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BLACK BELT

LEAN SIX SIGMA

SKILL SET

cimm™

LEAN & SIX SIGMA BLACK BELT SKILL SET

A GUIDELINE FOR
TRAINING AND CERTIFICATION

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A guideline for training and certification

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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., 2021).

CONTENT

INTRODUCTION

Within the domain of Lean and Six Sigma individuals can be trained and certified at different levels. The levels are listed in the Table below.

Belt level	Level
Lean Yellow Belt	Awareness
Lean Six Sigma Yellow Belt	Awareness
Lean Six Sigma Orange Belt	Foundation
Lean Green Belt	Practitioner
Lean Six Sigma Green Belt	Practitioner
Lean Black Belt	Expert
Lean Six Sigma Black Belt	Expert
Master Black Belt	Master

Table 1 - Overview of Lean Six Sigma Belt levels

The LSSA - Lean Six Sigma Academy® was established in September 2009 with the objective to develop an international recognized certification scheme for all Lean and Six Sigma Belt levels. For each level the LSSA Exam Board has developed Skill sets with clear criteria for skills and competences. These Skill sets specify which of the overall Lean and Six Sigma techniques are expected to be included within certain Belt level competencies.

The LSSA Black Belt Skill sets describe the assessment criteria for the theoretical and practical exam. Candidates are required to pass both elements to be recognized as a certified Lean or 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 certification and therefore does not require any prior completion of any other Belt(s). After completion of the Lean Six Sigma Black Belt you can subscribe for the Master Black Belt scheme.

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. Examination is provided through the LSSA directly or through APM Group Limited. The exams are open to all. Individuals can apply directly or sign up via one of the ATOs. It is recommended that candidates receive training through an ATO to prepare for certification. On the website you will also find information about how you can claim your Digital badge.

Figure 1 – LSSA digital badges

THEORETICAL ASSESSMENT CRITERIA

The assessment criteria for the theoretical exam are as follows:

- For Lean Black Belt:
  - The theoretical exam consists of 40 multiple choice questions.
  - The duration of the exam is 120 minutes.
  - The pass mark is set at 63% (25 marks or more required to pass).
- For Lean Six Sigma Black Belt:
  - The theoretical exam consists of 60 multiple choice questions.
  - The duration of the exam is 180 minutes.
  - The pass mark is set at 63% (38 marks or more required to pass).
- The exams are Open book exams, where a maximum of 2 books are allowed.
- A calculator or statistical software (e.g. Minitab) is allowed.
- You must be able to identify yourself with photographic ID.

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

PRACTICAL ASSESSMENT CRITERIA

The assessment criteria for the practical part include the submission of two practical projects that meet the following criteria:

- For Lean Black Belt: two successful projects at CIMM level-III (or higher).
- For Lean Six Sigma Black Belt: two successful projects at CIMM level-III and IV or higher.
- The project should have a significant impact to the organization (e.g. a financial impact of €50,000,- or a relevant CTQ has substantially been improved).
- The project must follow the DMAIC or DMADV roadmap.
- The templates for submitting the projects can be downloaded from the LSSA website (max. of 25 pages).
- The projects should be signed off by the Champion to declare that the projects have been carried out professionally and that objectives have been achieved and sustainable.
- A single Black Belt can submit the projects for certification in its role of project manager.
- The project must be submitted within three years after passing the theoretical examination.

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

- A 'Pass' result will be awarded when all criteria are addressed within the submission and are deemed to be 'Correct' or '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.

CONTINUOUS IMPROVEMENT MATURITY MODEL (CIMM)

CIMM summarizes best practices and techniques of different methodologies in one framework, for different stages of maturity. The CIMM framework describes five consecutive stages: Creating a solid foundation, Creating a continuous improvement culture, Creating stable and predictable processes, Creating capable processes and Creating future-proof processes. Within Lean only the first three levels apply. For Six Sigma all five levels apply.

For each instrumental technique in the CIMM framework, it is possible to indicate the associated desired behavior. The CIMM framework identifies a number of behaviors for each improvement technique, which helps determine whether or not the implementation of the technology in question will be a success and results in a lasting impact.

