENT TECHNIQUES

The Element 'Project Management Techniques' reviews a number of tools that are used during execution of the project.

U3.E5.PC1 **Time management** **Apply**
Propagate the importance and basic disciplines of time management. Apply the elements of time management. Set up team meetings, publish agendas and ensure that the right people and resources are available.

U3.E5.PC2 **Project progress** **Apply**
Apply project planning tools such as Gantt charts, critical path method (CPM) and program evaluation and review technique (PERT) charts. Apply basic disciplines of time management e.g. attending meetings, arriving on-time, coming prepared, being punctual and to the point. Organize Tollgate reviews to review progress with the Champion or project board.

U3.E5.PC3 **Project risk management** **Analyze**
Lead the development of risk analysis including resources, finance, customer impact, quality etc. Define mitigation actions.

U3.E5.PC4 **Project documentation** **Analyze**
Develop the proper vehicle for presenting project documentation (e.g. spreadsheet output and storyboards). Create project documentation in line with standard organization templates. Set up a structure to store project documentation properly.

U3.E5.PC5 **Lessons learned** **Apply**
Demonstrate and document the lessons learned from all phases of a project and identify how improvements can be replicated and applied to other processes in the organization.

U3.E5.PC6 **Project tracking** **Apply**
Demonstrate how projects fit together with other projects. Follow multiple projects timing and progress.

U4. LEVEL I – CREATING A SOLID FOUNDATION

The Unit 'Creating a solid foundation' reviews how to achieve a solid foundation for further process improvement programs. This foundation consists of a proper and organized work environment, reliable equipment and standardized work.

E1. ORGANIZED WORK ENVIRONMENT

The Learning Element 'Organized work environment' is about good housekeeping and how to set up a proper and safe work environment in a structured manner.

U4.E1.PC1 Organized work environment (5S) Analyze
Develop an organized work environment by applying 5S (Sort, Straighten, Shine, standardize, Sustain). Understand that an organized environment will improve safety and moral.

E2. STANDARDIZED WORK

The Learning Element 'Standardized work' is about implementing and improving standards.

U4.E2.PC1 Standardized work and Documentation Apply
Standardize tasks and processes to establish the foundation for continuous improvement and employee empowerment. Develop or modify documents, standard operating procedures (SOPs) and single-point-lessons to ensure that the improvements are sustained over time.

E3. QUALITY MANAGEMENT

The Learning Element 'Quality Management' is about developing procedures to identify and detect defects. Also preventing mistakes and avoiding problems will be discussed.

U4.E3.PC1 Quality Management System Apply
Propagate the quality management system and procedures. Identify opportunities for improvement.

U4.E3.PC2 Ongoing evaluation and auditing Apply
Identify and apply tools for the ongoing evaluation of the improved process, including auditing (internal / external), monitoring for new constraints and identification of additional opportunities for improvement.

U5. LEVEL II – CREATING A CONTINUOUS IMPROVEMENT CULTURE

The Unit ‘Creating a continuous improvement culture’ reviews how to create a continuous improvement culture at the shop floor. This Unit reviews setting up and facilitate Kaizen teams. It also reviews a number of problem solving techniques and tools.

E1. KAIZEN

The Learning Element ‘Kaizen’ reviews how to organize and facilitate improvement teams at the shop floor that work on Kaizen improvement initiatives.

U5.E1.PC1	Short Interval Management Implement and support Short Interval Management to initiate and drive continuous improvement initiatives.	Apply
U5.E1.PC2	Visual Workplace Develop the elements of Visual Workplace and describe how they can help to control the improved process.	Analyze
U5.E1.PC3	Root Cause Analysis Define and apply root cause analysis, recognize the issues involved in identifying a root cause. Apply problem solving process and tools.	Analyze
U5.E1.PC4	Kaizen events Empower and facilitate improvement teams and Kaizen events.	Apply

E2. BASIC QUALITY TOOLS

The Learning Element ‘Basic Quality Tools’ reviews a number of basic quality tools.

U5.E2.PC1	Visualization of data Propagate the purpose and use of data visualization, analysis and communication.	Apply
U5.E2.PC2	Basic Quality Tools Apply and analyze the outcome of basic quality tools: Check sheet; Pareto chart; Scatter plot; Bar chart; Pie chart; Time Series Plot, Histogram and Box plot.	Analyze

E3. BASIC MANAGEMENT TOOLS

The Learning Element ‘Basic Management tools’ reviews a number of tools that are very powerful in the problem solving process.

