CHALMERS
UNIVERSITY OF TECHNOLOGY

Improving Tier N Supplier Quality Assurance Management

Master's Thesis in the Master's Programme
Quality and Operations Management, Management and Economics of Innovation

KETAN PARESH DESHPANDE
PRITAM KUMAR PADHI

Department of Technology Management and Economics
Division of Service Management and Logistics
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2019
Report No. E 2019:072

MASTER'S THESIS E 2019:072

Improving Tier N Supplier Quality Assurance Management

KETAN PARESH DESHPANDE
PRITAM KUMAR PADHI

Tutors, Chalmers: Jan Lenning, Ida Gremyr
Tutors, Case Company: Mahmoud Afsharirad, Pierre Masclet

Department of Technology Management and Economics
Division of Service Management and Logistics
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2019

KETAN PARESH DESHPANDE

PRITAM KUMAR PADHI

Master's Thesis E 2019: 072

Department of Technology Management and Economics
Division of Service Management and Logistics
Chalmers University of Technology
SE-412 96 Gothenburg, Sweden
Telephone: + 46 (0)31-772 1000

Chalmers Digitaltryck
Gothenburg, Sweden 2019

Acknowledgement

We would like to start by thanking our industrial tutors Mahmoud Afsharirad and Pierre Masclet for giving us an opportunity to perform this Master Thesis at the case company and providing us calming assurance and support throughout the thesis work. Getting the thesis at the case company has certainly been one of the highlights and joys of our Masters study here in Sweden. The thesis has really helped us to get an insight of the framework followed at the automobile industry. Next we would like to thank our academic tutors at Chalmers University of Technology Jan Lenning and Ida Gremyr for their extensive support, patience and understanding for hearing our thoughts and helping us to complete the academic part of our Master Thesis.

In the end we would like to thank our parents Jyotsna and Ashok Kumar Padhi, Priyanka and Paresh Deshpande for their unconditional love and support throughout this journey of completing the Masters study. We know that it is hard to stay away from your children for a long period of time but at the same time your understanding that it is for the betterment of your child's future makes us believe in ourselves and gives us determination to pursue our dreams in life.

Pritam Kumar Padhi

Ketan Paresh Deshpande

Abstract

Improving the upstream supply chain has become increasingly important for companies, in order to ensure better quality of work at their tier N supplier level. By ensuring that the communication of their requirements is aligned upstream in the supply chain through supplier development activities, the OEMs can in turn improve the quality of their products, and prevent failures in the field from the parts and components coming from their tier N suppliers. The thesis work has been carried out at the case company operating in the automobile sector, at their Supplier Quality and Development (SQ&D) department. The report presents an analysis of internal interviews at the case company and interviews conducted at four benchmarked companies, three from automobile sector and one from non-automobile sector on how they work with the communication of requirements with their tier N supply chain. The results in the analysis are based on the empirical data and are then compared with the theoretical framework in the discussion. It is found that although OEMs do not have a full-fledged mechanism for communication of requirements upstream in the supply chain, they do have processes and tools such as Special Attributes Approval (SAA), Component Mapping Chart (CMC) and a pragmatic approach of monitoring in between milestones, when they are communicating their requirements to the tier 1 suppliers. The monitoring of their tier 1 suppliers by OEMs through these tools and processes ensures that the communication of the requirements to their tier 1 suppliers by them is aligned with the suppliers at the tier N level. The best practices and improvement suggestions derived from the processes and tools have been analyzed in results followed by their refinement in discussion.

Table of Contents

List of Tables

List of Figures

1. Introduction

Total quality management (TQM) can be seen as a continuously evolving management system, consisting of three interdependent components; values, tools and techniques. The aim of these components is to increase external and internal customer satisfaction with a reduced amount of resources (Hellsten & Klefsjö, 2000). One of the fundamental views in TQM is that the costs of poor quality such as inspection, rework, lost customers are far greater than cost of developing processes that produce high quality products and services (Hackman & Wageman, 1995). For the long-term organizational survival, it is absolutely essential to produce quality products and services (Hackman & Wageman, 1995). Therefore, partnership with the suppliers ensures that materials entering the organization are of acceptable quality (Hackman & Wageman, 1995). The requirement to improve supplier's quality and delivery performance, while at the same time reducing the costs of supplied materials and parts, has motivated buyers to engage in supplier development activities (Krause; Handfield & Scannell, 1998).