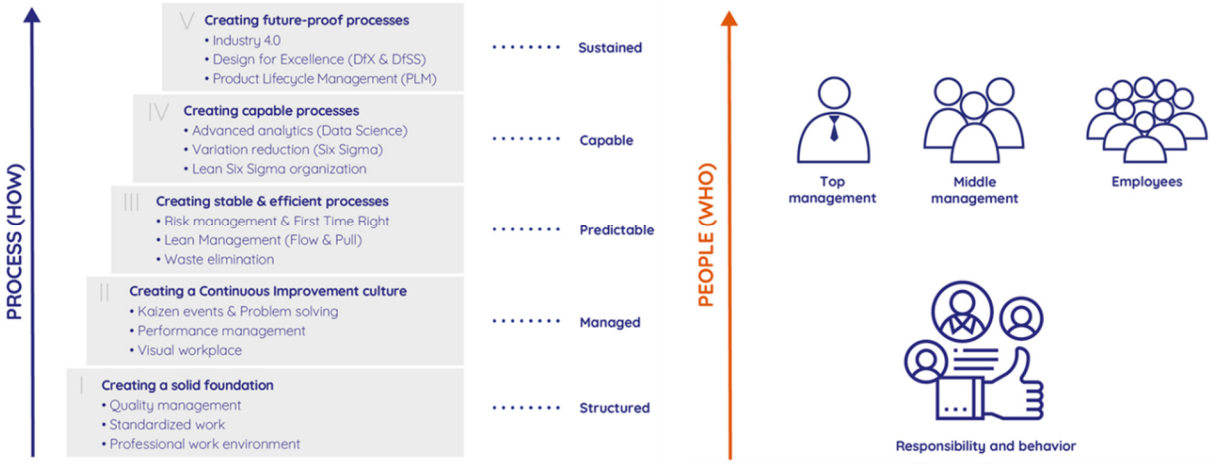

Figure 2 – CIMM Process (HOW) and People (WHO)

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 areas are called '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 sections]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 Belt. A 'Cognitive Level' has been assigned to each 'Performance Criteria' according to Bloom's Taxonomy [Appendix A].

Attendees that are preparing for Lean Black Belt certification should a able to measure up to the first six units (U1. till U6.). Attendees that are preparing for Lean Six Sigma Black Belt certification should a able to measure up to the eighth unit (U1. till U8.).

U1. WORLD CLASS PERFORMANCE

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

E1. CONTINUOUS IMPROVEMENT

The Learning Element 'Continuous Improvement' reviews the history, values and principles of the most common process improvement methodologies. Also, the culture within a continuous improvement organization as well as roles and responsibilities are reviewed.

U1.E1.PC1 **Continuous Improvement history** **Understand**
Understand the origins of quality management, TPM, Kaizen, Lean, Six Sigma and Agile.

U1.E1.PC2 **Continuous Improvement values and principles** **Analyze**
Propagate the Lean Six Sigma philosophy and principles. Deploy a continuous improvement culture within the organization, which represents the collective values, beliefs and principles.

U1.E1.PC3 **Continuous Improvement Maturity Model** **Analyze**
Assess and deploy the organization's maturity level of the organization, which is a combination of developing people and process.

U1.E1.PC4 **Continuous Improvement roles and responsibilities** **Apply**
Promote the various continuous improvement roles and responsibilities.

E2. CUSTOMER VALUE (VOC & CTQ)

The Learning Element 'Customer first' reviews customer identification (internal/external), customer requirements and the CTQ-measure.

U1.E2.PC1 **Voice of the Customer (VOC)** **Analyze**
Prioritize and translate the Voice of the Customer (VOC) requirements into internal specification requirements. Differentiate customer experience into dissatisfied, expected, satisfied and desired quality levels (e.g. KANO model).

U1.E2.PC2 **Critical to Quality (CTQ)** **Analyze**
Translate the Voice of Customer into external CTQs and internal CTQs. Construct a CTQ flowdown that represents the key measurable characteristics of a product or process whose performance standards or specification limits must be met.

