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Modular Integration of Automotive Industry Advanced Product Quality Planning (APQP) in the BRP-Powertrain Company's New Product Development Process

A Master's Thesis submitted for the degree of
"Master of Science"

supervised by
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28.02.2014, Wels, Austria

Affidavit

I, **XIAOMING WANG**, hereby declare

1. that I am the sole author of the present Master's Thesis, "MODULAR INTEGRATION OF AUTOMOTIVE INDUSTRY ADVANCED PRODUCT QUALITY PLANNING (APQP) IN THE BRP-POWERTRAIN COMPANY'S NEW PRODUCT DEVELOPMENT PROCESS", 84 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

Vienna, 28.02.2014

Signature

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Xiaoming Wang

Abstract

Powersport engine industry is characterized by a high concentration of capital and technology. A very large amount of initial investment is made in the new product development phase. If the new product development is not organized properly, the company will suffer huge losses. Meanwhile, as more capital inflows, competition among enterprises has become more and more intense. More stringent emissions regulations, along with consumer's need for more fuel efficient vehicles, create a challenge in manufacturer's mature economies. APQP (Advanced Product Quality Planning), one of five manuals in ISO/TS 16949 from QS-9000, as an advanced new product development project management method has increasingly been used by engine manufacturers.

Company BRP-Powertrain is a subsidiary of BRP (Bombardier Recreational Products Inc.). Its main products are high performance four-stroke and advanced two-stroke engines. In order to optimize its supplier chain management and new product development process, improve its market response and speed up the high-quality, low-cost new products development to meet customer needs, the supplier quality department of company BRP-Powertrain is trying to introduce APQP.

The purpose of this thesis is to create customized and standardized modular APQP element for company BRP-Powertrain based on its own new product development process. Firstly, the current state of its new product development process will be analysed and then it will be compared with APQP process. The results of these analyses provide the base to summarize and optimize the new product development process by creating customized and standardized modular APQP elements. Each element of the APQP process will be customized with company's specific requirements (organization, resources, time scope...) and modularly constructed. The implementation rules and procedures of the modules are also created.

Keywords: Gate Stage Process, APQP (Advanced Product Quality Planning), NPD (New Product Development), Supplier Chain Management, Quality Management, PPAP (Production Part Approval Process)

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1 Introduction

1.1 Background and Significance

In the last ten years, it became very difficult for global engine manufacturing industries. More stringent emissions regulations, along with consumer's need for more fuel efficient vehicles create a challenge in manufacturer's mature economies. The prices of key import commodities such as steel continue to rise, making the bad situation even worse. This trend led to increasing acquisition costs for manufacturers, severely squeezing profit margins. On the other hand, engine manufacturers in developing countries have seen a rapid increase in demand for combustion engines. China and other developing countries have sustained rapid income growth and expansion of road infrastructure revenues to boost the industry.

Under this background, in order to cope with global competition, global brand manufacturers must adapt their business to low cost, high quality international cooperation and simplified assembly. For many engine manufacturers, the introduction of high-quality planning program is an important way to penetrate the global market. Therefore, for companies, such as BRP-Powertrain, collaborative business model related to comprehensive quality control has become the key to success.

In recent years, the quality system QS-9000 has been introduced by many companies. APQP (Advanced Product Quality Planning), one of five manuals in ISO/TS 16949 from QS-9000, as an advanced new product development (NPD) project management method has increasingly been used by engine manufacturers. According to the automotive quality management system international standard, ISO/TS16949, this product development process/product realization process includes five phases (ISO 2007):

1. Plan and Define Program
2. Product Design and Development
3. Process Design and Development
4. Product and Process Validation
5. Feedback, Assessment and Corrective Action

The NPD process aims to harmonize the product development activities and to sustain better practice, it helps make the right decision at the right time, ensure constancy from one project to another and synchronize the activities from the different enterprises functions implicated in the product development. Furthermore, the supplier must be able to follow and support a new product development process and must make provisions for quality planning based on the guidelines in the APQP principles. Quality work upstream in the parts development process will affect the quality management of Tier 2 suppliers. The supplier must adapt their process, as required.

Company BRP-Powertrain is a subsidiary of BRP Inc.[1] (Bombardier Recreational Products Inc.). Its main products are high performance four-stroke and advanced two-stroke engines. In order to optimize its new product development process, improve its market response and speed up the high-quality, low-cost new products development to meet customer needs, the supplier quality department of company BRP-Powertrain is trying to introduce APQP.

BRP-Powertrain has the capabilities to produce a diversified portfolio – from small to large production batches. With a product portfolio that features individual solutions, the production and development process are customized to customer demands. In addition, BRP-Powertrain offers flexible solutions based on our global sourcing strategy with worldwide suppliers. Because of strategic decision of value chain optimization, some current suppliers are required to change. This task is carried out through teamwork in the CDG (commodity design group) following APQP process. The purpose of this thesis is to create customized and standardized modular APQP element (Figure 1) for company BRP-Powertrain based on its own NPD process which is a stage-gate process specifically designed for Bombardier Recreational Product. Each element of APQP is created with company's specific requirements (organization, resources, timing scope ...) modularly that these always come in the same form to use independently on the project category (or product category). Rules and procedures in the individual modules are created.

The main advantages of modular APQP elements for company BRP-Powertrain are summarized below:

- Increasing resource efficiency with reusing tools, rules and procedures from company BRP-Powertrain own new product development process;
- Optimization of the working process and interfaces between product development, purchase, supplier quality departments and suppliers by clear defined responsibility and ownership;
- Systematic supporting for relocation of suppliers in Global Sourcing Strategy;
- Increasing the working process stability and adaptability.

[1] BRP Inc. is a world leader in the design, manufacturing, distribution, and marketing of motorized recreational vehicles. BRP-Powertrain GmbH & Co KG, a subsidiary of BRP, specializes in the development and production of drive systems for products in the powersports industry. It is located in Gunskirchen, Austria.

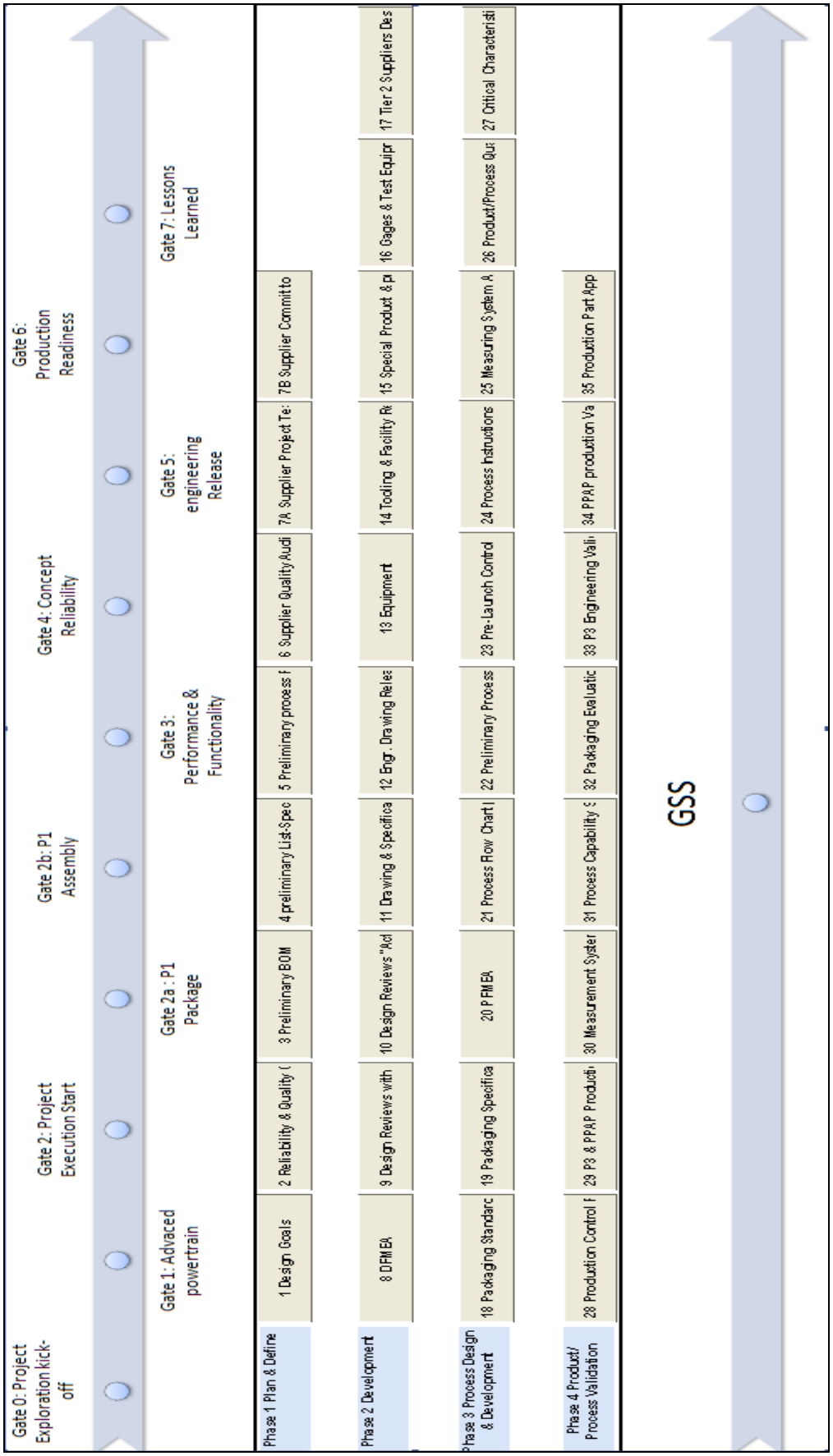

Figure 1: APQP Modules in BRP-Powertrain

1.2 Research Methods

Qualitative research methods have been applied in this thesis. Qualitative research is one of the common methods for study about exploring issues, understanding phenomena and answering questions. Researchers use qualitative research to define the problem or find a way to deal with the problem. In situations which are rarely known, it is often better to start with qualitative methods. It can help you with generating hypotheses that can then be tested by quantitative methods (Patton, M. 2002). The main features of qualitative research are:

- Systematic approaches to understand a given research problem;
- Collection of more realistic and detailed evidence, especially the information from local population (such as preferences, requirements, satisfaction, evaluation, habits, etc.);
- Findings of further unknown or obscure problems/questions that beyond the boundaries of the study.

Qualitative research has two different levels: the first level is no quantitative analysis of qualitative research, so the conclusion is often very general; the second is based on a quantitative analysis, a higher level of qualitative research. In practice, qualitative and quantitative research is often used in conjunction.

There are four most common qualitative research types:

- Observation method: direct observation of phenomena;
- In-depth interviews: one on one, face to face, flexile interactive style;
- Focus groups: not a problem solving meeting, not group discussions, but an interview;
- Brainstorming: Interactive discussions, good thinking mind and group participation.

New product development processes (NPD) are in a state of constant flux. Increases in the technology of new product development tools, product sophistication and continual shortening of product life cycles will require new product development groups to constantly change their processes. By this reason, it is difficult to find currently quantitative data. Furthermore, it is difficult to compare new product development data among different objectives. For instance, the processes and lead-times involved in developing an engine are hardly pertinent to using in a gearbox design. The specialized nature of product development allows limited comparisons the process level to similar industries. Therefore, according to qualitative research methods, it is common practice for NPD teams to look at benchmarking processes and adopt only the procedures that apply to their particular situation (Ristow, R. 2002).

A per-definition of research process is essentially a map of the qualitative research for project-specific factors such as inputs, outputs, process contents, starting events and

end events. In this study, a standard form, SIPOC (Figure 2) from company BRP-Powertrain, is used to define this research.

1.3 Objectives

The objectives of this study are:

1. Systematic study APQP system and BRP-Powertrain NPD process.
2. Actual state analysis of NPD and APQP process:
   a. Actual state analysis of NPD process
   b. Definitions of each APQP element in APQP reference manual
   c. Gap analysis between APQP and BRP-Powertrain NPD process
3. Create customized and standardized modular APQP elements to incorporate into BRP-Powertrain NPD process.
4. Develop implementation rules and procedures for the modular APQP elements.

1.4 Structure

As follows is a short description of the thesis:

Chapter 1. Introduction of the thesis research. The background, research methods and objectives are presented.

Chapter 2. Description of the theoretical fundamentals. Chapter begins with the definition of the Quality. Then the theories of QS9000 and ISO/ TS 16949 are introduced. Advanced product quality planning (APQP) is introduced in this chapter.

Chapter 3. This chapter describes the finding of this study: A gap analysis is completed comparing the APQP process to BRP-Powertrain New Product Development process.

Chapter 4. In this chapter, five elements from the APQP process will be selected for creating customized and standardized modular APQP for BRP-Powertrain.

Chapter 5. A plan for their implementation will be developed. The research results are evaluated.

Chapter 6. Conclusion and future work of this thesis. More areas of research and investigation are suggested.

Formblatt FB QA-039/A

Prozessdatenblatt (SIPOC)

Prozessname:	**Modular integration of automotive APQP in the BRP-**		Nr.:
Teilprozess von:	NPD	Prozesseigner:	**SQE**
Portfolio-Klasse:		Normkategorie:	

Lieferant (SUPPLIER):	Prozessinhalt (PROCESS):	Kunde (CUSTOMER):
SWR, IRK, SQEs, Example-Supplier	1. Plan and define objectives of the master thesis 2. Systematic study APQP and BRP Company's NPD process. 3. Current status analysis comparing reference manual APQP to the BRP's NPD : - Summarize definitions of each APQP element from APQP reference manual - Gap analysis between reference APQP elements and BRP's NPD steps 4. Create customized and standardized modular APQP elements from BRP-Powertrain's NPD process. 5. Develop implementation rules and procedures for the modular elements. 6. Writing up thesis	EK SQ AK PE PM Supplier FT
Eingang (INPUT):		**Ergebnis (OUTPUT):**
1. Suggestions for improvement of BRP's APQP 2. BRP's NPD documents 3. APQP reference manual 4. Current status of BRP's APQP(Individual interviews, relevant documents, etc.) 5. Acknowledgement from TU Wien 6. BRP Valcourt and Gunskirchen documents (Supplier Quality Manual, etc)		1.SIPOC and Masterplan 2.Gap analysis results 3.Customized and standardized modular APQP elements 4. Implementation rules 6. Master thesis

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Figure 2: SIPOC

2 Theoretical Fundamentals

This chapter focuses on the theoretical context of this thesis. The following general terms and definitions are taken from the international standards QS9000, ISO/TS16949 and APQP.

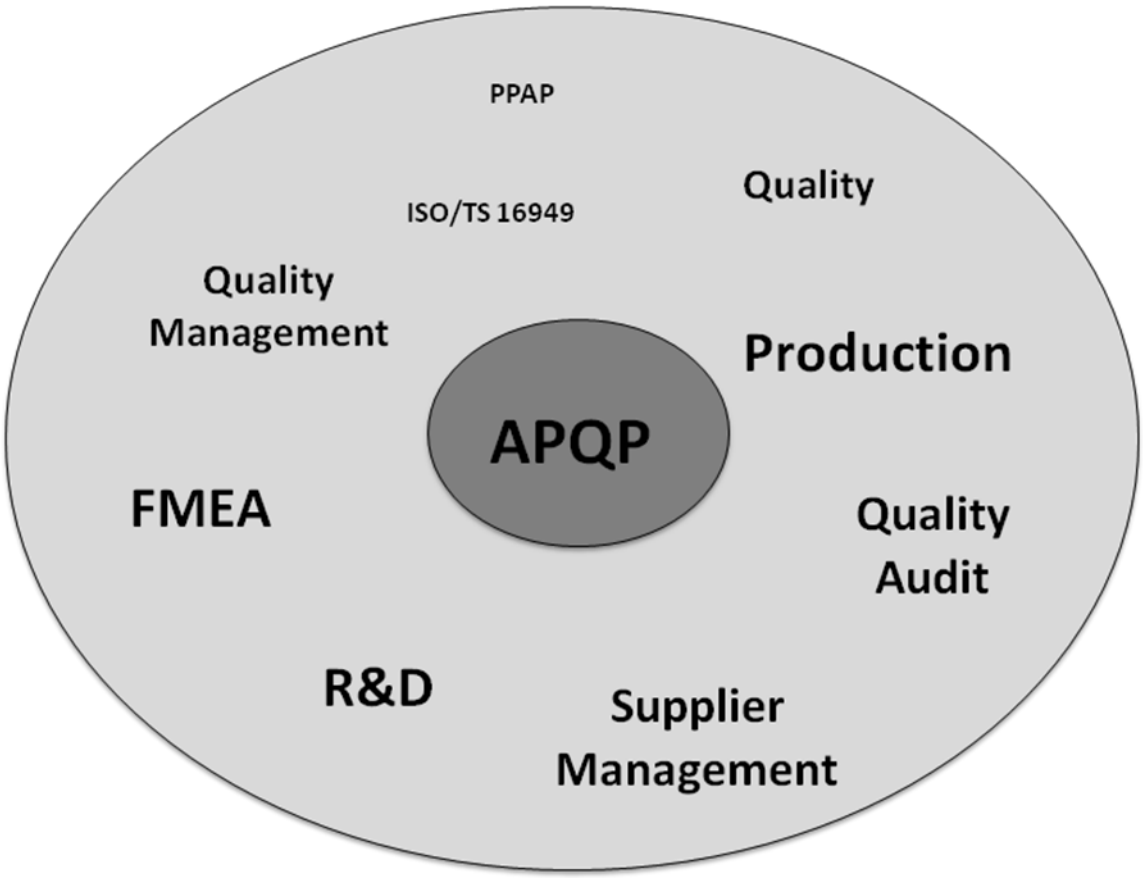


Figure 3: Theoretical Context

2.1 Quality

Quality is a benchmark to assess whether a set of inherent characteristics fulfils requirements. The characteristics can be qualitative or quantitative and there are various classes of characteristic, such as physical, mechanical, electrical, chemical or biological, sensory, behavioral, temporal, ergonomic and functional. On the other hand, quality is defined as the totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs (Durakbasa, M.N. 2009). In technical usage, quality has two meanings: 1) the characteristics of a product or service that bear on its ability to satisfy stated or implied needs. 2) A product or service free of defects. The achievement of

satisfactory quality involves all stages of the "quality circle" or life-cycle of the product as a whole (Durakbasa, M.N. 2013).

Product quality is the life of the product to adapt to social production and consumption needs and has the characteristics of its own; it is a concrete manifestation of the value of the product. It includes two aspects: the inherent quality and appearance quality.

- The inherent quality: inherent quality of the product is the intrinsic properties of the product, including performance, life cycle, reliability, security, economy five aspects.
    - Performance: refers to the product desired by the user with the physical, chemical and technical properties, such as strength, chemical composition, purity, power and speed.
    - Product life cycle: refers to product under normal conditions, the period of use, such as the life of houses, television picture tubes and computer.
    - Product reliability: refers to the product's use under the prescribed conditions, with no occurrence of failure, such as television with no color failure and accuracy of clock.
    - Product safety: refers to the degree of protection of people and the environment, such as safety degrees of water heaters, security guards, beer bottle and electrical products.
    - Product economy: refers to how much of the total cost over the product life cycle, such as the power consumption of air conditioners, refrigerators and other home appliances, and fuel consumption per hundred kilometers of cars.
- The appearance quality: refers to the external attributes of the product, including the product's shape, color, packaging etc., such as shape and color of a bicycle.

Comparing the characteristics of inherent and appearance quality, the former one is main and basic, because the appearance quality makes sense only when the inherent characteristics are guaranteed.

The following definitions reflect different ways of looking at what quality might mean.

- "Conformance to specifications" (Phil Crosby): The difficulty with this is that the specifications may not be what the customer wants; Crosby treats this as a separate problem.
- "Fitness for use" (Joseph M. Juran).
- Concentrating on; "the efficient production of the quality, that the market expects” (E. Deming).
- Quality model with two dimension models (Noriaki Kano) (Figure 4): this quality model is described with two dimensions: one dimension is "essential quality",

another is "attractive quality". The function in this model is near to the "fit for use".

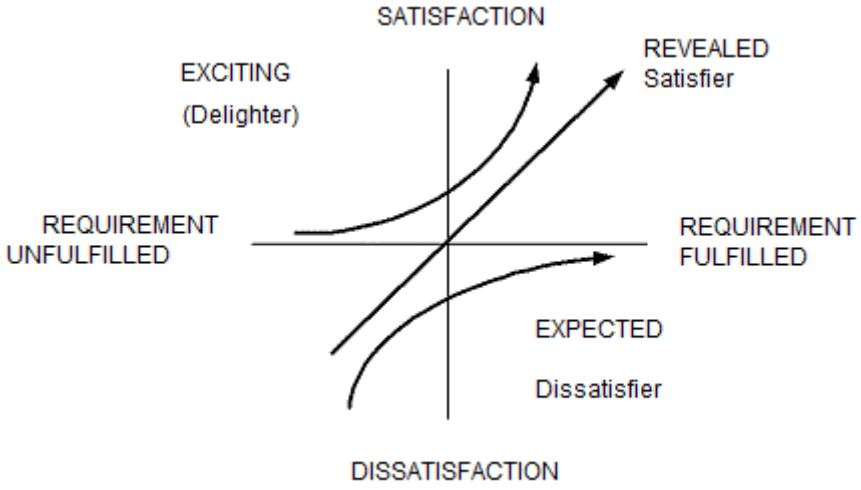


Figure 4: Noriaki Kano Two-dimensional Quality Model (Durakbasa, M.N. 2013)

As the expectations of customers grow day by day, to satisfy all these customers with quality improvement is becoming the primary target of the business. Some benefits of quality improvement are:

- Continuing improvement of customers relationship;
- Reduction of rework;
- Increasing on the overall profit of the company ;
- Giving the opportunity for global market;
- Improvement of the discipline of the company management system.

2.2 Quality Management

To succeed in the global marketplace for now and in the future, organizations will have to operate according to the principles of quality management (Figure 5) (Goetsch, D. 2003).Quality management is to determine the quality policy, objectives and responsibilities, and by the quality system of quality planning, quality control, quality assurance and quality improvement to make all the activities of all management functions to achieve. Coordinated activities to instruct and control an organization with regard to quality. Quality management is the responsibility of all levels of management but must be led by the top management. Its implementation involves all members of the organization. In quality management, it is a very important aspect that consideration is given to economic aspects (Durakbasa, M.N. 2009).