For the creation of supplier partnerships, it is suggested that vendors must be chosen not solely on the basis of price, but on quality as well. To ensure materials that are of the highest quality possible, it is recommended that organizations work directly with raw material suppliers, since supplier partnerships ensure that materials are of acceptable standard of quality, from the beginning (Juran, 1974; Ishikawa, 1985; Deming, 1986). To increase the quality of the component parts, at least 50 percent of the organizations that work with TQM collaborate with their suppliers in some way to increase the quality of the component parts (Lawler, Mohrman, & Ledford, 1992) and the objective is that TQM could be utilized by organizations for analyzing and improving their own work processes (Sashkin & Kiser, 1993).

An essential feature of the supply chain is an information flow which is timely and of high fidelity. But it may be withheld, masked and may be distorted which results in confusion (Childerhouse; Hermiz; Mason-Jones; Popp & Towill, 2003). The current thesis tries to overcome the information flow distortion, as the benchmarked companies would be sharing their practices and tools, for ensuring the communication of their requirements to their tier 1 suppliers reaches the suppliers at the tier N level. This would result in the generation of best practices from the benchmarked companies. Another limitation which the current study tries to overcome as argued in Amelia & Hale (2007), where it is highlighted that future study may benefit from the identification of whether the buying firms are pursuing a reactive supplier development or a strategic proactive supplier development approach. According to Krause et al. (1998), some firms are reactive in supplier development efforts as they attempt to develop the suppliers after the occurrence of the problem. In contrast, if the firms want a creation of a first-rate supply base and want to gain long-term competitive edge, they adopt a proactive approach i.e. they identify crucial commodities and the suppliers for them that require development.

Amelia & Hale (2007) argue that an important factor for improving firm performance is the emergence of information sharing between firms, as it is directly related to product quality

improvement and indirectly related to financial performance through product quality improvement. Hence, it can be deduced that the current study would be beneficial as it involves information sharing between firms resulting in a proactive strategic approach.

One of the ways to support information sharing is through benchmarking. Competitive benchmarking is strongly associated with TQM (Hackman & Wageman, 1995). It is consistent with the ideas of the TQM founders - W. Edwards Deming, Joseph Juran, and Kaoru Ishikawa, although it is not explicitly advocated by them. The ideas include developing means for assessment of customers' preferences, altering relationships with suppliers, using teams for problem solving and investing in training of problem-solving tools for employees in organizations. Benchmarking involves gathering information about 'best practices' from other organizations. Therefore, organizations that aim for improving their customer service can observe service practices in firms renowned for their service quality, regardless of their industry (Hackman & Wageman, 1995).

Matook; Lasch & Tamaschke (2009) argue that that few studies focus on the latter stage of the risk management frameworks as a means of enhancing product quality and supplier base performance. Also in their study, the authors undertook an approach of functional benchmarking as the suppliers of the manufacturing firm being benchmarked were not competitors. Each delivered different intermediate products that are used further within the production process of the manufacturer. In functional benchmarking, specific functions are compared at two or more organizations (Fong; Cheng & Ho, 1998).

The company under study, hereafter referred as 'Case Company' is taking measures for assuring quality and managing quality risks of tier N suppliers components and processes. To further optimize their supply chain, case company initiated a benchmarking activity with four companies

1.1 Purpose and research questions

This thesis has been initiated based upon the need for improving parts quality delivered from suppliers to a large manufacturing company in the automotive industry. The purpose of this thesis is to propose possible improvements of the processes and tools for tier N supplier quality assurance management. This purpose will be achieved through a benchmarking activity and by studying the case company's internal way of working.

