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Evaluation of Production Part Approval Process

ABB IEC LV Motors division

School of Technology and Innovations
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TIIVISTELMÄ:
Toimittajan suorituskyvyllä on suora yhteys yrityksen laatuun ja kustannuksiin. Erilaisilla työkaluilla yritys ja sen toimittajat pyrkivät yhteistyössä minimoimaan tuotelaatuun liittyviä riskejä ennen massatuotannon aloittamista. Production part approval process (PPAP) on autoteollisuudesta tunnettu työkalu toimittajalaadun hallintaan. PPAPin avulla voidaan varmistua, että näkemys tuotettavan komponentin laatuvaatimuksista on yhtenevä asiakkaan ja toimittajan välillä. PPAP koostuu useista työkaluista, jotka varmistavat tuotteen valmistusprosessin kyvykkyyttä niin asiakkaan kuin toimittajan näkökulmasta.

Tämä pro gradu -tutkielma on tehty tapaustutkimuksena ABB:n IEC LV Motors -divisioonaan. Tutkielman tavoitteena on 1) selkiyttää, millainen nykytila PPAP-työkalulla on kohdeyrityksessä – mitkä ovat sen koetut hyödyt ja haasteet sekä 2) määritellä, miten PPAP-prosessia voisi tulevaisuudessa kehittää ja 3) määritellä, miten siitä on mahdollista saada irti suurin mahdollinen hyöty. Näiden tavoitteiden saavuttamiseksi on suoritettu sisäisiä haastatteluja sekä benchmarking-haastatteluja ulkopuolisiin yrityksiin.

Tutkimuksen teoreettinen viitekehys käsittelee toimittajalaadun sekä PPAP:n teoriaa käsittäen PPAP:n historian, taustan, tavoitteen sekä tekniikan. Tutkielma on kvalitatiivinen tapaustutkimus. Empiirisessä osuudessa haastateltiin tapausyrityksen henkilöstöä. Haastattelujen tavoitteena oli kartoittaa prosessin nykytila globaalisti. Tämän jälkeen toteutettiin benchmarking-haastattelut kolmeen yritykseen, joista kaksi toimii asiakkaan roolissa ja yksi toimittajan roolissa. Benchmarking-haastattelujen avulla kartoitettiin PPAP-prosessien parhaita käytäntöjä muissa yrityksissä sekä prosessia toimittajan näkökulmasta.

Tutkimuksen tuloksena syntyi kuvaus siitä, millaisena PPAP tällä hetkellä koetaan ABB IEC LV Motors -divisioonassa, sekä miten PPAP:a voitaisiin jatkossa kehittää, jotta siitä saataisiin paras mahdollinen hyöty. PPAP:n nykytila määriteltiin kahdeksassa sisäisessä haastattelussa. Haastatteluissa nousi esiin prosessin koetun toimivuuden suuri vaihtelu eri tehtaiden välillä sekä epäkohtia yrityksen sisäisissä prosesseissa. Benchmarking-yrityksissä oli tunnistettavissa samanlaisia haasteita, mutta niihin oli osittain löydetty ajan mittaan ratkaisuja. Mikäli tunnistettuihin epäkohtiin tartutaan, on tapausyrityksellä mahdollisuus tehdä toiminnastaan kannattavampaa niin tuotelaadun, työn tehokkuuden kuin työn mielekkyydenkin näkökulmasta.

AVAINSANAT: PPAP, Production Part Approval Process, APQP, AIAG, Toimittajalaatu, ISO/TS 16949:2009

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ABSTRACT:

Supplier performance is directly related to company's quality and cost. With various tools, the company and its suppliers work together to minimize product quality risks before starting mass production. The production part approval process (PPAP) is a well-known tool for supplier quality management in the automotive industry. PPAP can be used to ensure that the view of the quality requirements of the component being produced is the same between the customer and the supplier. PPAP consists of several tools that ensure the capability of the product manufacturing process from the perspective of both the customer and the supplier.

This master's thesis has been done as a case study for ABB's IEC LV Motors division. The aim of the research is 1) to clarify the current state of the PPAP in the target company - what are its perceived benefits and challenges, and 2) to determine how the PPAP process could be developed in the future and 3) to determine how the utility of PPAP can be maximized. To achieve these goals, internal interviews and benchmarking interviews with external companies have been conducted.

The theoretical framework of the thesis consists of supplier quality and the theory of PPAP, including the history, background, aim, and technology of PPAP. The research is a qualitative case study. In the empirical part, the employees of the case company was interviewed. The aim of the interviews was to clarify the current state of the process globally. This was followed by benchmarking interviews with three companies, two in the role of customer and one in the role of supplier. Benchmarking interviews were used to identify best practices in PPAP processes in other companies as well as the process from a supplier perspective.

The study resulted in a description of what PPAP is currently perceived in the ABB IEC LV Motors division and how PPAP could be further developed to get the best possible benefit. The current state of PPAP was defined in eight internal interviews. The interviews showed a large variation in the perceived functionality of the process between the different factories, as well as lacks in the company's internal processes. Similar challenges could be identified in benchmarking companies, but solutions to them had partly been found over time. If the identified lacks are noticed and developed, the case company can make its operations more effective in terms of product quality, work efficiency and the meaningfulness of the work.

AVAINSANAT: PPAP, Production Part Approval Process, APQP, AIAG, Supplier Quality, ISO/TS 16949:2009

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Abbreviations

ABB	Asea Brown Boveri
AIAG	Automotive Industry Action Group
APQP	Advanced Product Quality Planning
BOM	Bill of Materials
CNMOT	ABB IEC LV Motors division factory in China
DFM	Design for Manufacturing
FIMOT	ABB IEC LV Motors division factory in Finland
FMEA	Failure Mode and Effect Analysis
IATF	International Automotive Task Force
INMOT	ABB IEC LV Motors division factory in India
IPS	Initial Process Studies
ISO	International Organization for Standardization
MSA	Measurement System Analysis
SQE	Supplier Quality Engineer
SQM	Supplier Quality Management
PLM	Product Lifecycle Management (system)
PLMOT	ABB IEC LV Motors division factory in Poland
PPAP	Production Part Approval Process
PSW	Part Submission Warrant
QPS	Quality Packing Specification
QRV	Quality Ranking Value (used in benchmarking company B)
R&D	Research and Development
TQM	Total Quality Management

1 Introduction

Over the time, different industries and companies have developed different tools and operating models to optimize quality and achieve consistent quality. Everyone has their own perceptions and experiences about what is the best mode of operation. However, a particular course of action cannot be copied from one company to another or from one industry to another as such but requires customization to achieve the best possible benefit. Because companies and their products are different, there is not one right way of action that works equally for every industry, company, and product. Some models may not work in a particular industry at all.

1.1 Background of the Thesis

With strong supplier quality management (SQM) system, you can ensure that you are constantly adding value to your customers' lives and exceeding their expectations (Demski, 2021). Manufacturers gain from having a stable supplier quality management process (Hansen, 2021). With SQM process organizations expect less variation and better reliability when suppliers can successfully regulate their output. However, so that these benefits to be achieved, organizations must work together to develop a relationship of mutual trust through shared expertise and resources, as well as support from important stakeholders in both companies.

To evaluate supplier performance, companies must analyse product quality, pricing, compliance, and a variety of other aspects (Church, 2021). It is challenging to check compliance at each level without a proper system. To avoid producing inferior products, companies must implement an acceptable supplier quality management approach. Poorly produced components can harm a brand's reputation, decrease customer loyalty, and lead to lost sales. They can also result in product recalls, which can have serious legal and financial consequences.

Today's supply chains are complicated, and companies rely on them to obtain raw materials and parts for their products (Church, 2021). Supplier approval, audits, raw material inspections and communication are an essential component of an effective supplier quality management strategy (Hansen, 2021).

In ABB IEC LV Motors division component quality assurance has long been based on audits, approval of samples, and incoming inspections but during the last years the company has begun to use Production Part Approval Process (PPAP) for more systematic and purposeful SQM. Implementing the new tool has been raising questions like how successfully ABB is going to use the tool and what concrete benefits the company is going to get from using PPAP. This thesis was started due to these questions and uncertainties. The case company (ABB IEC LV Motors division) is aiming at getting the best possible way to use PPAP in its daily work. PPAP is a topic of current interest for improvement and so the topic of this research has taken place in the team meetings in the year 2021.

1.2 Research Questions and Purpose of the Research

This research was done to clarify ABB IEC LV Motors' current situation of using PPAP and how it could be developed. This thesis aims to make it possible to create a better way of using of PPAP efficiently. Research questions for this thesis are as follows:

1. What is current situation of PPAP documentation in ABB IEC LV Motors division - what are the perceived benefits and disadvantages of PPAP at the moment?
2. How could PPAP processes be developed in the future?
3. How is it possible to get the best possible benefit?

1.3 Limitations

Key scope of the research is the supplier quality and PPAP documentation of ABB IEC LV Industrial Motors' suppliers. The thesis borders on experiences with the suppliers from whom the PPAP is currently required. An area to be left out of the research is for example

supplier approval process. The thesis has been made from the ABB point of view and the suppliers of ABB have not been interviewed to this research. Later in this thesis when talking about ABB, it means ABB's IEC LV Motors division.

A lot of focus in this thesis is on quality and various aspects around it because it is one of the most important factors in ABB and because the thesis has been created from the quality perspective with the help of stakeholders from the multiple functions and countries. Theoretical framework describes Advanced Quality Planning (APQP) in relation to the history of PPAP, but this thesis does not focus more thoroughly on APQP theory. Most of the focus is left for evaluation of current state of PPAP and processes around PPAP and for developing the processes.

1.4 Structure of the Thesis

Figure 1 presents the structure of the thesis in chronological order. The thesis consists of five chapters. After introduction and research methodology parts, the thesis consists of two main parts: a theoretical framework and empirical research. Empirical research has been made to the ABB IEC LV Motors division. The last chapter includes a conclusion and discussion of results and possible development ideas.

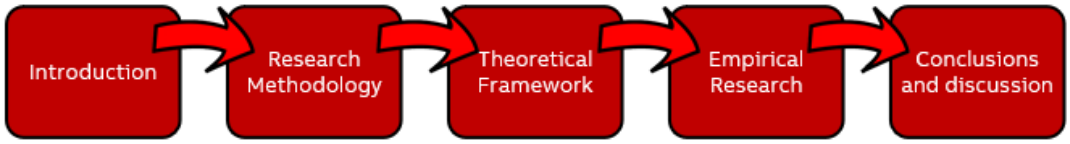

Figure 1. Structure of the thesis.

2 Research methodology

This chapter describes the methods for carrying out the study and arriving at an answer to the research question and objectives. The methodology specifies the procedures for data collecting and analysis. Finally, the research's reliability and validity, and the methodology for conducting the empirical investigation, are examined.

2.1 Case study approach

Thesis is a qualitative case study aimed at researching the capability of the Production Part Approval Process in ABB. Qualitative research values multiple perspectives, stakeholders, and participants (Simons, 2009). It is a single, unique study - the object to be studied can be, for example, a person, a policy, or a system. In this study, the target is the Enterprise Tool, in this case PPAP. In the initial phase, the company's personnel are involved in the development work, and in the final phase, the personnel of external companies are also involved. The data collection methods used in the study are presented in table 1.

Data collection	Data format	Analysis	Note
Literature review	Qualitative	Content analysis	Theory of supplier quality and PPAP based on scientific literature.
Internal Interviews (8 employees)	Qualitative	Content analysis	Interviewees from global organization and factories in China, Finland, India, and Poland.
Benchmarking interviews (3 companies)	Qualitative	Content analysis	Interviewees from three companies, two from the customer point of view and one from the supplier point of view of PPAP.