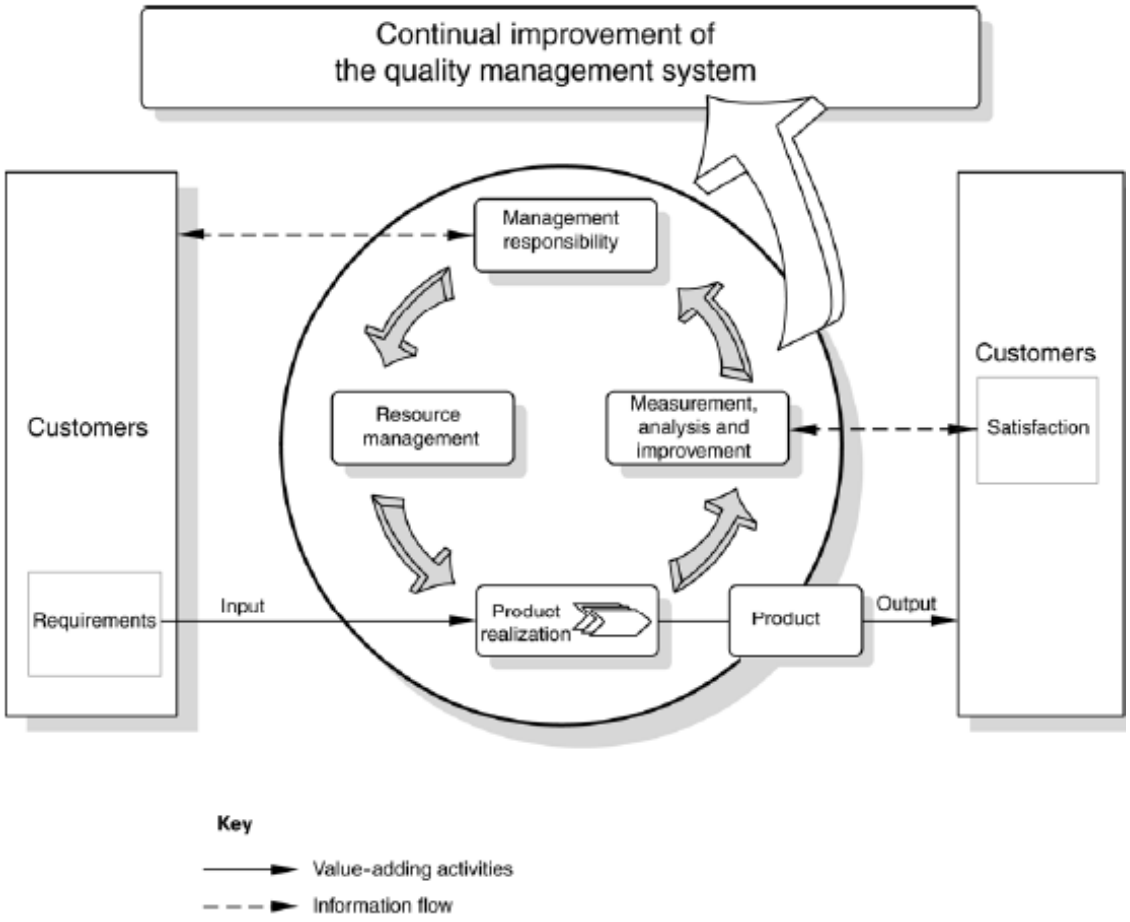


Figure 5: Process-based Quality Management Model (Osanna, P. 2002)

2.3 Process Capability

Process capability is a measurable property of the internal consistency of the process. It is determined by quality factors, and is usually used 6σ (standard deviation) to describe the process capability, the lower the value, the better the quality. When the process is in steady state, 99.73% of the product falls within the range of the 6σ, which includes almost all products.

Process Performance Index is the measure of process capability. It first appeared in the QS9000 which are developed by the U.S. Big Three auto companies. The Big Three defined the process performance index and process capability index, which are characteristic values to measure process performance. Process capability index reflects the inherent ability to process; process performance index reflects the performance of the current process.

Process capability index is an indicator of the process capability, which shows how close the process meets the technical specification (e.g. sizes, tolerances), generally is

abbreviated with C_p. There are different mathematic definitions of Process Capability Index (Durakbasa, M.N. 2009).

- Process Capability Index- Double Sided:

$$C_p = \frac{T}{6\sigma} = \frac{T_U - T_L}{6\sigma}$$

T is range of the tolerance, T_U is upper tolerance limit, T_L is lower tolerance limit, and σ is standard deviation.

- Process Capability Index- Single Sided:

Upper Specification Limit

$$C_{pu} = \frac{T_U - \bar{X}}{3\sigma}$$

T_U is upper tolerance limit, $\bar{X}$ is mean value, and σ is the standard deviation. If $\bar{X} \geq T_U$, then $C_{pu} = 0$, means process capability is insufficient. In this situation, process failure rate is more than 50%.

Lower Specification Limit

$$C_{pl} = \frac{\bar{X} - T_L}{3\sigma}$$

T_L is lower tolerance limit, $\bar{X}$ is mean value, and σ is standard deviation. If $\bar{X} \geq T_L$, then $C_{pl} = 0$, means process capability is insufficient. In this situation, process failure rate is more than 50%.

Details calculation of process capability and process capability index are shown in the Section 5.1 and Appendix B.

2.4 QS9000

2.4.1 Background of QS9000

QS9000 is "QS9000 quality system standard" for short. It was developed based on the quality standard requirements of supplier quality by the U.S Big Three automotive manufactures, Chrysler, Ford and General Motors. The main purpose of this standard is to reach the standards in accordance with standardized procedures, responsibilities, and processes (Fong, C. 2001). ISO9001(ISO 2008) is the basis of QS9000 which proposes additional special requirements of the automotive industry, and which combines Ford's quality system standards, the Chrysler's supplier quality assurance manual and General Motor's supplier requirements.

The reason for developing QS9000 and later on the ISO/TS16949, was that “The Big Three” had identified the need to coordinate the costumer-specific requirement on the

suppliers. The work started in 1988 when a workgroup in AIAG, Automotive Industry Action Group, were put together. AIAG is the Americas automotive industries branch organization where all companies active within the automotive industry are able to become members. Their first task was to standardize reference manuals, reports and technical nomenclature from the beginning. The first manual presented was the Measurement System Analysis, MSA, presented in 1990. In 1992 it was decided that the work should be extended with the objective to establish a common basic standard for the suppliers' quality system and tools for its evaluation. "The Big Three" considered that ISO 9000 was not sufficient to ensure the automotive industry requirements on the quality assurance and improvement work to be met. They wanted to give a more specific directive, setting higher demands on implementation, as well as strengthening their own position in the certification process (Wangenborn, T. 2010).

In 1994, the first Quality Systems Requirement was released. QS9000 was now a new standard for the quality systems and quality assurance. The standard consists of reference manuals as well as guidelines for manufacturer of tools (Eriksson, E. 2001). The reference manuals are QSA (Quality System Assessment), APQP (Advance Product Quality Planning) (APQP 2008), SPC (Statistical Process Control), MSA (Measurement System Analysis) (MSR 2010) and the last one is FMEA (Potential Failure Mode and Effects Analysis) (PFMEA 2008) (Wangenborn, T. 2010).

2.4.2 Purpose and Goal of QS9000

Purpose: QS-9000 determines the fundamental supplier quality requirements of Chrysler, Ford and General Motors and their affiliated companies for internal and external production. These companies are willing to work together with suppliers, by meeting the quality requirements, to ensure customers satisfaction, and continue to reduce disparities and waste, so that the end user, supplier, and the company itself receive benefits. The subsidiaries of U.S automotive companies and their suppliers overseas, such as in Australia, China and Japan have officially adopted this quality system.

Goal: The goal of QS-9000 is the development of fundamental quality systems which provide for continuous improvement, emphasize defect prevention and reduction of deviation and waste in the supply chain (ISO 1998).

It can be summarized as following points (Jenkins, G. 2013):

- Ensure product quality to meet customer requirements;
- Enhance quality systems for suppliers;
- Enhance process control, prevent failure, reduce production costs;
- Standardize the responsibilities and ownership in one organization to improve work efficiency;
- Participate in international competition;

- Effectively implement management thinking with focus on strategic development;
- Prevent quality accident;
- Reduce costs and improve business efficiency;
- Provide continuous improvement of quality management system;
- Prevent loopholes, and reduce cost and waste on the production line;
- Ensure customer's confidence;
- Increase profitability of organization.

2.5 ISO/TS 16949

2.5.1 Background of ISO/TS 16949

ISO/TS 16949 is a technical specification which applies specifically to the automotive industries. ISO/TS 16949 standard is a further development based on the ISO 9001 standard, which defines the international automotive quality system requirements, not only covering ISO 9001 standard, but also including specific automotive manufacturer requirements (Kartha, C.P. 2004). This technical specification, in conjunction with ISO 9001:2000, defines the requirements of quality management system for the design and development, production and, when relevant, installation and service of automotive-related products (ISO 2007). This technical specification systematically introduces the basic principles and applications of the five core tools in ISO/TSl6949 quality management system manual, which are Advanced Product Quality Planning (APQP), Control Plan (CP), Measurement Systems Analysis (MSA), statistical process control (SPC), production Part Approval (PPAP) (PPAP 2006) and potential Failure Mode and effects Analysis (FMEA), furthermore, focuses on how companies apply software implementation of SPC, MSA and FMEA into quality management system.

ISO/TS 16949 integrates the global automotive industry quality system standards from U.S., German, French and Italian, and also absorbs the vehicle management experience from Japan Automobile Manufacturers Association (JAMA). With the support of the ISO Technical Committee, ISO/TS 16949 is jointly developed by the International Automotive Group (IATF) and JAMA (Cassel, M.2007). It is a combination of the international standards QS9000, VDA 6.1, EAQF and AVSQ, briefly described in the following picture (Figure 6) (Wangenborn, T. 2010):

- QS9000 represents the American automotive industry
- VDA 6.1 (Verband der Automobilindustrie) represents the German automotive industry
- EAQF (Rèférential dÁptitude Qualité Fournisseurs) represents the French automotive industry

- AVSQ (ANIFA Evolution of Quality System) represents the Italian automotive industry

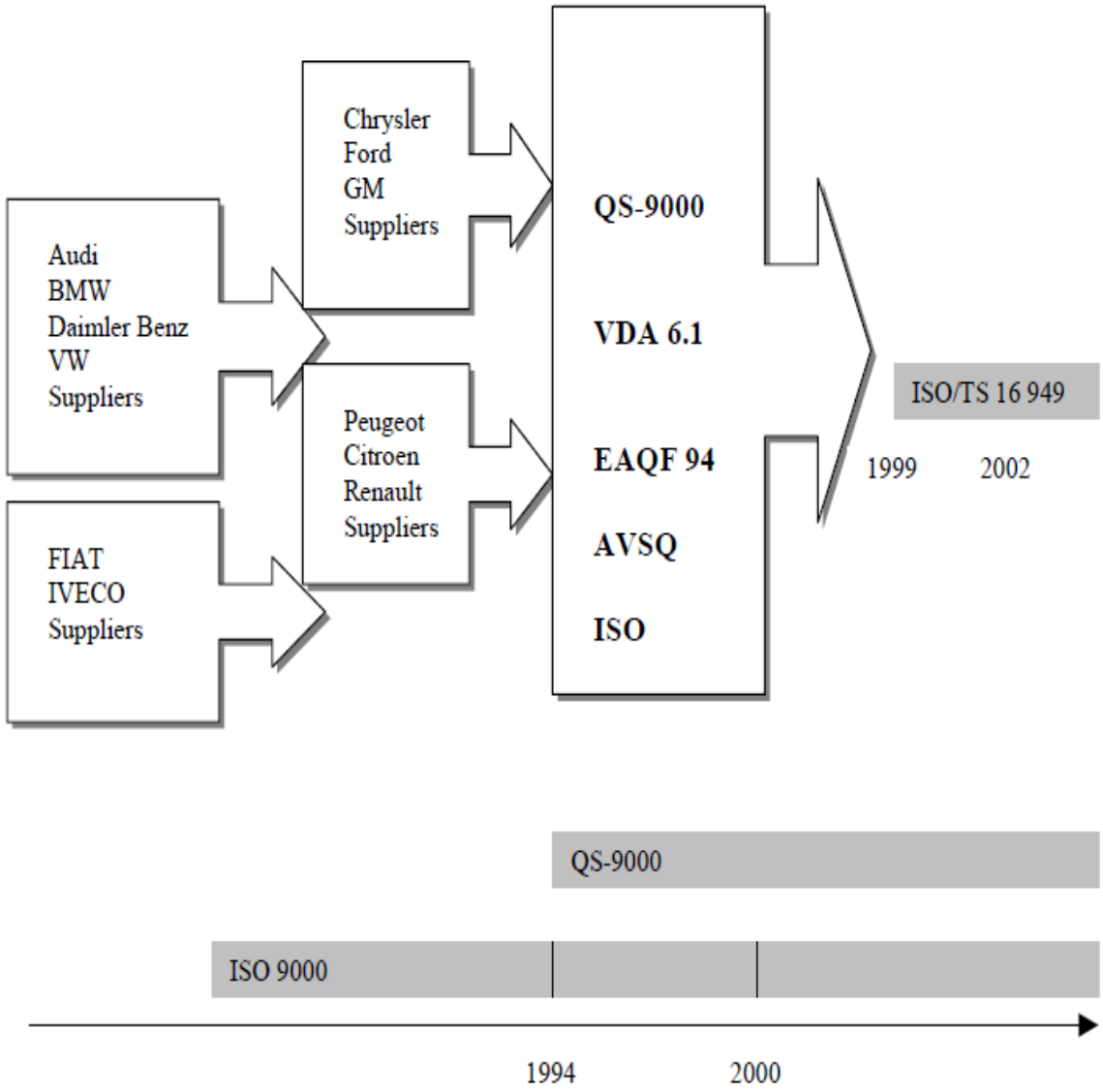


Figure 6: Development of ISO/TS 16949 (APQP 2008)

2.5.2 Purpose and Goal of ISO/TS 16949

Purpose: With the rapid development of international trade, a growing number of automotive parts suppliers are faced with a complex supply situation, in which supplies of automotive OEMs are from different countries at the same time. In this case, a supplier may follow different established quality system standards and receive multiple third-party certification audits, which possibly gives rise to international trade barriers, but also increases the inconvenience and cost to the supply chain. In order to avoid recertification and satisfy customer specific requirements, it is necessary to depend on the support and coordination of International Organization for Standardization, the Interna-

tional Organization for Standardization (ISO) issued in 1999 ISO/TS16949 specifications.

ISO/TS 16949 quality system for the automotive supply chain applies to all products and service suppliers. They can be engaged in:

- Products and materials production;
- Heat treatment, painting, plating and other surface treatment;
- Customer's other requirements for products.

Goal: International recognition of ISO/TS 16949 ensures that, with the ISO/TS 16949 certification, the credibility of your organization when bidding for global sourcing contracts or expanding business locally is guaranteed (ISOTS16949 2014).

Benefits to the automotive industry:

- Improve the product and process quality in supply chain;
- Integrate the best experience of the big automotive companies;
- Increase the confidence of global suppliers;
- Ensure the supplier quality standard consistency in supplier and sub-supplier;
- Reduce the deviation and waste, and improve overall productivity;
- Reduce the number of second party audits;
- Eliminate duplicate requirements of third-party audits;
- Provide a common platform for the requirement of international quality system;
- Simplify the transition process to ISO9001/2000;
- Benefit from updating the existing quality system.

2.6 APQP

The purpose of this Advanced Product Quality Planning and Control Plan guidelines developed jointly by Chrysler, Ford and General Motors is to communicate with suppliers (internal and external) and subcontractors. The APQP provides guidelines designed to produce a product quality plan which will support the development of a product or service that will satisfy the customer. The term "product" is meant as either product or service. The term "supplier" is meant to apply to suppliers and subcontractors. Some of the expected benefits in using these guidelines are: 1) A reduction in the complexity of product quality planning for the customers and suppliers; 2) A means for suppliers to easily communicate product quality planning requirements with subcontractors (APQP 2008, p.1).

APQP is a structured method, which is carried out before a new product into production, by quality planning, to development of specific requirements and to have the ne-

cessary information in order to understand the resources and ensure the quality of the design and manufacture (APQP 2008, p.3). Its goal is to increase the communication with everyone project involved to ensure the prescribed steps within the prescribed timeline. Effective product quality planning depends on the senior manager's commitment to achieve customer's satisfaction for the purpose. To effectively achieve the quality goals, the following objectives should be pointed:

- Take the customer needs into the whole product process from development to production and to service ;
- Continue improving customer's satisfaction;
- Avoid quality problems in mass production.

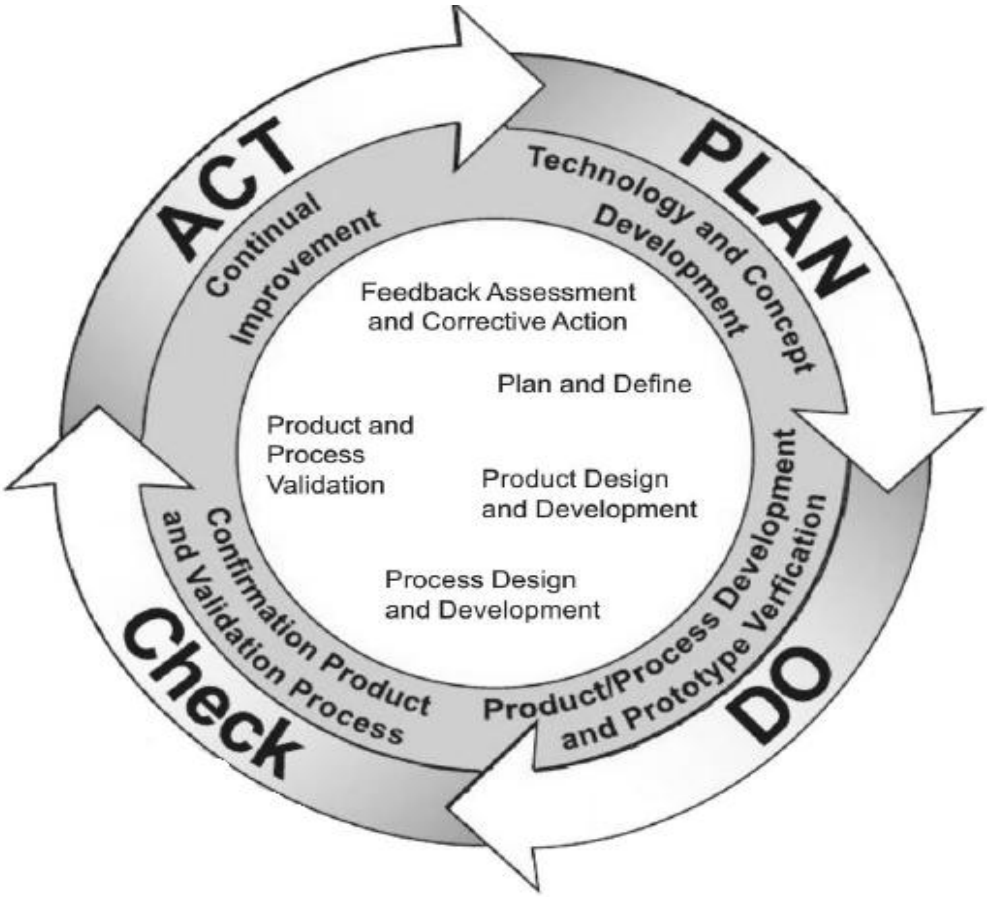


Figure 7: Product Quality Planning Cycle (APQP 2008)

As shown in Figure 7, the description of Product Quality Planning, APQP is a Plan-Do-Check-Do (PDCA) Cycle for product development and continuous improvement which can be realized by using the relative quality experience and knowledge gained from projects.

The keys of effective product quality planning are:

- Support of top management, including summarizing quality planning in each stage, involving in the practice problem, final evaluation of product quality planning process and so on.
- Team skills and communication skills.

Some of the benefits of Advanced Product Quality Planning and Control Plan (APQP 2008, p.3):

- Reduce the product quality planning complexity of customers and suppliers;
- As a method of providing a framework of easy communication between suppliers and subcontractors in product quality planning
- Meet the customer's requirements
- Meet the requirement of process change
- Avoid late changes
- Provide qualified products on time

The success of any program depends on meeting customer needs and expectations in a timely manner at a cost worth for value. The APQP process for new product development follows five phases (APQP 2008, p.5) (Figure 8 and Table 1):

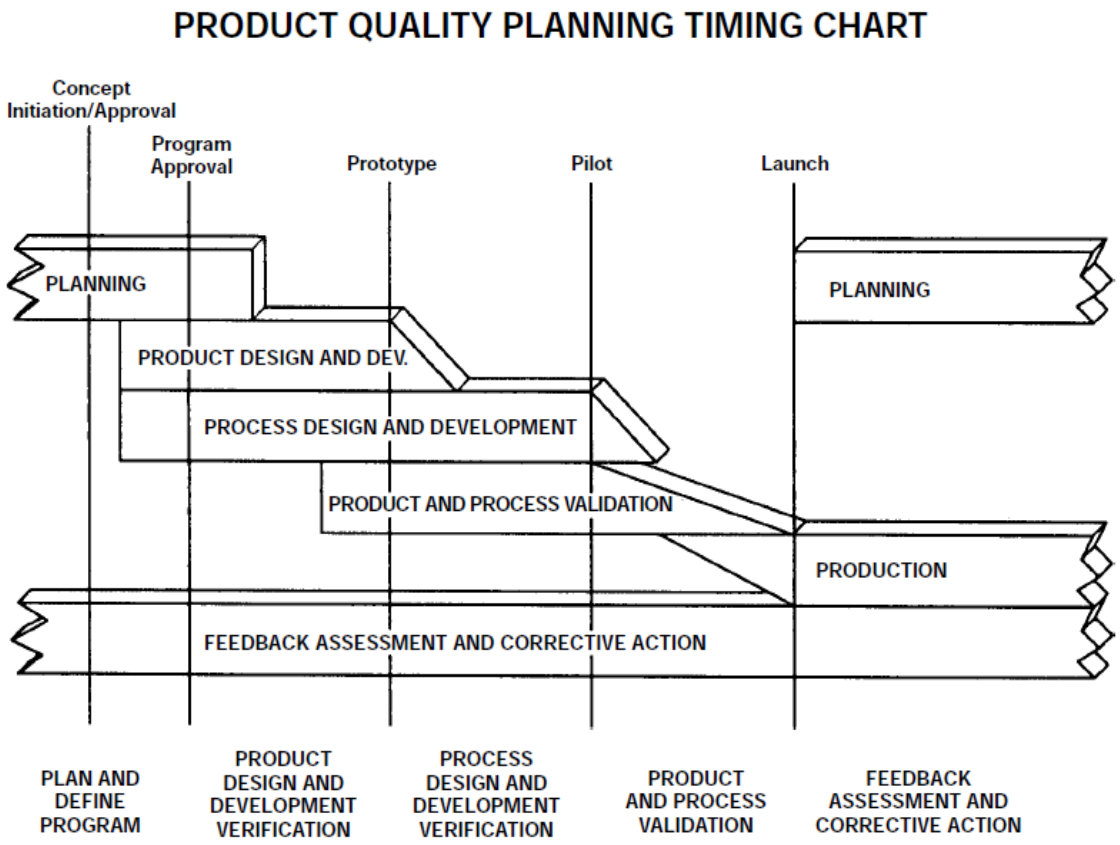


Figure 8: Product Quality Timing Chart (APQP 2008, p.5)

Table 1: APQP Phase and Task

Phase	Task
1. Phase	Plan and Define Program
2. Phase	Product Design and Development
3. Phase	Process Design and Development
4. Phase	Product and Process Validation
5. Phase	Feedback, Assessment and Corrective Action

Phase 1. Plan and Define Program: This phase describes how to define the needs and expectations of customers. All activities shall take into account the customer to provide products and services better than competitor's counterparts. The early phase of product quality planning process is to ensure that the needs and expectations of customer have been clearly understood. Input and output for the process according to the needs and expectations of the customers and product change processes (APQP 2008, p.7).

The inputs and outputs applicable to this section are as follows (Table 2).

Table 2: Inputs and Outputs in APQP Phase 1.

