WORKING IN THE AUTOMOTIVE INDUSTRY

APQP
MEASUREMENT SYSTEM ANALYSIS
SUPPLY CHAIN CONTROLLING SUPPLIERS
A-SPICE NORMS AND STANDARDS MULTIDISCIPLINARY
FUNCTIONAL SAFETY PPAP AND EMPB APPROACH
SIMULTANEOUS 8D CONTROL PLAN

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WORKING IN THE AUTOMOTIVE INDUSTRY SKILL SET | PRACTITIONER

A GUIDELINE FOR AUTOMOTIVE TRAINING AND CERTIFICATION AT PRACTITIONER LEVEL

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INTRODUCTION

The automotive industry is a sector that is growing on a worldwide level at different paces. While markets in Europe are stagnating, those of the BRICS countries (Brazil, Russia, India, China and South Africa) are almost exploding and opening up a huge economic potential. However, it is important to keep in mind the countries’ differences in culture, infrastructure, legislation, economy and environment. International vehicle manufacturers like Renault, Toyota, BMW or VW should be aware of the impact of these differences when establishing a factory, dealer network, or releasing a new type of vehicle in a new local market.

The automotive industry is changing more rapidly than ever. The first company dedicated to producing vehicles was the French company French Panhard et Levassor, in 1889. Peugeot followed only two years later. Since then, vehicles have changed significantly. This is a result of increasingly stricter legislation and regulation, as well as changing customer demands (behavior). Safety comes first. In the past, a vehicle used to be delivered with a tool case to be used in case of a breakdown. Nowadays, every vehicle released on the market has to be well developed and thoroughly tested during the construction process. This is executed using different methods and analyses. Clearly, this also means that the education of mechanics and engineers needs adaptation. As the automotive industry will continuously innovate, the technical schools are to anticipate on these changes. Self-driving cars and alternative fuel systems influence the way a vehicle is designed and produced. These changes will also affect the infrastructure. For example, think of all the necessary charging stations at parking lots, businesses, homes, etc. Moreover, how will a self-driving vehicle know where it is when it is in a tunnel?
AUTOMOTIVE ENGINEER SKILL SETS

The two released skill sets, one at Practitioner level (VET) and one at practitioner level (higher education), are the fundamental basis of all the training materials developed. They comprise the basic knowledge and the skills required in the modern automotive development and manufacturing processes, including the different sustainability dimensions.

The structure of the skill set is based on the ECQA skill set definitions. The structure consists of a number of ‘Units’, ‘Elements’ and ‘Performance Criteria’.

- **Unit**: The syllabus is presented by syllabus areas; each called a ‘Unit’. The chapters in the book reflect the ‘Units’ described in this syllabus.
- **Element**: Each ‘Unit’ consists of a number of ‘Elements’. Each element is described in a separate chapter in the book.
- **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 by an Automotive Engineer.
- **Level of Cognition**: A ‘Cognitive Level’ has been assigned to each ‘Performance Criteria’-description according to Bloom’s Taxonomy [5.]. This defines at which level it is expected to apply the respective tool, technique or skill.

This modular structure is reflected in the hierarchical numbering system used throughout this document, whereby each sub-component of the Domain (Unit > Element > Performance Criteria) is represented by its initial letter and listed sequentially, as in the example “U1.E2.PC3”, which indicates ‘the third Performance Criteria of the second Element in the first Unit’.

EXAMINATION AND CERTIFICATION

Examinations are provided through a number of ‘Examination Institutes’ (EIs), which use the skill set to develop exams. The exams are open to all. Individuals can apply directly to the EIs or sign up via one of the training organizations. It is recommended that candidates receive training to prepare for certification. Alternatively, candidates who wish to self-study have the option to apply directly for certification. For further information about examination please visit the ECQA webpage (www.ecqa.org) or the LSSA webpage (www.lssa.eu).
U1. INTRODUCTION

This unit is an introduction to the automotive sector in terms of its history, evolution and future, as well as key terms and key challenges. Characteristics of the sector are discussed, in particular the supplier structure, product and releases, and the importance of customer focus. Typical automotive engineering job roles are introduced to help learners orient themselves towards specific fields of interest.

A learning element giving an overview of a small selection of the most important legal documents, regulations and standards relevant for the sector.

The importance and essence of processes and process thinking in the automotive sector is also elaborated in this introductory module. The increasing dominance of mechatronic subsystems in modern vehicles implies an outstanding role of multidisciplinary challenges in engineering organizations and processes. This is also discussed in this introductory module, as is the important concept of simultaneous engineering.