U2. POLICY DEVELOPMENT AND DEPLOYMENT

The Unit 'Policy development and deployment' reviews how policy development and deployment help organizations in defining a continuous improvement strategy and to run efficiently in achieving their objectives.

E1. POLICY DEVELOPMENT

The Learning Element 'Policy development' explains the importance of a so-called True North and how to develop an operational excellence strategy.

U2.E1.PC1 **Vision & True North** **Apply**
Describe how Operational Excellence can be applied to processes in different types of enterprises.

U2.E1.PC2 **Transformation roadmap** **Apply**
Define a transition roadmap for a continuous improvement policy development and deployment program.

U2.E1.PC3 **Performance and financial metrics** **Analyze**
Define and implement a process of business performance management, which includes developing metrics as well as collecting, analyzing and reporting data about the performance of the organization. Evaluate financial measures e.g. cost of poor quality (COPQ), total cost of quality, working capital (WC) and inventory turn ratio (ITR).

E2. POLICY DEPLOYMENT

The Learning Element 'Policy deployment' is focusing on the execution process of the improvement strategy. Within this element financial and performance metrics will be reviewed.

U2.E2.PC1 **Management of change** **Apply**
Describe the impact breakthrough projects can have on process owners, internal and external customers and other stakeholders. Facilitate initiatives and apply techniques to manage change and overcome resistance (e.g. Kübler-Ross, stakeholder analysis, Kotter approach).

U2.E2.PC2 **Leadership** **Apply**
Propagate long term and meaningful objectives such as sustainability, dignity and creating an inspiring and healthy work environment throughout the organization. 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.PC3 **Hoshin Kanri (X-matrix)** **Apply**
Support the organization in the strategic planning process, applying Hoshin Kanri. Understand how Hoshin Kanri forms the link between policy development and policy deployment.

E3. COMPETENCE DEVELOPMENT

The Learning Element 'Competence development' reviews how to develop those who need to ensure that the strategy is implemented successfully.

U2.E3.PC1 **Learning organization** **Apply**
Guide people through the four stages of competence development including lessons learned from former projects.

U2.E3.PC2 **Coaching and intervision** **Apply**
Apply coaching and intervision to those involved in continuous improvement (e.g. Toyota Kata).

U2.E3.PC3 **Effective communication** **Apply**
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.

U3. PROJECT MANAGEMENT

The Unit 'Project Management' outlines the way improvement projects should be executed. A number of process improvement roadmaps is reviewed. The Unit also reviews project selection, team formation, planning and execution.

E1. MANAGING A PROJECT

The Learning Element 'Managing a project' reviews how to set up, plan and execute a project.

U3.E1.PC1 **Project selection** **Apply**
Define project selection criteria. Identify continuous improvement opportunities. Apply project selection techniques to select the projects that contribute to the strategy of the organization.

U3.E1.PC2 **Project charter** **Analyze**
Develop the project charter in relation to customer requirements and business goals. Develop and evaluate the problem statement, project boundaries (scope), objectives, benefits and measurable targets for the project. Support Green Belts in developing their project charter.

U3.E1.PC3 **Project team** **Apply**
Apply techniques to select team members (e.g. MBTI, Belbin). Facilitate the team through the classic stages of development: forming, storming, norming, performing and adjourning.

U3.E1.PC4 **Project planning** **Apply**
Select and construct time management techniques. Set up team meetings, tollgates and publish agendas and ensure that the proper people and resources are available. Ensure that the project will meet its requirements for time, quality and costs.

U3.E1.PC5 **Project execution** **Analyze**
Manage the project and apply the proper tools and techniques.

E2. PROCESS IMPROVEMENT ROADMAPS

The Learning Element 'Process Improvement Roadmaps' reviews a number of roadmaps, including PDCA and DMAIC.

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

U3.E2.PC2 **Lean Six Sigma Roadmap (DMAIC)** **Apply**
Apply the DMAIC roadmap for Lean and Six Sigma projects. Select the proper tools to use during the project.