In order to support this purpose three research questions have been formulated. These research questions would ensure that the work is aligned to the purpose. The following research questions have been formulated.

Q-1 How does the purchasing organization communicate its requirements to its tier 1 suppliers, ensuring that the initial information is aligned, unfiltered and not lost in the process?

Q-2 How does the purchasing organization ensure, if tier N suppliers are involved; that tier 1 suppliers communicate the requirements from the OEM to tier N suppliers?

Q-3 What are the best practices for improved supplier quality in tier N supply chain management?

1.2 Case Description

The case company's purchasing organization provides competitive advantages to the case company by selecting high performing suppliers to deliver the best possible products & services with the right quality output that add value for customers. Case company's purchasing is a global division providing expertise to secure purchasing excellence. The division supports the case company's mission by applying the principles of code of conduct and responsible sourcing to the purchasing processes.

The Supplier Quality & Development department (SQ&D), belonging to case company's purchasing organization, is driving the global supplier base towards premium automotive quality standards. The department is responsible for continuously improving the supplier base and the quality of purchased parts.

Based on recent analysis performed, a large share of customer related quality issues come from tier N suppliers (tier2, tier3 …). Although the case company always highlighted the supply chain importance in product quality, the SQ&D team want to standardize its process and consider the quality risks that comes from tier N suppliers' processes and products. To find out best practices, the case company's SQ&D team initiated this master thesis to perform a benchmarking activity on a few selected companies. The benchmarked companies are selected based on the SQ&D team's expertise, with the consideration of finding different segments leaders including some companies in the automotive industry.

Hence, the case company and the benchmarked companies have cooperated to share their practices and their internal processes, and assuring quality and managing quality risk of tier N suppliers' components and processes.

1.3 Scope and Limitations

The scope of the thesis is to benchmark four companies and study their way of handling tier N suppliers. The thesis has focused more on the quality factor of the products and processes as it has been initiated because of quality problems coming from tier 2 suppliers and beyond. There has been a limited focus on flexibility and reliability in the form of capacity requirements and monitoring in between milestones. In the scope of the thesis is also to interview case company – SQ&D department employees - to understand their way of handling the tier N suppliers.

One of the benchmarked companies is a tier 1 supplier to the case company but while performing the interviews the benchmarked company has been looked upon as an individual entity or organization, and how it handles its tier N suppliers. The remaining three companies are not suppliers to the case company.

Although advice and suggestions have been given at the end of the report, the implementation of the same is out of scope of this project. Identification of mechanisms and causes of failure in a customer's product, a reason to initiate the benchmarking activity, have also been agreed to be beyond the scope of this thesis.

1.4 Thesis outline

In this section a further detailed description of this thesis as well as a brief summary of each chapter is given. The disposition of the thesis is illustrated in the figure below.

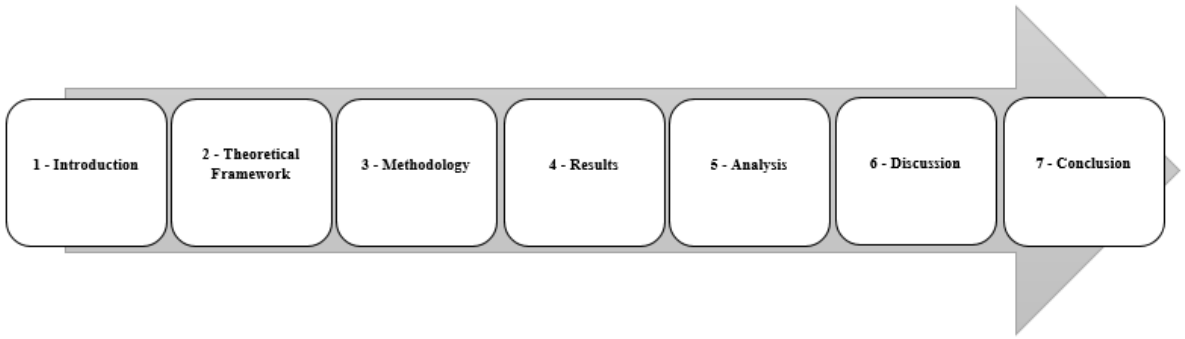

Figure 1. Outline of the master thesis

Chapter 1 – Introduction: The first chapter describes an introduction to TQM, Supply Chain Management (SCM) and benchmarking. Also, the limitations in the previous research, purpose of the thesis and research questions, the thesis scope and limitations are presented here.