Table 1. Data collection procedure.

2.1.1 Internal interviews

The current state data of PPAP and processes around it have been cleared through semi-structured interviews conducted by eight company employees working on the different ABB IEC LV Motors division factories, on China, Finland, India, and Poland and in global organization. With qualitative research and interviews, it is possible to get a comprehensive overview of the people's subjective experiences of how PPAP is perceived at present. The data is analysed qualitatively.

2.1.2 Benchmarking

Possible development ideas have been monitored by benchmarking the three companies via interviews. Benchmarking has been used for developing the PPAP and processes around it. With benchmarking, it is possible to find out, what kind of challenges there have been in the other companies and how the companies have solved the challenges. By using the benchmarking, it is possible to get the best possible utility of PPAP. The three companies were interviewed to the benchmarking to find potential development areas or ways to do PPAP more efficiently. The data is analysed qualitatively.

It is challenging to develop a single all-embracing definition of benchmarking (Stapenhurst, 2009). One of the most well-known definitions of benchmarking dates to 1979, when Xerox began using it to examine its unit manufacturing costs: “it is the continuous process of measurement of products, services and practices in relation to the strongest competitors, or to companies recognized as being leaders in their industries” (Forno et al., 2014 [Camp, 1989/2013]).

The Xerox definition says that benchmarking is an ongoing process, while Haapaniemi (2020, [Tuominen, 1993]), mention that benchmarking can be done once or can be made continuously. Benchmarking is defined by some as a comparison of practices, while others, and possibly most typically, define it as a comparison of both performance and practices (Stapenhurst, 2009).

Roger Milliken, the CEO of Milliken has defined that benchmarking is “Stealing shamelessly” (Stapenhurst, 2009). Benchmarking is not stealing, at least not without permission. Benchmarking is a method of measuring and improving our organizational performance by comparing ourselves with the best (Stapenhurst, 2009). One classical definition of benchmarking is that it is “the search for industry best practices that lead to superior performance” (Madsen et al., 2017 [Camp, 1989]). Benchmarking is also defined as "being humble enough to recognize that someone else is better and smart enough to learn how to become as good, if not better" (Seppänen-Järvelä, 2005).

Every time we compare data we are benchmarking (Stapenhurst, 2009). Several studies show that benchmarking is widely used in organizational practice (Madsen et al., 2017). Benchmarking is ranked second in the 2015 edition of Management Tools & Trends survey, with a 44 percent usage rate, and is ahead of other well-known management ideas like as the balanced scorecard and big data analytics (Rigby & Bilodeau, 2015).

According to a Fortune 1000 survey, 65 percent of organizations utilize benchmarking as a management technique to gain a competitive advantage (Forno et al., 2014 [Anand & Kodali, 2008]). Similarly, according to a survey conducted by the Chambre de Commerce et d'Industrie in France, 50 percent of the 1000 organizations utilize benchmarking on a regular basis, and 80 percent see it as a successful change management strategy (Maire et al., 2005). Jarrar and Zairi (2001) conducted a survey of around 227 businesses from 32 different countries and determined that it has been utilized in most sectors such as manufacturing, health services, insurance, financial services, construction, banking, government, and so on.

Benchmarking originates from Japan, where it was created as a quality development technology (Haapaniemi, 2020 [Tuominen, 1993]). The objectives include bridging performance gaps and quality gaps and achieving a competitive advantage (Lecklin, 2006). Benchmarking can also show that in some areas the gaps are so large that it is not worth

investing in eliminating them, but the outsourcing of a specific function and the use of purchasing services.

Benchmarking is based on a simple fact that "whatever the process (supply or production or sales or services) some organizations are already achieving world-class performance" (Zairi & Al-Mashari, 2005, [APQCI, 1999]). When ICL wanted to develop its distribution system, it benchmarked with Marks and Spencer (Zairi & Al-Mashari, 2005, [Hollings, 1992]). When Motorola was trying to speed the delivery process of its cellular phones, it paid visits to Domino's Pizza and Federal Express.

Improving the performance and competitiveness of your own organization is the goal of benchmarking. It makes it possible to take advantage of the success of another company in its own activities and it is possible for the parties to learn from. However, the challenge may be how to detect the strengths of best practice and how to use them to develop your own activities and improve policies. An organisation should be able to identify what kinds of issues it should become better for and how much, as well as what level of activity is achievable. The big and difficult question on top of these is how to bring about the necessary change. (Haapaniemi, 2020 [Hotanen, Laine & Pietiläinen 2001; Tuominen 1993]).

Benchmarking is done to identify better practices, determine the right goals-level, find new methods and ideas, eliminate prejudice locales, and learn best practices (Lecklin, 2006). According to Anand & Rambabu (2008, [Bhutta & Huq (1999)], benchmarking can be done in a variety of ways; some companies have used up to 33 steps, while others have only used four.

If someone can perform what you do better, faster, and/or cheaper, chances are they have different practices than you (Stapenhurst, 2009). Finding out what those practices are, customizing them to your situation, and implementing them are all likely to boost your performance. It should be remembered that copying or mimicking another organization and its policies into one's own activities is unlikely to lead to success (Haapaniemi,

2020). You must understand things more profoundly, to identify why someone else succeeds in the way it works.

It is argued that benchmarking has various advantages, including the search for new ideas, or "thinking outside the box," the improvement of processes, the acceleration of processes, and the more likely implementation of new ideas. Furthermore, benchmarking promotes a culture of continuous learning. (Zairi & Al-Mashari, 2005).

2.2 Reliability and validity

Due to the nature of qualitative research, ensuring reliability and validity is more challenging than, for example, quantitative research. Reliability and validity have been sought at every stage of the study. All research results are based on perceived things - not assumptions. It is possible to promote the reliability and validity of qualitative research by using triangulation (Mannila 2008).

Triangulation refers to the combination of different methods, researchers, data sources, and theories in research (Saaranen-Kauppinen & Puusniekka, 2006). Data collected using different methods and approaches may lead to conflicting research on the phenomenon, so triangulation makes it possible to increase the reliability of research. There are five types of triangulations: material triangulation, researcher triangulation, theoretical triangulation, method triangulation and analysis triangulation. At this thesis material triangulation has been used as there are multiple different items of information. Based on the study's measures and features, it was assumed that the study could be repeated.

3 Theoretical framework

In history, quality assurance efforts have been made to systematically coordinate the activities of the whole company (Lecklin, 2006). The goal of creating the quality management system was to reach a preventive way of working with quality errors and quality costs. The quality system includes stakeholders of the company: suppliers, partners, customers, owners, financiers and ultimately the surrounding society.

Is a quality management system of real benefit to companies or does it just bring more “paper-flavoured” documentation and bureaucracy (Lecklin, 2006)? A massive and pedantic can be built out of the system, drowning the essentials under the detail. The consequences can include employee’s frustration, a drop in motivation and a turn of the whole quality movement into negative and reluctant. When a system is understood and built into a quality management system, it is a company management utility that communicates strategies and plans through the entire enterprise in a systematic way. The quality system forces to determine and systematize operation and key processes.

Suppliers are part of the company's processes (Lecklin, 2006). The customer is not interested in whether poor quality is caused by the actions of the company or its supplier. He sees the company that sold the product as responsible for the entire operation. Too often cost-cutting requirements jeopardize quality objectives (Rewilak & Tokaj, 2012). The quality level of the suppliers must correspond to the quality level of the company (Lecklin, 2006).

The best results are obtained when suppliers are integrated into the company's management system and co-operate in the application of methods, techniques, and standards. The result is often savings in quality costs (ASQ, 2022).

3.1 Supplier Quality

Quality of the final product is no longer solely determined by its manufacturer. (Rewilak & Tokaj, 2012). It is the result of the quality of its components supplied by various suppliers. Supplier quality is a supplier's ability to deliver goods or services that will satisfy customers' needs (Hansen, 2021). Supplier quality management is defined as a system for managing supplier quality in a proactive and collaborative manner.

It is in the best interests of an organization to guarantee that its service or material suppliers provide the highest quality products and services while also adhering to pre-established requirements (ASQ, 2022). This is frequently accomplished using supplier quality management systems, which enable companies to monitor supply chains and check or audit products and services on a regular basis.

Supplier quality management starts with the product design and supplier selection process (ASQ, 2022). It lasts the entire life cycle of a product and the lifetime of the connection with that specific source. Proper supplier quality management strategies include taking inputs (such as employee effort, marketplace requirements, operating finances, raw materials, and supplies) and effectively and efficiently converting them into outputs valued by customers.

Supplier performance has a direct correlation to company's quality and costs (Harris & Harris, 2015). Supplier performance and quality are more than negotiating the best bulk material pricing or attaining the lowest purchasing price (ASQ, 2022). Organizations that follow standards can more easily enter new markets and save costs by using available resources in a better way (ISO, 2022). They can also become more competitive on the market by providing services or products that are accepted or desired on a global organization.

3.2 Production Part Approval Process

Production part approval process (PPAP) is used worldwide in car industry (AIAG, 2022). To approve the production process of parts and components, the vehicle industry requires Automotive Industry Action Group (AIAG) PPAP process. AIAG is unique not-for-profit organization where companies in the mobility industries have worked collaboratively to drive down cost and complexity in the supply chain (AIAG, 2022). AIAG was founded in 1982 by three largest automotive OEMs.

As an AIAG member you get an AIAG certification. AIAG certification means that AIAG's supply chain institute verifies that you have the knowledge to perform to core tool processes and you get a formal certification that you have the comprehension of tools required (AIAG,2022). Production Part Approval Process is one component of Advanced Product Quality Planning. Deliveries to the production process can begin only after the production and the product are approved according to the requirements of this system. Now over 4000 companies have AIAG membership, including e.g., GM (producing e.g., Cadillac and Chevrolet), Toyota, Tesla, Honda, Volkswagen, and Nissan (AIAG, 2022).

PPAP specifies the requirements for production part approval, including production and bulk materials. The purpose of PPAP is to determine if the organization understands all customer engineering design record and specification requirements and if the manufacturing process has the potential to consistently produce product that meets these requirements during an actual production run at rate quoted production rate. (AIAG, 2009). PPAP submission is required from both new parts and products, processes and technologies, or suppliers but also from different changes to an existing product (Shrotri & Dandekar, 2012).

Changes to an existing product could be for instance the following:

1. Change to construction, material, or component
2. New, additional, or modified tools
3. Upgrade or re-arrangement of existing tools
4. Tooling, production or equipment transferred to different site
5. Change of supplier or non-equivalent materials/services
6. Product or process changes on the component of the product
7. Product when tooling has been inactive for 12 months
8. Change in test or inspection method
9. Bulk material: new source of raw material
10. Change in product appearance attributes
11. Change in production process or method
12. Change of sub-supplier or material source

3.2.1 History and background

The history of PPAP has its roots in Western World car industry. In the late 1970s North American automakers and suppliers realized that vehicles made in Japan were selling well because they broke down less frequently than vehicles made in USA (Devos et al., 1996).

International Organization for Standardization (ISO), which was established in 1947, promotes worldwide trade through standardization (Devos et al., 1996). The ISO established the ISO 9000 series standard for quality management and quality warranty in 1987. In 1994, American automakers GM, Ford, and Chrysler combined existing standards and procedures used to select each company's part suppliers and established the ISO 9001 quality warranty system. It was intended to apply these rules to global companies, and the QS 9000 system was established in August 1994. Following that, companies from all over the world began to be certified.

Many companies having QS 9000 certification went bankrupt in various countries, causing issues with the certification system. Prior to this, International Automatic Task Force (IATF) was formed by American and European automakers, and an ISO/TS16949 quality system was designed to be built extension (Rewilak & Tokaj, 2012 [EN ISO 9001:2008, 2012]) for automotive industry based on ISO 9001:1994.