U3.E2.PC3 **Problem Solving Process (8D)** **Apply**
Facilitate the problem-solving process (e.g. 8D approach).

U3.E2.PC4 **Scrum** **Apply**
Facilitate self-organizing teams and define clear boundaries for self-organizing teams. Propagate Scrum in product development and continuous improvement initiatives.

U3.E2.PC5 **Design for Six Sigma roadmap (DMADV)** **Understand**
Describe the DMADV-roadmap for Design for Six Sigma projects.

U4. 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. PROFESSIONAL WORK ENVIRONMENT

The Learning Element 'Professional 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 and protocols.

U4.E2.PC1 **Standard Work** **Apply**
Standardize tasks and processes to establish the foundation for continuous improvement. Develop or modify documents, standard operating procedures (SOPs) and one-point-lessons to ensure that the improvements are sustained over time.

U4.E2.PC2 **Training within Industry** **Apply**
Implement Training Within Industry principles in the organization.

E3. QUALITY MANAGEMENT

The Learning Element 'Quality Management' is about developing procedures to identify and detect defects. Also preventing mistakes and avoiding problems is part of this element.

U4.E3.PC1 **Quality Management System** **Apply**
Propagate the quality management system and procedures. Facilitate the evaluation of processes, including auditing (internal / external) and identification of 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. VISUAL MANAGEMENT

The Learning Element 'Visual management' reviews how to set up a workplace that is organized and self-explaining.

U5.E1.PC1 **Visual Workplace** **Analyze**
Develop the elements of Visual Workplace and describe how they can help to control the improved process.

E2. PERFORMANCE MANAGEMENT

The Learning Element 'Performance management' reviews how to set targets, and how to organize the work to be done. The Learning Element also reviews how to facilitate improvement teams at the shopfloor that work on Kaizen improvement initiatives and Problem Solving.

U5.E3.PC1 **Daily stand-up meetings** **Apply**
Implement and facilitate stand-up meetings to drive continuous improvement initiatives. Understand basic principles of Scrum.

U5.E3.PC2 **Kaizen events and problem solving** **Analyze**
Describe and propagate the Kaizen principles. Empower improvement teams and facilitate Kaizen events. Develop root cause analysis, recognize the issues involved in identifying a root cause. Analyze problems by applying problem solving process and tools.

E3. BASIC QUALITY TOOLS

The Learning Element 'Basic quality tools' reviews techniques to visualize data and guidelines how to facilitate and participate in brainstorm sessions.

U5.E3.PC1 **Brainstorm techniques** **Apply**
Apply brainstorm techniques: Affinity diagram, 5-Why's and Ishikawa.

U5.E3.PC2 **Visualization of data** **Analyze**
Apply and analyze the outcome of basic quality tools to visualize data: Scatter plot, Pareto chart, Bar chart, Pie chart, Time Series Plot, Histogram and Box plot.

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 reviews tools which can be used to visualize and analyze the process flow as well as 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 and analyze the flow of a process.

U6.E1.PC1 **High-level process description** **Analyze**
Distinguish between key process input variables and key process output variables based on a high-level process map e.g. SIPOC.

U6.E1.PC2 **Process Flow diagram** **Apply**
Apply process mapping to visualize the flow of activities and decisions within a process.

MEASURE

E2. PERFORMANCE METRICS

The Learning Element 'Performance management' reviews performance metrics for both logistics as for quality.

U6.E2.PC1 **Performance metrics (Time)** **Analyze**
Calculate and analyze performance metrics related to time (e.g. takt time, cycle time, lead time, queue time, WIP and OEE). Apply Little's Law.

U6.E2.PC2 **Performance metrics (Quality)** **Analyze**
Distinguish and calculate performance metrics related to quality (e.g. ppm, DPMO, DPU and RTY). Describe the difference between a defect and a defective. Calculate rolled throughput yield for a number of defects.

E3. BASIC STATISTICS

The Learning Element 'Basic statistics' reviews different types of data, measurement scales and data collection tools. Also a set of measures (statistics) that characterizes a given set of data are reviewed.