Chapter 2 - Theoretical framework: This chapter presents relevant research on TQM and SCM that has been used in this thesis.

Chapter 3- Methodology: In this chapter the chosen research strategy and design, data collection and analysis, research quality and ethics are presented and explained how it has been implemented in the thesis.

Chapter 4 – Results: This chapter presents the empirical data collected from the semi structured interviews at the case company and the benchmarked companies.

Chapter 5- Analysis: This chapter visualizes and compares the data presented in the results chapter for the case company and the benchmarked companies.

Chapter 6 – Discussion: This chapter applies the relevant theory to the empirical data, answering the research questions and identifying opportunities where the best practices that can be implemented for improved supplier quality in tier N SCM.

Chapter 7 - Conclusion: The main findings of this study, and answers to the stated research questions are summarized in this last chapter. Based on the analysis and discussion in chapters 5 and 6, recommendations on five best practices and improvement suggestions in Tier N supply chain management are presented here to the case company through a bubble diagram along with suggestions for future research.

2. Theoretical Framework

In this section earlier studies of supplier quality and improvement are outlined to describe current state of the art. Literature studies in TQM have also been utilized for grounding the discussion and conclusions part as supplier management is not a standalone area of knowledge. The studies have helped for grounding the improvement suggestions both in the area of managing supplier partners but also in the case company's internal processes and procedures.

2.1. Total Quality Management

The concept of TQM is often described as some form of management philosophy based on a number of core values such as customer focus, continuous improvement, process orientation, everybody's commitment and learning from others (Hellsten & Klefsjö, 2000). These values are close to the core values presented by Bergman & Klefsjö (2010) and are called 'the cornerstones of TQM'. The six cornerstones are : (1) Focus on customers, (2) Focus on processes, (3) Continuous Improvement, (4) Base decisions on facts, (5) Let everybody be committed and (6)Top Management Commitment.

According to Dean & Bowen (1994), Total Quality (TQ) can be seen as a philosophy or an approach to management which could be characterized by its principles, practices, and techniques. The three principles are customer focus, continuous improvement, and teamwork. For continuous improvement, consistent customer satisfaction can be attained only through the principle of relentless improvement of processes that create products and services (Dean & Bowen, 1994). It also implies a commitment to constant examination of technical and administrative processes in search of better methods (Dean & Bowen, 1994). The bottom line for the continuous improvement principle is that organizations can be viewed as systems of interlinked processes and by improving these processes, the expectations of their customers can be met (Dean & Bowen, 1994).

Bergman & Klefsjö (2010) argue that the organizations must continuously improve to meet customer needs and expectations with the least expenditure, by being committed and focusing on the processes in the organization. Top management's consistent commitment with quality issues can be based on organizations' successful implementation of TQM, by creating conditions for participating in the work with continuous improvement. In addition the organization focus on systematic information about the needs, requirements, reactions and opinions of the customers. Therefore, in relation to the above, the two cornerstones of TQM, namely focus on processes and continuous improvement have been discussed.

2.1.1. Focus on Processes

For the long-term organizational survival it is absolutely essential to produce quality products and services (Hackman & Wageman, 1995). The focus on work processes highlights that the quality of products and services depends most of all on the processes by which they are designed and produced (Hackman & Wageman, 1995). According to Bergman & Klefsjö (2010, p.457) a process may be defined as:

"A network of interrelated activities that are repeated in time."