INPUTS	OUTPUTS
• Voice of the Customer	• Design Goals
• Business Plan/Marketing Strategy	• Reliability and Quality Goals
• Product/Process Benchmark Data	• Preliminary Bill of Material
• Product/Process Assumptions	• Preliminary Process Flow Chart
• Product Reliability Studies	• Preliminary Listing of Special Product
• Customer Inputs	• Product Assurance Plan
	• Management Support

Phase 2. Product Design and Development: In the second phase of product design, development and validation, we discuss the planning process to develop the design features and characteristics of the elements close to the final form. At this stage, the process used to ensure product quality planning requirements for engineering and other technical information about the comprehensive and rigorous assessment. At this stage, the initial feasibility analysis will be carried out to evaluate the potential problems that may occur in the manufacturing process. A feasible design must permit meeting production volumes and schedules, and be consistent with the ability to meet engineering requirements, along with quality, reliability, investment cost, weight, unit cost and timing objectives. Although feasibility studies and control plans are primarily based on engineering drawings and specification requirements, valuable information can be derived from the analytical tools described in this section to further define and prioritize the characteristics that may need special product and process controls. In this section, the Product Quality Planning Process is designed to assure a comprehensive and critical review of engineering requirements and other related technical information. At this stage of the process, a preliminary feasibility analysis will be made to assess the potential problems that could occur during manufacturing (APQP 2008, p.13).

The inputs and outputs applicable to this section are as follows (Table 3).

Table 3: Inputs and Outputs in APQP Phase 2.

INPUTS	OUTPUTS BY DESIGN RESPONSIBLE ACTIVITY
• Design Goals	• Design Failure Mode and Effects Analysis
• Reliability and Quality Goals	• Design for Manufacturability and Assembly
• Preliminary Bill of Material	• Design Verification
• Preliminary Process Flow Chart	• Design Reviews
• Preliminary Listing of Special Product	• Prototype Build - Control Plan
• Product Assurance Plan	• Engineering Drawings (Including Math Data)
	• Engineering Specifications
	OUTPUTS BY PRODUCT QUALITY PLANNING
	• New Equipment, Tooling
	• Special Product and Process Characteristics
	• Gages/Testing Equipment Requirements
	• Team Feasibility Commitment

Phase 3. Process Design and Development: In the third phase of the process, we discuss the main features in order to obtain a high-quality product development and manufacturing systems and associated control programs; product quality planning at this stage of the process to be completed depends on the successful completion of the task from the first two phases of the process. In this phase, the manufacturing system shall ensure to meet customer requirements, needs and expectations. In the process of design and development process, the following items must be completed as output, thus ensuring to establish a robust manufacturing system (APQP 2008, p.19).

The inputs and outputs are shown as follows (Table 4).

Table 4: Inputs and Outputs in APQP Phase 3.

INPUTS	OUTPUTS
• Design Failure Mode and Effects	• Packaging Standards
• Design for Manufacturability	• Product/Process Quality System Review
• Design Verification	• Process Flow Chart
• Design Reviews	• Floor Plan Layout
• Prototype Build - Control Plan	• Characteristics Matrix
• Engineering Drawings	• Process Failure Mode and Effects Analysis
• Engineering Specifications	• Pre-Launch Control Plan
• Material Specifications	• Process Instructions
• Drawing and Specification Changes	• Measurement Systems Analysis Plan
• New Equipment, Tooling	• Preliminary Process Capability Study Plan
• Special Product and Process	• Packaging Specifications
• Gages/Testing Equipment	• Management Support
• Team Feasibility Commitment	

Phase 4. Product and Process Validation: In the fourth phase of products and processes validation, we mainly discuss the main features of the evaluation through trial production run to validate the manufacturing process. In the trial production run, the product quality planning team shall confirm whether to follow the control plan and process flow diagram, whether the product meets the customer's requirements, and shall pay attention to the related concerns on official production before running the investigation and resolution (APQP 2008, p.25).

As follows, the inputs and outputs are shown in Table 5.

Table 5: Inputs and Outputs in APQP Phase 4.

INPUTS	OUTPUTS
• Packaging Standards	• Production Trial Run
• Product/Process Quality System	• Measurement Systems Evaluation
• Process Flow Chart	• Preliminary Process Capability Study
• Floor Plan Layout	• Production Part Approval
• Characteristics Matrix	• Production Validation Testing
• Process Failure Mode	• Packaging Evaluation
• Pre-Launch Control Plan	• Production Control Plan
• Process Instructions	• Quality Planning Sign-Off
• Measurement Systems Analysis	
• Preliminary Process Capability	
• Packaging Specifications	
• Management Support	

Phase 5. Feedback, Assessment and Corrective Action: The fifth phase is the feedback, assessment and corrective action, which is a continuation of product and process validation. In the manufacturing stage showing all special and general deterioration of reasons, the output can be evaluated which is the evaluation of product quality planning time validity. Organization is obliged to make all the features to meet customer requirements. Special features must meet targets specified by the customer (APQP 2008, p.29) (Table 6).

Table 6: Inputs and Outputs in APQP Phase 5.

INPUTS	OUTPUTS
• Production Trial Run	• Reduced Variation
• Measurement Systems Evaluation	• Customer Satisfaction
• Preliminary Process Capability Study	• Delivery and Service
• Production Part Approval	
• Production Validation Testing	
• Packaging Evaluation	
• Production Control Plan	
• Quality Planning Sign-Off	

3 Analysis of Present Situation

3.1 Company BRP-Powertrain

BRP-Powertrain GmbH & Co KG (until 2008 BRP-Rotax GmbH & Co. KG) is an Austrian company which develops and manufactures engines. It is a subsidiary of Bombardier Recreational Products Inc. (BRP), a Canadian company which is active around the world as a leading international premium manufacturer of motorized recreational vehicles (Rotax 2013).

In 2009, BRP merged Rotax and Evinrude Johnson to the Powertrain Division, which is headquartered in Gunskirchen. Under the internationally recognized brand name Rotax, BRP-Powertrain manufactures in Gunskirchen, Austria (with its more than 1,100 employees) and Juarez, Mexico, high performance engines for snowmobiles, watercraft and boats, off-road vehicles (All Terrain Vehicles) and roadsters from BRP (Figure 9). Besides that BRP-Powertrain develops engines for BMW- and Husquarna-motorcycles, for light and ultra light aircraft as well as for karts.

Figure 9: Products of BRP Inc. (Stiebinger, C. 2011)

As pioneer and market leader in the powersports industry, BRP has a location at its disposal in Austria known worldwide as the hub of the automotive industry due to its proximity to the European high-tech-community (universities, universities of applied sciences, apprenticing companies and supply structures).

BRP-Powertrain has facilities on three continents (Europe, Asia and South America) (Figure 10). The company's products are sold in more than 80 countries, 19 of which have their own direct sales network.

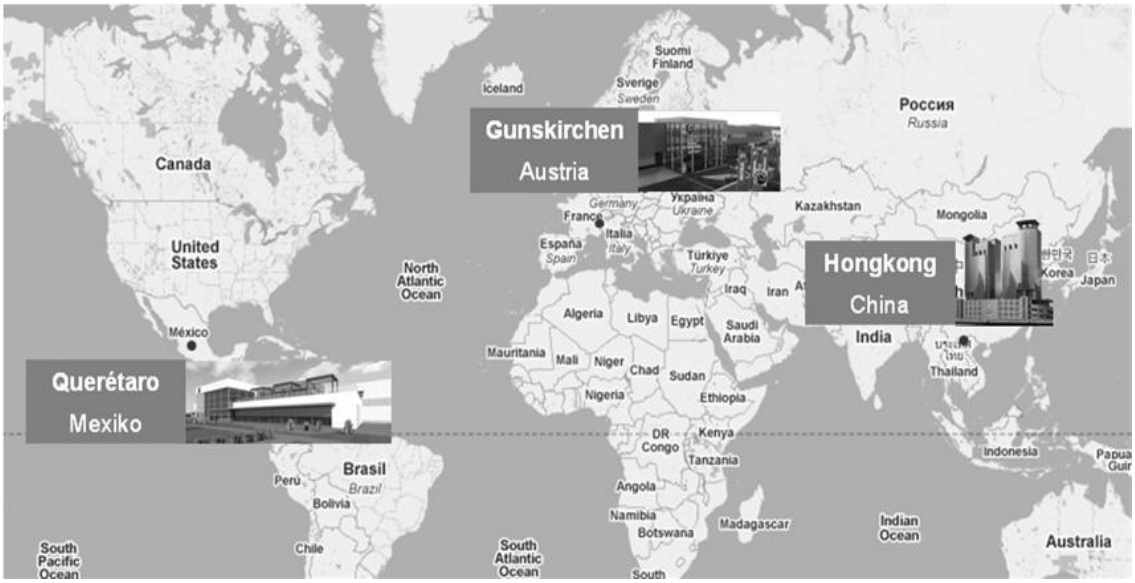


Figure 10: Global Facilities of BRP-Powertrain (BRP 2012)

BRP-Powertrain History (BRP 2012)

2011 Total of 7 million Rotax® engines produced
2010 Start of production of Rotax® engines for BRP's first SSV; the Can-Am® Commander
2010 First Rotax® 4-stroke engine out of the ACETM family
2009 Renaming to BRP-Powertrain GmbH & Co KG
2009 Moving to the new Regional Innovations Centrum (RIC)
2008 Start of production of the first Rotax® 2-stroke engine out of the E-TEC® family
2008 Start of production of 1.200 ccm 4-stroke engine
2007 Start of assembly of ATV engines in Juárez, Mexiko
2007 Presentation of the revolutionary Can-Am® SpyderTM Roadster with a Rotax® engine
2006 Total of 6 million Rotax® engines produced
2003 Bombardier sells Bombardier Recreational Products – renaming of Bombardier-Rotax
2002 First Rotax® 2-stroke engine with electronic injection (2-TEC® for Ski-Doo®)
2001 First Rotax 4-stroke engine out of the 4-TEC®
2000 Start of Rotax-Quality-Production-System (RQPS)
1998 Start of production of Rotax® engines for ATVs
1988 Start of production of Rotax® engines for Sea-Doo® watercrafts
1983 Start of production of Rotax® engines for karts
1982 Start of production of Rotax® 4-stroke aircraft and motorcycle engines

First Rotax® aircraft engine certified

1971 Total of 1 million Rotax® engines produced

1970 Bombardier acquires Rotax-Werk AG – renaming to Bombardier-Rotax GmbH

1962 Start of production of Rotax® engines for Ski-Doo® snowmobiles

1959 Lohnerwerke Ges.m.b.H. takes over the stock majority

1947 Move to Gunskirchen near Wels, Austria

1943 Operations are relocated to Wels, Austria

1930 Fichtel & Sachs AG acquires Rotax-Werk AG, relocation to Schweinfurt, Germany

1920 Rotax-Werk AG founded in Dresden, Germany

In 2013, BRP Inc. is returning to the public markets with a modest-sized offering that will leave its current owners with voting control of the company.

BRP-Powertrain's facility in Austria is ISO 9001:2008 certified. Customer focus, continual improvement, process approach and hands-on involvement of top management – These are the quality management principles that enable BRP-Powertrain to ensure product quality and consistency for customers.

What's more, BRP-Powertrain's Austrian subsidiary is a Part-21 organization[2] and has a European Aviation Safety Agency (EASA) Design Organization Approval (DOA), giving BRP-Powertrain the authorization to design aircraft engines. In addition to this, the EASA Product Organization Approval (POA) gives the right to build certified aircraft parts and engines.

3.2 BRP-Powertrain's NPD Process

To ensure a lean, efficient and standardized Product Development for every project, it is important for all employees of BRP-Powertrain to have the same understanding of the New Product Development Process (NPD); the following description is from BRP-Powertrain NPD Process.

NPD is a Stage-Gate process (Figure 11) especially designed and tailored for BRP for the development of new products (engines) and revision of existing products (engines).

A stage-gate development process (Figure 12) is a process that requires to set a series of short term objectives predefined at the beginning of a project in such a way that it will ensure a team to achieve the ultimate target by focusing on those objectives one set at the time.

NPD Stage-Gate process integrates:

- Flexibility: by giving the possibility of establishing the gates and corresponding deliverables that best adapt to the complexity of the project.

[2] EASA Part-21 is a aircraft certification by European Union.

- Rigor: by requiring that these milestones are clearly scheduled and approved at the beginning of the project.
- This is possible through the Master Gate Plan

NPD is standardizing the product development process by:

- Ensuring consistency from one project to the other
- Allowing the right decision taking at the right time
- Giving a common language and a better communication

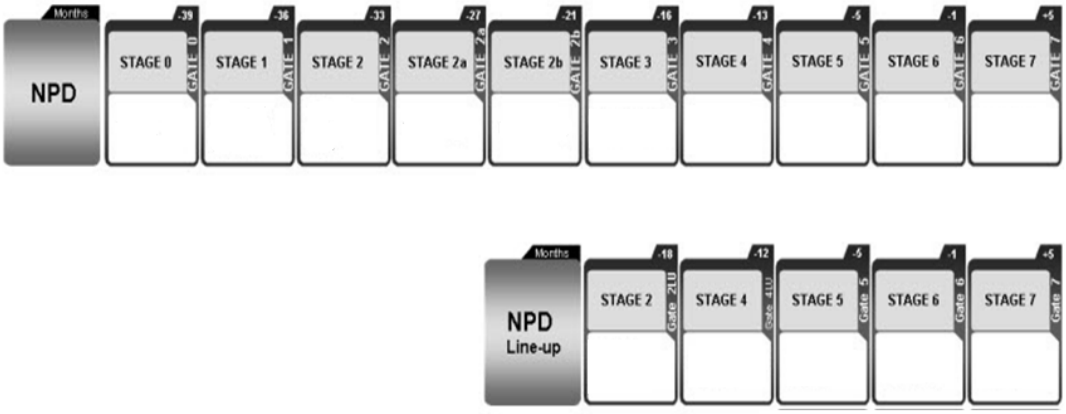


Figure 11: Stage-gate NPD Process (BRP 2011)

The NPD process has been divided in activity periods called "Stages" and in quality control check points called "Gates" at which a project manager presents a list of standardized deliverables to top managers for approval. Stages are activity periods where the project team focuses on the accomplishment of a set a standardized short term objectives called deliverables. "Gate meetings" are important decision points where accomplishment of deliverables is evaluated and where Gates receive Green, Yellow or Red status. For a development project to be successful, every gate needs to become Green. In other words, development teams need to close issues for which the gate was not Green.

The NPD process is applied for every project listed in the Master Gate Plan.

There different definitions in the NPD process:

PDR: Project Development Review; Multifunctional team meeting once a month and responsible for:

- Follow-up of project development plan
- Insure product orientation is well respected during development phases

- Gate review and approval from Gate 0 to 7 (PRT)

PSC: Multifunctional team meeting periodically based on a predefined annual schedule for each division:

- Product portfolio management at the division product level
- Defining new product orientation
- Making sure that the development is done with respect to the orientation of the product

FPL: FPL = Functional Project Leader; A NPD project team is composed out of project leaders from all departments: Product Development, Production, Purchasing, Sales & Marketing, Quality, Supplier Quality, After Sales and Finance. In case of an Outboard or Aircraft projects additional FPL's are part of the project team: for example P&A (Parts & Accessories) or Airworthiness.

MGP: Master Gate Plan The key document for NPD which contains the project schedules for all NPD projects. Program Management is the keeper of the Master Gate Plan, A new project can only be added to the MGP after confirmation from the PDR or PSC

SIPOC: Supplier-Input-Process-Output-Customer diagram: format used to describe the NPD deliverables.

In this NPD process, each team has his own responsibilities.

Program Management: The role of Program Management (Figure 13) is to carry out the cross functional project coordination of every NPD project. The Program Manager organizes Project team meetings to follow up on the NPD deliverables with all FPL's. The Program Manager reports to PDR the results of the NPD project at every Gate or on demand if the project situation requires immediate action.

Project management is essential for fast and efficient product development. It will lead to outstanding products. To achieve such a result, project management needs the commitment of top management, excellent communication, teamwork and training. It also needs to be part of the organizational culture.

FPL: The functional project leader is responsible for the execution of the department related deliverables according the NPD process. The FPL's have not necessarily to carry out the deliverables themselves, the FPL's have to organize the work in their departments and report back in the Project Team Meeting to the Program Manager about the status and completeness of the work assigned.

The entire NPD process and the responsibilities are described in the NPD process in the PRT Intranet.

The NPD intranet site (Figure 14) contains the description of the NPD process for new products (engines) as well as the NPD process for Model Year projects which is used for revisions of existing products (engines).

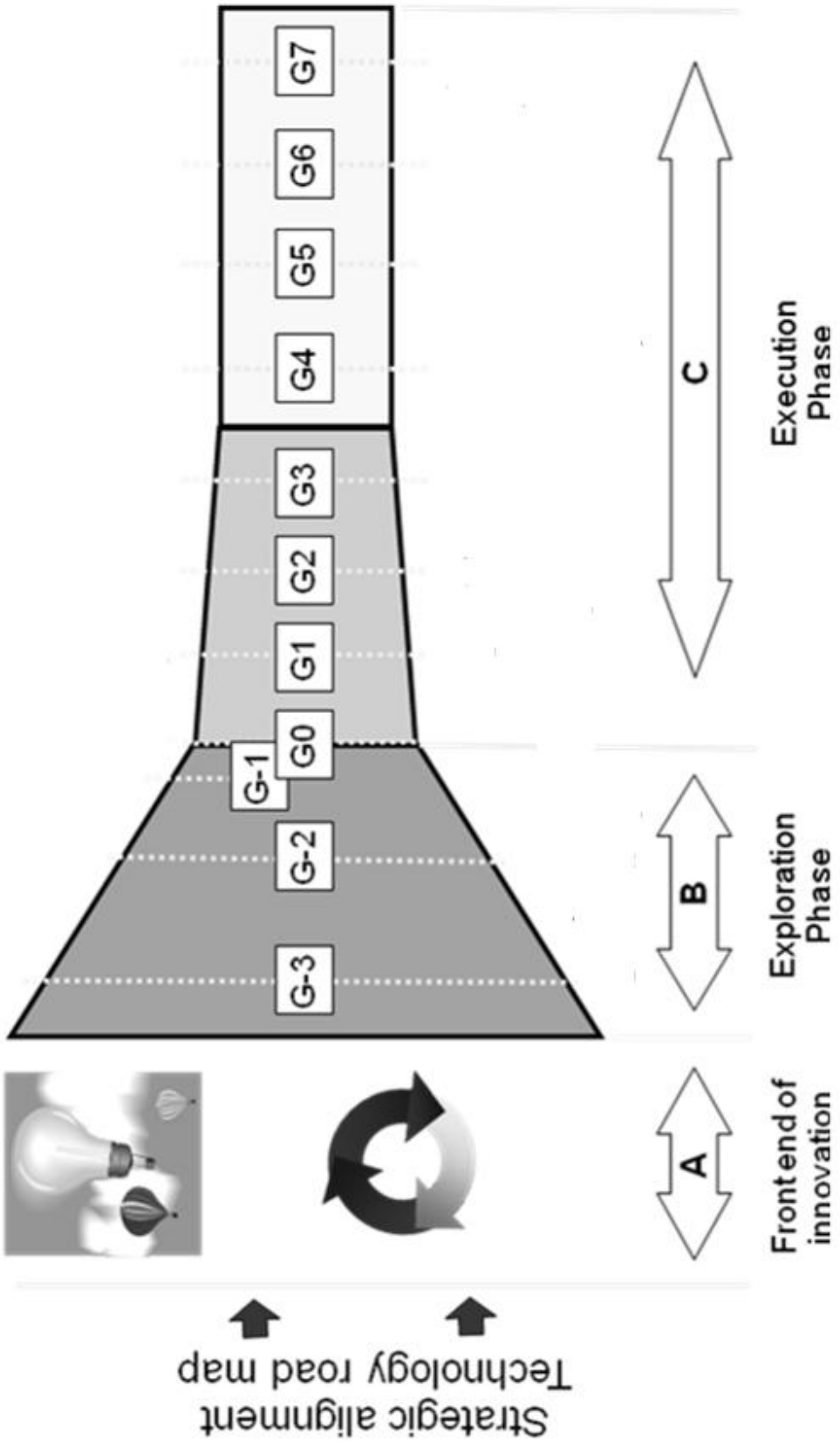


Figure 12: NPD Process (BRP 2011)

The NPD process is divided in Stages which are completed by a Gate. For each Gate the deliverables are listed. The description of every Gate contains: responsible department, requirements for the deliverable, process to accomplish the deliverable, result, used documents/forms/procedures.

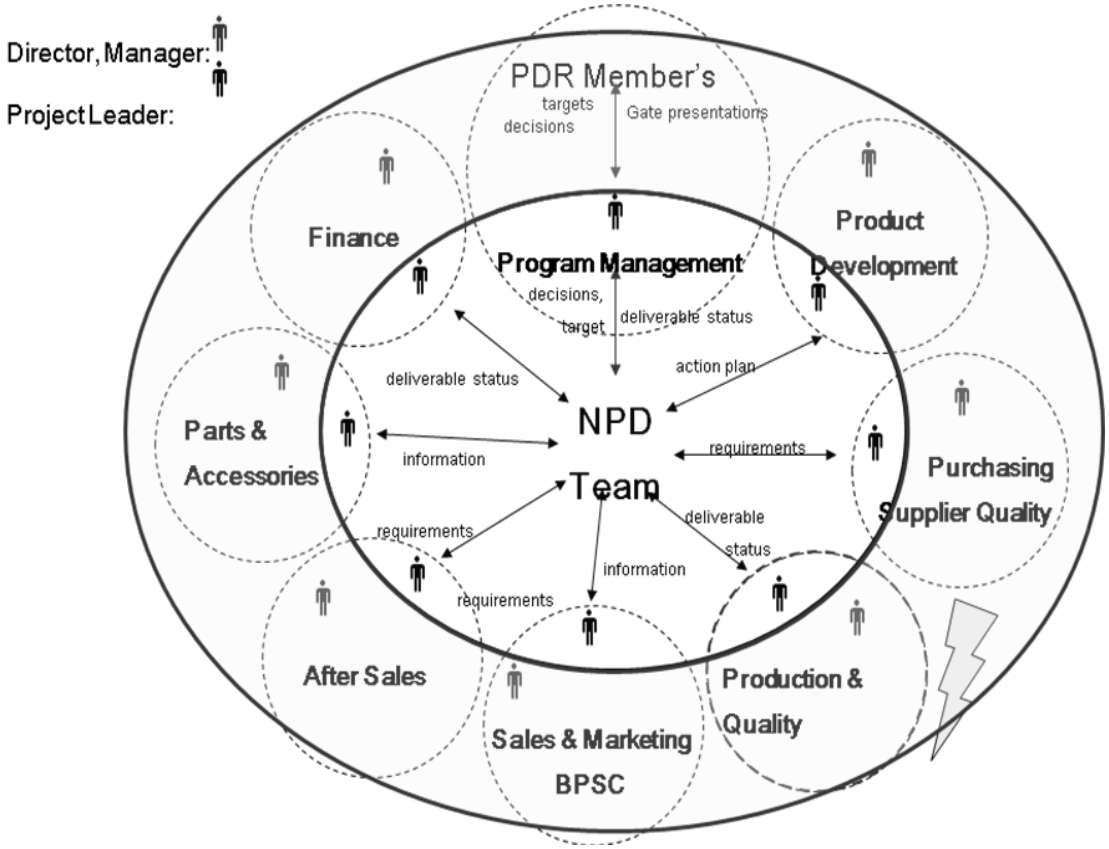


Figure 13: Project Management, Roles & Responsibilities (BRP 2011)

At the beginning of every project stage the Program Manager together with the FPL's has to define which deliverables are needed to complete successfully the project stage. These deliverables have to be indicated in the NPD team meeting minutes and PDR presentations as not needed or not relevant to pass the specific Gate.