A new ISO/TS 16949 standard for automotive industry was developed with the assistance of the International Standards Organization (ISO) 176 Technical Committee, the International Automotive Task Force (IATF), and the Japan Automobile Manufacturers Association (JAMA) to provide automotive industry suppliers with a set of system quality management standards throughout the entire process, including design, development, production, and service (Misztal et al., 2016). It is based on ISO 9001 and national quality standards in the automobile industry, and it may be readily integrated with existing standards. The standard ISO/TS 16949-2002 is explained by ISO (2022) as; Quality management systems - Particular requirements for the application of ISO 9001:2000 for automotive production and relevant service part organisations.

After that the quality of North American automakers has risen dramatically due to the improvement of quality (Devos et al., 1996). This improvement in quality was achieved not by focusing only on the quality of their products, but also by developing and sustaining a corporate culture that emphasized quality.

In 2003, GM hired retired Toyota executive Tatsuhiko Yoshimura, an expert in vehicle durability, to critique GM's procedures (Lathrop, 2010). These days, the quality of the big three American automakers is now comparable to that of the Japanese (Devos et al., 1996).

ISO/TS 16949 includes the following five core tools (Lungren et al., 2019, Misztal et al., 2016).

1. Advanced Product Quality Planning (APQP)
2. Production Parts Approval Process (PPAP)
3. Failure Mode and Effects Analysis (FMEA)
4. Statistical Process Control (SPC)
5. Measurement System Analysis (MSA).

However, the requirements contained in these documents do not sufficiently protect interests of car manufacturers in terms of quality and timely deliveries, therefore the great American car manufacturers: Chrysler, Ford and General Motors have developed additional requirements for suppliers, the so called quality manuals, including among others: APQP (Advanced Product Quality Planning) (Rewilak & Tokaj, 2012 [ISO/TS 16949:2009, 2012]) and its complement – the PPAP procedure (Rewilak & Tokaj, 2012 [AIAG, 2008]). The first edition of the APQP was published in 1994, and current revised 2nd edition was published in 2008 (Lungren et al., 2019 [Chrysler Corporation et al., 2008]). The first edition of PPAP was published in 1993, followed by a second edition in 1995 and a third edition in 1999 (Lathrop, 2010).

There are the following five phases in the APQP (Luke, 2019).

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

PPAP is 4th phase of APQP (Luke, 2019). Over the years, PPAP has become more well-known than APQP (Lathrop, 2010). In auditor talk, PPAP is really the evidence that APQP has been executed. Even if the PPAP is known as car industry tool, later it has since begun

to spread to other industries. The case company of the thesis doesn't follow APQP but uses some parts of it.

3.2.2 PPAP levels

PPAP includes five different levels (PPAP, 2020). According to Quality-One International (2022) it is not necessarily essential to submit all the elements for PPAP approval. The organization must submit the materials and / or records listed in the table 2.

Level 1	Part Submission Warrant (PSW) only.
Level 2	PSW with product samples and limited supporting data.
Level 3	PSW with product samples and complete supporting data.
Level 4	PSW and requirements defined by the customer.
Level 5	PSW with product samples and all supporting data available for review at the supplier's manufacturing location.

Table 2. PPAP levels (Quality-One, 2022).

3.2.3 PPAP documents

Complete PPAP documentation contains 18 requirements for the portion to be submitted. All required levels (all 18 levels are not always required) need to be met for the part to receive a supply permit for serial production. It is good to allocate a fair amount of time for this, since different tests and their documentation will last about 9 months. Elements 1-16 and 18 are similar in all companies. A description for each element can be found from the table 3.

1	**Design Records Documentation**	A part drawing.
2	**Engineering Change Documentation**	A full description of the change not yet recorded in the design record but incorporated in the product, part, or tooling.
3	**Customer Engineering Approval**	The engineering trial with sample production parts performed by the customer.
4	**DFMEA - Design Failure Mode and Effect Analysis**	A design-specific application of FMEA.
5	**Process Flow Diagram**	Depicts all the steps involved in the production of the part.
6	**PFMEA - Potential Failure Mode and Effect Analysis**	Evaluates each step in the production process to identify potential problems during the assembly of each part.
7	**Control Plan**	Mirrors the PFMEA: how potential faults are checked throughout in the incoming inspection, assembly process, or during the inspection of the finished parts.
8	**Measurement System Analysis Studies**	Includes e.g., the Gauge R&R, bias, linearity, stability, for all new or modified gages, measurement, and test equipment.
9	**Dimensional Results**	A list of all the dimensions of the ballooned part drawing and measurement results.
10	**Material/Performance Tests Results**	A list of all the tests that have been run on the part.
11	**Initial Process Studies**	Demonstrates the dependability of essential procedures SPC (statistical process control) charts are included.
12	**Qualified Laboratory Documentation**	All industry certifications for validation testing.
13	**Appearance Approval Report**	Customer approval on final product appearance, which includes colour, texture, fit, and other factors.
14	**Sample Production Parts**	Sample from initial production run.
15	**Master Sample**	A sample part that has been approved by both the client and the supplier.
16	**Checking Aids**	A comprehensive list of all equipment used to inspect and measure parts.
17	**Company specific documentation**	List of customer's specific requirements for PPAP process.
18	**PSW - Part Submission Warrant**	A summary of the whole PPAP submission.

Table 3. PPAP elements (AIAG, 2009).

Element 17 includes company specific documentation. ABB 's PPAP documentation package has totally 13 ABB-specific documents: elements 17.1-17.13. The elements have been described in the table 4.

17.1	**Reverse Engineering of Existing Parts**	NOTE: THIS MUST BE COMPLETED, PRIOR TO PPAP KICK-OFF. REQUIRED if this part is or has been in production by a different supplier or ABB. This is a part-to-drawing comparison, with the part coming from the prior manufacturer. This is in-place to protect against prior-undocumented design changes, or drift in manufacturing. Revisions to the ABB drawing may result from this comparison.
17.2	**Compliance Requirements (RoHS, etc.)**	All compliance requirements are defined and captured here, including REACH, RoHS, Conflict Minerals and ABB Prohibited & Restricted Substances.
17.3	**Enhanced Control Plan for Launch**	This is in place for the first 3 months of production. It involves redundant inspection and controls to ensure zero defects during launch. The launch control plan is more rigorous than the serial production control plan.
17.4	**Sub-Tier Supplier Oversight**	Define the oversight with sub-tiers suppliers (approve suppliers, qualify parts, surveillance, audits, etc.). Heavy emphasis on critical manufacturing processes like casting, forgings, heat treat, painting, coatings, welding. Load critical sub-tier PSW's when required.
17.5	**Production Trial Run (PTR) at ABB Plants**	Coordinate a low-volume trials with ABB plant(s). ABB plants will likely A) conduct first article inspection (FAI) to compare results to supplier's lab results and B) place parts in production to ensure they meet assembly & quality requirements.
17.6	**Run-at-rate**	This shall be conducted when volume is critical to ABB. Run-at-rate proves the ability to run production and yield the defined volume with the expected quality. The volume produced during run-at-rate shall define the maximum that the supplier is contracted to manufacturer.
17.7	**Packaging**	Define adherence to ABB Packaging Standards. Also capture here the type of packing that will be used. Load pictures, drawings, etc.
17.8	**ABB owned assets**	List of all ABB owned tooling, equipment, machines etc. Define how are they tagged or identified. Capture pictures. Define end-of-life for all assets.
17.9	**Preventative Maintenance**	Define the preventative maintenance plan for A) ABB owned tooling, B) supplier owned tooling / equipment. A predictive maintenance system like Maximo is preferred. End of life for all tooling / equipment should be defined in the PM system, triggering discussions between supplier and ABB.
17.10	**Rework & Repair**	Define what rework or repair requires ABB involvement or approval / what is allowable without ABB involvement.
17.11	**Frozen Process Change Request & Approval Acknowledgement**	A documentation signed by supplier leadership, stating they will request and obtain approval from ABB prior to shipping non-conforming parts to ABB.
17.12	**Supplier Deviation Request & Approval Acknowledgement**	Placeholder for other requirements identified by the qualification team.
17.13	**Other**	A summary of the entire PPAP submission. This is signed by the supplier & ABB at the time of completion of PPAP.

Table 4. ABB specific PPAP elements (ABB IECL LV Motors PPAP template, 2022)

3.2.4 PPAP approval

In ABB, PPAP document package is compiled into Excel. Part Submission Warrant (PSW) is a form that summarizes the PPAP package (Pulido, 2013). The approval of the PSW indicates that the quality engineer has inspected the package and that the customer has not discovered any issues that would prevent its approbation. ABB's PSW document presented in pictures 1 (phases 1-11) and 2 (phases 12-18).

ABB	ABB Part Submission Warrant PSW						ABB Motors and Generators
Doc. no: T-01-001							
Gold Sections to be filled out by ABB					Blue sections to be filled out by supplier		
1. Part Information							
ABB Part No:	3BSY611100-BVA				Part Revision:	B	
ABB Part Name:	Stator machined				Drawing Rev:		
Required PPAP Date:					PPAP level	Level 3	
2. Supplier and Manufacturing site information							
					Manufacturing site (if different location)		
Supplier Name:				Supplier Name			
Address				Address			
City, State/ProvCountry				City, State/Prov, Country			
3. Supplier reason for submission / Comments							
Comments:							
4. PPAP Element Review							
ABB SQE instructions to supplier (selection of elements)					Supplier submission	ABB SQE review of supplier submission	
	Submit Retain not required na - not applicable	Level 2	Level 3	Level 4 Customized	Supplier acknowledge completion	Approve/Reject	Comments
1	Design Records	Submit	Submit				
2	Engineering Change Documents	Retain	Submit				
3	Engineering Trial Approval	na	na				
4	DFMEA	na	na				
5	Process Flow Diagram	Retain	Submit				
6	PFMEA	Retain	Submit				
7	Control Plan	Submit	Submit				
8	Measurement System Analysis	Submit	Submit				
9	Dimensional Results	Submit	Submit				
10	Mat'l &/or Performance Tests	Submit	Submit				
11	Process Studies (SPC / Cpk)	Submit	Submit				

Picture 1. ABB PSW template, phases 1-11 (ABB IEC LV Motors PPAP template, 2022).

12	Approval of Lab	Retain	Submit				
13	Appearance Approval	Submit	Submit				
14	Sample Product	not required	not required				
15	Master Sample	not required	not required				
16	Measurement Tools / Checking Aids	Retain	Submit				
17,1	Reverse Engineering of existing parts	Submit	Submit				
17,2	Compliance Requirements (RoHS, etc.)	Submit	Submit				
17,3	Enhanced Control Plan for Launch (GP12)	Retain	Submit				
17,4	Sub-Tier Supplier Oversight	Retain	Submit				
17,5	Production Trial Run (PTR) at ABB Plants	Submit	Submit				
17,6	Run-at-Rate (GP9)	not required	Submit				
17,7	Packaging	Retain	Submit				
17,8	ABB owned assets	Submit	Submit				
17,9	Preventative Maintenance	Retain	Submit				
17,10	Rework & Repair	Retain	Submit				
17,11	Frozen Process Change Request (FPCR) & Approval - Acknowledgement	Submit	Submit				
17,12	Supplier Deviation Request (SDR) & Approval - Acknowledgement	Submit	Submit				
17,13	Other	Submit	Submit				
18	Part Submission Warrant (PSW)	Submit	Submit				

5. ABB Disposition

Comments:	

6. Signatures

	Write in name as electronic signature	Date
Supplier Representative		
ABB SQE or Quality Engineer		
ABB Engineering (optional) *1		

*1 - SQE or Quality Engineer determines when ABB Engineering sign-off is required (typically elements 9, 10, 11, 17.1)

Picture 2. ABB PSW template, phases 12-18 (ABB IECL LV Motors PPAP template, 2022).