E1. AUTOMOTIVE INDUSTRY

The Learning Element ‘Automotive industry’ explains the most important moments in the history and evolution of the automotive as well as the future and key challenges. Also the structure of the supply chain and the most important differences to other branches will be discussed.

<table>
<thead>
<tr>
<th>U1.E1.PC1</th>
<th>History and Evolution</th>
<th>Remember</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Recall the history and developments within the automotive industry.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>U1.E1.PC2</th>
<th>Definitions, Terms, and Abbreviations</th>
<th>Remember</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Recall automotive definitions, terms, and abbreviations.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>U1.E1.PC3</th>
<th>Supply Chain</th>
<th>Understand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Describe the supplier structure of the automotive industry.</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>U1.E1.PC4</th>
<th>Key Challenges</th>
<th>Understand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Understand the key challenges of the automotive industry.</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>U1.E1.PC5</th>
<th>Automotive Industry versus other Branches</th>
<th>Understand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Understand the differences with others branches (e.g. aerospace, medical, defense, consumer electronics, etc.).</td>
<td></td>
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</table>

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<thead>
<tr>
<th>U1.E1.PC6</th>
<th>Evolution and Future</th>
<th>Understand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Understand what the future of the automotive industry could be like (e.g. electric, hydrogen, self-driving car).</td>
<td></td>
</tr>
</tbody>
</table>
E2. CHARACTERISTICS IN THE AUTOMOTIVE
The Learning Element ‘Characteristics in the Automotive’ explains the customer focus and the formal procedures like product and process releases and change notifications.

U1.E2.PC1 Product and Process Release
Understand the product and process release and change notifications within the automotive industry.

U1.E2.PC2 Customer Focus
Recall the role of customers’ expectations and specifications.

U1.E2.PC3 Job Roles
Understand the engineering job roles in the automotive industry and their differences.

U1.E2.PC4 Specification Documents
Identify specification documents (e.g. customers’ specifications, software requirements, etc.).

E3. LEGISLATION, REGULATIONS, AND STANDARDS
The Learning Element ‘legislation, regulations, and standards’ introduces the most relevant regulations, laws and directives for the automotive industry. It introduces the product liability and safety law and the homologation process and continues with the description of several international standards, starting with the most well-known and widely recognized ISO/TS 16949.

U1.E3.PC1 Legislation and Regulations
Identify and apply the legislation and regulations there are in the automotive industry.

U1.E3.PC2 Standards
Identify and apply the existing norms and standards (e.g. ISO/TS 16949, ISO 26262, APQP, VDA, ISO/IEC 15504, etc.). Understand the key objectives and concepts underlying the several norms and standards, its complexity, and the relations between them.

E4. PROCESS THINKING
The Learning Element ‘Process Thinking’ explains the different processes within automotive companies and the multidisciplinary approach.

U1.E4.PC1 Primary Process
Understand the primary process of a company.

U1.E4.PC2 Automotive Process Landscape
Understand the automotive process landscape.

U1.E4.PC3 Changes on Product and Process
Understand the consequence(s) of changes on product and process

U1.E4.PC4 Multidisciplinary Approach & Simultaneous Engineering
Understand
Understand the multidisciplinary and simultaneous engineering approaches.

**U2. PRODUCT AND PROCESS DEVELOPMENT**

This unit focuses on selected engineering aspects of product and process development in the automotive sector. Departing from the explanation of the notion of the product life cycle and sustainability, a closer look is taken at the development phase of the product life cycle by discussing the development process, as well as the typical activities carried out in the context of this process. The notion of systems engineering is explained, as it is of particular importance in modern vehicles where system-level functions are implemented by numerous cooperating subsystems. The explanation of the V-cycle establishes the link between system-level and component-level development activities.

Functional safety, i.e., the safe behavior of subsystems in case of failure, is discussed in the context of a module on risk management. This module also contains an introduction to FMEA, i.e., Failure Mode and Effect Analysis, which is one of the most important methods of risk management on both product and process levels in automotive.

**E1. PRODUCT LIFECYCLE MANAGEMENT**

The Learning Element ‘Product Lifecycle Management’ explains the significance of the product life cycle and its management for the product creation and support process. The relationship between product life cycle management and environmental sustainability is pointed out. A particular focus is directed on the engineering for the end-of-life as a key lever to increase sustainability.

**U2.E1.PC1**  **Different Levels**  **Understand**
Understand the life cycle at different levels (e.g. software, hardware, system, product, service, infrastructure, safety, security).

**U2.E1.PC2**  **Designing for End-of-life**  **Understand**
Understand the complexity from designing until End-of-life (EOL) of a vehicle.