According to Bergman & Klefsjö (2010), a central factor in process management is adoption of a holistic view of the organization and improving the following in the processes:

- Quality, i.e. the capability to satisfy the needs and expectations of the customers.
- Efficiency, i.e. how efficiently the resources in the organization are utilized by the processes to produce results.
- Adaptability, i.e. adaptation of the processes to the changed pre-requisites.

The authors further argue that simplification is one of the important steps in productivity and quality improvement, as many of the processes in use today are unnecessarily complex (Bergman & Klefsjö, 2010).

According to Heher & Chen (2017) a process map for a given activity is a representation of sequence of actions for that activity, helping to explain and visualize all the steps of a process. Mapping of processes is better than standard operating procedures (SOP) as SOPs are written in a narrative format, making it a challenge for workflow and redesign analysis. Also, process maps act as tool provider for understanding the true processes efficiently and rapidly.

Organizations are well aware of the workflows in their own respective fields but they rarely pay attention to other organizations' workflows, which are equally important for achieving their common goals (Heher & Chen, 2017). Process mapping thus can be related to a process of building trust and consensus as it is a product of collective intelligence, often requiring brainstorming sessions involving the relevant stakeholders from all involved areas. It is the first and most important step for the digestion of complex workflow information, following which plans for targeted quality improvements could be developed (Heher & Chen, 2017).

2.1.2. Continuous Improvement

The principle of learning and continuous improvement highlights that the long term health of an enterprise depends on treating quality as a never ending quest (Hackman & Wageman, 1995). The commitment to continuous improvement ensures that people will never stop learning about the work they do and thereby creating opportunities to develop better methods for carrying out existing work (Hackman & Wageman, 1995).

According to Bergman & Klefsjö (2010) there has been continuous growth for external customer demands for quality. As a result of this, there is appearance of new technological solutions and creation of new types of business activities. Hence, it is pivotal that the goods and services formed, are produced with continuous improvement by an organization. The basic rule of continuous improvement is that there is always a way to get improved quality with the utilization of less amount of resources. This results in a win-win situation that benefits the employees, customers and organizations (Bergman & Klefsjö, 2010). The authors further argue that the popular motto 'Do it right the first time' must be interpreted carefully, because while improving products and processes, the organizations must dare to make some mistakes. The important thing is to realize and accept the mistakes, and try to learn from them. The mistakes must be turned into an assets by using the process information provided, to increase the knowledge about its opportunities for improvement (Bergman & Klefsjö, 2010).

2.2. Methods for Supplier Development

Teamwork can be defined as collaboration between managers and non-managers, between functions, and between customers and suppliers. In order for achieving customer focus and continuous improvement teamwork is essential. In the principle for teamwork it is stated that it is achieved by collaboration throughout an organization as well as with customers and suppliers, resulting in perceived benefits such as synergy, loyalty through partnerships (Dean & Bowen, 1994).

According to Krajewski & Ritzman (2004), the creation of a synchronized flow of materials and information from suppliers to their customers is one of the critical requirements of effective supply chain management (SCM). However, there lies a challenge in finding suppliers already organized to meet a buyer's requirements for quality, delivery, flexibility and cost. One of the effective ways to tackle this problem for the buying firm is develop their suppliers in ways that improve the suppliers' capabilities (Hartley & Choi, 1996; Krause et al., 1998).

The provision of technical support to key suppliers is one of the most frequently cited activities (Krause, 1997; Krause et al., 1998; Krause, Scannell & Calantone, 2000). The support might consist of for example direct investment in equipment and personnel, evaluation of supplier performance, sharing feedback on the evaluation of suppliers' performance, and sharing feedback on the evaluation results, visiting suppliers' plants and supplier certification (Hartley & Choi, 1996; Krause, 1997; Krause et al., 1998). This in turn would help reducing the buyer's transaction costs through improved supplier performance (Krause, 1999).