3.2.5 Criticism towards PPAP

The certifications and tools provide a framework in which a company can strive towards its quality goals (Ferguson, 1993). However, it does not ensure that a company has quality-conscious employees or that its product is accepted by customers. To get the best possible benefit of quality tools it is important to engage the entire organization (Lathrop, 2010).

Lundgren (2019) presents the findings of research in Sweden automotive manufacturing industry (The Swedish Governmental Agency for Innovation Systems, 2014). According to the findings, companies use a lot of time on PFMEA risk assessment activities. At the companies, PFMEA was carried out in cross-functional teams consisting of product designers, process planners and manufacturing engineers. The teams were lead and coordinated by a PFMEA coordinator. It was discovered that complex organizational structures, task complexity, and a lack of effective tools all contributed to the work's inefficiency. A common experience at the studied companies was that outcome of PFMEA is highly dependent on the group's constitution. The difference between having a skilled PFMEA moderator or not could influence the resulting PFMEA document and its validity a lot.

Another finding was that use of inappropriate tools such as Microsoft Excel might result in massive and complex PFMEA spreadsheet documents that required significant manual work (Lundgren, 2019 [The Swedish Governmental Agency for Innovation Systems, 2014]). Manufacturing engineers at the companies experienced the output of PFMEA work to be low in comparison to the work effort required. As a result, PFMEA documents may not be revised as part of routine continuous improvement activities.

PPAP Manager (2019) presents on its blog the seven wastes of PPAP. Also, the blog criticizes the use of PPAP in Microsoft Excel because it causes wastes of wait and transportation. A typical PPAP documentation solution is an Excel spreadsheet with 18 tabs, one for each document. In this case, the first PPAP element to be filled cannot be sent until the last document is completed and entered the Excel. That causes waiting. Related to transportation, at this case the usage of Excel and email to manage PPAPs is like that it takes more time than necessary gathering the PPAP documents.

In addition, the blog raised issues e.g., related to waste due to defects, overproduction, unnecessary inventory, and motion (PPAP Manager, 2019). Rejecting a PPAP because it does not meet customer standards is not only expensive, but it usually attracts negative

attention from your customer's quality department. A good way to eliminate defects is to agree with your customer on the acceptance/reject criteria for PPAPs in the form of a PPAP Checklist. You can save time by ensuring that the documents fit your customer's requirements before submitting them. To eliminate the waste of motion and to improve communication between the customer and suppliers, hold regular meetings and try to use video conferencing instead of just email. Find a platform that makes communication easier with real-time notifications.

If you lack a PPAP Management system, you can easily fall into overproduction situation where you may be working in a PPAP that is not needed anymore or in a PPAP that will be needed 3 months later when you should be working in another urgent PPAP needed this week (PPAP Manager, 2019). The waste of inventory relating to the excess of work required to complete unnecessary PPAPs. When there are several revision changes, each revision must have an approved PPAP. Make a full PPAP for one version and then for the following versions you can use PPAPs with fewer elements validating only what changed from one revision to next.

4 Empirical Research

4.1 ABB IEC LV Motors Division

Thesis is prepared for the ABB IEC LV Motors division. ABB IEC LV Motors division manufactures electric motors on the frame sizes 71 to 500, on the output power from 0,18 kW to 355 kW. ABB is a pioneer in the development of energy-efficient motors (ABB, 2021). Division IEC LV Motors has six factories in five countries: Finland (Vaasa), Poland (Aleksandrów Łódzki), India (Bangalore & Faridabad), China (Shanghai) and Sweden (Västerås). Thesis has been prepared from a global perspective, so it contains interview material from the perspective of factories in Finland, Poland, India, and China.

4.2 Current state

Current state of the PPAP and of the processes around PPAP was cleared through interviews. Interviews clarified that how employees saw the PPAP – how do the communication, information flow and responsibilities between the different stakeholders work and what are possible perceived challenges and development ideas related to PPAP.

4.2.1 Interviews

A total of eight interviews were conducted. Interviewees were from Finland (FIMOT), Poland (PLMOT), China CNMOT, and India (INMOT) factories and from the global organization of IEC LV Motors division. Working positions of all interviewees were related to the PPAP, but with different ways – interviewees were in the specialist positions as well as management positions. Interviews were conducted both through Teams and face-to-face depending on the interviewees' working location. All participants received interview questions in advance and each interview was recorded. Interview questions are available in appendix 1.

Interviewees were Quality Engineers and Quality Managers from different levels of organization. Interviewees' working years at ABB varied between 1 and 29 years and the

average of working years in ABB was 15. All interviewees are either using PPAP daily or at least weekly basis or they are enabling and supporting the using of PPAP from the global perspective but do not actually use the tool. Depending on the position and job description the proportion of workload associated with PPAP varies. About half of interviewees are working with PPAP on a weekly and others on daily basis. For some of interviewees "it takes more than 80% from working time". Several interviewees mentioned that more time and capacity has recently been spent on PPAPs.

4.2.2 Current state

The perceived current state varies quite much between the factories and between the working positions. The tool has been in use in Asia (CNMOT and INMOT) for many years, in PLMOT for four years and in FIMOT it has been started to implement approximately one year ago so the factories are in a bit different stage with the using of tool. Naturally, in FIMOT it is still at the training level, in Asia it has become more routine and in PLMOT it is it is becoming a routine. On a general level, ABB is going to invested more in the supplier quality in the future.

> *"At the division level, more will be invested in supplier quality in the future - now we are thinking about and planning that change (how can we get more focus on it). The aim is to eliminate the idea of ordering from where the cheapest can be obtained. Always prioritizing to safety, sustainability, and quality. Price is never a factor in sacrificing quality."*

Interviewees mainly saw the potential of PPAP, but they also saw several uncertainties with it. Employees of the global organization has the same opinion: PPAP is not working well enough. The tool has raised opposition in us because it is perceived as a heavy process. PPAP should get implemented for day-to-day working. Several interviewees mentioned that PPAP has become a top-down requirement and it is not tailored and implemented to the use of the ABB's factories well. Interviewees felt that tool has been transferred to ABB directly from the automotive industry, without tailoring it to fit to ABB's operations.

Interviewees felt that PPAP process is quite clear to individual employees, but generally not clear to all ABB employees. The employer has offered trainings, but there is huge lack of practical trainings. When PPAP has been brought as to be immediately applied, then it is very difficult to implement it because people have not understood what the goal and the purpose of PPAP is.

The process and practices vary between the factories. High level process flow of PPAP is described in the figure 2.

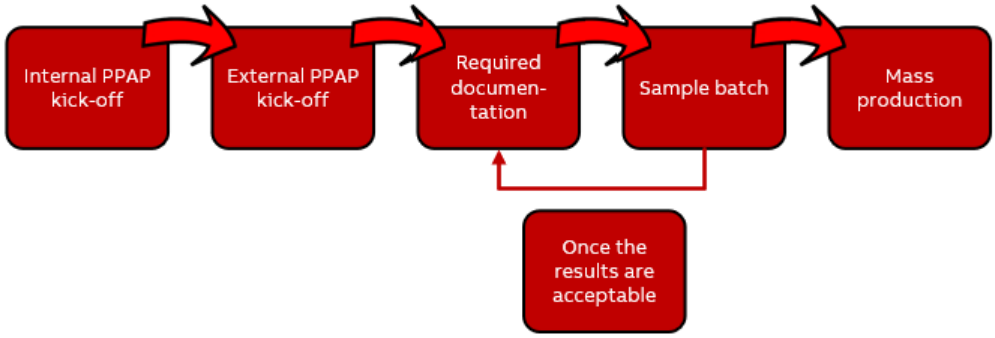

Figure 2. Simplified PPAP process.

Some years ago, PPAP was required from a few suppliers. Now the aim is that PPAP would be required from all suppliers in future. When ABB has new products which the supplier hasn't produced before, there is a kick-off meeting and people get connected with each other of the PPAP team. Then the supplier follows the requirements of the PPAP to run the process. If it is known that the supplier is good, there is no internal kick off meeting. If the supplier has supplied components to the ABB's other IEC LV Motors division's factories, then PPAP is not needed. Also, there is a back door on the guide: "unless SQE decides otherwise." If there is evidence that the current supplier's products are starting to have quality problems, PPAP can be used to force the supplier to focus on quality and possible to solve the quality problem.

In PLMOT the required PPAP level is always four, but in FIMOT selection of the level of PPAP has been included to the first step of process.

> *"In PLMOT, PPAP is done in the case of a new supplier or a new component. If the supplier is familiar or the part has been ordered from an ABB, PPAP will not be made. Level 4 is required from suppliers. Main documents we require are process flow, FMEA, Process Capability and MSA. Then we order a sample batch. Measurements can also be made at our other factories to save time. The factory takes the measurements, communicates with the supplier, and sends the results to the original factory. PPAP is a good tool to bring together different tools. At the same time, however, it is very complicated."*

The sample process has been in use for years: "It has been a kind of mini-PPAP. The new supplier sends a sample, we inspect it and give feedback for supplier. If everything is ok, we approve the sample and move to the mass production. If there are problems, we reject sample, the supplier will make the improvements and we start a new round of approval". Samples have helped to analyse things to be fixed and pointed out. The challenge with the sample process is that it does not go into the manufacturing processes of the supplier. There is no certainty that the supplier will be able to produce same quality level on normal every-day working conditions and mass production. Samples might have received extra attention or checks due to that customer checks the samples with extra accuracy.

Roles and responsibilities should be recorded to know how much capacity should be reserved for each step and responsibility. PPAP can't be under the responsibility of the local SQE primarily. The new guidelines firstly want that there must be held an internal kick-down meeting , which decides the PPAP level. Research & Development team (R&D), procurement team and supplier are invited to the meeting. Currently, the goal is to add checkpoint to the R&D project in the gate model, so PPAP should be considered at this stage. R&D indicates which parts should be documented as it has the best understanding of which parts in a product are critical.

4.2.3 Knowledge of the tool and training from company's side

"PPAP is a good tool to bring together different tools. But at the same time, it is very complicated." Some of interviewees felt that the PPAP process is easy and straightforward for them, but at the same time realized that it is not very clear to all ABB employees.

The tool should be implemented for daily work and for company's everyday working culture. The challenges of the process were perceived as many steps as possible, a lot of terms, and the difficulty of understanding the purpose of PPAP. Most of the interviewees felt that ABB has provided enough trainings and the trainings are of high quality. They have a good understanding of the general level of PPAP, but the level of detail understanding of the different tools is rather weak. Many of the interviewees felt that they have comprehensive knowledge in theory but lack of practical knowledge.

> *"PPAP is not the easiest tool to understand - in the process there are many steps, lots of terms and it is difficult to understand what the purpose is. It is not enough to go through one training and start using the tool. It requires at least one to a few times to do PPAP with someone Expert."*

The criticism has been given related to business unit specific tailoring of PPAP: "The toolkit is familiar, but how they are applied and what is a sensible way to apply them in our operations". The training was not modified at ABB, for example, there wasn't ABB's product in the examples. It was also seen as a challenge that ABB currently has many employees who have been trained e.g., via Teams and who are formally qualified on paper to make and implement PPAPs. However, real skills are quite weak or depend on individual employees. "I do not think it is possible to make PPAP in practice on the basis to these trainings" The specific tools inside the PPAP require even more learning. The employer offers pretty good trainings, but PPAP needs more repetition to understand it.