After all deliverables have been assessed, the top managers (PDR) will give an overall gate evaluation:

- Gate Released / GREEN Gate: A Green Gate means that the review committee (PDR) is satisfied with the completion of all applicable deliverables of the Stage and authorizes the team to move ahead with the project.

- Gate Preliminary Released / YELLOW Gate: Deliverables are not all satisfactory and an action plan must be established but the team can proceed to the next stage. The action plan should specify the timeframe and actions required to bring the deliverable's to a satisfactory level. The gate will be passed after full resolution of the action

plan. No future gate will be passed as Green until the previous gate issues have been moved from yellow to green.

Figure 14: NPD Intranet Site Screen

• Gate Not Released / RED Gate: Some or all deliverables are not satisfactory and at least one of them is a show stopper for the entire project. The gate is not passed and the team cannot proceed to the next stage. The project is in jeopardy and all possibilities must be envisioned by the PDR (action plan, re-scope, re-evaluate its portfolio ranking, and allocate more resources, delay or cancel). No future Gate will be passed as Green, Yellow or Red until the previous gate issues have been moved to Yellow or Green.

3.3 Gap Analysis

This section presents a gap analysis on present situation of BRP-Powertrain NPD process in against the APQP process. In the analysis, the process timing plan and procedural steps of existing NPD process is compared to APQP reference manual and published as a gap analysis, which will serve as the basis for creating customized and standardized modular for the next chapter.

3.3.1 Research Methods

The method in this study is performed by gap analysis which is a useful and simple tool that helps identify the gap between the present situation and the future state that researcher wants to reach at the beginning of a project, when developing a business model (MindTools 2013).

The main sources of information in this gap analysis are the employees from BRP-Powertrain supplier quality department because they know the work processes and have experience with relevant documents, data and work equipment. The responsibility of supplier quality department is to support the supplier partnerships while driving quality improvement initiatives at the suppliers to meet or increase customer satisfaction goals. There are five main teams in supplier quality department in BRP-Powertrain (Figure 15). The steel team is responsible for steel parts, aluminum team for aluminum parts, plastics team for plastics parts and electronics team for electronics parts. The team of supplier quality development is responsible for all activities relating to supplier selection, evaluation and supplier performance. In the analysis, different kinds of work task plans, standard operating procedures and work instructions which contain the important information about the NPD process will be analyzed.

There are a variety of methods for the gathering of information: interview, questionnaire, observation and document analysis. For this specific analysis, the information collection is mainly performed by a combination. Basic is interviews (mostly face to face interview) which are supplemented by document analysis. At the beginning, mostly free interviews are used to get a good overview of the process. In further steps, some standardized interviews are carried out.

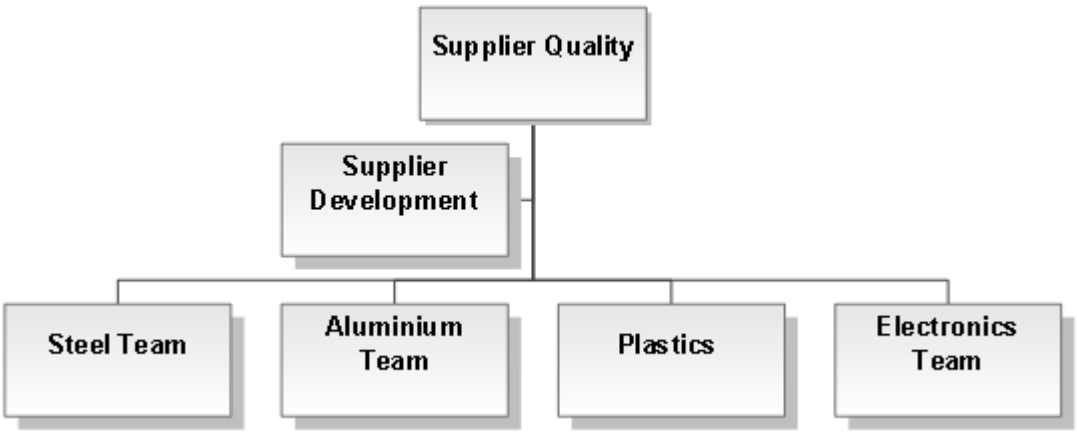


Figure 15: Organization of supplier quality management department

3.3.2 Objectives

The objectives in this analysis include:

1. Compare the timing chart plan in APQP process to the Stage-Gate phases in BRP-PowetrainNPD process;
2. Compare each procedural elements of APQP to the activities in current BRP-Powertrain NPD process.

3.3.3 Baseline

The ISO / TS 16949 quality management standard is introduced by automotive industries and their suppliers, the automotive specific quality requirements should be prepared before their products enter the automotive supply chain. Therefore, we chose BRP-Powertrain own new product development (NPD) profess as reference, to compare this process with APQP reference manual. We simplify, reduce and re-integrate the main task of the lower levels of the NPD process to review the scope of activities. Then, through the analysis of the operation process, the similarity is displayed in percentage. We determined the necessary sub processes and convert them into functional modules (Ben, R. 2011).

3.3.4 Results

1) Similar Timing Plan Structure

The product quality timing plan in APQP is an overview of the development process with phases of the projects labeled. It has been divided in five overlapping processes. In this process, the team would expand upon this plan and drill it down to include tasks, assignments and timing. A well-organized timing chart should list tasks, assignments, and/or other events. Also, the chart provides the planning team with a consistent format for tracking progress and setting meeting agendas (APQP 2008). According to APQP timing plan, at begging of the product develop process, a cross-function team is organized and their team members are trained to have a common understanding of this process. Individual processes are managed with help of determined outputs, which fulfillment is required for progress to the next process (Plura, J. 2010). The cross function team leader is responsible for bringing the performance within the required deadline.

Likewise, as mentioned in section 3.2, the BRP-Powertrain NPD process has a Stage-Gate structure; this process has a similar process plan, which provides the framework for the project teams to develop a detailed timeline. The BRP-Powertrain NPD gate plan defines which gates will be required at certain points in time for a project and which deliverables are required at each stage. Responsibilities for each deliverable are also clearly defined in the gate plan. Once the gate plan is approved, it becomes the checklist to be used at each gate meeting to ensure that the deliverables are successfully completed.

At the gate meeting, top managers evaluates if the results are satisfactorily achieved in term of completeness and quality. In this NPD process each gate is presented in separate tab in which a gate summary is disclosed with the gate objectives and a concise definition of the deliverables associated to the stage. The department management is responsible to organize the execution of the department deliverables in time and with the right quality.

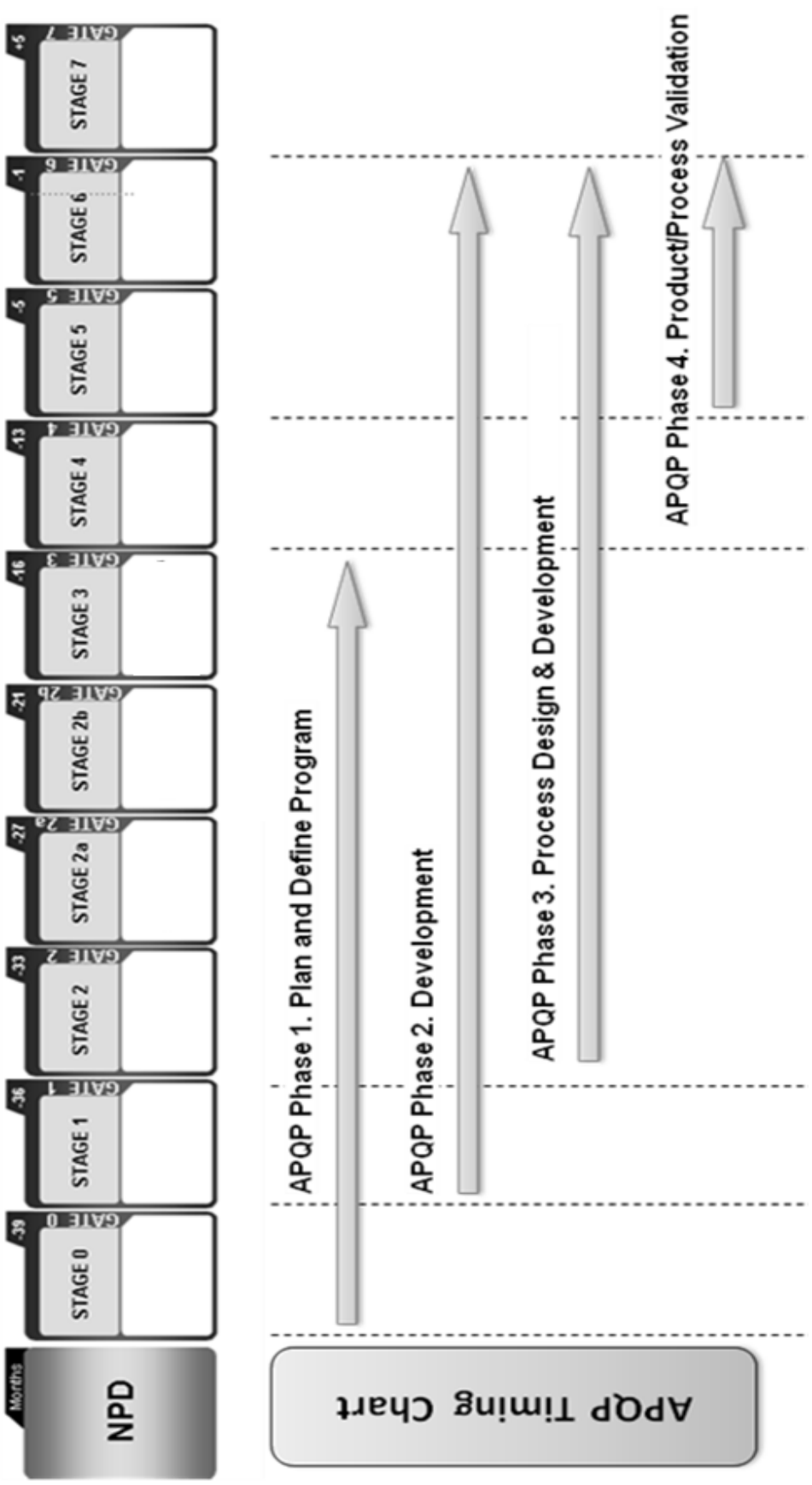


Figure 16: NPD vs. APQP Process Timing Plan

Both processes ensure rigor by requiring that these milestones (i.e. the gates) be clearly scheduled and approved at the beginning of the project. It also disciplines the employees to ask themselves the right question at the right time to maximize the chances of project success. Therefore by these means there is no difference between both processes. The comparison is displayed in figure 16.

2) Gap in Procedural Elements

The APQP process has a set of procedural elements that can be compared to the current BRP-Powertrain NPD process. These elements make up the bulk of the procedures and task-orientated work that a project team must complete in the new product development process (Ristow, R. 2002). In this section, the research question is what deviations the current NPD process has compared to the APQP process. Each element of APQP was evaluated and compared to relevant NPD sub processes, in order to identify what are the requirements, work instructions, operation processes and responsibilities in the sufficient level at BRP-Powertrain.

The research was carried out by researching the BRP-Powertrain NPD process training material, interview and employing the researcher's own experience. Many interviews were started to evaluate and audit the current status of NPD process against APQP. The target interviewees are not only from supplier quality department but also from product development, packing, production and purchasing departments. They are employees in one organization, but on different tasks and have the needed working experience of concerning current operative environment and procedures.

For the purposes of this research, some results from the gap analysis of procedural elements are summarized as follows:

The Gap analysis between these two processes illustrates that the two systems are very similar. Both systems rely on cross-function teams to increase communication and to complete a variety of requirements. The terminology may differ between them, but the same major elements exist in both systems (Ristow, R. 2002). The Tables blew (Table 7 ~ 14) are adapted results from the gap analysis.

The key areas where gaps exist, in the researcher's opinion, are 'Supplier Project Team Commitment', 'Design Reviews "Actions" completed', 'Tier 2 Suppliers Design Review', 'Packaging Standard', 'Packaging Specification', 'Product/Process Quality System Review', 'Packaging Evaluation', 'PPAP Production Validation Testing' and 'Production Part Approval Process (PPAP)'. Because not all elements are in an urgent need in BRP-Powertrain, the researcher will focus on the creation of some selected elements, which will be discussed in the chapter 4.

Table 7: Gap Analysis of APQP Element 5 ‘Preliminary Process Flow Chart’

APQP Element	**Phase**	**Nr.**	**Name**	**Defination**			
	Phase 1. Plan and Define Program	**5**	Preliminary Process Flow Chart	Process flow chart			
Selected NPD Steps	**Phase**	**Nr.**	**Name**	**Responsibile**	**Workinstructions/ Formula**	**Input**	**Output**
	P0	G2a.17	Supplier Selection	Purchasing	BE-102_Anfrage, Angebot Sourcing Meeting (ZMSM3)	P3-BOM, GSS, Agility aspects, Nafta/Meufta, drawings and specifications; max. capacity, weekly assembly quantities; nomination schedule in Follow-Up Tool; project master data sheet	Selection for new parts done according to Follow-Up Tool schedule. (6-digit part no., quality information in part master created.) Supplier selcted.
		G2b.18	Supplier Selection	Purchasing	G2a.17	G2a.17	G2a.17
	P1	G3.16	Supplier Selection	Purchasing	G2a.17	G2a.17	G2a.17
				Supplier	Feasibility Study, FB BE-514/B		
Difference △ Yes /No	No Difference, 90% same, end of action should be defined						
Remark	Interview Sch*						

Table 8: Gap Analysis of APQP Element 15 ‘Special Characteristics

APQP Element	**Phase**	**Nr.**	**Name**	**Defination**			
	Phase 2. Development	**15**	Special Product and Process Characteristics	Special product and process characteristics element			
Selected NPD Steps	**Phase**	**Nr.**	**Name**	**Responsibile**	**Workinstructions/ Formula**	**Input**	**Output**
	P0	G2b.28	CTQ Process Capability	Quality	VA 08-001_CTQ Prozess.pdf	P1 Quality Inspection Instruction, Design FMEA's, Preliminary Risk Assement, Existing process capabilities, Evidence of process capabilities from first line parts,	Filled out CTQ's with corresponding process capabilities. Status report with risk assessment and action plan for each gate.
	P3	G5.30	Release P3 CTQ Process Capability	same above	same above	Critical Dimensions, Tolerances, DFMEAS (from product development), available PFMEAS, existing process capabilities, Evidence of process capabilities from first line parts, Feasability studies, Lessons learned from earlier projects	same above
	PR	G6.15	Release PPAP CTQ Process Capabiity	same above	same above	same above	Process capability must be proved. 100% of CTQ must be compliant.
Difference Δ Yes /No	No Difference, 90% same, end of action should be defined						
Remark	Interview Cz*						

Table 9: Gap Analysis of APQP Element 27 ‘Review at Supplier’

APQP Element	**Phase**	**Nr.**	**Name**	**Defination**			
	Phase 3 Process Design & Development	**27**	Critical Characteristics Matrix – Review at Supplier	Review on-site at the suppliers manufacturing location.			
Selected NPD Steps	**Phase**	**Nr.**	**Name**	**Responsibile**	**Workinstructions/ Formula**	**Input**	**Output**
	PR	G6.08	Audit of Process Capabilities purchased parts	Supplier Quality	AA BE-311 Lieferantenaudit & Besuche	CTQ list; production and quality concept.	Production processes & parts released.
Difference Δ Yes /No	No Difference, 90% same, end of action should be defined						
Remark	Interview May*						

Table 10: Gap Analysis of APQP Element 30 ‘Measurement Sys. Evaluation’

APQP Element	**Phase**	**Nr.**	**Name**	**Defination**			
	Phase 4 Product/Process Validation	**30**	Measurement Systems Evaluation	Measurement system evaluation			
Selected NPD Steps	**Phase**	**Nr.**	**Name**	**Responsibile**	**Workinstructions/ Formular**	**Input**	**Output**
	P3	G5.02	Initial Sample Tests	Product Development; Supplioer Quality	RON 436 - Ablauf bei Erstmusterprüfung	Parts; ISIR from supplier, FSR reports in SAP (measurement and lab reports) and dates from ZCAS	Installation test completed in EMP report, functional test completed.
Difference ∆ Yes /No	No Difference, 90% same, end of action should be defined						
Remark	Interview May*						

Table 11: Gap Analysis of APQP Element 31 ‘Process Capability Studies’

APQP Element	**Phase**	**Nr.**	**Name**	**Defination**			
	Phase 4 Product/Process Validation	**31**	Process Capability Studies	Process Capability Plan			
Selected NPD Steps	**Phase**	**Nr.**	**Name**	**Responsibile**	**rkinstructions/ Form**	**Input**	**Output**
	P3	G5.02	Initial Sample Tests	Product Development; Supplioer Quality	RON 436 - Ablauf bei Erstmusterprüfung	ISIR from supplier, FSR reports in SAP (measurement and lab reports) and dates from ZCAS	Installation test completed in EMP report, functional test completed.
Difference △ Yes /No	No Difference, 90% same, end of action should be defined						
Remark	Interview May*						

Table 12: Results of Gap Analysis for all APQP Elements - A

APQP			Relevent NPD Steps		Gap
Phase	Nr.	Name	Nr.	Name	
Phase 1. Plan and Define Program	1	Design Goals	G0	Kick-off	No
			G1	Advanced Powertrain Concepts	
			G2	Project Execution Start	
			G2a	P1 Package	
			G3	Performance & Funtionality	
	2	Reliability & Quality Goals	G2	Project Execution Start	No
	3	Preliminary BOM	G1	Advanced Powertrain Concepts	No
			G2	Project Execution Start	
	4	Preliminary List – Special Product & Process Characteristics	G2a	P1 Package	No
			G2b	P1 Assembly	
	5	Preliminary Process Flow Chart	G2a	P1 Package	No
			G2b	P1 Assembly	
			G3	Performance & Funtionality	
	6	Supplier Quality Audit	G3	Performance & Funtionality	No
	7A	Supplier Project Team Commitment	Empty		Yes
	7B	Supplier Commitment to PPAP Process	G2a	P1 Package	No
			G2b	P1 Assembly	
			G3	Performance & Funtionality	
Phase 2. Development	8	Design Failure Mode Effects Analysis(DFMEA)	G2b	P1 Assembly	No
			G3	Performance & Funtionality	
	9	Design Reviews (w/supplier)	G2	Project Execution Start	No
			G2b	P1 Assembly	
			G3	Performance & Funtionality	
	10	Design Reviews "Actions" completed	Empty		Yes
	11	Drawing & Specification Changes (design freeze)	G2a	P1 Package	No
			G2b	P1 Assembly	
			G3	Performance & Funtionality	
			G4	Concept Raliability	

Table 13: Results of Gap Analysis for all APQP Elements - B

APQP			Relevent NPD Steps		Gap
Phase	Nr.	Name	Nr.	Name	
Phase 2. Development			G5	Engineering Relase	
			G6	Rroduction Readiness	
	12	Engineering Drawing Released	G2a	P1 Package	No
			G2b	P1 Assembly	
			G3	Performance & Funtionality	
			G4	Concept Raliability	
			G5	Engineering Relase	
			G6	Rroduction Readiness	
	13	Equipment	G1	Advanced Powertrain Concepts	No
			G2	Project Execution Start	
			G2a	P1 Package	
			G2b	P1 Assembly	
			G3	Performance & Funtionality	
			G5	Engineering Relase	
	14	Tooling and Facility Requirements	G1	Advanced Powertrain Concepts	No
			G2	Project Execution Start	
			G2a	P1 Package	
			G2b	P1 Assembly	
			G3	Performance & Funtionality	
			G5	Engineering Relase	
	15	Special Product and Process Characteristics	G2b	P1 Assembly	No
			G5	Engineering Relase	
			G6	Rroduction Readiness	
	16	Gages and Test Equipment	G1	Advanced Powertrain Concepts	No
			G2	Project Execution Start	
			G2a	P1 Package	
			G2b	P1 Assembly	
			G3	Performance & Funtionality	
			G5	Engineering Relase	
	17	Tier 2 Suppliers Design Review	Empty		Yes

Table 14: Results of Gap Analysis for all APQP Elements - C

APQP			Relevent NPD Steps		Gap
Phase	Nr.	Name	Nr.	Name	
Phase 3. Process Design & Development	18	Packaging Standard	Empty		Yes
	19	Packaging Specification	Empty		Yes
	20	Process Failure Mode and Effects Analysis (PFMEA)	G2b	P1 Assembly	No
			G4	Concept Raliability	
			G5	Engineering Relase	
	21	Process Flow Chart (final)	G5	Engineering Relase	No
			G6	Rroduction Readiness	
	22	Preliminary Process Capability Plan	G5	Engineering Relase	No
			G6	Rroduction Readiness	
	23	Pre-Launch Control Plan	G3		No
			G5	Engineering Relase	
			G6	Rroduction Readiness	
	24	Process Instructions	G4		No
			G5	Engineering Relase	
			G6	Rroduction Readiness	
	25	Measuring System Analysis (G R & R) - Plan	G5	Engineering Relase	No
			G6	Rroduction Readiness	
	26	Product/Process Quality System Review	Empty		Yes
	27	Critical Characteristics Matrix – Review at Supplier	G6	Rroduction Readiness	No
Phase 4 Product/Process Validation	28	Production Control Plan	G5	Engineering Relase	No
	29	P3 & PPAP Production Trial Run	G5	Engineering Relase	No
	30	Measurement Systems Evaluation	G5	Engineering Relase	No
	31	Process Capability Studies	G5	Engineering Relase	No
	32	Packaging Evaluation	Empty		Yes
	33	P3 Engineering Validation Testing	G5	Engineering Relase	No
	34	PPAP Production Validation Testing	Empty		Yes
	35	Production Part Approval Process (PPAP)	G6	Rroduction Readiness	No
	36	Quality Planning Sign-Off	Empty		Yes

3) Insufficient Using of Standard Documentation Formats

The company BRP-Powertrain has good procedures and practices in NPD process, which can share to the relevant APQP element. From observation, the work instructions and techniques are used, but not standardized in procedures. It is realized that it should be necessary to investigate to understand why the standard tools are not efficient in utilization.