A buyer provides support to suppliers with a primary motive of improving its own product quality and reduce costs through enhanced supplier performance. As a result of these improvements, a buyer gets competitive, resulting in increase of its products or services sales (Hartley & Choi, 1996; Krause et al., 2000). In relation to above, there lies two aspects that need to be discussed for effective supplier development namely information sharing within and between firms.

2.2.1 Information sharing within firms

The supply chain integration literature suggests that organizations should strengthen their internal integration prior to integrating themselves with the suppliers and customers (Bardi; Raghunathan & Bagchi, 1994; Narasimhan & Kim, 2001). Therefore, information sharing within a firm should precede the information sharing between firms and the undertaking of supplier development support as it is essential for helping organization members to identify critical issues (Bhatt, 2000) regarding their suppliers (Crocitto & Youssef, 2003). This embodies a coordinating mechanism for promoting teamwork necessary for providing effective support to suppliers (Dewett & Jones, 2001).

2.2.2 Information sharing between firms

According to Krause (1999) and Sriram & Stump (2004), the sharing of information between a firm and its key suppliers could have a direct effect on the quality of a buyer's products as it results in improved relationships with suppliers. Better relationships with the suppliers helps in improving the quality of the buyer's products as it results in enabling suppliers for early stage involvement in the buying firm's design of products or services (Burt, 1989; Flynn; Schroeder & Sakakibara, 1995; Forza & Flippini, 1998; Shin; Collier & Wilson, 2000; Tan, 2001; Trent & Monczka, 1999). If the suppliers work with cross-functional product development teams, they could assist purchasers in choosing materials and parts that could be produced most efficiently (Flynn et al., 1995; Tan, 2001; Trent & Monczka, 1999). Early stage involvement of suppliers also ensures that they could provide suggestions regarding product and/or component simplification (Forza & Flippini, 1998; Trent & Monczka, 1999). Hence, it could be deduced that early stage supplier involvement in the buying firm's design of products or services would help buyers to design quality into their products.

2.3 Supplier Development using Benchmarking

The usage of high quality materials and parts is the first step in producing quality products, as materials and parts supplied with the required quality attributes will positively affect the quality of the buying firm's products (Kaynak, 2002). The supplier quality support activities result in improved buyer-supplier performance (Humphreys; Li & Chan, 2004) resulting in enhanced quality of the product or service for the buying firm (Krause et al., 2000). Supply-base reduction is one of the outcomes of supplier development support (Fynes; Voss & de Búrca, 2005; Krause, 1997; Krause et al., 1998), which is argued to result in improved product quality for buyers (Kaynak, 2002).

The establishment of modern benchmarking activities could be dated back to 1940s when reverse engineering of military equipment was done by the governments (Stapenhurst, 2009). In the 1950s and 1960s the American factories were visited by the Japanese industrialists for gaining insights into mass production methods. In the 1970s leading organizations were visited by Xerox for discovering what level of performances were possible and the methods for achieving those levels of performances. Following this, the usage and application of

benchmarking has grown rapidly, encompassing service or product, financial, functional, facility, strategic and project benchmarking (Stapenhurst, 2009).

Stapenhurst (2009) argues that few of the reasons for benchmarking by organizations are as following:

- For the enhancement of improvement culture
- For short cutting the improvement process
- Acting as a driver for improvement
- An aid for planning/budgeting/ target setting
- For solving specific problems
- For achieving Business Excellence Awards by using it as a part of a submission.
- For building up a network of like-minded people
- For justifying proposals

Benchmarking is also one of the useful tools for process improvement and problem solving (Stapenhurst, 2009). The key uses of benchmarking are as following:

- Selection and prioritization of projects.
- Searching for appropriate solutions
- Identification of appropriate target performance levels.

Benchmarking's prevalence in the TQM programs is derived primarily from its inclusion as a Baldridge Quality Award criterion (Malcolm Baldridge National Quality Award Consortium, 1990). According to Hackman & Wageman (1995), benchmarking performs multiple functions consistent with TQM philosophy such as (1) Determination of expectations of the customers from the competition as a part of customer requirement assessment, (2) Learning of alternative work processes and (3) Guiding the establishment of quality-improvement goals.