**E2. ADVANCED PRODUCT QUALITY PLANNING**

The Learning Element ‘Advanced Product Quality Planning’ (APQP) explains the different phases within product and process development and their most important activities and tools used in these phases.

**U2.E2.PC1**  **Objectives**  **Understand**
Understand the objectives of APQP, why and when it's used.

**U2.E2.PC2**  **Phases**  **Understand**
Identify the different phases of APQP.
E3. SYSTEMS ENGINEERING
The Learning Element ‘Systems Engineering’ explains the essential automotive engineering principles, starting from a system level down to component level. It introduces the automotive development process and the most important related activities and concepts. A particular focus is made on the development of automotive subsystems containing electrics/electronics and software.

U2.E3.PC1 Breakdown Structure of a Vehicle
Understand the complexity of a vehicle and its systems.

U2.E3.PC2 System Level Development
Understand Product Development Process, and V-Model.

U2.E3.PC3 Component Level
Understand the development lifecycle.

E4. RISK MANAGEMENT
The Learning Element ‘Risk Management’ describes risk management and risk management tools like functional safety hazard and risk analysis and FMEA. The element describes how to apply the FMEA and how to perform a functional safety hazard and risk analysis.

U2.E4.PC1 Risk Management Process
Understand the purpose of risk management.

U2.E4.PC2 Failure Mode and Effect Analysis
Apply
Motivate the risks and safety issues, taking in consideration the several systems in a vehicle and their interference. Understand the process FMEA and recall the process risks.

U2.E4.PC3 Functional Safety
Apply
Review Failure Mode Effects Analyses and diagnostic analysis. Review the hazard and risk analyses based on ISO 26262 and IEC 61508.
U3.PRODUCTION

The third training unit deals with the automotive production process, with a particular focus on the quality assurance measures based on Six Sigma principles. The key topics here include the Process Capability (a measure for the variation in the process) and Process Control, mainly based on statistical tools applied to data measured in the process.

Since the suppliers have a key role in the automotive development and production process, the assurance of the quality they deliver is essential to the total quality management of the product creation process. This training element therefore discusses supplier control and assessment schemes, in particular Automotive SPICE®, which is used by automotive OEMs to assess their suppliers’ mechatronics development process quality worldwide.

Change management is an important activity throughout the entire product creation process, because changes can happen at every moment.

E1. PROCESS CAPABILITY

The Learning Element ‘Process Capability’ describes how to calculate the process capability and performance in relation to specification limits.

U3.E1.PC1 Variation Understand Understand the difference between special cause and common cause variation.

U3.E1.PC2 Process Capability Indices Apply Calculate and interpret process capability indices, \( \text{Cp and Cpk} \), to assess process capability.


E2. PROCESS CONTROL

The Learning Element ‘Process Control’ describes different tools used for controlling processes, it explains how to perform measurement systems analyses and their control methods in order to identify out-of-control situations and deviations over time.


U3.E2.PC2 Controlling Processes Understand Describe how and why processes are controlled during production.
U3.E2.PC3  **Statistical Process Control**  Analyze
Describe the objectives of SPC, including monitoring and controlling process performance and tracking trends. Apply SPC for reducing variation in a process.

U3.E2.PC4  **Control Plan**  Analyze
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.

U3.E2.PC5  **Gage R&R study**  Understand
Understand the difference between repeatability and reproducibility (R&R) and the meaning of the number of distinct categories.

**E3. SUPPLIER QUALITY ASSURANCE**

The Learning Element ‘Supplier Quality Assurance’ describes the significance of supplier quality assurance process and their tools to evaluate and control the suppliers. The element describes how to collect and analyze documents for the PPAP and EMPB and perform supplier audits according to the VDA 6.3 standard.

U3.E3.PC1  **Controlling Suppliers**  Apply
Identify the risks of a supplier and can take the needed action by using PPAP, EMPB, and VDA 6.3.

U3.E3.PC2  **PPAP and EMPB**  Apply
Use PPAP and EMPB.

U3.E3.PC3  **Auditing Suppliers**  Apply
Prepare a supplier audit (VDA 6.3).

U3.E3.PC4  **Automotive Spice Assessment**  Understand
Understand Automotive SPICE® and why and how Automotive SPICE® Assessments are performed.

**E4. MANAGEMENT OF CHANGE**

The Element ‘Management of Change’ explains the importance of a change management process in product and process development as well as in released processes with the focus on evaluating the impact of the risk in terms of costs, timing, quality and prepare a change notification to the customer.

U3.E4.PC1  **Risk of Changes**  Apply
Calculate and review the risks when changes are being proposed/made. Is able to fill out a Change notification.