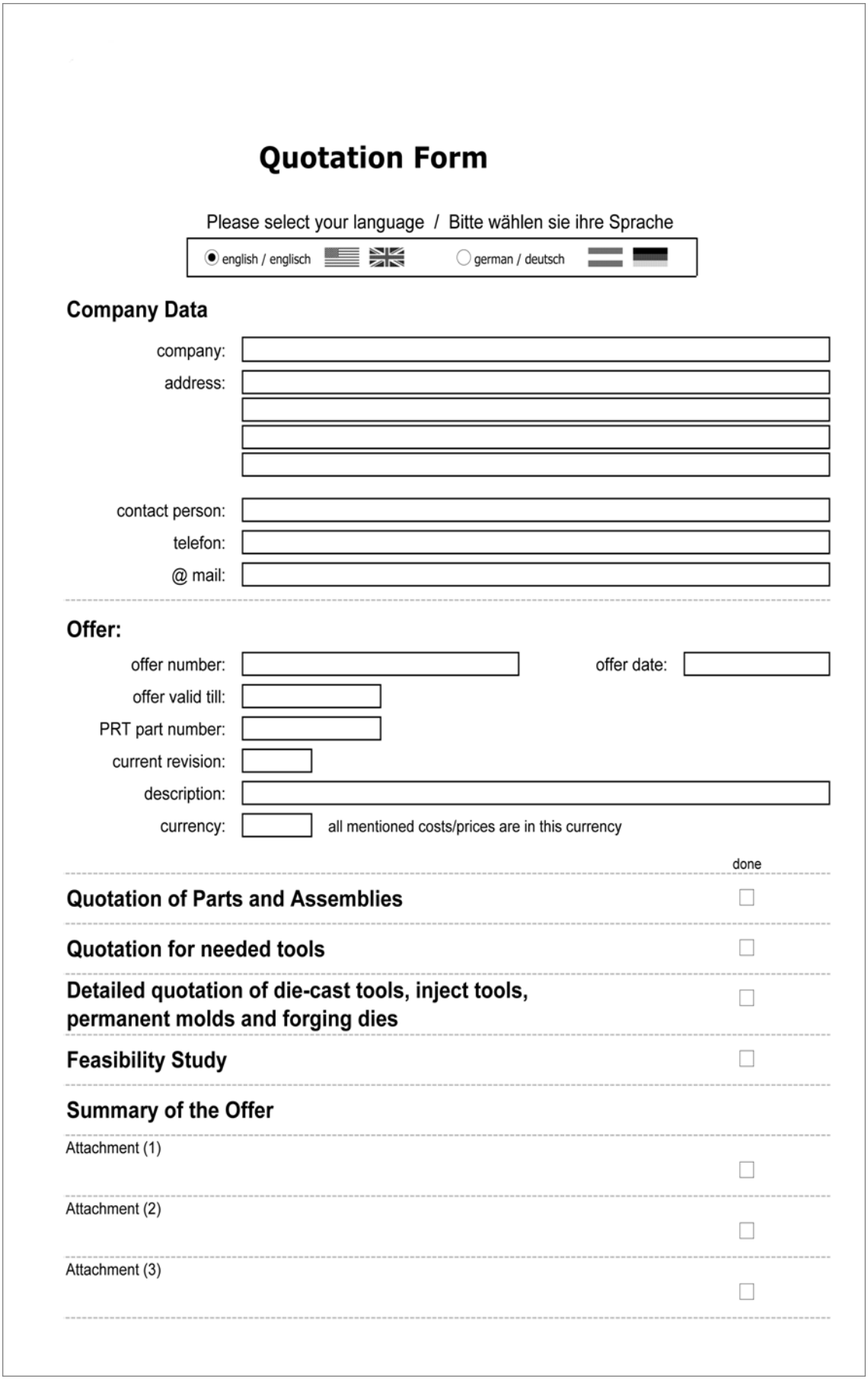
In the early stage of APQP, phase 'Plan and define program', there is a sub process 'Preliminary Process Flow Chart'. The definition of this element is: The supplier should give a representation of the production process with a preliminary process flow chart (APQP 2008). This preliminary process flow chart is a simplified description of the planned sequence of operations, at a minimum, the items listed in Table 15 should be considered by the Product Quality Planning Team (Schaeffler 2003).

Table 15: Items in 'Preliminary Process Flow Chart'

Aim	To provide a foundation for investment planning, Process FMEA, production plan, control plan and visual aids.
Expectations	To ensure the sequence of all mass production stages and inspection stages from goods inwards through to goods issue.
Documentation with supplier	1) Process flow diagram 2) Machine setting plan

It was observed by interviewees that the definition of this APQP element is very similar to one sub process of supplier selection (Figure 18) within the NPD process. At beginning of this process, the selected supplier receives an inquiry email from buyer of BRP-Powertrain with attachment of a specific BRP-Powertrain Quotation Form (Figure 17) and is requested to fill out the form. This form contents a formal statement of promise: company data, offer, quotation of parts and assemblies, quotation for needed tools, detailed quotation of cost tools, inject tools, permanent molds and forging dies. It also contains terms of process flow diagram and machine setting plan which are very in line with APQP's requirements.

After this form is filled out and sent back by supplier, the buyer should manually enter the data into BRP-Powertrain's supplier portal which is a SAP-ERP based information platform.



Quotation Form

Please select your language / Bitte wählen sie ihre Sprache

(•) english / englisch ( ) german / deutsch

Company Data

company:

address:

contact person:

telefon:

@ mail:

Offer:

offer number: offer date:

offer valid till:

PRT part number:

current revision:

description:

currency: all mentioned costs/prices are in this currency

	done
Quotation of Parts and Assemblies	☐
Quotation for needed tools	☐
Detailed quotation of die-cast tools, inject tools, permanent molds and forging dies	☐
Feasibility Study	☐
Summary of the Offer	
Attachment (1)	☐
Attachment (2)	☐
Attachment (3)	☐

Figure 17: Quotation Form

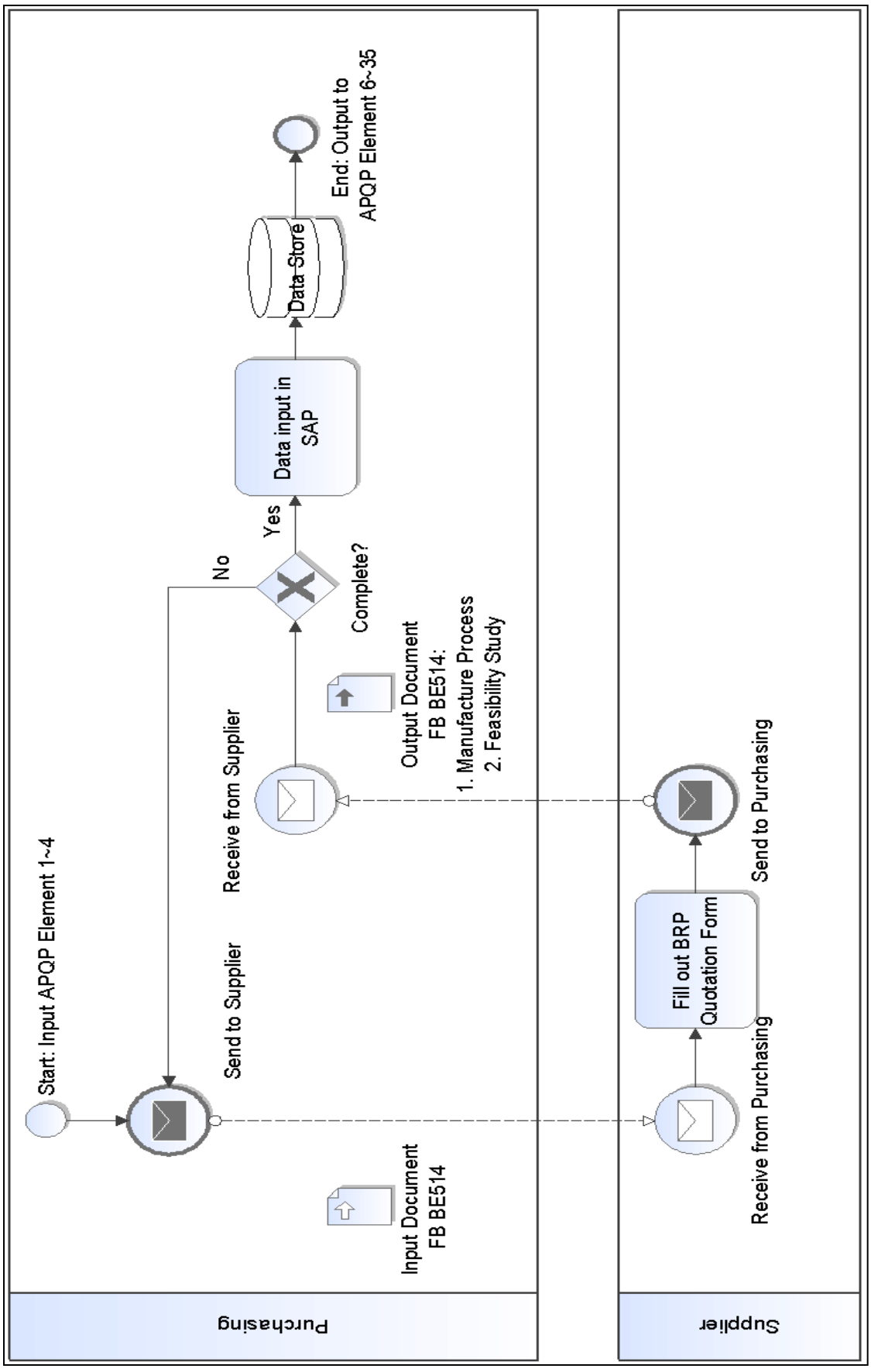


Figure 18: Process Flow of ‘Preliminary Process Flow Chart’

But the BRP-Powertrain NPD process currently does not have a uniform format for this operation process. Project teams carry out this process by different individual methods, and the mentioned BPR-Powertrain Quotation Form is not 100% in use. In order to further analyze this problem, 10 parts were selected randomly from different current product development projects, the relevant buyers are asked by researcher how important the standard Quotation Form in the reality and if it is not used what is the reason?

The result shows: only 20% employee are using the BPR-Powertrain Quotation Form (see Figure 19 and 20).

ID	Material	Short Text
1	900210191	VENTILDECKEL
2	900210291	STEUERTRIEBDECKEL
3	210612	GENERATORFLANSCH
4	900210897	KUPPLUNGSDECKEL KPL.
5	900225053	DAEMPFERFILTER
6	910265834	KABELBAUM
7	900434856	LOSRAD
8	910436255	KETTENSPANNSCHIENE KPL.
9	900630292	FORMDICHTUNG
10	835091	DOPPELRAD

Figure 19: Part List in Study of BRP-Powertrain Quotation Form

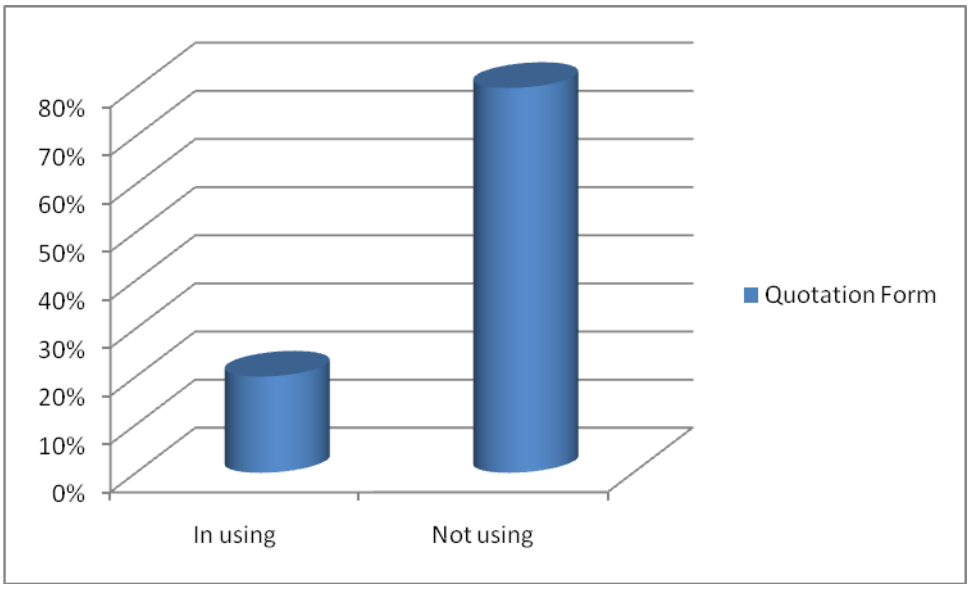


Figure 20: Statistics of using BRP-Powertrain Quotation Form

As follows is a description of the reasons:

- The quotations form is usually used for potential new suppliers/ complete new product parts;
- This form is suitable for parts cost > one Euro and quotation for a very limited number of parts is not necessary to use this form;
- It is not compulsory to use this form.

In the practice, the prescribed procedures are handled very individually and the standard BRP-Powertrain Quotation Form in this process is not efficiently used in the operation process, is less concerned about process format and continuity. This current process is very costly in terms of format and continuity.

The requirements of APQP are not taken in mind at the sufficient level. In order to reach the aspired level of performance, according to the APQP, its process flow must be clearly defined. Implementation of the modular APQP tools will help project teams better understand the suppliers in the early product design phase, at least in term of process standardization. The creation of this standard modular APQP element will be done in the chapter 4.

4) Missing Consistency of Information Exchange

Regarding to the complexity of communication and data exchange occurring among the system integrator has to widely examine the functions of internal operation management and the modes of external communication (Figure 21) (Ben, R. 2011).

Since many years, BRP-Powertrain hast established his ERP system that support a variety of business functions. Theoretically all the necessary information is stored in this database. People in different departments all see the same information and can update it, when one department finishes with the tasks it is automatically routed via the ERP system to the next department. A case study was carried out based on the reality of information exchange in BRP-Powertrain.

All parts used in the production of engines by BRP-Powertrain are subject to a system of classification which enables all parties concerned (in-house or external) to plan and implement their processes with regard to the type and application of the component. The parts are classified according to the origin of their designs and according to a rating depending on their application.

The quality label indicates the extent of supervision required, as estimated by the Quality Department of BRP- Powertrain. It is also a method to express how critical a part is for the engine.

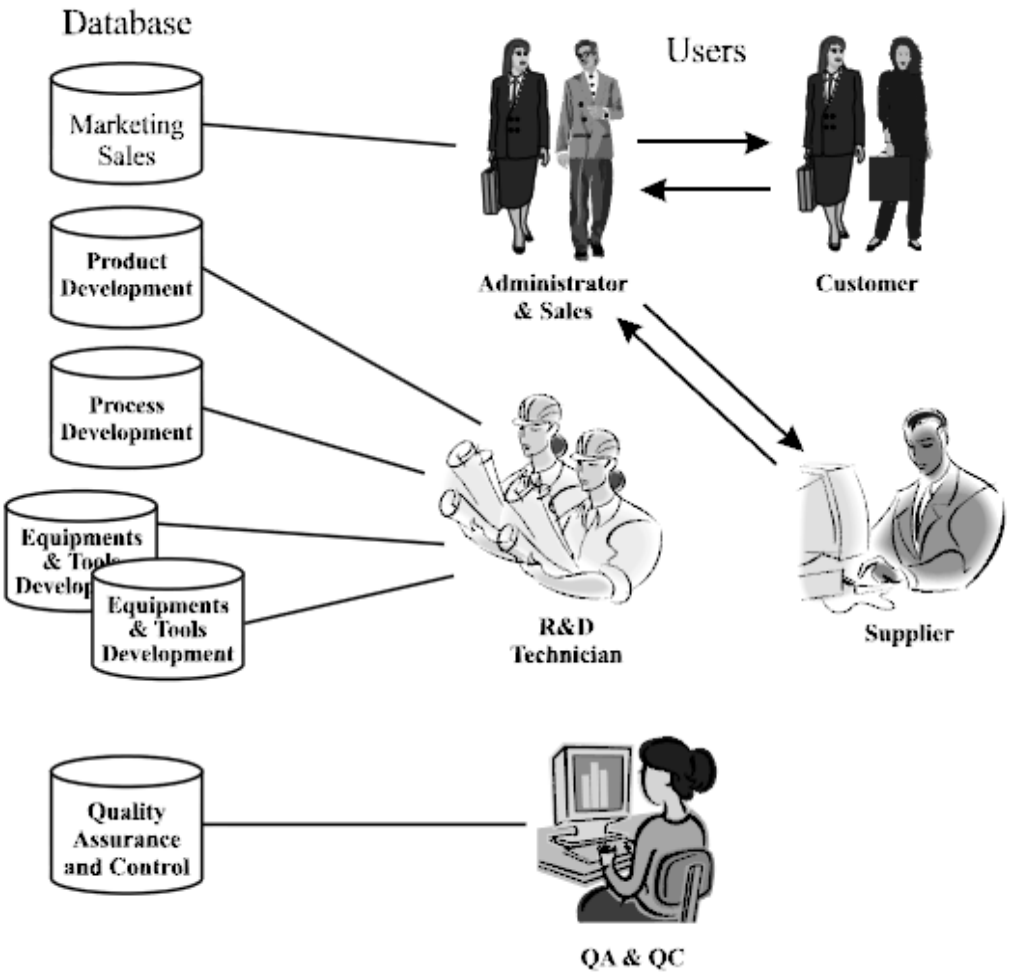


Figure 21: Dispersed and Separated Resource Allocation (Ben, R. 2011)

BRP-Powertrain makes the following minimum requirements on the suppliers according to the parts categories as listed in a chart. Parts with the quality labels ‘A2’, ‘A3’, ‘R2’ and ‘R3’ are combined with feasibility analysis. The submission of an offer to produce such parts requires a feasibility analysis (with the help of a BRP-Powertrain Feasibility Form (See in Figure 22)), in which the supplier details his ability to produce the requested part within the constraints of the system at his disposal.

In the supplier selection phase, after receiving this feasibility study form from supplier, the data should be saved into the BRP-Powertrain SAP system in order to enhance the efficiency of information exchange. In the research work completed by BRP-Powertrain supplier quality engineer, Kurt Irion, shows that the implementation of this process is very individual. If this quotation is not carried out via supplier portal, like via email, this feasibility study should be manually stored in SAP, otherwise it will not be found in SAP system.

FEASIBILITY STUDY
MACHBARKEITSANALYSE

Supplier / Lieferant:	
Part Name / Teilebezeichnung:	
Part Numb. / Teile Nr.:	
Revision:	
Offer Number / Angebotsnummer:	
Date / Datum:	
Offer valid until / Angebot gültig bis:	
Name / Name:	

Feasibility Study * / Machbarkeitsanalyse *

1. *Is the product sufficiently specified, in order to be able to provide a feasibility analysis?*
Ist das Produkt ausreichend spezifiziert um eine Machbarkeitsanalyse ausführen zu können? ○ yes / ja

---

2. *Is the product reliably producible by you and your possibly selected sub-suppliers, in accordance with the provided documents?*
Ist das Produkt gemäß den Vorgabedokumenten von Ihnen und eventuellen Sublieferanten prozesssicher herstellbar? ○ yes / ja

---

3. *Is a provisional manufacturing concept and a test concept available? If so, pls. enclose it for BRP analysis.*
Liegt ein vorläufiges Fertigungs – und Prüfkonzept vor? Wenn ja, Beilage zur Analyse. ○ yes / ja

---

4. *Do you identify any "specific characteristics" relevant to manufacturing? If yes, how do you plan to manufacture and control it?*
Ergeben sich aus Lieferantensicht fertigungsrelevante "besondere Merkmale"? Wenn ja, welche und wie sieht die Fertigung und Kontrolle aus? ○ yes / ja

---

5 a. *Are there any plans to outsource processes (e.g. heat treatment, coating, machining, ect.), if so, which?*
Sind fremdvergebene Prozesse (z.B. Wärmebehandlung, Beschichtung, Bearbeitung, usw.) geplant, wenn ja welche? ○ yes / ja

5 b. *Is the quality responsibility for these external processes covered within your total quality responsibility of the product?*
Wird hierfür die Systemverantwortung übernommen? ○ yes / ja

---

6. *Are there any characteristics, materials or processes which, if they would be modified, would lead to a cost reduction and/or a quality improvement?*
Gibt es Merkmale, Werkstoffe oder Prozesse bei denen eine Veränderung zu einer Kostenreduktion und/oder Qualitätsverbesserung führen würde? ○ yes / ja

---

7. *Are Terms & Conditions, RON's and engineering specifications available and understood?*
Sind alle Begriffe, Bedingungen, RON's und "engineering specifications" verfügbar und verstanden? ○ yes / ja

Figure 22: Feasibility Study Form

This will increase the workload of data exchange and difficulties in communication to internal and external in the future. Therefore, we need to consider re-designing the necessary process with APQP tools to improve the current process and the operational environment. Actually, BRP-Powertrain is starting to improve the supplier portal, which connects with SAP system, in order to bridge the information gap between different involved departments: suppliers, buyers, developments, etc. In the past couple of years increasingly manufacturing involvement on project teams has spurred increasing interest in SAP. Suppliers are beginning to get involved by SAP efforts with project team. In the future, BRP-Powertrain needs to continue increase its efforts and institutionalize of SAP system.

4 Create Modular APQP Elements

In this chapter, five elements from APQP process are selected to create as customized and standardized modular APQP elements. Based on the gap analysis results above in chapter 3, the researcher recommends the creation of 'Preliminary Process Flow Chart', ' Special Product and Process Characteristics', ' Critical Characteristics Matrix – Review at Supplier' and ' Measurement Systems Evaluation'. Furthermore, the researcher also recommends adding 'Process Capability Studies'. This selection decision is based on high prioritization of supplier quality by BRP-Powertrain Company's management.

In order to meet the APQP requirements of, a structured set of activities are designed. Policies, standards, guidelines, activities, and work instructions are defined as modular APQP elements (Ristow, R. 2002). They include all roles, responsibilities, tools and management controls to reliably deliver the outputs.

In this thesis, all flow charter processes are created graphically by iGrafx® FlowCharter®. iGrafx[3] ® Flow Charter ® is a simulation tool for process design. It offers the most comprehensive and user-friendly functions for process modeling and analysis, and helps organizations to understand and optimize their business processes. iGrafx simplifies the graphical representation of processes by which financial and operation information is easily understandable (iGrafx 2013).

4.1 APQP 5. Preliminary Process Flow Chart

Definition of APQP Element 5 Preliminary Process Flow Chart: The anticipated manufacturing process will be described using a process flow chart developed from the preliminary bill of material and product/process assumptions (APQP 2008).

Preliminary Process Flow Chart is a small but important facet in the APQP system. The need for preliminary process flow chart differs based on the complexity of the product being produced. The production flowchart shows how you intend to manufacture your product as stages, the equipment and tools you have planned to use and quality control check and displays the planning to ensure that these checks are written into the making sequence (V.Ryan 2010). The supplier quality engineer will check this process flow to meet the customer's requirements. The process should be as close as possible to the process used during mass production.

The standard "Preliminary Process Flow Chart", which should be filled out by suppliers, is created by BRP-Powertrain project team in the BRP-Powertrain Quotation Form FB BE-514 (Figure 19), but not commonly used.