U6.E3.PC1 **Data types and Measurement scales** **Analyze**
Propagate the importance of reliable and accurate data. Describe and distinguish between qualitative and quantitative data (continuous and discrete data). Define and analyze nominal, ordinal, interval and ratio measurement scales. Apply Likert scale to convert an ordinal scale into a discrete interval scale.

U6.E3.PC2 **Data collection tools** **Analyze**
Define and analyze tools for collecting data e.g. data sheets, check sheets, concentration diagrams and questionnaires.

U6.E3.PC3 **Descriptive statistics** **Apply**
Calculate population parameters and sample statistics: measures of central tendency, measures of dispersion, ratios and proportions.

ANALYZE

E4. VALUE STREAM ANALYSIS

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

U6.E4.PC1 **Value adding versus Non-value adding** **Analyze**
Distinguish value adding from non-value adding and necessary activities.

U6.E4.PC2 **Value Stream Mapping (Current State)** **Apply**
Apply Value Stream Mapping to construct a Current State Map of the process to identify waste and non-value adding activities.

U6.E4.PC3 **Process Mining** **Understand**
Understand the way process mining can support the analysis of flow within the organization. Recall what product attributes are needed for process mining.

IMPROVE

E5. REDUCING MUDA (WASTE)

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

U6.E5.PC1 **Waste identification** **Analyze**
Identify and analyze process Waste (Muda): Overproduction, Waiting, Transport, Overprocessing, Inventory, Movement, Defects and Unused expertise.

E6. REDUCING MURI (OVERBURDEN)

The Learning Element 'Reducing Muri' reviews how to identify overburden in the organization. This element also reviews how to implement flow and work balancing to reduce overburden.

U6.E6.PC1 **Flow** **Analyze**
Describe the importance of flow for reducing Muri. Develop flow in the organization.

U6.E6.PC2 **Work balancing** **Analyze**
Describe the importance of Work balancing for reducing Muri. Develop Work balancing.

U6.E6.PC3 **Resource management** **Apply**
Describe how competence management supports the reduction of Muri. Set up and apply a competence management system.

E7. REDUCING MURA (UNEVENNESS)

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

U6.E7.PC1 **Pull** **Analyze**
Describe the importance of pull for reducing Mura. Develop and implement pull in the organization by applying Kanban systems.

U6.E7.PC2 **Volume and Type leveling** **Apply**
Implement a balanced process flow by both volume leveling, type leveling and one piece flow. Differentiate between the different order fulfilment strategies.

U6.E7.PC3 **Quick Change Over (SMED)** **Apply**
Reduce change over times by implementing Single Minute Exchange of Die (SMED).

E8. 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.

U6.E8.PC1 **Value Stream Mapping (Future State)** **Analyze**
Define the gap between the current state and the target condition. Develop a Future state map using Value Stream Mapping. Apply techniques to reduce Muda, Mura and Muri.

CONTROL

E9. PROCESS AND QUALITY CONTROL

The Learning Element 'Process and Quality control' 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.E9.PC1 **First Time Right (FTR)** **Analyze**
Deploy the importance of the First Time Right principle. 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 (Jidoka). Apply Poka Yoke to prevent quality problems.

U6.E9.PC2 **Process FMEA (pFMEA)** **Apply**
Prepare all elements of a Process FMEA, calculate the risk priority number (RPN) and action priority (AP). Review the effect of FMEA results on processes, products and services.

U6.E9.PC3 **Control plan** **Apply**
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.

E10. TOTAL PRODUCTIVE MAINTENANCE (TPM)

The Learning Element 'Total Productive Maintenance' reviews the coherence between reliable systems and equipment and continuous improvement.

U6.E10.PC1 **TPM principles** **Apply**
Describe the eight pillars of TPM and describe how it can be used for process improvement. Apply elements of TPM to control the improved process.

U6.E10.PC2 **Overall Equipment Effectiveness (OEE)** **Apply**
Calculate the Overall Equipment Effectiveness (OEE) performance metric. Calculate utilization.

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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.

MEASURE

E1. STATISTICAL TECHNIQUES

The Learning Element 'Statistical techniques' 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.E1.PC1 **Variation** **Analyze**
Evaluate special cause and common cause variation.