Some interviewees felt that using the tool is a new normal: "I don't have problems nowadays. All files have the same structure. It is not so complicated from my perspective". PPAP is not just learning at the beginning but continuous learning. Learning continues all the time. Trainings are recorded and it is possible to return to them. Some of the suppliers are more experienced, but there are also a lot of suppliers who have not any background with PPAP, so some training is needed. In any case, the development is very rewarding, so it is worth investing in.

4.2.4 Communication, roles, and responsibilities

The level of internal and external communication shared opinions. Some of interviewees experienced that there are not available clear enough instructions for how to communicate with internal or external partners and the communication doesn't work now. In PLMOT the communication and responsibilities were experienced really clear for people who use the tool. Interviewees who are working on a global organization mentioned that there are instructions available, and they have developed the communication between the EM (Emerging Markets) teams and factories.

Communication between ABB and the supplier vary. In CNMOT the process was felt to be quite clear, but they commented that after kick-off meeting the communication is poor. In FIMOT the communication with the supplier has seen a huge uncertainty – who is going to contact the supplier if e.g., something has been changed with the drawing. The big challenge right now is that there is no clear system for making changes, for example when there's a new revision of drawing, how we communicate that to the supplier. The change management of drawings is currently based on the presumption that the supplier is following the supplier portal and noticing any changes from there. There is not any kind of confirmation system from where we can see that the supplier has noticed the change. Who oversees that the PPAP is updated by the supplier and in what way? Supplier quality engineer (SQE) does not have the resources to do everything. Change management is a big challenge and our change management tools are inadequate.

Most communication with the supplier is via email. Email is a challenging tool because material disappears there over time. In addition, email is not a transparent tool, as all material is only available in email messages of the parties.

> *"Communication is not sufficient. Sending revisions to suppliers via email is inferior to a company of this size. New revisions should include coordination to ensure that the change has been received and implemented by the supplier. Person-based email communication is anything but the capability of a leading electric motor manufacturer. If we think about how much money we lose here, it's huge sums."*

The documents should have clear management and coordination as well as a system to assure us that the supplier has noticed the change. "This is also a straight message about how we manage our drawings ourselves." There should be some portal for documentation. Before, the materials related to PPAP were in SharePoint and anyone with the rights got to watch the documents. A portal for PPAP documentation is going to be created in INMOT and CNMOT.

PPAP related communication, information flow and requirements between the quality team and the procurement team has been seen quite sufficient and clear. There is high-quality cooperation between quality team and procurement team on both local and global level, and cooperation is perceived as natural. The challenges that have emerged are mainly different timelines: "Sometimes procurement team wants to do things quickly and they do not take enough contact to quality team. In addition, there is a different way of working between different people and this can lead to misunderstandings.

> *"We are in the same boat and seeking solutions in good cooperation. It is a bit unclear that who is the counterpart for who - who communicates at the same level so that communication is mutually beneficial."*

Also, at a higher level, cooperation is made between quality team and procurement team. Things are agreed beforehand, and quality team and procurement team are lobbying the same things into local factories. At a local level SQE mentioned that it would be good to know in advance that such a task is coming for SQE. If R&D starts developing a new product, it would more effectively if there came info that this kind of task is coming soon.

Roles and responsibilities between the local factories and global level were not clear enough. People who were working in manager positions thought that instructions were clear. Instead, people working in engineer positions felt that responsibilities were not properly defined. In addition, at the local level, SQEs did not know what was happening at the global level. There was no transparency between the local and global levels. However, a more precise definition of roles and responsibilities is currently underway.

4.2.5 Perceived usefulness of PPAP

All interviewees saw the potential in PPAP. Those who have used it for a long time felt that PPAP is "very helpful, very useful and very important for supplier quality". PPAP forces a supplier to think through their processes; to do process descriptions, control plans and forces to think processes more carefully. We have different levels of suppliers. With suppliers at a good level, the benefit isn't that big. For suppliers who are not at so good level, PPAP might be useful. The benefit was seen in saving money by eliminating expensive risks in advance. PPAP increases transparency. PPAP is a message to our customer that we are a supplier of sufficient quality to do the PPAP documentation. At the same time, our suppliers should be of sufficient quality to make the PPAP to us.

> *"There should be understanding on both sides that what is important about PPAP. High level supplier quality can be done without PPAP, but PPAP cannot be done without high level supplier quality. If the supplier is not high quality, it can't do PPAP. Is it worth to collaborate with suppliers that can't make PPAP? Is it worth for customer to buy a motor from us if we can't make PPAP with them? At the same time, it is an indication in ABB that we are capable enough. Constantly, our customers also demand PPAP. To them, PPAP is a natural tool to control suppliers. We need to have the readiness to do that with our suppliers. So PPAP is useful for supplier quality, but it requires a pre-quality supplier. PPAP is not able to develop the supplier from zero quality but is capable of verifying the supplier's quality return capability."*

There are upsides but also downsides of PPAP. The upside is that the tool was also seen as a good support for negotiating with a supplier: "PPAP is the argument when talking with suppliers. Everything must be in tolerance." PPAP opens eyes to doing, for example it has implications for our drawings — what are critical things and how things can be done. I think there will be even more benefit soon as we get ahead and get the organization to understand what PPAP is and when it is needed. As a downside has been seen that SQEs and suppliers have too many reports to fill and sometimes the reports are not suitable for the products.

4.2.6 Main challenges and key improvements from internal interviews

The main challenges that exist with PPAP in interviewees daily working were the lack of knowledge, lack of practical training, attitude and resistance to change, process implementation, critical to quality issues, the unclear process around PPAP, supplier's competence and time resources.

4.2.6.1 Training

As earlier mentioned, the interviewees felt that there is a huge lack of practical trainings of our own employees and suppliers. Interviewees felt that they don't have a sufficient level of expertise to analyse documents received from the supplier, although there has been training and material available: "There would be a need for smaller workshops where you practically make documents!"

Some of interviewees perceived that it is very difficult for some suppliers to understand what some of the tools included PPAP are and how they should be used. Understanding of proper requirements and tools we are using in the PPAP is important. How to communicate this to suppliers in such a way that suppliers understand this usefulness. For Indian suppliers, PPAPs are a daily job, but not for suppliers in Europe. The Finnish business culture is not the best possible for this kind a process.

4.2.6.2 Attitude and Resistance towards change

Many people think that PPAP just slows down and complicates working. "Jumping and doing PPAP systematically requires input and a lot of learning. It is challenging when everyone is in a hurry and have accustomed old modes of action. It requires an attitude that I understand why this is important, I understand that this requires input and I understand that requires a bit extra to learn how to do PPAP".

The interviewees felt that implementation of the PPAP has not been thought out. There has come a requirement from the upper level, and no one in the trainings made it clear

what the goal of PPAP is, how this will be implemented, and what impact this will have for different people. Who implements this for the use of the factory, for example, and who communicates to the suppliers? “It should be a decision by the whole organization that this is used or not used. Not a way that some single function is trying to push this, and others are like does not apply to R&D, does not apply to design, does not apply to anything.”

It must be remembered that whenever you go out to do a development project or change the thinking, you fall to the zero and then you get up and you can make a big step up. Now, suppliers are bottleneck: ABB’s suppliers should have the resource and the ability to meet the requirements of the process: “I don't mean that there should be some office person who fills out forms and excels, but in production there should be an operator who can measure parts correctly and be able to calculate the process performance and would be able to critically look at our documents (which of these requirements being able to fill, what measuring instruments it requires, etc.)”. The supplier is a bottleneck now, but if ABB do things right and they have good suppliers in the future and they learn, then the problem will shift to our engineering.

4.2.6.3 Communication and information flow

Internal communication: “It would be good to know in advance that this kind of task is coming. When R&D is going to make a new product, they would inform the quality team and then quality could know in advance what's coming. It would be easy to start to do PPAP when you knew the background.” Also, clear modes of operation between quality and sourcing (samples): “Does this somehow affect to FMEA? Does this affect to Control Plan? Do we still have adequate measuring instruments? Every single situation of change would require review.”

Internal and external information flow is an unclear process: “Most people don't know where we store the PPAPs. Externally it would be valuable if we have a website for the reports, where suppliers can easily find all aspects of information. Sometimes even SQE

can't find the material. We have hundreds of samples, so it is hard to find materials from many years ago.

4.2.6.4 Process

Now in FIMOT the implementation of PPAP depends on a few people. Competence should be implemented throughout the organization. There is needed a clarification for which components PPAP is made, for which not – what is the scope of PPAP in the division. Clear instructions are needed – on what parts to do and on what parts not to do - what the scope is. It would be good if at first there was a small core team that practices, experiments and applies for that model.

Process around the changes is unclear. What is the path of communication of change, e.g., a revision change? Does it come from the supplier when the supplier notices that there has been a change to the document? Is the supplier aware of any changes? Who oversees the PPAP update and in what way? SQE does not have enough resources to follow everyone and everything. At all, there are challenges with old drawings, documents, and revision management. Critical to quality factors are not defined clear enough. That has been perceived challenging when documentation does not help identify quality-critical issues.

> *"We have a long history and old drawings — there are no defined the points critical to quality (=e.g., these three points and measures are the most relevant and the others less important). It is a big challenge when making PPAP if you have a big number of "important" dimensions in the drawing, but all numbers are not really that important. It is challenging when documentation doesn't help identify things critical to quality."*

With new products, PPAP must be linked to the R&D gate model. The collaboration should start at the engineering stage so that the quality department know the backgrounds and can start to do the PPAP. Cooperation between R&D and quality should be developed so that critical to quality factors are clearly defined in the drawings. The

possible challenge is that all information is now put in one (or two) paper. We are unable to identify which issues are most important.

When new products are under development, the R&D would already be developed in the product development/design stage the most possible manufacturable. At first, ABB should focus on our own doing: for engineering, R&D, and manufacturing. A good chance would be to start training with a new product group and its components with something sufficiently different, e.g., with e-mobility motors. When new products are coming, the R&D would already develop the product design for the most possible manufacturable.

Even if the supplier does PPAP, we still do an inspection on the delivery. No information has been received that there is any intention to change this. PPAP cannot be based on the system that the inspection on the delivery is checked whether poor quality products were included.

4.2.6.5 Internal challenges which affect to PPAP

One of the interviewees mentioned that now the revision management of drawings of the company is “a chaos with no control" and it must be developed in the future so that the supplier can also trust for the quality of our documents.

> *“If one of the suppliers fails, then the whole ABB fails. We do not have a separate supplier quality. Supplier quality means ABB quality. Suppliers are a critical part of the chain. We must be able to trust the quality of our suppliers and suppliers must also be able to trust for our quality – for our documentation, specs and change management must be of high quality.”*

The good practicalities with the engineering are also needed: “If we make a bigger change to drawings, there should be a new product code, not a new revision.”

4.2.6.6 Other challenges and development ideas

In addition to these, the challenge was perceived that time resources are sufficient for only a limited number of PPAPs. Too many reports need to be included into PPAP and only SQE reads some of reports.

There could be several different types of PPAPs for different uses. PPAP for low quantity, PPAP for high quantity, PPAP for the frame and PPAP for the castings. The PPAP process should be divided into several subprocesses. Most repeated challenges and improvement ideas from internal interviews are summarised into table 5.

	Challenges	**Improvement ideas**
Trainings	• Lack of practical training • Lack of supplier's knowledge	• Smaller workshop trainings
Process	• How to implement the PPAP for factory use • Unclear roles and responsibilities • Communication with the supplier (e.g. revision change) • Defining critical to quality factors	• Internal information between engineering, R&D, and quality that what is coming • A small core team that at practice, experiment and apply for the optimal PPAP model • Not inspections on the delivery for PPAP-qualified components
Tools	• Revision management • Way to define critical to quality factors	• Shared website for the PPAP related instructions and documents (with the supplier) • Critical to quality factors documentation • Including PPAP to the R&D gate model • Design for manufacturing thinking • Internal awareness of where PPAPs are stored
Attitude	• PPAP just slows down and complicates working	• The decision and commitment of the entire organization to make PPAPs

Table 5. Summary of challenges and improvement ideas by topics based to the internal interviews.