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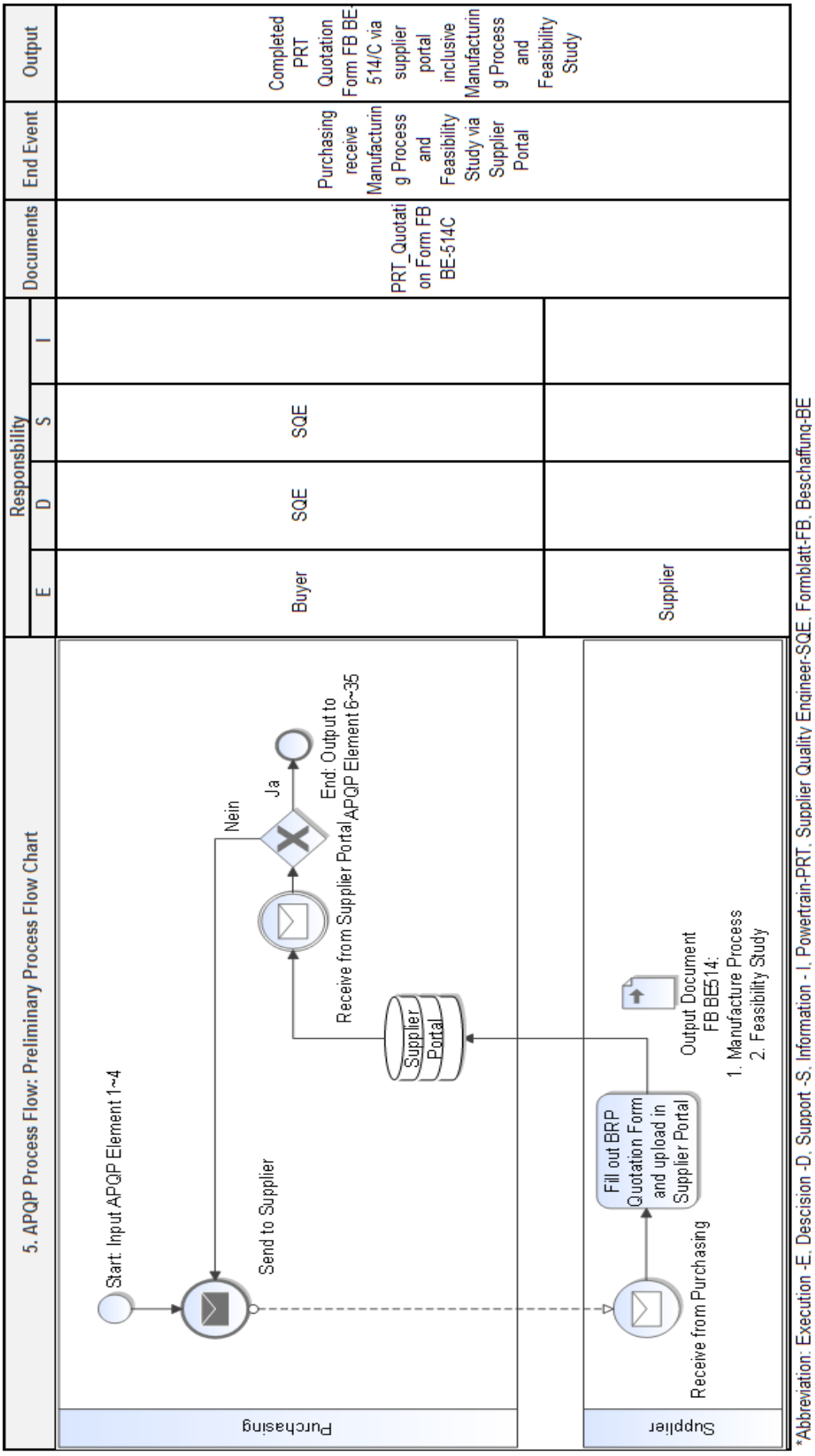

Figure 23: Modular APQP Element 5 Preliminary Process Flow Chart

As mentioned in chapter 3, at moment the implementation of quotation process and using of the standard quotation form at BRP-Powertrain are more or less individually.

According to APQP and ISO/TS 16949:2002's requirement, the researcher suggests continue to use this quotation form as necessary working sub process which must be performed in the quotation process. Since BRP-Powertrain project team was familiar with this form, only a little training will be required for implementation, if necessary.

On a more strategic level, the researcher proposes a long term solution based on the supplier portal and in this process the BRP-Powertrain Quotation Form FB BE-514 must be used. As mentioned before, BRP-Powertrain has established a supplier portal which connects to an electronic ERP software package SAP. The supplier portal is intended to improve communication with suppliers and facilitate the execution of certain processes (in Purchasing, Supplier Chain Management, Production, Product Development, etc.). It can be used for communication (viewing, downloading and confirming) of, among other things, schedule lines, JIT delivery schedules and returnable packages, as well as execution of the request for quotation / quotation or the initial sample process. It can also be used to send technical drawings and RONs. Suppliers on the BRP-Powertrain Supplier Portal shall have all necessary hardware and software to login the portal. The supplier can view the requests for quotations on the portal and give quotations online. Rollout of this modular APQP element will not require updating the supplier portal website on the Intranet.

Figure 23 shows the suggestion of researcher on this APQP element. Firstly a buyer in BRP-Powertrain sends a quotation request to a selected supplier. In this request, it will include the access information to the supplier portal and a request for filling out the BRP-Powertrain Quotation Form FB BE-514, inclusive of 'Preliminary Process Flow Chart' and 'Feasibility Study', if the supplier completes the form and submits the request via the supplier portal. This request data will be securely stored in SAP and the purchase remainder is automatically created and e-mailed to the requester. With support from suppler quality engineering, the buyer checks all RFQ inquiry documents and approves the use for quotation or request changes to design as necessary. If the RFQ Information meets the requirements, this APQP element will be closed and the quotation information will be used to the next step for sourcing meetings, otherwise, the buyer keeps communicating with suppliers until qualified information are fully submitted.

4.2 APQP 15. Special Product & Process Characteristics

Definition of APQP Element 15 Special Product & Process Characteristics: Special product and process characteristics element is built on element #4 "Preliminary List – Special Product & Process Characteristics. It is a result of the "design review". This element #15 is the supplier's response as to how they are going to address these critical characteristics in their control plan (APQP 2008).

Special Characteristics are product or process characteristics that affect safety or compliance with regulations, fitness, function, performance or subsequent processing of

product (Inteva 2012). Suppliers must be able to implement process controls for Special Characteristics and to identify Special Characteristics and to follow and support the BRP-Powertrain NPD process. The supplier must have the human and material resources required to meet these requirements.

In BRP-Powertrain, supplier quality engineers will meet with the concerned parties for this work package. Input shall be prepared and a supplier quality engineer will make a list of CTQs which describes the special characteristic features, as a basis, the list of which will be used as BRP-Powertrain Standard Form FB 08-001-1.

Supplier quality engineers create this list that lists all critical to function and manufacture features. In the project CTQ meeting, the points of all departments are included in the CTQ - list:

- Points from a technical perspective (experience, field...)
- Points from structural point of view (Design FMEA)
- Points from the production / acquisition (manufacturability, process stability)
- Points of assemblability , process stability
- Points of endurance testing from P1 to PPAP.

It must be ensured by the departments that these critical characteristics are taken into account in the default documents (drawings, test plan, control plan ...). The quality engineer maintains this list, and documents the progress, the information is stored in the CTQ database. The quality engineer makes a rough schedule of the CTQ projects at least once per quarter. Suppliers may be required to provide capability results according to the CTQ database defined by BRP-Powertrain project team.

As mentioned above, BRP-Powertrain company design team has a B2B Supplier Portal; it was extended by the module "initial sample inspection". Also this module will be used by all suppliers to manage the first sampling process more efficient and to improve the quality. On the initial sampling with B2B Supplier Portal supplier have to deliver the first sample report before the parts, which will be evaluated by the responsible supplier quality engineer. The delivery can only take place after positive findings of the initial sample report. In this report it will be provided the necessary information in response to the CTQ database.

Figure 24 shows the suggestion of researcher on this APQP element. Firstly, a supplier must be selected by the project team. To begin with, the supplier quality team in BRP-Powertrain sends a request to a selected supplier. In this request, it will include the access information to the supplier portal which includes the user name, password and link to portal. After log-on, in the selection screen, optional criteria can be selected (e.g. general information, logistics, product-lifecycle-mgmt, purchasing and quality).

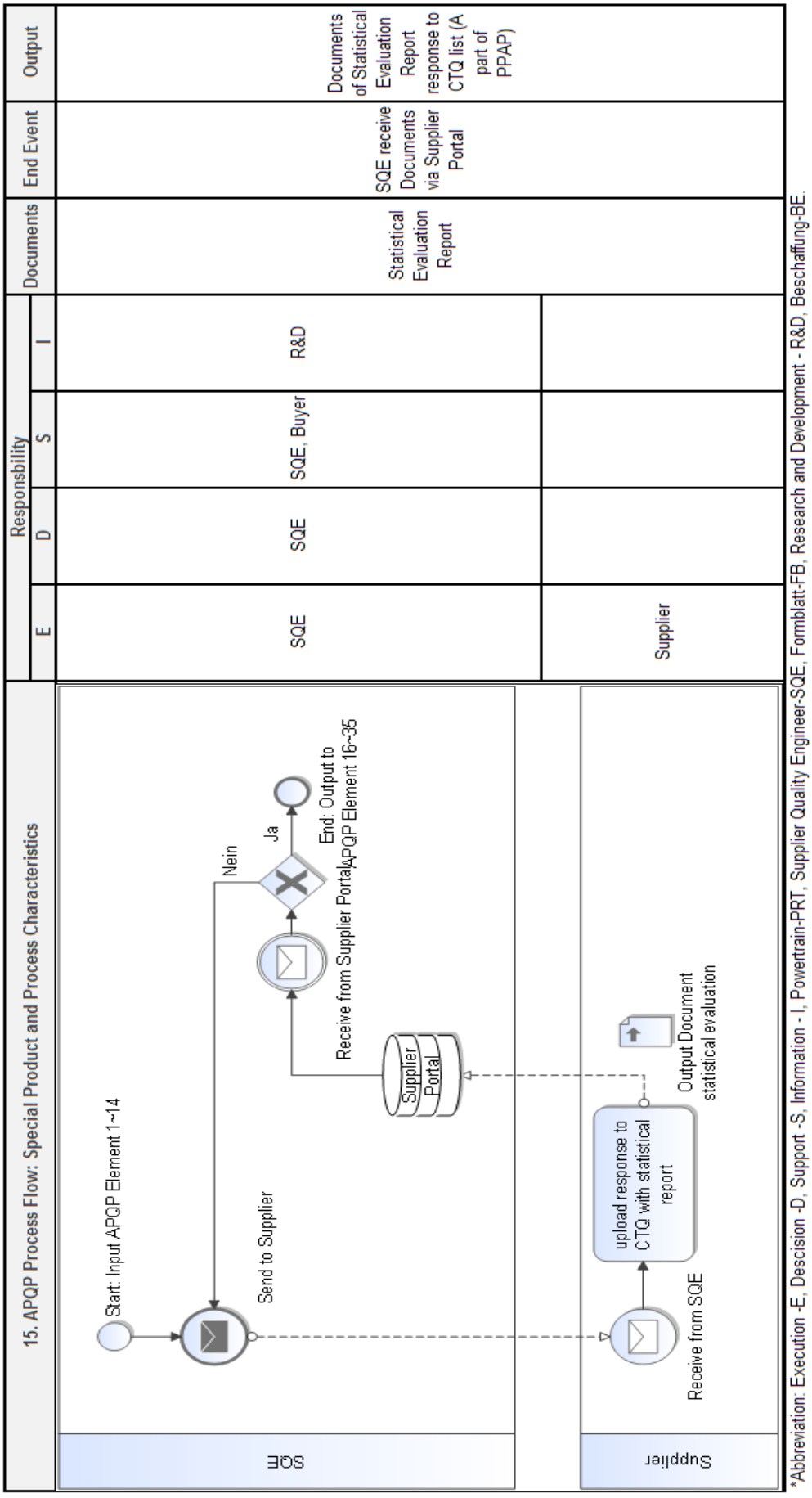

Figure 24: Modular APQP Element 15 Special Product & Process Characteristics

Figure 25: Supplier Portal Screen A (BRP 2010)

According to the APQP element special product & process characteristics, the area ‘Quality’ will be selected (Figure 25). After the click has been conducted based on corresponding criteria, initial sample inspection information are displayed with the appropriate status, which either displays actions to be carried out by SQ or describes the current vendor status (Figure 26 and 27). Document exchange between BRP-Powertrain and vendor takes place mainly via this internet page. In this window all documents "for BRP-Powertrain" and "from BRP-Powertrain" can be viewed, downloaded and uploaded. Cover sheets filled in (VDA or PPAP) are available to the vendor, who has to fill in his vendor-specific information. As the sampling reason as well as the sampling scope is defined by BRP-Powertrain, the required scope of the sampling is immediately visible for the vendor – this flow of information is particularly advantageous in terms of technical changes for reduced sampling - for new parts, a complete sampling is to be carried out in accordance with RON436, as usual. The documents are now signed (by the vendor and BRP-Powertrain) digitally in PDF format - so a written signature is not required.

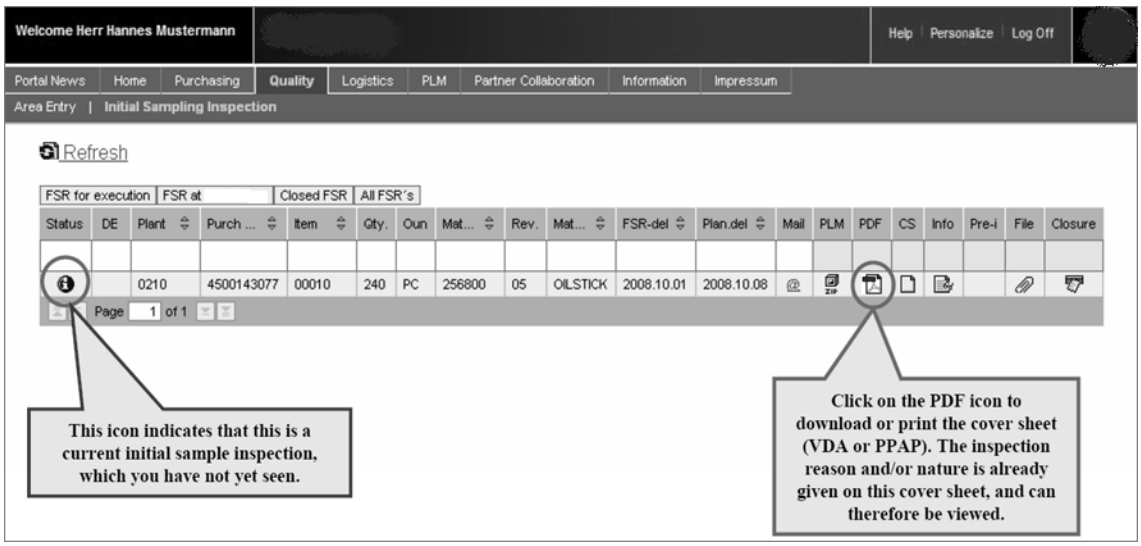

Figure 26: Supplier Portal Screen B (BRP 2010)

Furthermore, a version of the documents (incl. saving VDA and PPAP cover sheets in PDF format) is available, then click on the e-mail icon to send an e-mail to the supplier quality operator responsible for this initial sample inspection, this action is the end event of this APQP element.

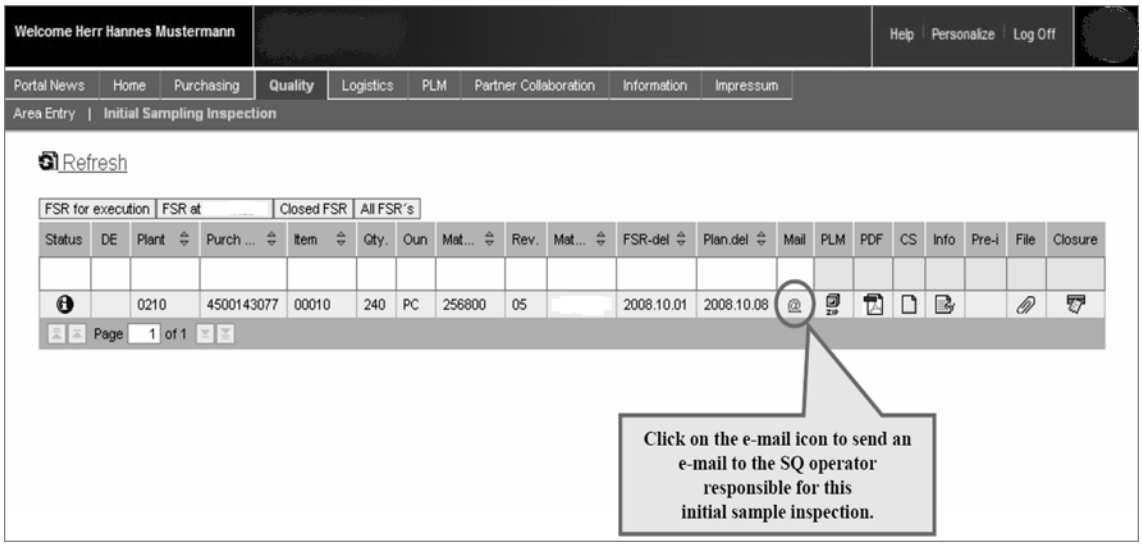

Figure 27: Supplier Portal Screen C (BRP 2010)

4.3 APQP 27. Critical Characteristics Matrix – Review at supplier

Definition of APQP Element 27 Critical Characteristics Matrix – Review at Supplier: this is a review of the critical characteristics matrix features controls, on-site at the suppliers manufacturing location (APQP 2008).

The business practices of suppliers have a direct impact on your organization. If you have a supplier whose required products are not delivered on time, it will directly affect revenues. Therefore, suppliers audit and review is a necessary part in a quality management system (Johnson, R. 2014). Critical Characteristics Matrix is generated at the Design Review and is completed as the validation process progresses. This document links designated and high risk features with the identified controls. Suppliers may use this document in support of the Pre-Production Control Plan ensure products are manufactured under controlled conditions and in conformity with the drawing and specification requirements (TRW 2012).

In BRP-Powertrain, the supplier audit and review will be comprehensively carried out in the factory with the manufacturer's rating of the quality system. It is an activity to assess a supplier's quality system. This audit is usually carried out before suppliers are chosen, but may be required at any time BRP-Powertrain deems it important. A quality audit also verifies some to the process audit elements, but only generically and limited to processes relevant to BRP-Powertrain.

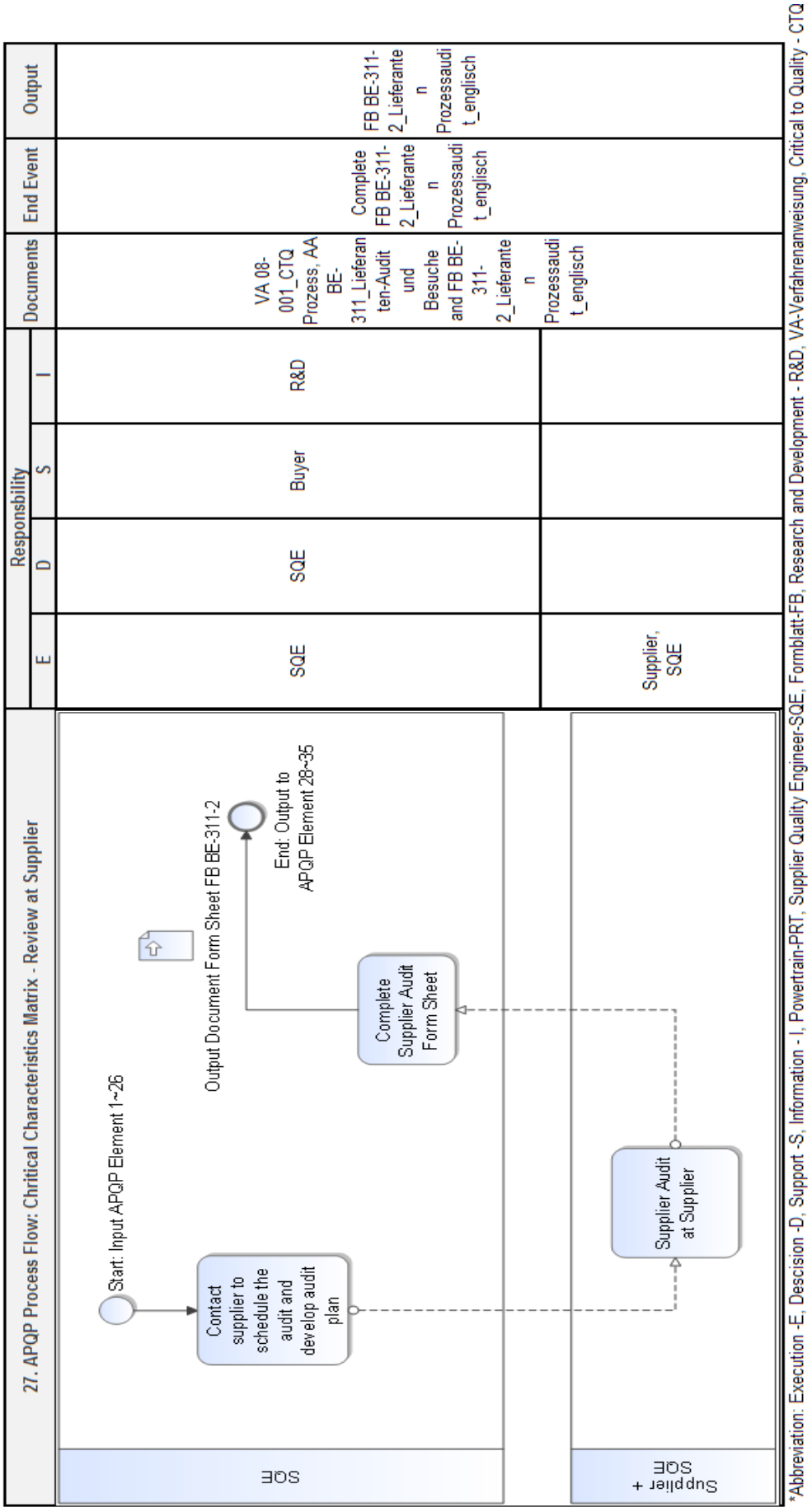

Figure 28: Modular APQP Element 27 Critical Characteristics Review at Supplier

	FORM SHEET Supplier Audit	Seite : 1 von : 16

1. Overall Evaluation

Audit No.:

Audit date:

Auditing Company:

Auditors:
Escort:

Audited company (short Supplier):

QM-System of the supplier:

Address:

Participants of the audited company:

Audited process/product/service:

Reason for the audit: Potential New Supplier ☐ Already Existing Supplier ☐ Aircraft(QSV) Audit ☐
Quality Problem ☐ Re-Evaluation ☐

Degree of conformity: %

Grading:

Comment:

Completion of action plan: For all major and minor nonconformities we expect an appropriate corrective action plan within 2 weeks latest. Major Non-conformities shall be closed within one month, Minor Non-conformities shall be closed within 3 month.

Responsibility/Scheduled date:

Date, Signature
Auditor(s)

Date, Signature
audited company

Figure 29: Supplier Audit Form

Another element subject to assessment is the supplier's capacity to follow and support quality development process. In this context, it is the supplier's development process, and their team's roles and responsibilities which will be assessed. The supplier will be notified in advance of the audit, and the documentation will send. It includes organization, procedures, equipment, tools and processes and is used to determine the extent to which the manufacturer is able to produce quality products for the production and / or spare parts requirements. To exam specific areas and processes of the supplier organization based on a defined CTQ database which are effectively implemented in practice. Write down the evaluation, with recommendations and supportive evidence by means of the BRP-Powertrain company Standard Form FB BE-311 (Figure 29).

If it shall be noted that the defects will be marked if found during the audit and review process. Provide the supplier with the evaluation and discuss the concerns your supplier has. If form sheet FB BE-311 is completed by the supplier quality engineer, it means this APQP element is closed. Figure 28 shows the suggestion of researcher on this modular APQP element.

4.4 APQP 30. & 31. Measurement Systems Evaluation & Process Capability Studies

Definition of APQP Element 30 Measurement Systems Evaluation: The specified measurement devices and methods shall be used to check the control plan identified characteristics to engineering specification and subjected to measurement system evaluation during or prior to the production trial run (APQP 2008).