U7.E1.PC2 **Sampling** **Analyze**
Develop and apply appropriate sampling methods that ensure representative data e.g. random sampling, stratified sampling and systematic sampling. Calculate power and sample size for common hypothesis tests.

E2. 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.E2.PC1 **Continuous distributions** **Apply**
Interpret Probability Density Functions and Cumulative Distribution Functions. Apply continuous distributions: Normal, Weibull, Student's t, Chi square, F-distribution, Lognormal and Exponential distribution. Apply normality test (Anderson-Darling) describe shape parameters (Skewness and Kurtosis).

U7.E2.PC2 **Discrete distributions** **Apply**
Apply discrete distributions: Poisson, Binomial. Apply the central limit theorem.

U7.E2.PC3 **Data transformation on non-normal data** **Apply**
Identify non-normal data and use Box-Cox or Johnson transformation.

E3. MEASUREMENT SYSTEMS

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

U7.E3.PC1 **Measurement systems analysis** **Analyze**
Define and implement measurement methods for both continuous and discrete data. Analyze measurement systems for continuous data. Interpret repeatability and reproducibility (R&R), stability, bias, linearity, precision to tolerance and number of distinct categories.

U7.E3.PC2 **Attributive agreement Analysis** **Analyze**
Analyze measurement systems for qualitative properties. Establish attribute agreement within appraiser, between appraisers and appraisers versus standard.

ANALYZE

E4. 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.E4.PC1 **Hypothesis testing** **Analyze**
Define and analyze the significance level, power, type I and type II errors in statistical tests.

U7.E4.PC2 **Confidence Intervals** **Analyze**
Calculate confidence, prediction and tolerance intervals. Distinguish between statistical and practical significance.

E5. TESTS FOR MEANS, VARIANCES AND PROPORTIONS

The Learning Element 'Tests for means, variances and proportions' reviews the most common hypothesis tests to investigate the difference between population means (μ); difference in variances (σ); difference in proportion (p) and difference in counts (λ). Also the ANOVA analysis is reviewed.

U7.E5.PC1 **Tests for means** **Apply**
Apply and analyze hypothesis tests for means.

U7.E5.PC2 **Tests for variances** **Analyze**
Apply and analyze hypothesis tests for variances.

U7.E5.PC3 **Analysis of variance (ANOVA)** **Analyze**
Apply ANOVA. Analyze the results and the main effect and interaction plots.

U7.E5.PC4 **Tests for proportions** **Analyze**
Apply and analyze hypothesis tests for proportions.

U7.E5.PC5 **Chi-square tests** **Analyze**
Apply and analyze Chi-square goodness-of-fit test and Contingency tables.

U7.E5.PC6 **Non-parametric tests** **Analyze**
Apply and analyze non-parametric tests: Mann-Whitney, Kruskal Wallis and Mood's median test.

E6. 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.E6.PC1 **Correlation coefficient** **Analyze**
Calculate and analyze the correlation coefficient. Determine its statistical significance (p-value) and recognize the difference between correlation and causation.

U7.E6.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.E6.PC3 **Multivariate studies** **Apply**
Apply attributes data using (binary) logistic regression to investigate sources of variation.

U7.E6.PC4 **Logistic regression analysis** **Apply**
Apply multivariate studies such as principal components and factor analysis.

E7. PROCESS CAPABILITY AND PERFORMANCE

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

U7.E7.PC1 **Process Capability (Cpk)** **Analyze**
Apply and analyze process capability studies. Develop sampling plans to verify stability. Calculate and analyze Cp and Cpk to assess process capability.

U7.E7.PC2 **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.E7.PC3 **Process Performance (Ppk)** **Analyze**
Calculate and analyze Pp and Ppk to assess process performance. Interpret the relationship between capability and performance indices.

U7.E6.PC4 **Process Capability for attributes data** **Apply**
Calculate the process capability and process sigma level for attribute data.