4.3 Best practices from benchmarking interviews

To get a better understanding of how PPAP could be developed in ABB, there is examined how PPAP is used in other companies. Totally three companies have been interviewed. Interview questions are available on the appendixes 2 and 3 and summary of both interviews on appendixes 4 and 5. These three companies were working with PPAP at a daily basis. Basic information of companies' background with PPAP has been shown in the table 6. The companies A and B are on customer role and require PPAP from its suppliers. company C requires some parts of PPAP also from its suppliers, but at this interview company C plays the role of supplier who makes PPAP to its customer.

	Company A	Company B	Company C
Years used PPAP	Long time on a company, implementing stage at this division	Since 2015	Since 2000
Role of PPAP	Requires PPAP from the supplier	Requires PPAP from the supplier	Makes PPAP for the customer
Quantity of PPAPs	4 per person per year	50-100 per year	Now 2 open PPAPs

Table 6. Summary of benchmarking companies.

Benchmarking companies have confronted some of the same challenges that ABB has faced – for example resistance towards change.

4.3.1.1 Training

Company A has an own in-house training program. PPAP is part of a larger supplier toolkit. The goal is for everyone who works with PPAP to be trained to understand how the tool works. Everyone has not the same training, training is tailored to different departments or employees. The trainings are for about 10 people at a time and are held a few times a year.

A few general trainings have been offered from the division level on the company B, but the learning has mainly taken place locally through practice. ach factories have the

responsibility of PPAP locally, so the activities must be tailored to suit the local factory. The best practice teaching is a skilled employee with whom PPAP is done. Company B has also offered PPAP training for a few suppliers. In addition, they have a small guideline for the supplier on how to use PPAP.

From the Company C point of view, external trainings (e.g., by the IATF) is quite theoretical. Instead of that the customer audits / certification audits and discussion with the customers are a good way to learn from findings. The audit has encountered a situation where a serious deviation from production has been found (the process has not gone as described in the PPAP) and, as a result, human resources have had to be increased to invest in the quality of the work.

4.3.1.2 Attitude and resistance towards PPAP

Company A has met the similar challenges during the implementing the PPAP. There has risen a resistance towards PPAP – why is this being done and what is the value of PPAP. However, the benefits of PPAP have been demonstrated through practice: “This could have been avoided if PPAP had been used”. Through this, the value of the tool has been understood better in the company.

The implementation of the tool and the team involved must be trained and committed - including the supplier. The supplier will only be interested if they see value and benefit (e.g., more orders in the future) of PPAP. If the supplier knows that this is a one-time project, then they have no interest in doing PPAP properly.

4.3.1.3 Process

In the company B, PPAP has used with suppliers. Basically, PPAP level 3 is made for all the parts the company has designed and which are made with our own tool. The goal is to make PPAPs for all products already in production as well.

> *"We have done QRV (Quality Ranking Value) calculation for the components of the existing product. There were about 250 components in the product bill of materials BOM, but through QRV calculation, the scope has 60 components, for which 60 PPAPs are to be created. In addition, we have designed a policy of ordering only PSW from a supplier of standard components with a low QRV value."*

By using QRV ranking, Company B determine the quality ranking value (what effect a part has on the performance and safety of the product, and how the part is made, where it is made, and who makes it) according to which PPAP level to choose. This is done e.g., for all new tools procured for component manufacturing by the supplier. Procurement is very actively involved in this. When company B compete with tool suppliers, PPAP is already involved at this stage.

"In our company, from the division level has been defined responsibilities so that R&D is responsible of PPAP. In the factory level we have found that it is more natural that product engineering has a responsibility to monitor, through PPAP, what comes out of product development. That means we in product engineering are doing work that does not become a goal for us. The reason for the change is that the task of product development is to design new products. If they also do this documentation, quality assurance, then the function observes its own working. Therefore, product maintenance is the "observer" of R&D. In the past, quality played a bigger role, but it was found that this is a tool for quality that they can base and rely on, so it was found that it may not be appropriate for quality to organize PPAP. Of course, quality is strongly involved in making PPAP."

PPAP was initially a new thing for the supplier and required resources from the supplier. We should have included at the bidding stage the specification that the PPAP documentation is included in the tool delivery. Initially, we had to discuss with the supplier whether PPAP is part of the price of the tool or whether a separate price should be paid for it. We were also surprised by the amount of work that goes into making one PPAP. Since then, there has been mainly positive feedback from suppliers.

The company C mentioned that all products they produce are customer's own. They want to be involved in the design of the product right from the start so that they know that the product can be manufactured. Design for Manufacturing (DFM) is an important step before starting PPAP. DFM affects straight to the lead time of PPAP. “When a customer sends a request for quotation and specs, we have to say immediately if we are unable to meet any requirement. Once the specs are accepted, it is difficult to change requirements at a later stage. There has been a situation where we have not pre-tested the capabilities of our process sufficiently and are unable to meet customer requirements. Sufficient data on capability needs to be collected in advance to make the approval process go through better. We have had situations where we have declined the Part Submission Warrant (PSW) because we have not yet been able to get Initial Process Studies (IPS) approved”.

PPAP can be a long process. On company C, one of PPAPs has been made for four years. At its longest, the approval of the PPAP process has taken six years in the company C: “The processes take a long time, as we do not meet the customer's requirements. The product works in practice and is even delivered to the customer all the time, but there is no official approval. These are challenges in small nuances that we cannot reach. Alternatively, we will continue to try to develop our product to meet customer requirements, or the customer will ease their requirements in terms of tolerances”.

From the Company C point of view, there are big differences between customers. There is a weekly meeting with some, with interaction and even training. Some customers will only contact you if there are any problems. Close cooperation is a better way to work, because then both parties will stay up to date and there will be no surprises. At the same time, it is possible to optimize doing, and not to do too much. “We have provided support to our suppliers to complete their FMEAs, for example.”

4.3.1.4 Tools

Companies A and C stored their PPAPs and other PPAP related documents in M-Files. Company A consider that SharePoint could be a working tool for live working, but revision management works better in M-Files. All companies use Excel to make PPAPs. Company B has created all calculations to Excel so that Visual Basic counts the calculations in the background of PPAP Excel and via that using the document package as easy to use as possible. Excel is ok for compiling data, but the company must look for better tools for document management in the future. Company B have now the version four of the PPAP Excel template going in their everyday use.

> *"Operations are constantly being developed based on feedback from suppliers and other stakeholders. We do not want to overload the supplier, e.g., to do work that is not considered useful. For example, the number of measurements easily grows huge and becomes data that we do not benefit from. We actively solicit feedback from PPAP suppliers and PPAP is developed based on the feedback. We may at some point drift quite far from the original version, but PPAP needs to be scaled to fit our operating environment."*

On Company A the critical to quality factors are defined internally and regularly checked for updates. A new product is always a normal risk project because there is no previous experience with it. Critical to quality factors have been defined on the technical Specification. "In addition, e.g., for welding we also have a welding map that defines quality-critical welds."

On the Company B, R&D has a big role to play with PPAP. Initially, critical dimensions were added to the drawings. Today, in addition to drawings, there is used a QPS (Quality Packing Specification) that defines other inspections (including what visual inspections should be performed on a part). R&D team defines what needs to be inspected and quality team determines the frequency at which inspections are performed. On the company C the customer clearly defines the critical to quality requirements. Critical to safety issues and critical to functionality issues are defined separately in the drawings. Company use a product lifecycle management (PLM) system Windchill for where a few suppliers

have rights, and they see the latest revisions from there. Otherwise, new revisions will be sent by email.

From the company C point of view, the customer has not always defined things critical to quality precisely enough: “We have manufactured the product according to their specs, but the customer has not been satisfied and has demanded more from us”.

At a general level, company B felt that PPAP is perceived as a useful tool. PPAP has brought systematicity and orderliness to operations. In addition, PPAP is a good tool for supplier auditing. Once the supplier has verified with PPAP that this is how we make the part, we can demand that “show where do you have the checkpoints of this Control Plan”. Summary of key improvements from benchmarking companies showed in the table 7.

Category	Observed development areas based on benchmarking
Training	• Simple general knowledge of PPAP for whole company (what PPAP means and what it aims to achieve) • Tailored more deep trainings for different departments • Small trainings (~10 persons) • Practical training with Expert (”Mentoring”)
Process	• Ranking system (Quality Ranking Value, QRV) • Including PPAP already to the competitive tendering • Active development of PPAP package based to the feedback from stakeholders • Roles between R&D, engineering, and quality team • Defining and updating the critical to quality factors
Tools	• M-files or other software for revision management • Active development based to the feedback from stakeholders • Optimal way to define critical to quality factors – drawing, map or QPS (Quality Packing Specification) ?
Attitude	• Practical examples of situations that could have been avoided with PPAP • Motivating supplier with the future benefit

Table 7. Observed development areas based on benchmarking.

5 Conclusions and discussion

The results of empirical research are summarized in this chapter of the thesis. It also contains a discussion and conclusion between the theory and the study's conclusions. Finally, it suggests potential future research options that might be pursued to further development of processes.

5.1 Conclusion

The research began by defining the challenges and aims of the thesis, which was followed by limiting the subject of research and becoming more familiar with ABB IEC LV Motors division, which served as the case company in this study. Following the discussion of the thesis's background, the theory underlying the methodological investigation were explained, and by relying on the theories. Following the explanation of the research technique, PPAP and its history, background, goal, and technology were thoroughly researched using multiple literatures obtained on the issue.

Objectives for this study were:

1. Clarifying the current situation of PPAP documentation in ABB IEC LV Motors division - what are its perceived benefits and disadvantages of PPAP at the moment.
2. Identifying how PPAP processes can be developed in the future.
3. Identifying how it is possible to get the best possible benefit of PPAP.

The perceived benefits of PPAP at the moment are its potential for e.g., minimizing quality errors in the future, amount, and quality of theoretical training of PPAP, and the fact that PPAP is a tool that can be utilized when negotiating with a supplier. The perceived disadvantages regarding to PPAP were unclear objective – why PPAP is worth to implement, what is it objective, how is it applied by ABB, how is it achieved, lack of practical training, defining critical to quality factors and revision management.

The question of how PPAP may be improved is partly complicated because all organizations, their product portfolios, personnel, and working cultures are unique, and even factories within the same company can differ. During this research, it became clear that it is not possible to create a single system that is adequate for all applications. PPAP can be complicated to implement at first, but it can increase supplier quality while also saving a lot of money and time. The methodical implementation of PPAP sets the foundation for high-end quality production companies like ABB, making supplier quality and management crucial. PPAP documentation should be given adequate time to verify that it is comprehensive and accurate.

The interview responses vary from side to side, signalling that people working at different positions saw the situation differently – global organization saw the situation clearer while others saw challenges and areas for development. In conclusion from both internal and benchmarking interviews, the longer PPAP has been used, the clearer it is perceived to be. The tool can take several years to find its own role and process in the company. PPAP is a tool that may be thought of as tailored to the needs of a company over time as needs, ways of working, and systems evolve.

It is natural and understandable that a large, leading electrical motor company wants to evolve and improve its operations. There is a desire to develop throughout the company. The challenge is that communication between the global organization and local factories is incomplete. After the target state is defined at the global level, it has been communicated to the factory so that the change causes resistance to change.