U5.E3.PC1	Brainstorm Techniques Apply brainstorm techniques: Affinity diagram, 5-Why's and Ishikawa.	Apply
U5.E3.PC2	Decision making Select and apply decision making techniques e.g. Cause & Effect matrix and multi-voting.	Apply

U6. LEVEL III – CREATING STABLE AND EFFICIENT PROCESSES

The Unit 'Creating stable and efficient processes' reviews how the logistical flow of processes can be improved and made more stable, predictable and efficient. This Unit also reviews tools which can be used to visualize and analyze the process flow. This unit also reviews a number of tools and techniques that can be used to improve efficiency, effectiveness, productivity and agility of processes. All Level III Learning Elements and Performance Criteria follow the DMAIC structure.

DEFINE

E1. PROCESS MAPPING

The Learning Element 'Process Mapping' reviews a number of tools to map the process flow that can be used in both Lean and Six Sigma projects.

U6.E1.PC1	Process Flow diagram Apply process mapping to visualize the flow of activities and decisions within a process.	Apply
U6.E1.PC2	High level process description Distinguish between key process input variables and key process output variables based on a high level process map e.g. SIPOC.	Analyze

MEASURE

E2. LEAN PERFORMANCE METRICS

The Learning Element 'Lean Performance Metrics' reviews different types of data, measurement scales and Lean performance metrics. This Element also reviews process flow analysis.

U6.E2.PC1	Process Flow analysis Analyze process flow and utilization. Apply Little's Law.	Analyze
U6.E2.PC2	Lean Performance metrics Analyze Lean performance metrics e.g. takt time, cycle time, lead time, queue time, WIP, yield and OEE.	Analyze
U6.E2.PC3	Data types Describe and distinguish between qualitative and quantitative data (continuous and discrete data).	Analyze
U6.E2.PC4	Measurement scales Define and analyze nominal, ordinal, interval and ratio measurement scales. Apply Likert scale to convert an ordinal scale into a discrete or continuous interval scale.	Analyze

ANALYZE

E3. VALUE STREAM ANALYSIS

The Learning Element 'Value Stream Analysis' reviews how to create a Value Stream Map of the current situation.

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| U6.E3.PC1 | Value Adding versus Non Value Adding
Distinguish value added from non-value added activities. | Analyze |
| U6.E3.PC2 | Value Stream Mapping (Current State)
Apply Value Stream Mapping to construct a Current State Map of the process to identify waste and non-value added activities. | Apply |

IMPROVE

E4. REDUCING MUDA (WASTE)

The Learning Element 'Reducing Muda' reviews how to identify Waste in the organization and in the processes.

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| U6.E4.PC1 | Waste identification (for the Operation)
Identify and analyze the 8 types of operational waste (Muda); Overproduction, Waiting, Transport, Overprocessing, Inventory, Movement, Defects, Unused expertise. | Analyze |
| U6.E4.PC2 | Waste identification (for the Customer)
Identify and analyze the 7 types of customer waste (Muda); Opportunity Loss, Delay, Unnecessary Movement, Duplication, Incorrect inventory, Unclear Communication and Errors. | Analyze |

E5. REDUCING MURI (OVERBURDEN)

The Learning Element 'Reducing Muri' reviews how to identify overburdening the organization and how to implement flow and work balancing to reduce overburden. This element also reviews the relations between Lean with TPM and TOC.

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| U6.E5.PC1 | Flow
Describe the importance of flow for reducing Muri. Develop flow in the organization. | Analyze |
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- | | | |
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| U6.E5.PC2 | Work balancing
Describe the importance of Work balancing for reducing Muri. Develop Work balancing. | Analyze |
| U6.E5.PC3 | Total Productive Maintenance (TPM)
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. | Apply |
| U6.E5.PC4 | Competence Management (Skill Matrix)
Describe how competence management supports the reduction of Muri. Set up and apply a competence management system. | Apply |

E6. REDUCING MURA (UNEVENNESS)

The Learning Element 'Reducing Mura' reviews how to identify unevenness in the organization and in the processes. This element also reviews a number of techniques to reduce unevenness.