IMPROVE

E8. 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.E8.PC1 **Principles and terminology** **Analyze**
Design experiments by determining the objective, selecting factors, responses and measurement methods. Apply DOE elements: responses, factors, levels, transfer function, run order, randomization, balanced designs, residual error, main effects, interaction effects, replicates, repetitions, curvature and centerpoints.

U7.E8.PC2 **Two-level full factorial experiments** **Analyze**
Design and analyze full factorial experiments. Understand and apply contrast, covariate, blocking.

U7.E8.PC3 **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.E8.PC4 **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

E9. 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.E9.PC1 **Control charts** **Analyze**
Describe the objectives of SPC. 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.E9.PC2 **Tests for special causes** **Analyze**
Interpret control charts and distinguish between common and special cause variation using rules for determining statistical control.

U8. LEVEL V - CREATING FUTURE-PROOF PROCESSES

The Unit 'Creating future-proof processes' is about applying Lean Six Sigma techniques in the product development process with the objective to design products and services 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** **Understand**
Understand the lifecycle for products from creation, engineering, manufacturing to service and disposal.

U8.E1.PC2 **Innovation management** **Understand**
Participate in new product and process development.

E2. DESIGN FOR SIX SIGMA

The Learning Element 'Design for Six Sigma' 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.E2.PC1 **Design for Excellence (DFX)** **Understand**
Understand the impact of design for excellence and modularization on cost, manufacturability, producibility and maintainability.

U8.E2.PC2 **Quality Function Deployment (QFD)** **Understand**
Understand that QFD can be applied to translate customer requirements into product performance measures.

U8.E2.PC3 **Design FMEA (dFMEA)** **Understand**
Describe key functions of a design, the primary potential failure modes relative to each function and the potential causes of each failure mode. Describe critical parameter management (CPM) and the DMADV roadmap.

U8.E2.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.E2.PC5 **Tolerance Analysis** **Understand**
Understand the basic principles of tolerance analysis using worst case, RSS, Monte Carlo and empirical methods.

E3. THE FOURTH INDUSTRIAL REVOLUTION

The Learning Element 'The fourth industrial revolution' reviews the role of continuous improvement methodologies that currently used and the fourth industrial revolution.

U8.E2.PC5 **Industry 4.0** **Understand**
Understand the future of operational management. Describe elements of Industry 4.0.

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, Assess, Assure, Calculate, Convert, 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, Deploy, 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 uses 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 uses this level in their skill sets.

APPENDIX B – PRACTICAL PROJECT ASSESSMENT CRITERIA

Kaizen & Lean project criteria PDCA

Phase	Nr	Criteria
Plan	1	Project addresses a clear problem description or business opportunity.
	2	Problem description has been clearly defined.
	3	Goals have been clearly defined and are measurable.
	4	VOC and VOB have been clearly defined and requirements are understood.
	5	Scope of the project has been clearly delineated.
	6	Key stakeholders have been identified.
	7	Relevant CTQ(s) have been selected and a CTQ-flowdown has been constructed.
	8	High level process description has been made (e.g. SIPOC).
	9	The collected data has been proven to be representative for the project.
	10	Validity of the data has been verified in an appropriate way.
	11	Historical data has been used to visualize process performance over time.
	12	Performance against requirements has been checked.
	13	Variation in the process has been considered (common cause or special cause).
	14	Short term versus long term performance has been considered.
	15	Process has been mapped in detail (e.g. VSM Current State).
Do	1	Potential factors of influence have been determined.
	2	Analysis have been used to identify factors with highest influence.
	3	Hypothesis for root cause has been defined properly.
	4	Input data has been collected and analyzed correctly.
Check	1	Graphical and statistical techniques have been applied to investigate root causes.
	2	Major root causes have been identified.
	3	Conclusions are clear and have demonstrated strong evidence/are statistically valid.
	4	Risks have been identified and addressed (e.g. pFMEA).
	5	Improved process meets the requirements of the VOC and VOB.
Act	1	There is a clear communication and action plan towards the stakeholders.
	2	The client (Champion) has approved the improvement proposal.
	3	An improvement of the CTQ compared to the baseline is demonstrated.