Definition of APQP Element 31 Process Capability Studies: These are the results of element # 22 "Preliminary Process Capability Plan. It is provided from the supplier for review by the Quality Engineer at this stage before PPAP is formally submitted so there is adequate time for evaluation/action plans before production is required (APQP 2008).

As mentioned above, the initial phase of new supplies must be effected smoothly, in the interest of economic efficiency. Product characteristics shall be agreed in the form of specifications and supply contracts. Any deviation is a disturbance which will consequently increase costs. Supportive evidence shall be supplied for the initial samples that the supplier is able to meet the specifications required by BRP-Powertrain under serial production conditions.

In the case of serial parts manufactured for the first time or changed, features are checked and documented in measurement reports. These are dimensional, material and / or functional tests of initial samples with regard to all specifications agreed between BRP-Powertrain and supplier. Compilation of all the given set data and actual data. Initial sample test reports must be submitted in German or English.

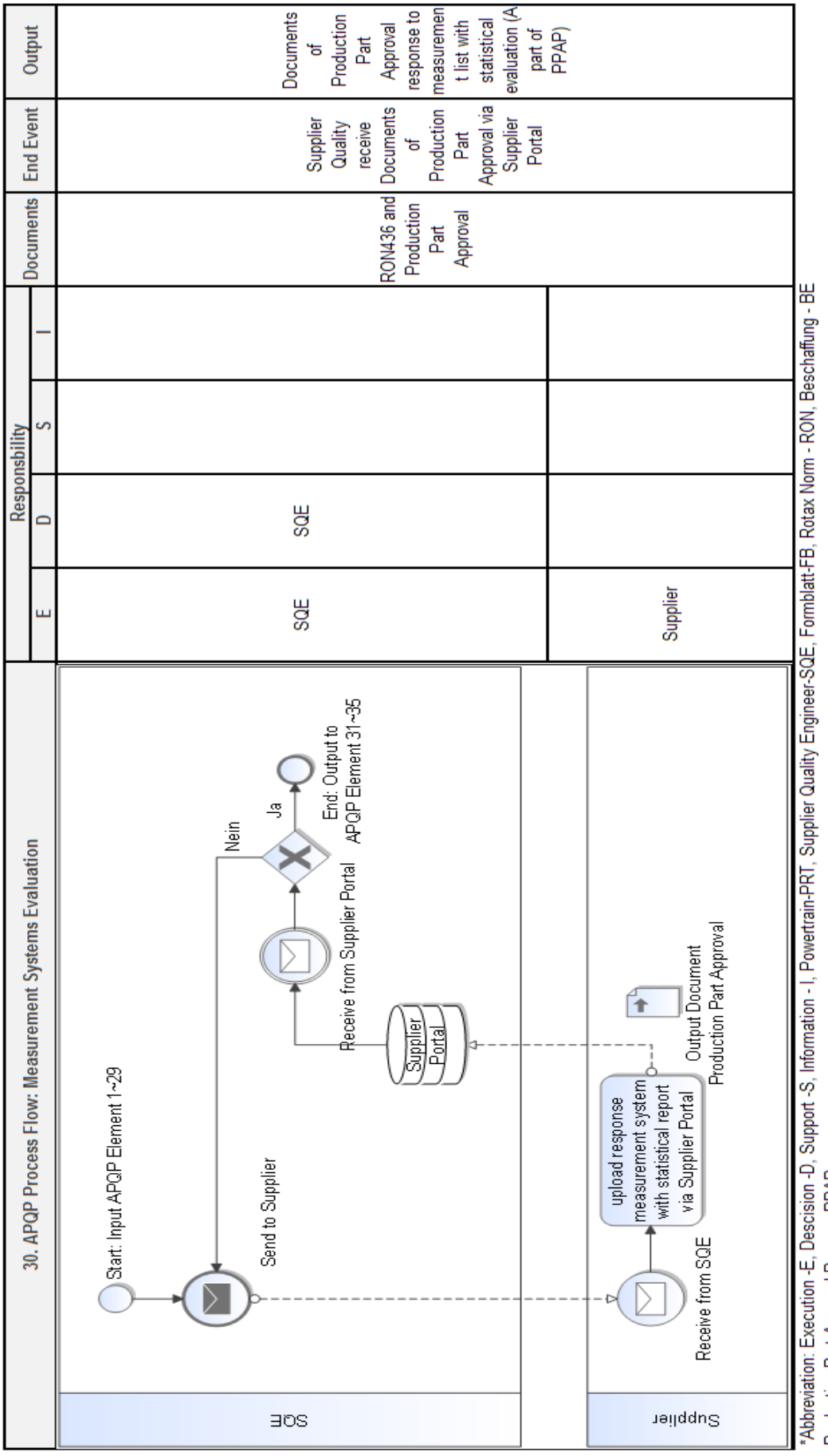

Figure 30: Modular APQP Element 30 Measurement Systems Evaluation

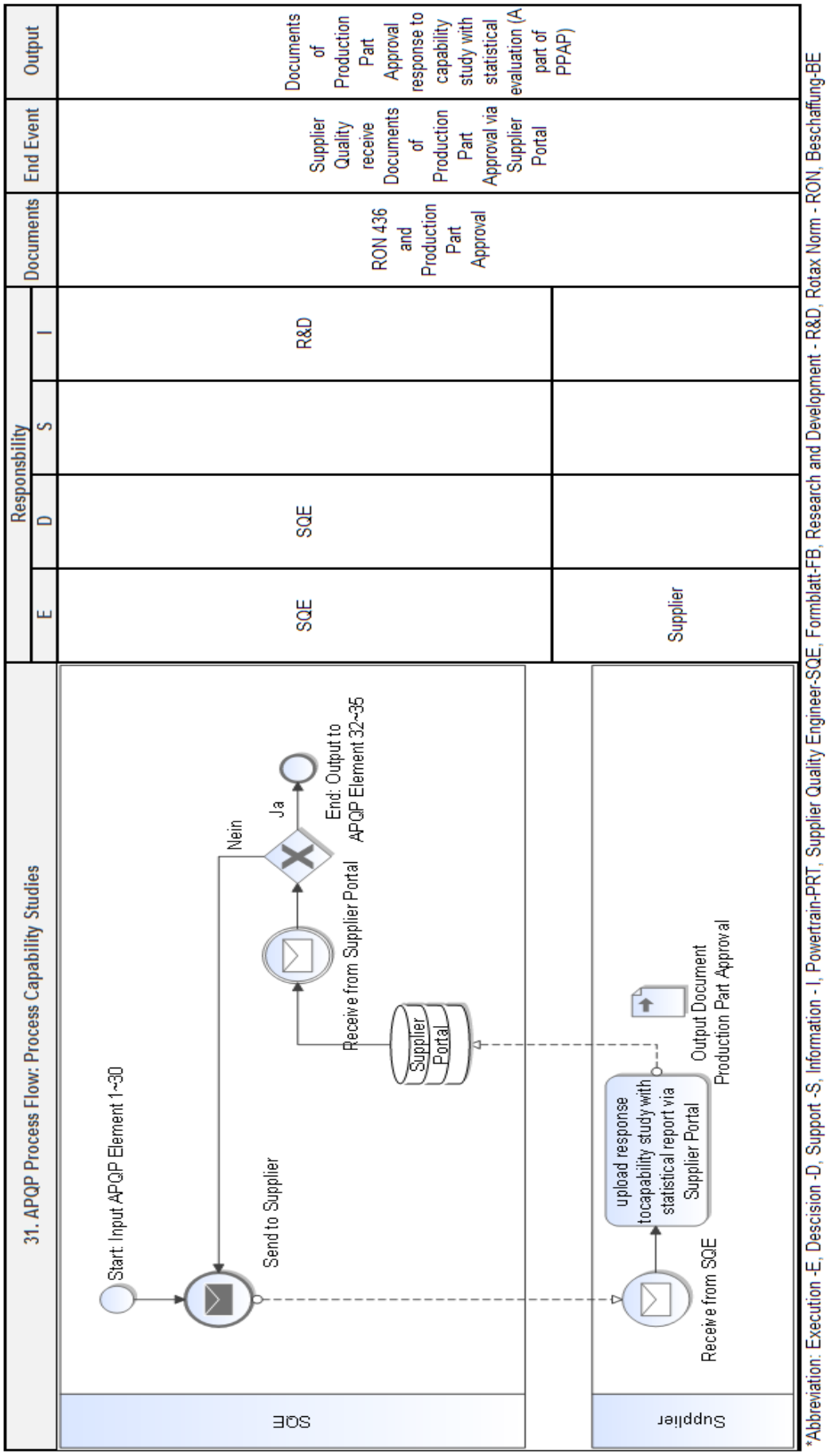

Figure 31: Modular APQP Element 31 Process Capability Studies

According to the APQP elements: Measurement Systems Evaluation and Process Capability Studies, the initial sample test report shall include the list of tools and devices and process capability study. These procedures are carried out by BRP-Powertrain Supplier Portal which was mentioned in section 4.1 and 4.2. Firstly, the supplier quality engineer from BRP-Powertrain sends request to the selected supplier. The supplier adds the completed initial sample test report cover sheet with the completed test results sheets via supplier portal. The header of the test results sheet must be completely filled in to identically match the contents of the cover sheet. The supplier then uploads the completed Production Part Approval Process report together with the initial sample parts to BRP- Powertrain. The initial sample parts and packaging are clearly labeled.

BRP-Powertrain (the buyer) inspects the initial sample/initial sample report as they see it proper, writes down the results on the assessment page, and returns the initial sample test report and the decision to the supplier. If the results meet the requirements, this APQP element will be closed and the information will be used to the next step, otherwise, the buyer and supplier quality engineer would communicate with suppliers until qualified information are fully submitted. Figure 30 and 31 show the suggestions of researcher on these modular APQP elements.

5 Implementation and Evaluation

5.1 Implementation

The new created customized and standardized modular APQP element ‘Process Capability Studies’ is now selected to be tested in the actual engine project. As mentioned in gap analysis (section 3.3), this process should be connected with NPD process Gate 5 (Prototype 3 phase). The defined content of this element (process flow, responsibility, documents, end event and outputs) has been discussed with the project teams to help them understand the process in a better way.

Crankshaft is a very important part in combustion engine which transfers the combustion energy into kinetic energy in form of rotation; therefore it is important in the crankshaft manufacturing processes to keep the product quality (e.g. diameter, length …) within the defined engineering tolerances. In this real case, the company Y Industry is supplier of crankshaft (Figure 32) for BRP-Powertrain. They primarily produce precision tools, agricultural machinery, precise parts for automobile and motorcycle.

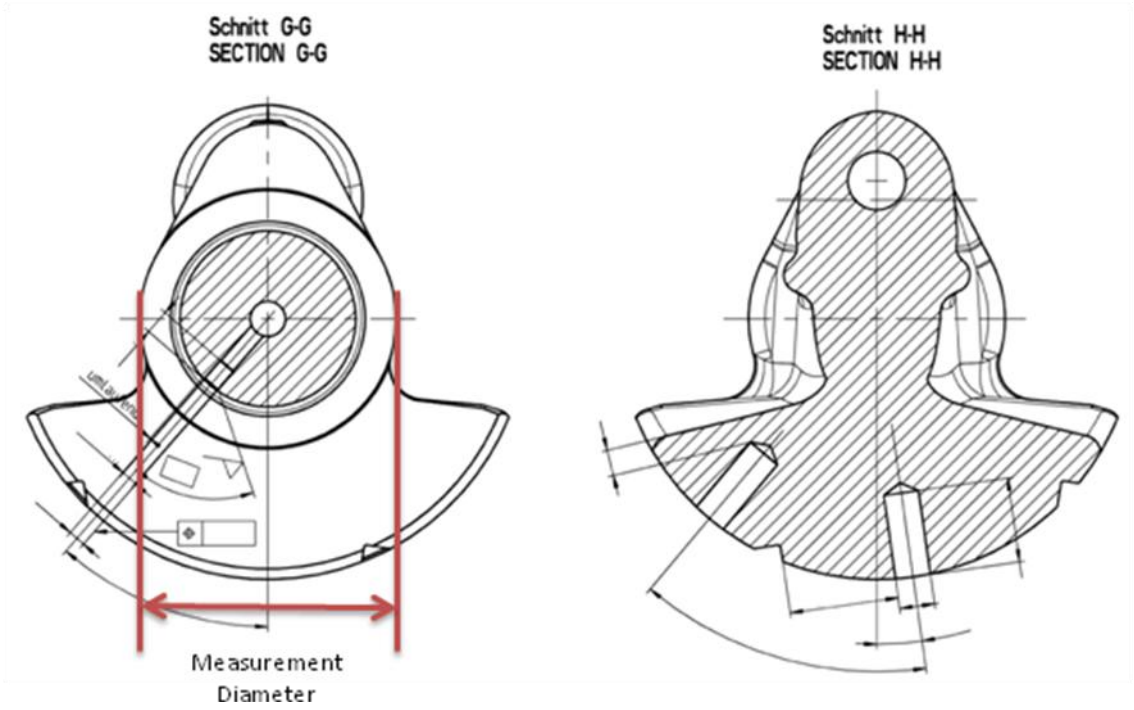

Figure 32: Crankshaft

As the figure 31 shows, the suggested process flow for ‘Process Capability Studies’, this APQP element carries out in following steps:

Step 1. The supplier quality engineer of BRP-Powertrain contacts the company Y Industry to request a process capability study of the product crankshaft. Communication

mainly takes place via the tab "Text" and is structured like a "Chat", which contains a history. Communication is possible at every status - upon saving the company Y Industry is notified by e-mail that there is a new message in the portal (see in Figure 33).

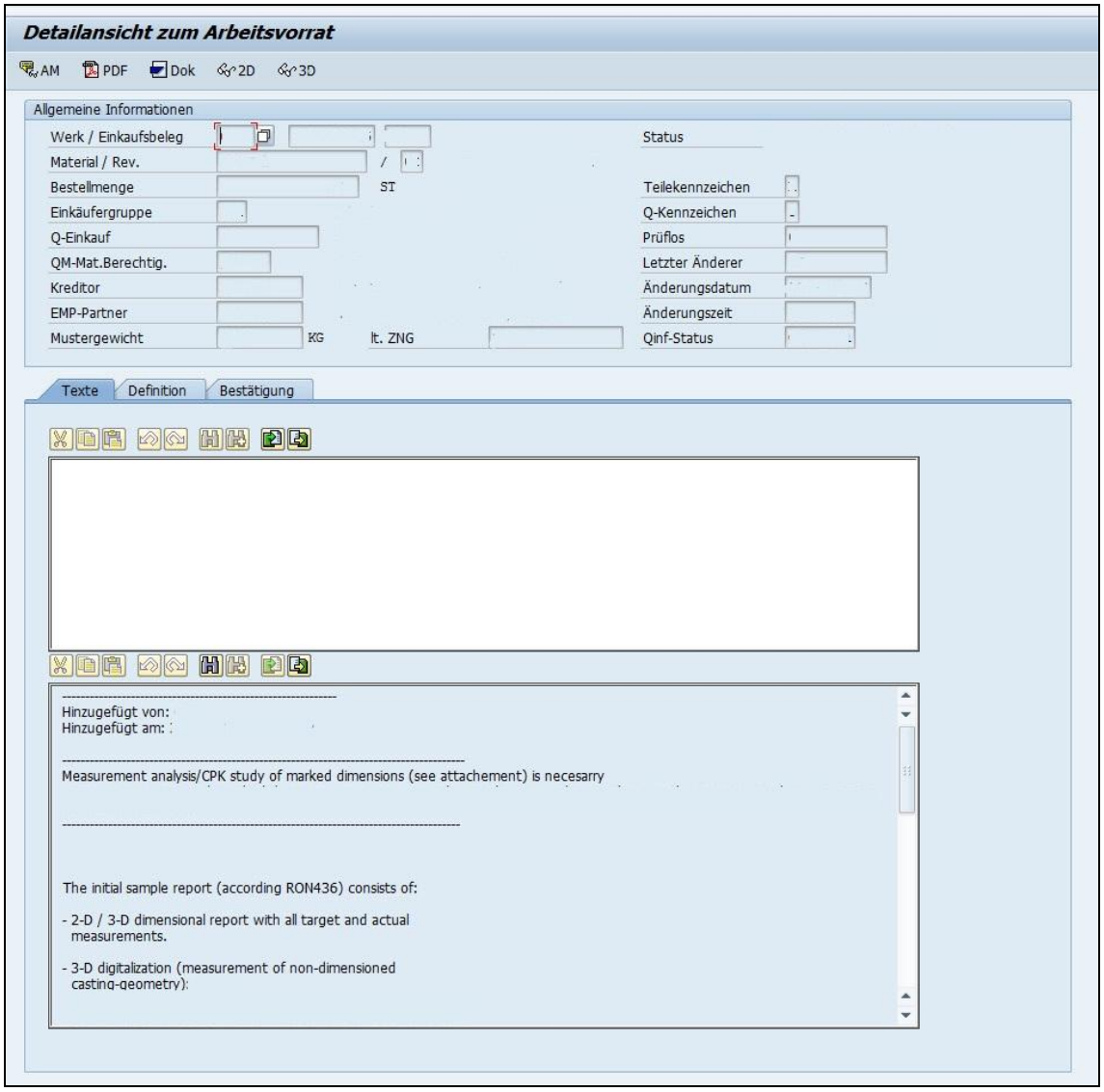

Figure 33: SQE Request via Supplier Portal

After the request sending, the supplier quality engineer keeps in touch with the company Y Industry, in order to make sure all design and specification requirements are properly understood by the Y Industry and that the process will develop the potential to produce product in conformity with the requirements during the production process.

Step 2. Based on the historical production issues, the supplier Y Industry spends some time in summarizing a documentation of production part approval process (PPAP). This report is to be drawn up according to international standards such as VDA volume 2 (VDA 2012), or QS-9000 PPAP in the 3rd level (PPAP 2006). It consists of two different sections: a cover sheet and any number of sheets for test results.

Cover sheets which are already filled in (VDA or PPAP) are made available to the Y Industry, who must fill in Y Industry -specific information (obligatory fields are marked with a red asterisk).

As the sampling reason as well as the sampling scope is already defined by BRP-Powertrain, the required scope of the sampling is immediately visible for the Y Industry – this flow of information is particularly advantageous in terms of technical changes for reduced sampling - for new parts, a complete sampling is to be carried out in accordance with RON436, as usual.

The purpose of this report is to determine if the production process will produce product that meets the customer BRP-Powertrain's requirements. In the documentation from company Y Industry, according to the requirements from BRP-Powertrain, a detail description of the capability study of the crankshaft diameter is given in the following analysis. In this analysis, we use the measurement data of diameter from company Y Industry to determine process capability based on Q-DAS Software. According to international standards ISO 7870 (ISO 2012), this analysis can also be carried out in other format with control charts (detail calculation in Appendix B).

Table 16: Measurement of Crankshaft Diameter

Measurement of Diameter in [mm]											
1	34.017581	**11**	34.016798	**21**	34.017535	**31**	34.017179	**41**	34.018232	**51**	34.017624
2	34.01642	**12**	34.01671	**22**	34.017208	**32**	34.018705	**42**	34.01729	**52**	34.017552
3	34.017116	**13**	34.016745	**23**	34.01726	**33**	34.018252	**43**	34.01701	**53**	34.017556
4	34.016389	**14**	34.017219	**24**	34.017239	**34**	34.017586	**44**	34.017477	**54**	34.017159
5	34.017882	**15**	34.017466	**25**	34.017206	**35**	34.018012	**45**	34.017253	**55**	34.017175
6	34.016534	**16**	34.017862	**26**	34.017448	**36**	34.016655	**46**	34.017549	**56**	34.017202
7	34.017095	**17**	34.017852	**27**	34.017485	**37**	34.01659	**47**	34.017159	**57**	34.017791
8	34.017144	**18**	34.017516	**28**	34.017372	**38**	34.017199	**48**	34.017335	**58**	34.017897
9	34.01684	**19**	34.017541	**29**	34.018283	**39**	34.017723	**49**	34.018077	**59**	34.01774
10	34.016672	**20**	34.018173	**30**	34.018091	**40**	34.01872	**50**	34.017446	**60**	34.01757

Based on the measurement, the average value and range are calculated:

Average Value:

$$\bar{x} = \frac{\sum x}{n} = \frac{\sum x_1^{60}}{60} = 34.017432$$

Range:

$$R = x_{max} - x_{min} = 34.0187 - 34.0164 = 0.0023$$

Sample Size:

$$n = 60$$

The standard deviation and control limits (lower and upper limits) are computed using following formulas according to normal distribution:

Standard Deviation:

$$s = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n-1}} = \sqrt{\frac{\sum_{i=1}^{60}(x_i - \bar{x})^2}{60-1}} = 0.000521$$

Upper Control Limit:

$$X_{ob3} = \bar{x} + 3s = 34.018986$$

Lower Control Limit:

$$X_{un3} = \bar{x} - 3s = 34.015860$$

In BRP-Powertrain, the specific lower (OSG) and upper limits (USG) are defined in engineering drawing for crankshaft:

Specific Lower Limits:

$$USG = 34.009$$

Specific Upper Limits:

$$OSG = 34.025$$

The control chart of this capability study is shown in Figure 34 which is generated from Q-DAS Software.