The challenge may be that in a global organization, things are planned for a long time, making the issue clear and familiar in the global organization over time. When a point of development is revealed to local factories, change comes to the local factory too quickly and with too much pressure. The most challenging situation is a combination of these, a situation where the goal is long considered and clear to the global organization and the

matter is brought to the local factory with incomplete information, quickly and with pressure.

On the other hand, interviews indicated that a lot of training has been provided, but the reasons and concrete for making the change are exhausting. One of the responsibilities of change management is to justify the planned change to the organization (Lehtonen-Hanhinen, 2016), i.e., to answer the question of why the change is being made. It may also be that the reasons for the change have been stated, but not many times or clearly enough, because there are people in the employees who feel they have not received the information.

The lack of practical training emerged as a perceived challenge in the interviews. An in-house training program could be a benchmark, but on the other hand, ABB already has something like that. It's just very theory-focused right now. Perhaps the company should develop their in-house training program so that practical learning takes place in smaller groups or perhaps even through mentoring. One of the biggest questions was what kind of tool should be customized to serve the purpose of the company. From the very beginning, to eliminate resistance to change, an advantage could be gained through practical examples - "This could have been avoided if PPAP had been used". Through this, the value of the tool is better understood in the company. In general, step-by-step sub-targets could help to understand and achieve the goal, because of which PPAP can be made for all products after X years.

I recommend that ABB benchmark the Company B's system in the PPAP process to determine the Quality Ranking Value of the product. Using QRV ranking, the company rate the risks kind what effect a part has on the performance and safety of the product, and how the part is made, where it is made, and who makes it. The value makes it possible to quantify which products are made into PPAP and which PPAP level is used. With QRV, the target can be delineated more consistently than by qualitatively defining different clusters. Also, there should consider the quantity of components in supplier's batch,

because it is not valuable to make PPAP with all 18 elements e.g., for two customized components.

Currently, the main responsibility for organizing PPAP in the case company lies with SQE. In Benchmarking Company B, the main responsibility was on product management, and it was done in close collaboration with R&D, and PPAP was rather a tool for the quality function to negotiate and appeal to product quality. The company justified the operating model in such a way that a certain function cannot do the job and monitor the result of its own work. The tool cannot depend on a single function. It doesn't work that SQE makes a PPAP, SQE monitor its own work via the PPAP and PPAP is also SQE's tool for negotiation. In any case, it is impossible to define a ready-made operating model without longer-term testing and developing cycle.

A clear challenge for ABB is to determine the critical to quality factors. As a benchmark in Company B, several different methods have been used to define CTQs: drawing, map or QPS. If it is not possible to add CTQ factors to the drawing, there could be a separate map or a separate list for the CTQ factors. ABB could make use of one or, alternatively, more of the methods, depending on what it considers most practical. Based on the experience of supplier benchmarking, Company C, in the optimal situation, the supplier would be included in the Design for Manufacturing process already at the R&D or design stage, allowing the product to be manufactured and possibly as risk-free as possible, considering critical to quality factors. On the other hand, I don’t know if it’s practically possible in production where volumes are high.

The revision management has also been identified as a development target. Two of the benchmarking companies uses M-files for the revision management. The interviewees of the companies mentioned that M-files is really good tool for that usage, but SharePoint is good for live work. On the other hand, the benchmarking companies use M-files only for their own document management. The stakeholders don’t have the access to those revisions. Maybe the M-files could have potential for internal revision

management, but there might be even more developed cloud-based systems on the market at these days.

If PPAP as an output of APQP is the evidence that the APQP has been executed, is it possible to get the best possible benefit about the PPAP if you don't follow APQP? To get the best possible benefit of PPAP, it might be needed to follow the whole APQP process. There might be a room for future research. Secondly, whether APQP and PPAP is certainly the best or right way in the ABB environment, or should it be applied from somehow? APQP and PPAP were originally created for mass production, but some of the production is customized and the series are small, so following PPAP and APQP as such may not be ideal.

5.2 Discussion

Benchmarking as single research can open the eyes of company management and help to develop better solutions (Lecklin, 2006). However, the benefit to be achieved will remain short-term unless benchmarking leads to a continuous learning process. Continuous benchmarking cooperation e.g., between different ABB divisions could help both parties to identify the challenges in their own process and possibly find solutions to them.

As further research, document change management of drawings and PPAP's could be one topic to explore and develop in the future. It is currently a major challenge for ABB. So that the processes work with external stakeholders, they must first be made to work internally within the company. Another topic for further research could be to work with an ABB supplier to review how the supplier sees ABB's process compared to other customers and what the supplier thinks about ABB's concept. Also, quantitative research on the benefits of PPAP after some time it has been used by us might be valuable to research.

The results and ideas for improvement discussed in this study will hopefully increase ABB's understanding of the current state of the PPAP process and serve as a tool for developing the PPAP process. Based on these research findings, the company's PPAP

process should be able to be improved by implementing these changes as the management deems best.

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Appendix 1: Internal interview questions

1. How is your current role connected to PPAP?
2. How and how much do you use PPAP in your role?
3. Describe how the PPAP process works in our division.
4. What level do you feel your own understanding is at regarding PPAP?
    a. Do you feel that you have received enough training?
5. How easy and clear is the PPAP process?
6. How does communication work internally and externally within a PPAP project?
    a. Are the instructions clear and understandable?
    b. Are there enough instructions?
7. How useful PPAP is for supplier quality?
    a. How the quality of the products meets the requirements set with suppliers who uses PPAP (e.g., how much there has been opened complaints to the supplier)?
8. Has there been problems with the samples?
9. What kind of communication there is between ABB and the supplier including e.g., communication systems and procedure? (for example, when the quality requirements (e.g., drawing, material specifications, painting) change, or when the quality of the products does not meet the requirements)?
    a. Is the communication at a sufficient level and clear?
    b. Is there a clear system for make the possible changes to the requirements?
    c. What happens when the drawings become a new revision? How do you start the process?
10. Are PPAP related communication, information flow and requirements between quality team and procurement team sufficient and clear?
11. Are the roles and responsibilities between local and global clear?
12. Which are the main challenges that exist with PPAP in your work?
13. How PPAP or processes around it could be developed?
14. Do you have any other recommendations what we should investigate and who we should talk to further investigation of PPAP?

Appendix 2: Benchmarking Interview Questions – Supplier PPAP

1. How is your current role connected to PPAP?
2. What level do you feel your own understanding is at regarding PPAP?
3. What level do you feel the understanding is on whole company at regarding PPAP?
4. What role does PPAP play in your organization?
5. How long have you used PPAP as a daily tool?
6. How many PPAPs do you make, e.g., per year?
7. What tool do you use to make PPAPs?
8. Where do you store PPAPs?
9. What kind of challenges did you face when you were implementing PPAP into the organization? How were these challenges resolved?
10. Did the introduction of PPAP face resistance to change during implementation?
11. What kind of trainings do you have related to PPAP in your organization? Are the trainings practical?
12. What kind of challenges have you faced with PPAP over time?
13. Do you see challenges related to PPAP in the future?
14. Have there been any challenges in communicating either internally within the organization or externally with suppliers? How were these challenges solved?
15. Where do you communicate with the supplier?
16. How and at what stage are critical to quality factors considered?
17. Revision management: How are changes in drawings communicated to the supplier?
18. Do you somehow measure the benefits of PPAP?
19. How useful PPAP is for supplier quality?

Appendix 3: Benchmarking Interview Questions – Customer PPAP

1. How is your current role connected to PPAP?
2. What level do you feel your own understanding is at regarding PPAP?
3. What level do you feel the understanding is on whole company at regarding PPAP?
4. What role does PPAP play in your organization?
5. How long have you used PPAP as a daily tool?
6. How many PPAPs do you make, e.g., per year?
7. What tool do you use to make PPAPs?
8. Where do you store PPAPs?
9. What kind of challenges did you face when you were implementing PPAP into the organization? How were these challenges resolved?
10. Did the introduction of PPAP face resistance to change during implementation?
11. What kind of trainings do you have related to PPAP in your organization? Are the trainings practical?
12. What kind of challenges have you faced with PPAP over time?
13. Do you see challenges related to PPAP in the future?
14. Have there been any challenges in communicating either internally within the organization or externally with customers? How were these challenges solved?
15. Where do you communicate with the customer?
16. How and at what stage are critical to quality factors considered?
17. Revision management: How are changes in drawings communicated with the customer?
18. Do you somehow measure the benefits of PPAP?
19. How useful PPAP is for quality of products?
20. Has the customer offered support to make PPAP?

Appendix 4: Benchmarking interviews – Supplier PPAP

		Company A	Company B
0	**Current role**	Supplier Development & Quality Manager	Product Engineer Manager, Senior R&D Engineer, Quality Specialist
1	**How is your current role connected to PPAP?**	I organize the PPAP process.	PE: When PPAP is required from suppliers, the preparation of documentation is the responsibility of product engineering. R&D: Process owner. When tools are procured for product development, the tools are approved in accordance with PPAP. I'm taking the process forward with the suppliers. QS: My job includes e.g. supplier quality and PPAP. I am involved in a program to do lighter PPAP documentation for already approved products with suppliers.
2	**What level do you feel your own understanding is at regarding PPAP?**	I have a few years of background in PPAP. I have been working with PPAP for over 3 years. I feel that my understanding is at a good level: I understand what the different tools are and what benefits they offer.	We all have good skills. On the other hand, for example, detail data analysis does not have its own field of expertise.
3	**What level do you feel the understanding is on whole company at regarding PPAP?**	PPAP is up to individuals. Not everyone is aware of PPAP.	Pretty good. Most company employees know about PPAP - at least what PPAP means and what it aims to achieve.
4	**What role does PPAP play in your organization?**	We make PPAP for our own customers and require PPAP from our suppliers.	PPAP is used with suppliers. Basically, PPAP level 3 is made for all the parts we have designed and made with our own tool. The goal is to make PPAPs for the products already in production as well. We have done QRV (Quality Ranking Value) calculation for the components of the existing product. There were about 250 components in the product BOM, but through QRV calculation, the scope has 60 components, for which 60 PPAPs are to be created. In addition, we have designed a policy of ordering only PSW from a supplier of standard components with a low QRV value. Using QRV ranking, we determine the quality ranking value (what effect a part has on the performance and safety of the product, and how the part is made, where it is made, and who makes it) according to which PPAP level to choose. This is done e.g. for all new tools procured for component manufacturing by the supplier. Procurement is very actively involved in this. When we compete with tool suppliers, PPAP is already involved at this stage.
5	**How long have you used PPAP as a daily tool?**	PPAP has long been used in the company. However, this is a large organization and PPAP is being implemented in this unit.	From 2015. PPAP started as a pilot project and is constantly expanding.