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| U6.E6.PC1 | Pull
Describe the importance of pull for reducing Mura. Develop and implement pull in the organization by applying Kanban systems. | Analyze |
| U6.E6.PC2 | Volume and Type leveling
Implement a balanced process flow by both volume leveling, type leveling and one piece flow. | Apply |
| U6.E6.PC3 | Quick Change Over (SMED)
Reduce change over times by implementing Single Minute Exchange of Die (SMED). | Apply |

E7. VALUE STREAM IMPROVEMENT

The Learning Element 'Value Stream Improvement' reviews how the techniques and tools that reduce Muda, Muri and Mura can be applied in constructing a Future State Value Stream Map.

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| U6.E7.PC1 | Value Stream Mapping (Future State)
Define the gap between the current state and the target condition. Prepare a Future state map using Value Stream Mapping. Apply techniques to reduce Muda, Mura and Muri. | Apply |
|------------------|---|--------------|

CONTROL

E8. FIRST TIME RIGHT

The Learning Element 'First Time Right' looks at how results that have been achieved in process improvement projects can be sustained. This element reviews the following techniques and principles: Process FMEA, Control plan, Jidoka and Poka Yoke.

U6.E8.PC1	Process FMEA (pFMEA) Prepare all elements of a Process FMEA, calculate the risk priority number (RPN) and review the effect of FMEA results on processes, products and services.	Apply
U6.E8.PC2	Control plan Prepare a control plan to document and hold gains. Define controls and monitoring systems. Transfer of responsibility from the project team to the process owner.	Apply
U6.E8.PC3	Jidoka & Poka Yoke Implement a culture of stopping to fix problems to get quality right the first time. Empower the work force to stop the line when there is a quality problem. Apply Poka Yoke to prevent quality problems.	Apply

U7. LEVEL IV – CREATING CAPABLE PROCESSES

The Unit 'Creating Capable Processes' focuses on reducing variation in a stable process with the objective to create a process capable of meeting customer requirements. This Unit reviews the application of Six Sigma and statistical tools used to assure a valid and reliable performance measurement system, to collect data and to analyze the performance of processes. Six Sigma focuses on quality breakthrough improvement projects. All Level IV Learning Elements and Performance Criteria follow the DMAIC structure.

DEFINE

E1. CRITICAL TO QUALITY

The Learning Element 'Critical to Quality' reviews how to translate the Voice of Customer (VOC) into a CTQ flowdown that represents the key measurable characteristics of the product or process.

- | | | |
|------------------|---|--------------|
| U7.E1.PC1 | Critical requirements
Define and describe various CTx requirements (critical to quality (CTQ), cost (CTC), process (CTP), safety (CTS) and delivery (CTD)) and align projects with those requirements. | Apply |
| U7.E1.PC2 | CTQ Flowdown
Translate the Voice of Customer (VOC) into external CTQ's and internal CTQ's. Construct a CTQ flowdown that represents the key measurable characteristics of a product or process whose performance standards or specification limits must be met. | Apply |

MEASURE

E2. SIX SIGMA PERFORMANCE METRICS

The Learning Element 'Six Sigma Performance Metrics' reviews a number of metrics that are often used in Six Sigma projects. The element also reviews a number of sampling methods for assuring data accuracy and integrity.

- | | | |
|------------------|--|----------------|
| U7.E2.PC1 | Defects and Defectives
Distinguish between natural process limits and specification limits. Distinguish and calculate Six Sigma process performance metrics (e.g. PPM, DPMO, DPU and RTY). Describe the difference between a defect and a defective. | Analyze |
| U7.E2.PC2 | Sampling methods
Develop and apply appropriate sampling methods that ensure representative data e.g. random sampling, stratified sampling and systematic sampling. | Analyze |

U7.E2.PC3	Data collection tools	Analyze
	Define and analyze tools for collecting data e.g. data sheets, check sheets, concentration diagrams and questionnaires.	

E3. STATISTICS

The Learning Element 'Statistics' reviews the basic terms of sample and descriptive statistics.

U7.E3.PC1	Descriptive statistics	Apply
	Calculate population parameters and sample statistics e.g. proportion, mean and standard deviation.	
U7.E3.PC2	Variation	Analyze
	Evaluate special cause and common cause variation.	
U7.E3.PC3	Basic probability concepts	Apply
	Describe and apply probability concepts such as independence, mutually exclusive events, multiplication rules, complementary probability and joint occurrence of events.	

E4. DISTRIBUTIONS

The Learning Element 'Distributions' reviews a number of continuous and discrete distributions. The element also reviews the central limit theorem and a number of probability concepts.