Table 2 - Project Practical Assessment PDCA

Lean en Six Sigma project criteria DMAIC

Phase	Nr	Criteria
Define	1	Project addresses a clear problem description or business opportunity.
	2	Problem description has been clearly defined.
	3	Goals have been clearly defined and are measurable.
	4	VOC and VOB have been clearly defined and requirements are understood.
	5	Scope of the project has been clearly delineated.
	6	Key stakeholders have been identified.
	7	Relevant CTQ(s) have been selected and a CTQ-flowdown has been constructed.
	8	High level process description has been made (e.g. SIPOC).
Measure	1	The collected data has been proven to be representative for the project.
	2	Validity of the data has been verified in an appropriate way.
	3	Historical data has been used to visualize process performance over time.
	4	Performance against requirements has been checked.
	5	Variation in the process has been considered (common cause or special cause).
	6	Short term versus long term performance has been considered.
Analyze	1	Process has been mapped in detail (e.g. VSM Current State).
	2	Potential factors of influence have been determined.
	3	Analysis 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 are clear and have demonstrated strong evidence/are statistically valid.
Improve	1	Risks have been identified and addressed (e.g. pFMEA).
	2	Improved process meets the requirements of the VOC and VOB.
	3	There is a clear communication and action plan towards the stakeholders.
	4	The client (Champion) has approved the improvement proposal.
	5	An improvement of the CTQ compared to the baseline is demonstrated.
Control	1	Standards are adjusted and documentation has been updated (pFMEA, CP).
	2	Rolls and responsibilities have been described.
	3	Employees are instructed and/or trained.
	4	Evidence of 'In-Control situation' is available and sufficient.
	5	Improvements have proven to be sustainable.
	6	Measures have been put in place to monitor process performance.
	7	Project report has been completed. Lessons learned have been communicated.
	8	Champion signed that project targets and/or savings have been achieved.
	9	The controller signed the project for approval.

Table 3 - Project Practical Assessment DMAIC

Design for Six Sigma project criteria DMADV

Phase	Nr	Criteria
Define	1	Project addresses a clear problem description or business opportunity.
	2	Project charter includes the risks to investigate.
	3	Goals have been clearly defined and are measurable.
	4	VOC and VOB have been clearly defined and requirements are understood.
	5	Scope of the project has been clearly delineated.
	6	Key stakeholders have been identified.
	7	Functional requirements have been defined.
	8	High level process description has been made (e.g. SIPOC).
Measure	1	Risks or customer requirements have been made tangible and specific.
	2	Historical data and issues have been taken into account.
	3	Customer requirements have been translated into technical requirements.
	4	Relevant CTQ(s) have been selected and a CTQ-flowdown has been constructed.
	5	It has been defined how the CTQs are measured.
	6	The measurement procedure has been validated (Gage R&R).
Analyze	1	All risks have been identified and a mitigation plan is available (e.g. dFMEA)
	2	Design concepts have been develop.
	3	Potential factors of influence have been identified.
	4	Data have been collected and analyzed.
	5	Transfer functions Yi = f(X1, X2,…,Xn) have been developed.
	6	Graphical and statistical techniques have been applied to investigate risks.
	7	Transfer function shows (theoretical) that capability meets customers specifications.
	8	There is a clear difference between confirmed and non-confirmed information.
Design	1	Validation plan is designed.
	2	Samples, prototypes or concepts are available for validation.
	3	Risk mitigation measures have been identified (e.g. Poka Yoke, Control Plan).
	4	Product Lifecycle management and reliability have been addressed (if applicable).
	5	Optimum settings for all significant factors of influence have been defined.
Verify	1	Pilot run results have been evaluated.
	2	Factors of influence will be controlled in a way that the risk will not appear.
	3	Documentation has been updated (pFMEA, CP, SOPs).
	4	Training has been performed for the new product/process.
	5	Project report has been completed. Lessons learned have been communicated.
	6	Full scale ramp-up plan has been developed.
	7	Project has been completed within time and budget.
	8	Champion has signed off the project.

Table 4 - Project Practical Assessment DMADV


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