6	**How many PPAPs do you make, e.g. per year?**	Personal target 4 per year (comprehensive PPAPs). A variation can be made from a single product, with the existing PPAP covering a large part of the materials and updating only some of the materials.	It varies a lot. Several different levels of PPAP have now been introduced. We currently do 50-100 PPAPs per year. In the future, the numbers are likely to increase.
7	**What tool do you use to make PPAPs?**	Excel. When there is a lot of material, the size of the Excel file grows to a huge size. At some point, a better system should be devised for this.	Excel. Data transfer in Excel works well - all calculations are done in Excel so that Visual Basic counts in the background, making the document package as easy to use as possible. Excel is ok for compiling data, but we need to think better tools for document management in the future.
8	**Where do you store PPAPs?**	In M-Files. Both PPAP documents and other related documents. SharePoint could be a working tool for live work, but revision management works better in M-Files.	Officially, document management is in SharePoint. Currently, SharePoint is a weakness in the process.
9	**What kind of challenges did you face when you were implementing PPAP into the organization? How were these challenges resolved?**	There have been challenges - why is this being done and what is the value of this? However, the benefits of PPAP have been demonstrated through practice: “This could have been avoided if PPAP had been used”. Through this, the value of the tool is better understood.	1. From the division level has been defined responsibilities so that R&D is responsible of PPAP. In the factory level we have found that it is more natural that product engineering has a responsibility to monitor, through PPAP, what comes out of product development. That means we in product engineering are doing work that does not become a goal for us. The reason for the change is that the task of product development is to design new products. If they also do this documentation, quality assurance, then the function observes its own working. Therefore, product maintenance is the “observer” of R&D. In the past, quality played a bigger role, but it was found that this is a tool for quality that they can base and rely on, so it was found that it may not be appropriate for quality to organize PPAP. Of course, quality is strongly involved in making. 2. In the beginning, we just went straight to ask the supplier for PPAP, but we had to quickly get back to what the supplier is doing PPAP against. We do not have enough high-quality material to ask suppliers for PPAP. 3. PPAP is perceived as heavy documentation. 4. PPAP was initially a new thing for the supplier and required resources from the supplier. We should have included at the bidding stage the specification that the PPAP documentation is included in the tool delivery. Initially, we had to discuss with the supplier whether PPAP is part of the price of the tool or whether a separate price should be paid for it. We were also surprised by the amount of work that goes into making one PPAP. Since then, there has been mainly positive feedback from suppliers. "
10	**Did the introduction of PPAP face resistance to**	Yes. Everyone don't see the benefits of PPAP.	-

	change during implementation?		
11	**What kind of trainings do you have related to PPAP in your organization? Are the trainings practical?**	We have our own in-house training program. PPAP is part of a larger supplier toolkit. The goal is for everyone who works with PPAP to be trained to understand how the tool works. Everyone has not the same training, training is tailored to different departments / employees. The trainings are for about 10 people at a time and are held a few times a year.	A few general trainings have been offered from the division level, but the learning has mainly taken place locally through practice. Responsibility and doing are in the factories, so the activities must be tailored to suit the local factory. The best practice teaching is a skilled employee with whom PPAP is done. We have held PPAP training for a few suppliers. In addition, there is a small guideline for the supplier on how to use the tool.
12	**What kind of challenges have you faced with PPAP over time?**	1. Revision management. 2. Involving and engaging employees and the supplier in making the PPAP. PPAP can be a new tool for the supplier. However, the supplier can see the potential here: if they work with the customer to start making PPAP, the customer is more likely to commit to buying the product from the supplier in the future as well. But there are also suppliers who have questioned the tool. We usually keep a kick-off meeting for the supplier, where we tell you what it is and what this PPAP is. The content of the documentation package will be reviewed with the supplier in the different steps as the project progresses - the next step will be reviewed individually before starting. 3. Some of the problems we have had are related to the quality of our own material. The mistakes were not just the fault of the supplier. 4. Challenges we have faced with suppliers: a) Are the instructions always followed (e.g., tightening torques)? b) If there is a complex product with a lot of parts, the instructions can be dozens of pages. If the supplier has been manufacturing the component for a long time, the challenge is to get them to recheck the work instructions continuously to notice the changes. c) Suppliers do not want to share work instructions with us, as we would even be able to start manufacturing the product ourselves based on extensive material. However, we do spot checks where we check a certain stage and go through the instructions that there are all stages fulfilled. "	We currently have version four of the PPAP Excel template going. Operations are constantly being developed based on feedback from suppliers and other stakeholders. We do not want to overload the supplier, e.g., to do work that is not considered useful. For example, the number of measurements easily grows huge and becomes data that we do not benefit from. We actively solicit feedback from PPAP suppliers and PPAP is developed based on the feedback. We may at some point drift quite far from the original version, but PPAP needs to be scaled to fit our operating environment.

13	**Do you see challenges related to PPAP in the future?**	Document Management: Email and Excel may not be the best tools. Updating changes - what should be considered at the time of the change?	A PPAP document should be a living document that is updated in collaboration with the supplier. The goal would be for the supplier to update the PPAP and find it useful to him.
14	**Have there been any challenges in communicating either internally within the organization or externally with suppliers? How were these challenges solved?**	In the main, communication works well, although there have been situations where there have been misunderstandings. Cooperation works when communication is clear and adequate.	When new types of situations or changes arise, there are still internal challenges to who is responsible. Mainly the operation and communication are clear. In the beginning, there were challenges with the supplier as we did not include PPAP and its concrete content in the call for tenders. Currently, the challenge is mainly schedules.
15	**Where do you communicate with the supplier?**	In e-mail as well as in meetings. Usually, we have a kick-off meeting and depending on the project a few follow-up meetings.	Email and Windchill.
16	**How and at what stage are critical to quality factors considered?**	Critical to quality factors are defined internally and regularly checked for updates. A new product is always a normal risk project because we have no previous experience with it. Quality critical factors have been defined on the technical Specification. In addition, for welding, for example, we also have a welding map that defines quality-critical welds.	R&D has a big role to play here. Initially, critical dimensions were added to the drawings. Today, in addition to drawings, we have a QPS (Quality Packing Specification) that defines other inspections (including what visual inspections should be performed on a part). QPS includes FTS (Functional Testing Specification) and VTP. R&D defines what needs to be inspected and quality determines the frequency at which inspections are performed.
17	**Revision management: How are changes in drawings communicated to the supplier?**	By email. Suppliers do not have access to M-Files. M-files is for your own document management. We also have a few SharePoint that the supplier has access to.	We use a PLM system Windchill. A few suppliers have rights to Windchill, and they see the latest revisions from there. Otherwise, new revisions will be sent by email.
18	**Do you somehow measure the benefits of PPAP?**	By the number of complaints. Even if PPAP is done, errors can still occur.	PPM (Parts Per Million Defective) and supplier-PPM are the only direct metrics. At some point, the development can be seen in the lead times of product development projects.
19	**How useful PPAP is for supplier quality?**	PPAP is a useful tool. It is important that everyone involved in making PPAP understands how it works and what the benefits are. Risk management is at a better level when using PPAP. The implementation of the tool and the team involved must be trained and committed - including the supplier. The supplier will only be interested if they see value / benefit (e.g., more orders in the future). If the supplier knows that this is a one-time project, then they have no interest in doing PPAP properly.	At a general level, PPAP is perceived as a useful tool. PPAP has brought systematicity and orderliness to operations: drawings, QPS, FTS, PTP, PPAPs are the whole base on which work is done in production. In addition, PPAP is a good tool for supplier auditing. Once the supplier has verified with PPAP that this is how we make the part, we can demand that “show where do you have the checkpoints of this Control Plan”.

Appendix 5: Benchmarking interview – Customer PPAP

		Company C
0	**Current role**	Development Manager and Quality Manager
1	**How is your current role connected to PPAP?**	A large part of the development manager's responsibilities includes IATF products. The Quality Manager is involved in making the PPAP process. PPAP is a shared process between the development manager and the quality manager: the NPI process belongs for the development manager and the approval phase for the quality function.
2	**What level do you feel your own understanding is at regarding PPAP?**	Good average. There are customer-specific differences in requirements. Some have lower requirements, some more stringent. Learning is continuous.
3	**What level do you feel the understanding is on whole company at regarding PPAP?**	-
4	**What role does PPAP play in your organization?**	In the past, a small team has done PPAP. The process has changed, and a larger team is involved in documentation and risk management. The requirements are being refined into work instructions, so it is good for production to be aware of PPAP as well. We do not have our own products. All products are customer's own. We want to be involved in the design of the product right from the start so that we know that the product can be manufactured.
5	**How long have you used PPAP as a daily tool?**	At least from the beginning of the 21st century.
6	**How many PPAPs do you make, e.g., per year?**	PPAP is a long process. We currently have two open PPAPs. One of them has been made for four years. At its longest, the approval of the PPAP process has taken six years. The processes take a long time, as we do not meet the customer's requirements. The product works in practice and is even delivered to the customer all the time, but there is no official approval. These are challenges in small nuances that we cannot reach. Alternatively, we will continue to try to develop our product to meet customer requirements, or the customer will ease their requirements in terms of tolerances.
7	**What tool do you use to make PPAPs?**	Excel. Quite a working tool so far - nothing better has been invented.
8	**Where do you store PPAPs?**	Revision management is in M-Files. The documents will be updated if the drawings become new revisions or, for example, the delivered product becomes a complaint.
9	**What kind of challenges did you face when you were implementing PPAP into the organization? How were these challenges resolved?**	-
10	**Did the introduction of PPAP face resistance to change during implementation?**	Possibly. However, there is no resistance to change nowadays.

11	**What kind of trainings do you have related to PPAP in your organization? Are the trainings practical?**	External training (e.g. by the IATF) is quite theoretical. Customer audits / certification audits and discussion with the customers are a good way to learn from findings.
12	**What kind of challenges have you faced with PPAP over time?**	1. Design for Manufacturing (DFM) is an important step before starting PPAP. DFM affects the lead time of PPAP. When a customer sends a request for quotation and specs, we have to say immediately if we are unable to meet any requirement. Once the specs are accepted, it is difficult to change requirements at a later stage. There has been a situation where we have not pre-tested the capabilities of our process sufficiently and are unable to meet customer requirements. Sufficient data on capability needs to be collected in advance to make the approval process go through better. We have had situations where we have declined the PSW (Part Submission Warrant) because we have not yet been able to get IPS (Initial Process Studies) approved. 2. At some point, the quality engineer alone did a lot of risk assessment and the idea of PPAP is not fully realized. This has been developed and today risk assessment is done as a team. 3. Understanding. PPAP also slows down operations. You must understand why you are looking for approval instead of just doing things. The work must comply with the work instructions. Sometimes there is a need to change the work instructions. Sometimes it is difficult for operator to understand that a change should be implemented throughout the chain, including the FMEA and Control Plan, among others, rather than just making a change to the work instructions. 4. How risk assessment is implemented in practice. 5. PPAP is laborious and require resources. PPAP has demanded an increase in human resources in our company. The audit has encountered a situation where a serious deviation from production has been found (the process has not gone as described in the PPAP) and, as a result, human resources have had to be increased to invest in the quality of the work. Our aim is to provide the quality engineer with sufficient resources to make high quality PPAPs. 6. Sometimes the customer has not defined things critical to quality precisely enough. We have manufactured the product according to their specs, but the customer has not been satisfied and has demanded more from us.
13	**Do you see challenges related to PPAP in the future?**	Adequacy of resources if PPAP requirements expand or the number of PPAPs increases.
14	**Have there been any challenges in communicating either internally within the organization or externally with customers? How were these challenges solved?**	We are a small organization, so internal communication works well.
15	**Where do you communicate with the customer?**	By email. Some files are shared through the customer's portal. However, the link to the portal will come via email.
16	**How and at what stage are critical to quality factors considered?**	The customer clearly defines the critical to quality requirements. Critical to safety issues and critical to functionality issues are defined separately in the drawings.

17	**Revision management: How are changes in drawings communicated with the customer?**	Our own revision control is through M-Files.
18	**Do you somehow measure the benefits of PPAP?**	-
19	**How useful PPAP is for quality of products?**	We feel that PPAP is a good tool, and we should try to take full advantage of it.
20	**Has the customer offered support to make PPAP?**	There are big differences between customers. There is a weekly meeting with some, with interaction and even training. Some customers will only contact you if there are any problems. Close cooperation is a better way to work, because then both parties will stay up to date and there will be no surprises. At the same time, it is possible to optimize doing, and not to do too much. We ourselves have provided support to our suppliers to complete their FMEAs, for example.