U7.E4.PC1	Continuous distributions	Apply
	Interpret Probability Density Functions and Cumulative Distribution Functions. Apply continuous distributions: Normal, Chi square, Student's t, F-distribution, Weibull, Lognormal and Exponential distribution. Apply normality test (Anderson-Darling) describe shape parameters (Skewness and Kurtosis).	
U7.E4.PC2	Discrete distributions	Apply
	Apply discrete distributions: Poisson, Binomial and Hypergeometric.	
U7.E4.PC3	Central limit theorem	Apply
	Apply the central limit theorem.	
U7.E4.PC4	Data transformation on non-normal data	Apply
	Identify non-normal data and use Box-Cox or Johnson transformation.	

E5. MEASUREMENT SYSTEMS

The Learning Element 'Measurement Systems' reviews how to evaluate measurement systems.

U7.E5.PC1	Measurement methods Define and implement measurement methods for both continuous and discrete data.	Apply
U7.E5.PC2	Measurement systems analysis Analyze measurement systems for continuous data. Interpret repeatability and reproducibility (R&R), stability, bias, linearity, precision to tolerance and number of distinct categories.	Analyze
U7.E5.PC3	Attributive Agreement Analysis Analyze measurement systems for qualitative properties. Establish attribute agreement within appraiser, between appraisers and appraisers vs. standard.	Analyze
U7.E5.PC4	Metrology Apply elements of metrology, including calibration systems, traceability to reference standards, the control and integrity of standards and measurement devices.	Apply

ANALYZE

E6. HYPOTHESIS TESTING & CONFIDENCE INTERVALS

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

U7.E6.PC1	Hypothesis testing Define and analyze the significance level, power, type I and type II errors in statistical tests.	Analyze
U7.E6.PC2	Confidence Intervals Calculate confidence, prediction and tolerance intervals. Distinguish between statistical and practical significance.	Analyze
U7.E6.PC3	Sample size Calculate power and sample size for common hypothesis tests.	Apply
U7.E6.PC4	Tests for means, variances and proportions Apply and analyze hypothesis tests for means, variances and proportions.	Analyze
U7.E6.PC5	Chi-square tests Apply and analyze Chi-square goodness-of-fit test and Contingency tables.	Analyze

- U7.E6.PC6 Non-parametric tests Analyze**
Apply and analyze non-parametric tests: Mann-Whitney, Kruskal Wallis and Mood's median test.

E7. CORRELATION AND REGRESSION

The Learning Element 'Correlation and Regression' describes the predictive models using regression techniques to determine the relation between factors on a response.

- U7.E7.PC1 Correlation coefficient Analyze**
Calculate and interpret the correlation coefficient. Determine its statistical significance (p-value) and recognize the difference between correlation and causation.
- U7.E7.PC2 Regression analysis Analyze**
Apply linear and polynomial regression analysis. Analyze the regression model for estimation and prediction. Interpret the residual analysis to validate the model.
- U7.E7.PC3 Analysis of variance (ANOVA) Analyze**
Apply ANOVA. Analyze the results and the main effect and interaction plots.
- U7.E7.PC4 Multivariate studies Analyze**
Apply and analyze multivariate studies such as principal components and factor analysis.
- U7.E7.PC5 Logistic regression analysis Apply**
Apply attributes data using (binary) logistic regression to investigate sources of variation.

E8. PROCESS CAPABILITY AND PERFORMANCE

The Learning Element 'Process Capability and Performance' explains process capability and performance in relation to specification limits.

- U7.E8.PC1 Process capability studies Analyze**
Apply and analyze process capability studies. Develop sampling plans to verify stability.
- U7.E8.PC2 Process capability indices Analyze**
Calculate and analyze Cp, Cpk and Cpm to assess process capability.
- U7.E8.PC3 Short-term and long-term capability Analyze**
Describe and use appropriate assumptions and conventions when only short-term data or attributes data are available and when long-term data are available. Analyze the relationship between long-term and short-term capability.

- U7.E8.PC4** **Process performance indices** **Analyze**
Calculate and analyze Pp and Ppk to assess process performance. Interpret the relationship between capability and performance indices.
- U7.E8.PC5** **Process capability for attributes data** **Apply**
Calculate the process capability and process sigma level for attribute data.
-

IMPROVE

E9. DESIGN OF EXPERIMENTS (DOE)

The Learning Element 'Design of Experiments' reviews efficient ways of experimenting. Design of Experiments examines the influence of factors and interactions on a process.