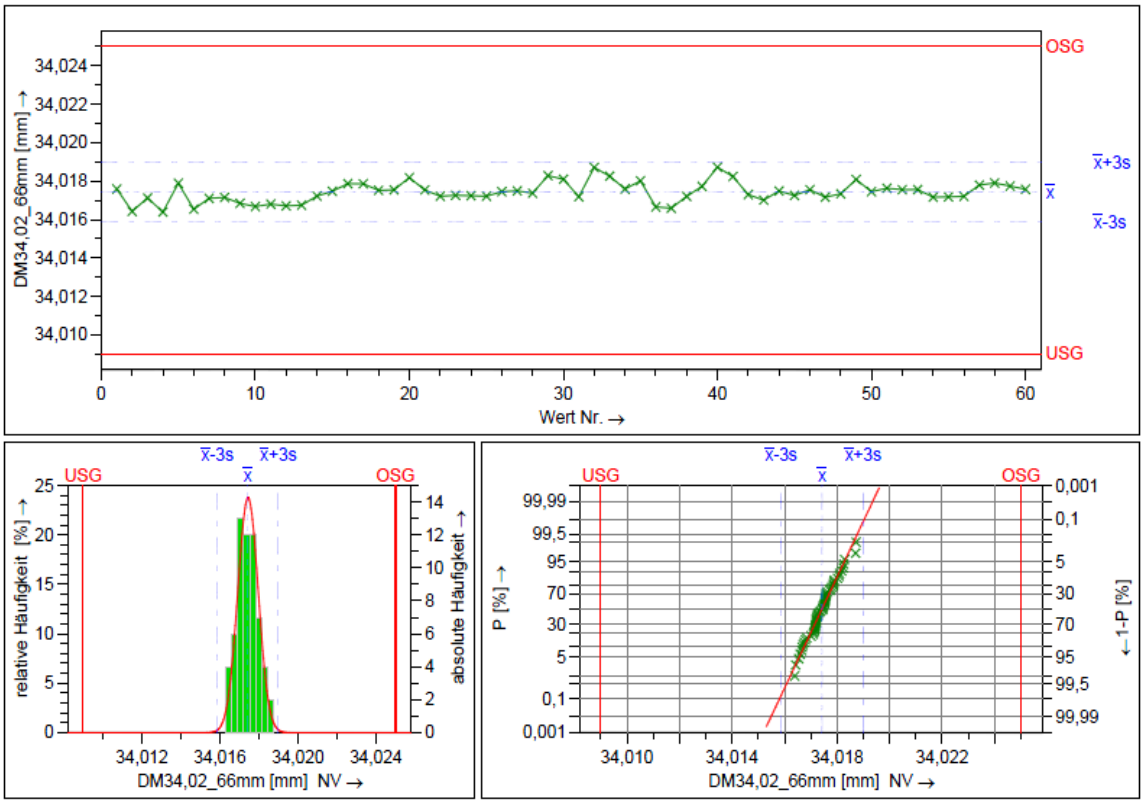

Figure 34: Capability Study

Potential Capability Index:

$$C_m = \frac{OSG - USG}{X_{ob3} - X_{un3}} = \frac{34.025 - 34.009}{34.018986 - 34.015860} = 5.12$$

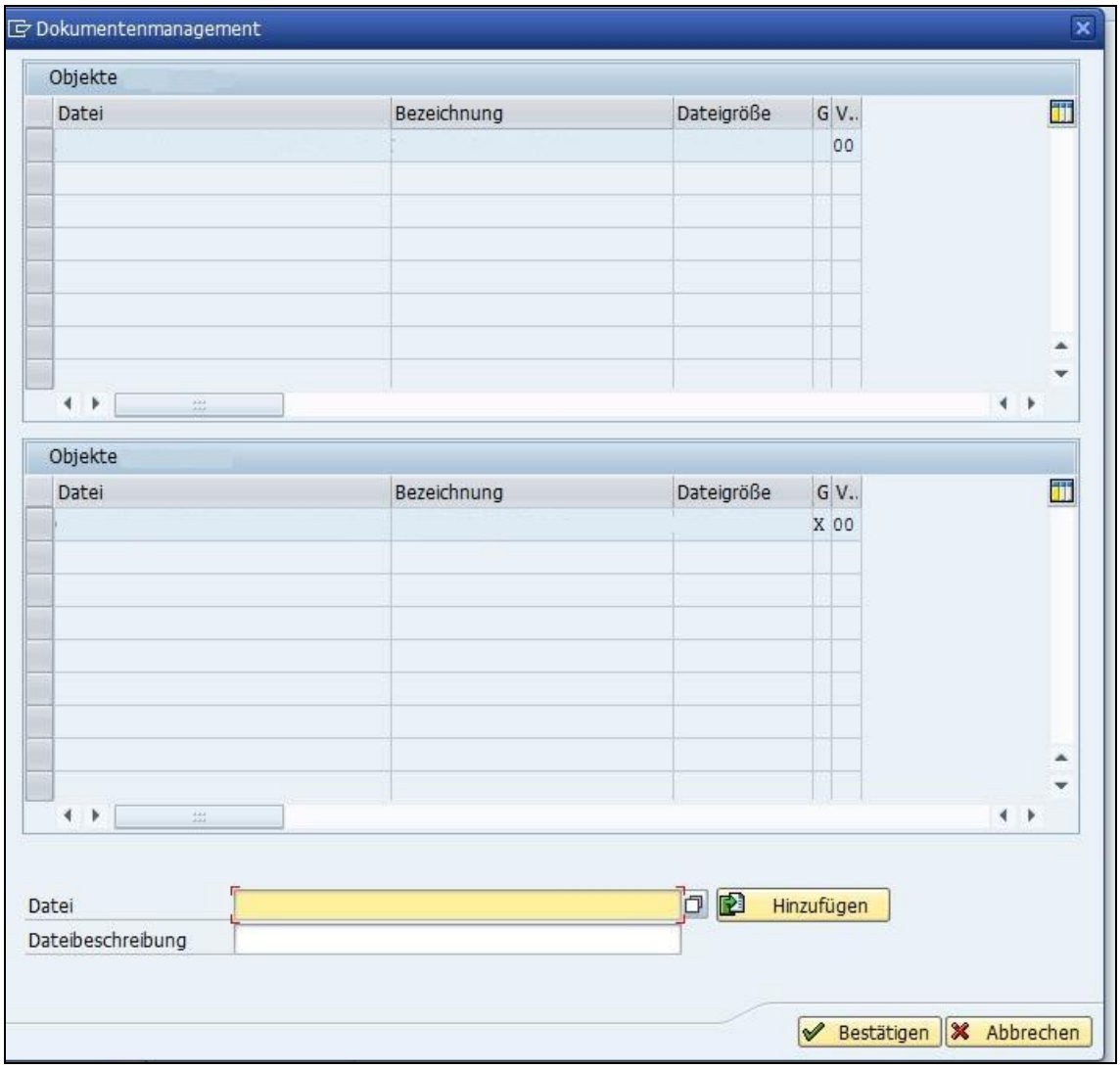

Figure 35: Supplier Portal Document Management

Critical Capability Index:

$$C_{mk} = \min\left\{\frac{\bar{x} - USG}{\bar{x} - X_{un3}}; \frac{OSG - \bar{x}}{X_{ob3} - \bar{x}}\right\}$$

$$= \min\left\{\frac{34.017432 - 34.009}{34.017432 - 34.015860}; \frac{34.025 - 34.017432}{34.018986 - 34.017432}\right\} = 4.85$$

The above calculated Potential Capability Index and Critical Capability Index are fulfilled the requirements of BRP-Powertrain.

$$C_m = 5.12 \rightarrow 3.95 < \mathbf{5.12} < 6.35$$

$$C_{mk} = 4.85 \rightarrow 3.69 < \mathbf{4.85} < 6.00$$

This document is uploaded by supplier via the supplier portal. Document exchange between BRP-Powertrain and company Y Industry takes place mainly via document management (Figure 35). In this window all documents "for BRP-Powertrain" and "from BRP-Powertrain" can be viewed.

Step 3. After PPAP documentation is uploaded, this documentation will be evaluated by BRP-Powertrain. The supplier quality engineer inspects the report which inclusive the results of capability study as they see fit, the records the results on the assessment page in supplier portal, and returns the report plus decision to the supplier.

In this real case, the initial sample inspection by BRP-Powertrain from the supplier Y Industry was completed with a positive result and thus was released for series production. The Y Industry and buyer will be informed of this result by e-mail. The supplier quality engineer attaches a cover form (Begleitschein) of PPAP to this report (Figure 36). The results are finally presented to the new engine project team at regular project meeting.

But if the initial sample inspection by BRP-Powertrain was completed with a negative result and thus was not released for series production. The initial samples were either evaluated with "Released under condition – re-sampling required" or "Rejected" - therefore the vendor must satisfy/carry out the requirements/corrections defined by the NPD SQE and/or SQ and then present this with a re-sampling. The vendor and buyer will be informed of this result by e-mail.

Figure 36: Initial Sample Cover Form

5.2 Evaluation

After adaption of the modular APQP elements into BRP-Powertrain NPD process, as expected at the beginning of the project, it can be supposed that the following aspects are significantly improved:

1. Increasing company own resource efficiency

   Product Quality Planning is a structured approach, which is based on the ultimate customer oriented, to develop a product to ensure that the steps are needed to make the product satisfying. It defines the various stages of project development tasks on aspects of schedule, cost, resources, and others. In BRP-Powertrain, the similar processes and tools in company own NPD processes have been designed during the last 15 years. In this thesis, the modular APQP elements are adapted from NPD process and can be used in Global Sourcing Strategy project and new product development process, which avoids the repetitive works for design of processes and tools in Global Sourcing Strategy.

2. Optimization of the work process and interfaces between different departments

   In the early stage of the product quality planning is to assign responsibility to a cross function team. This team will include representatives from product development, supplier quality, purchase, supplier and others. In new customized and standardized modular APQP elements, the functions, tasks, responsibility and ownership are clearly defined and the quality planning team establishes lines of communication with other departments and suppliers. It provides people with a clear picture of how their work fits into the organization. The operations in both processes (product development process and Global Sourcing Strategy) will be improved because of the thoroughly documented procedures with clear instructions.

3. Systematic supporting for relocation of suppliers in Global Sourcing Strategy

   In BRP-Powertrain, the most cooperative suppliers will be moved up to the level of strategic suppliers or even alliance partners. With the modular APQP elements, the operations can be performed more effectively.

4. Increasing the working process stability and adaptability

   With the clear design of the process procedure and structure, the process will be adaptable to environmental changes; it will remain steady under unfavorable conditions.

6 Conclusions and Future Work

6.1 Conclusion

This research studies the incorporation elements of advanced product quality planning system into new product development process by taking an example of company BRP-Powertrain. By learning the new product development process, gap analysis and the characteristics of the products, studying how the product in case to use the APQP to connect with the new product development process in engine industry and then by interviewing the relevant staffs involved, the following conclusions are made according to the actual application situations:

1. Advanced Product Quality Planning (APQP) plays a very important role in modern new product development management but too many documented procedures will influence the concurrent engineering project in case of excessive procedures related to the product development. However, the APQP based new product quality management system can be constructed by use of the information management technology (such as BRP-Powertrain Supplier Portal, SAP/ERP System), which can reduce the waste of engineering time and increase of efficiency of using resource. In the case of BRP-Powertrain, based on the information platform, the management could adopt the APQP based new product development process and refer to the historical/actual data so as to reduce time for new product development and minimize errors.
2. To use APQP to adopt the complete new product development process, and perform such tools as PPAP, FMEA and SPC in a right and efficient way, so as to prevent the occurrence of the problem and reduce the risk for breach of the market demand. Improvement of the success rate of product development will improve the product quality and customer satisfaction and even the overall profit of the company.
3. Customized and standardized modular APQP elements will be used in the supplier quality management (such as in GSS), and different phases in the overall product develop process. The definitions of modular APQP are clearly described in a breakdown structure, which provides a frame of supplier quality management and product development process for the company BRP-Powertrain, efficient solution for the previous problems related to the supplier quality and interface between different departments, help the company improve the supplier quality management, reduce the quality cost and obtain more economic efficiency.
4. The implementation of modular APQP element ‘Process Capability Studies’ into BRP-Powertrain’s new engine project showed that the modular APQP elements

are good applicable to the current complex structure of supplier management and product development process in days of rapid changing of technology and management tool. It is recommended that the company and employees shall continuous introduce new advanced management methods to improve work efficiency and increase the company profit.

6.2 Future Work

Because this APQP project has just started in company BRP-Powertrain since six months, only selected elements are completed. It is not a long time from the implementation and adaption of APQP in BRP-Powertrain, so the new modular APQP elements are only tested in one sub process of selected engine development project, over all adaption of which only take the first step. Therefore, the quantity of samples and problems arising are not very sufficient until now, which means further study is needed for the next step:

1. In this thesis, we completed the customized and standardized modular APQP elements 5., 15., 27., 30. and 31. In the future, all remaining elements from APQP reference manual should be completed based on own new product development and the incoming problems resulted from the actual work situations, including added or amended sub-processes and overall processes.
2. Commitment and participation from the management play a very important role in the implementation process of modular APQP elements. In the implementation processes such as training, case study and workshop are required, if there is lack of commitment from the management level, the implementation team will face the situation of shortage of resources, the heavy workload will led to low morale and fall into dilemma.
3. An end of this thesis is not an end of the APQP project in company BRP-Powertrain. Since a further analysis pertaining to the above issues is not made, I will take them as my main subjects at work and study in the future.

Bibliography

APQP (2008): Advanced Product Quality Planning and Control Plan Reference Manual. 2nd ed.. Chrysler Corporation, Ford motor Company, and General Motors Corporation, New York

Ben, R. (2011): Addressing the Quality Aspect for the Formulation Process in Emergent Strategy Making. Journal of Quality, Vol. 18, pp.155-172

BRP (2012): BRP-Powertrain Company Introduction. Unpublished material, BRP-Powertrain, Gunskirchen

BRP (2011): BRP-Powertrain NPD Training. Unpublished material, BRP-Powertrain, Gunskirchen

BRP (2010): BRP-Powertrain Initial Sample Inspection. Unpublished material, BRP-Powertrain, Gunskirchen

Cassel, Michael (2007): ISO/TS 16949 QM in der Automobilindustrie umsetzen. Carl Hanser Verlag GmbH & Co. KG, Munich

Durakbasa, M.N (2009): Quality in Industry. Abteilung Austauschbau und Messtechnik, Vienna University of Technology, Vienna

Durakbasa, M.N. (2013): Total Quality Management – TQM and Nanotechnology. Unpublished course material, Vienna University of Technology, Vienna

Johnson, R. (2014): How to Audit a supplier. http://www.ehow.com/how_5431213_audit-supplier. html: retrieved on January 6, 2014

Eriksson, E. (2001) Goda råd om QS-9000, Andra utgåvan, Institutet för Verkstadsteknisk Forskning, Mölndal

Fong, C. (2001): QS 9000: an overview and comparison with ISO 9000. The TQM-Magazine, Vol.13, No.5, pp.315-318

FMEA (2008): Potential Failure Mode and Effect Analysis Reference Manual. 4nd ed.. Chrysler Corporation, Ford motor Company, and General Motors Corporation, New York

Goethsch, D. (2003): Quality Management Introduction to Total Quality management for Production, Processing, and Services**.** 4th ed.. Person Education Inc., New Jersey

iGrafx (2013): iGrafx 2013 Tutorials, iGrafx GmbH, Munich

Inteva (2012): Supplier Requirements Manual of Inteva Products for use with ISO/TS 16949:2009. Inteva Products, Michigan

ISO (1998): Quality System Requirements QS-9000. 3rd ed.. International Organization for Standardization. Geneva

ISO (2007): Technical Specification ISO/TS 16949. 3nd ed.. International Organization for Standardization. Geneva

ISO (2008): Quality Management Handbook DIN ISO 9001, International Organization for Standardization. Geneva

ISO (2012): Controls Charts ISO/FDIS 7807-2, International Organization for Standardization. Geneva

ISOTS16949 (2014): ISO/TS 16949. www.dnvusa.com/industry/automotive/services/iso_ts__16949/: retrieved on January 7, 2014

Jenkins, G. (2013): QS 9000 Training Materials. Pennsylvania State University, Pennsylvania

Kartha, C.P. (2004): A comparison of ISO 9000:2000 quality system standards, QS9000, ISO/TS 16949 and Baldrige criteria. The TQM Magazine, Vol. 16, No. 5, pp.336

MindTools (2013): Gap Analysis. Mind Tools Ltd. London

MSR (2010): Measurement System Analysis Reference Manual. 4nd ed.. Chrysler Corporation, Ford motor Company, and General Motors Corporation, New York

Osanna, P. (2002): Qualitätssicherung und Qualitätsmanagement. Abteilung Austauschbau und Messtechnik, Vienna University of Technology, Vienna

Patton, M. (2002): A Guide to Using Qualitative Research Methodology. Medecins Sans Frontieres, Geneva

PPAP (2006): Production Part Approval Process Reference Manual. 4nd ed.. Chrysler Corporation, Ford motor Company, and General Motors Corporation, New York

Plura, J. (2010): Procedures and Methods of Quality Planning and Their Use for Forming Process Optimization. Engineering the Future, Vol. 8, No. 13, pp.257-280

Ristow, R. (2002): Incorporating Elements of the Automotive Industry Action Group's Advanced Product Quality Planning (APQP). Research Paper, University of Wisconsin-Stout, Wisconsin

Rotax (2013): Rotax.Wikipedia. http://en.wikipedia.org/wiki/Rotax: retrieved on November 10, 2013

Sanongpon, K. (2009): Automotive Process-based New Product Development: A Review of Key Performance Metrics. Proceedings of the World Congress on Engineering 2009, Vol .1, London, ISBN: 978-988-17012-5-1

Schaeffler (2013): Advanced Product Quality Planning – APQP Elements. Schaeffler AG, Herzogenaurach

Stiebinger, C. (2011): Downsizing in the recreational products industry –Fact or Fiction?. The Working Process of the internal Combustion Engine 2013, Graz

Thissen, F. (1998): Arbeits-, Lern- und Präsentationstechniken. Unpublished course material. Hochschule für Bibliotheks- und Informationswesen Stuttgart, Stuttgart

TRW (2012): Supplier Requirements Manual of TRW Automotive. TRW Automotive Inc., Michigan

V.Ryan(2010): Production. http://www.technologystudent.com/despro_flsh/prodflow1.html: retrieved on December 16, 2013

VDA(2012): Volume 2 Quality Assurance for Supplies Production process an product approval PPA. 5nd ed.. VDA, Berlin

Wangenborn, T. (2010): Design Process Enhancement. Master Thesis, Mälardalen University, Västerås

List of Abbreviations

AA	Work Instruction (Arbeitsanweisung)
AK	Advanced Construktion
AK/EE-CDG	Designer in Commodity Development Group
BRP	Bombardier Recreational Products
CDG	Commodity Development Group
CTQ	Critical to Quality
DTQC	Design to Quality and Cost
EK	Einkauf
FB	Formblatt
FMEA	Failure Mode and Effects Analysis
GSQ	Global Supplier Quality
NPD	New Product Development
PE	Product Development
PPAP	Production Part Approval Process
PM	Project Management
PRT	Powertrain
RFQ	Request for Quotation
RON	Rotax Norm
(R)TRD	(Rotax) Technical Requirement Document
SQE	Supplier Quality Engineer
SPC	Statistical Process Control
SQE	Supplier Quality Engineer
SQ	Supplier Quality

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Appendix A: PPAP Cover Sheet

cover sheet

Sender

Addressee

☐ **Production process & product release report**

☐ **DwSpA**

Submission level:

☒ First sampling
- ☒ New part
- ☐ Product modification (specification modification)
- ☐ Production relocation
- ☐ Modification in production process
- ☐ Production suspension longer than 12 months
- ☐ Tool modification / correction
- ☐ Modification in purchased parts
- ☐ Change of suppliers
- ☐ Others

☐ Resampling
- ☐ New Sampling

☐ **Reports other samples**

Enclosures / Inspected		
☒ 01 Dimensional check	☐ 09 EMC - test	☐ 17 Test equipment list
☐ 02 Functional check	☐ 10 Reliability test	☐ 18 Test equipment certificates
☒ 03 Material test	☐ 11 Design - FMEA	☐ 19 EU - Safety data sheet
☐ 04 Haptic test	☐ 12 Construction release	☐ 20 Material data sheet
☐ 05 Acoustics test	☐ 13 Process - FMEA	☐ 21 Means of transport / packaging
☐ 06 Odor test	☒ 14 Process flow chart	☐ 22 Certificates
☐ 07 Appearance test	☒ 15 Production control plan	☐ 23 Process acceptance
☐ 08 Surface test	☐ 16 Process capability verification	☐ 24 Others

Supplier / Production location: /		**Customer:**	
ID number/DUNS-Code:		ID number:	
Report no.:	Index: 00	Report-no.:	Index:
Name: Part number: Drawing number: Status/Date: /		Name: Part number: Drawing number: Status/Date:	
Delivery note no./ date: /		**Goods receipt no./ -date: /**	
Delivery quantity: 0 PC Batch number: Sample weight:		Order no./ -date: Unloading site: Logistic Center	

Supplier Confirmation:

We confirm that the sample inspections were performed in accordance with VDA Volume 2, Chapter 4.

☐ The IMDS data report was created under the IMDS-ID-No:

Name: Department: Phone: Fax: E-Mail:	Comments:
Date: Signature:	

Customer decision	**Total**	**Single release**																						
		01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Approved	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Approved with conditions, resampling required	☐																								
Rejected, resampling required	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Deviation approval no.: Valid until: quantity: 0 resampling due date:

For returns, delivery note no./-date: /

Name: Department: Phone: Fax: E-Mail:	Comments: Date: Signature:

Appendix B: Quality Control Charts ISO 7870

This analysis is based on the mathematic description in Section 2.3.

Data from diameter measurement of Crankshaft in Section 5.1

Sample Number	Production Period					
	1	2	3	4	5	6
1	34.017581	34.016534	34.016798	34.017862	34.017535	34.017448
2	34.01642	34.017095	34.01671	34.017852	34.017208	34.017485
3	34.017116	34.017144	34.016745	34.017516	34.01726	34.017372
4	34.016389	34.01684	34.017219	34.017541	34.017239	34.018283
5	34.017882	34.016672	34.017466	34.018173	34.017206	34.018091
Sum X	170.08539	170.08428	170.08494	170.08894	170.08645	170.08868
Mean Xi	34.017078	34.016857	34.016988	34.017789	34.01729	34.017736
Ri	0.0014923	0.0006101	0.0007562	0.0006564	0.0003287	0.0009112

Sample Number	Production Period					
	7	8	9	10	11	12
1	34.017179	34.016655	34.018232	34.017549	34.017624	34.017202
2	34.018705	34.01659	34.01729	34.017159	34.017552	34.017791
3	34.018252	34.017199	34.01701	34.017335	34.017556	34.017897
4	34.017586	34.017723	34.017477	34.018077	34.017159	34.01774
5	34.018012	34.01872	34.017253	34.017446	34.017175	34.01757
Sum X	170.08973	170.08689	170.08726	170.08757	170.08707	170.0882
Mean Xi	34.017947	34.017377	34.017452	34.017513	34.017413	34.01764
Ri	0.0015265	0.0021298	0.001222	0.000918	0.0004657	0.0006949

Statical Calcualtion	
Sum (Mean Xi)	408.209079
Sum Ri	0.0117118
Mean (Sum (Mean Xi))	34.0174232
Mean (Sum Ri)	0.00097598

Control Limit Constants	
n	5
A2	0.577
D4	2.114
D3	0

Control limits for sample means:

Upper Limit

$$OEG = Mean\big(Sum(Mean\,Xi)\big) + A2 \times\ Mean(Sum\,R) =\ 34.0179864$$

Lower Limit

$$UEG = Mean\big(Sum(Mean\,Xi)\big) - A2 \times\ Mean(Sum\,R) =\ 34.0168601$$

Control limits for range:

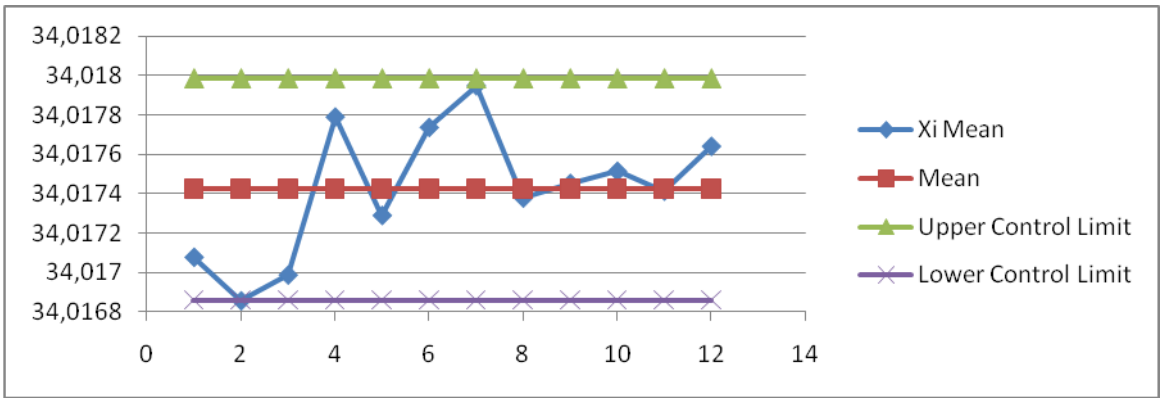
Upper Limit

$$OEG = D4 \times\ Mean(Sum\,R) =\ 0.002063229$$

Lower Limit

$$UEG = D3 \times\ Mean(Sum\,R) =\ 0$$

X-Charts



R-Charts