U3.E4.PC2  **Change Notifications**  Apply
Define change notification, PPAP, and EMPB.

<table>
<thead>
<tr>
<th>U3.E4.PC3</th>
<th>Changes during Design and Development</th>
<th>Understand</th>
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<tbody>
<tr>
<td></td>
<td>Understand the interface with change management in design and development.</td>
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</table>
U4. CONTINUOUS IMPROVEMENT

This fourth and last unit deals with continuous improvement as an intrinsic element of successful automotive development and production processes. The key elements are tools and methods for problem finding, analyzing, and solving, lean manufacturing (i.e., the minimization of non-value-adding activities in the manufacturing process), quality awareness, as well as approaches to sustaining improvements.

E1. PROBLEM SOLVING

The Learning Element ‘Problem Solving’ describes how to apply the ‘Eight Steps Problem Solving Method’ used to approach and resolve problems.

<table>
<thead>
<tr>
<th>U4.E1.PC1</th>
<th>8D</th>
<th>Apply</th>
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<tbody>
<tr>
<td></td>
<td>Apply the eight disciplines problem solving process which is used to approach and resolve problems.</td>
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<table>
<thead>
<tr>
<th>U4.E1.PC2</th>
<th>Problem solving techniques</th>
<th>Apply</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Define and apply root cause analysis, recognize the issues involved in identifying a root cause. Apply problem solving process and tools.</td>
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<thead>
<tr>
<th>U4.E1.PC3</th>
<th>Kaizen events</th>
<th>Apply</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Setup and lead Kaizen events.</td>
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</table>

E2. LEAN MANUFACTURING

The Learning Element ‘Lean Manufacturing’ describes the values and principles of Lean Manufacturing and its role in the automotive industry. The element describes also how the most common tools are applied.

<table>
<thead>
<tr>
<th>U4.E2.PC1</th>
<th>Lean Manufacturing in the Automotive Industry</th>
<th>Understand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Describe Lean Manufacturing and interpret Lean Manufacturing in the automotive chain.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>U4.E2.PC2</th>
<th>Applying Lean Manufacturing</th>
<th>Apply</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Apply Lean Manufacturing tools such as process mapping, value stream mapping, 5S, Kanban, flow, and pull.</td>
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</tbody>
</table>
E3. QUALITY AWARENESS
The Learning Element ‘Quality Awareness’ is about the most important factors influencing the quality awareness in the organizational culture. It investigates leadership and commitment, team formation and teamwork, as well as cultural diversity and their influences on quality culture. A quality culture in automotive organizations is the necessary requirement for providing a high-quality product to customers.

U4.E3.PC1 Leadership and Commitment
Understand
Describe the type of leadership needed in the automotive industry. Describe what commitment is and its importance.

U4.E3.PC2 Interdisciplinary Nature of Quality
Understand
Understand that the interdisciplinary expertise is fundamental for tackling complexity in innovation cycles.

U4.E3.PC3 Cultural Diversity and its Influence
Understand
Understand cultural diversity (not only nationalities but also between job roles).

E4. SUSTAIN IMPROVEMENTS
The Learning Element ‘Sustain Improvements’ describes the methods for sustaining improvements and how to apply them in order to prevent mistake, avoiding problems in the future and optimize processes.

U4.E4.PC1 Sustaining Improvements and Changes
Apply
Define and apply methods for maintaining improvements to become a learning organization (standardization and documentation). Standardize and review lessons learned.

U4.E4.PC2 Quality Management
Apply
Propagate the quality management system and procedures. Identify opportunities for improvement.

U4.E4.PC3 Standardized Work
Apply
Standardize tasks and processes to establish the foundation for continuous improvement and employee empowerment. Prepare documents, standard operating procedures (SOPs) and one-point-lessons to ensure that the improvements are sustained over time.

U4.E4.PC4 Lessons Learned
Apply
Identify and document lessons learned from all phases of a project. Identify possible improvements and ownership.
U4.E4.PCS  Ongoing monitoring, evaluation and auditing

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.
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 [6].

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 [5]. 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.

Understand
Read and understand descriptions, communications, reports, tables, diagrams, directions, regulations, etc. In the skill set the following verbs were used at this level: Describe, Follow, Identify, Interpret, Participate, Understand.

Apply
Know when and how to use ideas, procedures, methods, formulas, principles, theories, etc. In the skill set the following verbs were used 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. In the skill set the following verbs were used 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. This level is not used in the skill set.

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. This level is not used in the skill set.
APPENDIX B – REFERENCES

[1.] Department of Trade and Industry UK, British Standards for Occupational Qualification, National Vocational Qualification Standards and Levels.


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