- | | | |
|------------------|--|----------------|
| U7.E9.PC1 | Principles of experiments and terminology | Analyze |
| | Understand the limitations of One-Factor-At-a-Time (OFAT) experiments. Understand why Design of Experiments (DOE) is a more efficient way of experimenting. Apply and analyze DOE principles and terms: responses, factors, levels, transfer function, run order, randomization, balanced designs, residual error, main effects, interaction effects, replicates, repetitions, curvature and centerpoints. | |
| U7.E9.PC2 | Planning experiments | Analyze |
| | Plan, organize and evaluate experiments by determining the objective, selecting factors, responses and measurement methods and choosing the appropriate design. | |
| U7.E9.PC3 | Two-level Full factorial experiments | Analyze |
| | Design and analyze full factorial experiments. Understand and apply contrast, covariate, blocking. | |
| U7.E9.PC4 | Two-level fractional factorial experiments | Analyze |
| | Design and analyze fractional factorial experiments and describe how confounding affects their use. Understand and apply alias tables and folding, | |
| U7.E9.PC5 | Response Surface Modeling | Analyze |
| | Design and analyze Response Surface Models (RSM) such as Box Behnken and Central Composite Designs. Analyze the response surface using path of steepest ascent and apply Evolutionary Operations (EVOP). | |

CONTROL

E10. 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.E10.PC1 | SPC Objectives and benefits | Analyze |
| | Describe the objectives of SPC, including monitoring and controlling process performance and tracking trends. Design SPC for reducing variation in a process. | |
| U7.E10.PC2 | Control charts | Analyze |
| | Select and construct the following types of control charts: Xbar-R, Xbar-S, individuals and moving range (I MR), median, p, np, c, u, short-run SPC and moving average. | |
| U7.E10.PC3 | Tests for Special Causes | Analyze |
| | Interpret control charts and distinguish between common and special cause variation using rules for determining statistical control. | |
| U7.E10.PC4 | Selection of variables | Apply |
| | Identify and select critical characteristics for control chart monitoring. | |
| U7.E10.PC5 | Acceptance sampling | Apply |
| | Design sampling plans based on acceptable quality level and rejectable quality level. Describe and apply rational sub grouping. | |

U8. LEVEL V - CREATING WORLD CLASS PRODUCTS AND SERVICES

The Unit 'Creating World Class products and services' is about applying Lean 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.

E1. PRODUCT LIFECYCLE MANAGEMENT (PLM)

The Learning Element 'Product Lifecycle Management' reviews the entire lifecycle of products from inception, engineering, and manufacturing to service and disposal.

U8.E1.PC1	Product Lifecycle Management	Understand
	Understand the lifecycle for products from creation, engineering, manufacturing to service and disposal.	

E2. INNOVATION MANAGEMENT

The Learning Element 'Innovation Management' reviews frameworks and roadmaps for new product and process development, including the DMADV Design for Six Sigma roadmap.

U8.E2.PC1	Product and Process Development	Apply
	Apply methods for new product and process development.	

U8.E2.PC2	Design for Six Sigma	Apply
	Describe and select appropriate DfSS roadmaps: DMADV (define, measure, analyze, design, verify) and IDOV (identify, design, optimize, verify). Identify how they relate to DMAIC and how they help close the loop on improving the end product/process during the design (DfSS) process.	

U8.E2.PC3	Organizational Agility	Apply
	Apply project management methods that fit the Agile methodology.	

E3. DESIGN FOR SIX SIGMA TECHNIQUES

The Learning Element 'Design for Six Sigma techniques' reviews a number of methodologies and techniques that can be applied within Design for Six Sigma, such as Quality Function Deployment, Reliability engineering and Tolerance analysis.

U8.E3.PC1	Quality Function Deployment (QFD)	Understand
	Understand that QFD can be applied to translate customer requirements into product performance measures.	

U8.E3.PC2	Design FMEA (DFMEA)	Apply
	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. Select between DFMEA and PFMEA. Apply critical parameter management (CPM).	

- U8.E3.PC3** **Design for X (DFX)** **Apply**
Describe and eliminate design constraints, including design for cost, design for manufacturability and producibility, design for test and design for maintainability.
- U8.E3.PC4** **Reliability** **Understand**
Understand that reliability specifications and design tests can be used to demonstrate reliability specifications. Understand basic principles of failure rate function of life time tests.
- U8.E3.PC5** **Tolerance Analysis** **Understand**
Understand the basic principles of tolerance analysis using worst case, RSS, Monte Carlo and empirical methods.
-

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.

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. Bloom's Taxonomy divides educational objectives into three 'domains': Affective, Psychomotor and Cognitive. This Skill set only notices the Cognitive domain. The 'Levels of Cognition' are in rank order - from least complex to most complex. The Black Belt skill set only uses the levels 'Understand', 'Apply and 'Analyze'.

Remember

Recall or recognize terms, definitions, facts, ideas, materials, patterns, sequences, methods, principles, etc. The LSSA uses the following verb at this level: Recall.

Understand

Read and understand descriptions, communications, reports, tables, diagrams, directions, regulations, etc. The LSSA uses the following verbs at this level: Describe, Follow, Identify, Interpret, Participate, Understand.

Apply

Know when and how to use ideas, procedures, methods, formulas, principles, theories, etc. The LSSA uses the following verbs at this level: Apply, Assure, Calculate, Define, Demonstrate, Divide, Eliminate, Empower, Facilitate, Implement, Motivate, Organize, Plan, Prepare, Present, Promote, Propagate, Review, Select, Standardize, Support, Use.

Analyze

Break down information into its constituent parts and recognize their relationship to one another and how they are organized; identify sublevel factors or salient data from a complex scenario. The LSSA uses the following verbs at this level: Analyze, Construct, Design, Develop, Distinguish, Evaluate, Lead, Manage, Translate.

Evaluate

Make judgments about the value of proposed ideas, solutions, etc., by comparing the proposal to specific criteria or standards. The LSSA does not use this level in their skill sets.

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. The LSSA does not use this level in their skill sets.

APPENDIX B – DETAILED PRACTICAL ASSESSMENT

This appendix describes a detailed overview of the practical assessment criteria. A 'Pass' result will be awarded when all criteria are addressed within the submission and are deemed to be 'Correct' or 'Not Applicable'.

- Any criteria that has a grey box in the 'Not Applicable' column is mandatory and may not be claimed as 'Not Applicable'
- The submission must contain a justification of any criteria that is claimed to be 'Not Applicable'.

The result of the practical assessment will be either Pass or Fail. No score will be given. In the event of a 'Fail' result, brief guidance will be given on those criteria that are deemed 'Missing' or 'Incorrect'. Subsequently, a single retake resubmission is allowable.

Define	1	Project addresses a clear business opportunity (GB: 20k€ p/year; BB: 50k€ p/year).
	2	Problem description has been clearly defined.
	3	Goals have been clearly defined. Project objectives are measurable.
	4	VOC and VOB have been defined clearly. Requirements have been understood.
	5	Scope of the project has been clearly delineated.
	6	Key stakeholders have been involved and informed.
	7	Relevant KPI's have been selected / CTQ-flowdown has been constructed.
	8	SIPOC has been made.
Measure	1	Data has been collected / selected properly.
	2	The collected data has been proven to be representative for the project.
	3	Validity of the data has been verified in an appropriate way (Gage R&R if applicable).
	4	Historical data has been used to visualize process stability and performance over time.
	5	Variation in the process has been considered (common cause or special cause).
	6	Short term versus long term performance has been considered.
	7	Performance against requirements has been checked.
Analyze	1	Process has been mapped in detail (e.g. Process Flow / VSM Current State).
	2	Potential factors of influence have been determined.
	3	Cause & Effect / FEMA have been used to identify factors with highest influence.
	4	Hypothesis for root cause has been defined properly.
	5	Input data has been collected and analyzed correctly.
	6	Graphical and statistical techniques have been applied to investigate root causes.
	7	Major root causes have been identified.
	8	Conclusions have demonstrated strong evidence / statistically valid.
Improve	1	Improved process meets the requirements of the VOC and VOB.
	2	Risks have been assessed (e.g. pFMEA).
	3	Resistance for change has been overcome / Risks have been mitigated.
	4	Internal and external clients have accepted the new process.
	5	Improvements have been proven to be successful. (Capability study if applicable).
Control	1	Evidence of 'In-Control situation' is available and sufficient.
	2	Improvements have proven to be sustainable.
	3	Measures have been put in place to monitor process performance.
	4	Documentation has been updated (pFMEA, Control Plan, SOPs).
	5	Training has been performed for the new process.
	6	Project report has been completed. Lessons learned have been communicated.
	7	Champion has been involved and signed the project.
	8	Controller signed that project savings / benefits have been achieved.

Figure 3 – Practical Assessment Criteria

It is important for businesses and organizations 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 second revision of the Black Belt skill set.

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