According to Matook et al. (2009) where the authors put focus on supplier development using a benchmarking approach, it is argued that 90% of the organizations attribute great importance to the risk management of their supply chain, because the organizations' purchasing activities have a considerable influence on their financial performance. It is also emphasized by Hartley & Choi (1996), who mention that long-term relationship with low risk suppliers can prevent firms from struggling in a dynamic business environment. When the products provided by the suppliers are strategically important, difficult to substitute and of major importance for overall production, disruptions in the flow of the products might exert a major impact on the firm's position in the market (Matook et al., 2009). According to Ritchie & Brindley (2007a), management responses should be activities to manage the supplier risks. Among these responses, some of the potential threats a firm faces from supplier risks is mitigated by supplier relationship development. Firms search for partners that are experienced in relationship development. The development of suppliers aims at improving supplier performance and enlarging firm's supplier base with viable partners (Krause; Handfield & Tyler, 2007).

Knowledge sharing is recognized as an important success factor for various supplier development activities as it facilitates the transition from a general transactional relationship to a cooperative relationship which offers mutual benefits (Krause et al., 1998). The understanding of the relationship increases with the timely and effective sharing of knowledge of the manufacturer's requirements (Krause et al., 1998). Bagchi (1997) argues that the ultimate goal of benchmarking is to learn from each other and incorporate process and product advancements so that benchmarking enables innovation rather than imitation. It exposes a firm's weakness and simultaneously provides bases for action. The benchmarking approach can be used as a tool for continuous improvements in quality and performance (Dattakumar & Jagadeesh, 2003). Matook et al. (2009) argue that the approach is particularly appropriate and useful for supplier development as it facilitates the identification of high performers (i.e. low risk performers) who may have achieved 'best practice' (Camp, 1995) and present an action plan for performing improvements**.** With the integration of benchmarking into supplier development and thus, into supplier risk management, a shift from a past-oriented to a future-focused management approach is enabled. This exercise can create an awareness of the vulnerability and criticality of the supply chain processes between buyers and suppliers.

3. Methodology

The methodology proposed in this section has been utilized for answering the research questions. The structure of the methodology involves a literature study, collection of empirical data through interviews, and data analysis. Table 1 below embodies the summary of research methodology for this study.

Table 1: Summary of research methodology chosen for the study

Purpose	Empirical data used to answer questions	Research Design
Proposal of possible improvements in the processes and tools for tier N supplier quality assurance management	• SQ&D Documents (SQAM,APQP,PPAP,PPCN) • Interviews with benchmarked companies • Focus groups with internal SQEs	Multiple case studies with a comparative design approach

3.1 Research Strategy and Design

Qualitative research is emergent as the methodologies change during the research. It has been emphasized by Maxwell (2005) who mentions that design in a qualitative research is an ongoing process involving back and forth movement among different components of the goals, the assessment of the goal implications, theories, research questions, methods and validity threats. According to Bryman and Bell (2011), inductive theory is built from observations and is the outcome of findings from the qualitative research that the researcher would be conducting on which the theory would be built. Deductive theory on the other hand means that on the basis of theory known about a topic, a hypothesis is deduced by the researcher which is being subjected to empirical scrutiny. After analyzing the findings, changes are being made to the theory. It is typically associated with quantitative research approach.

'Case Study' was chosen to be performed to support our qualitative data through an inductive approach as emergent theories would be created based on the data collected and our interpretations as researchers. A 'Comparative Design Approach' has been incorporated in this study as according to Bryman and Bell (2011, p.63), 'identical methods have been analyzed for two or more contrasting cases, which embodies the logic of comparison. In this design, qualitative research strategy takes the form of multiple case study, where the researcher is in a better position to establish the circumstances in which the theory will hold ground.' It was ideal to perform the case study in different industries as there might be different potential in using

these tools based on the organization. This is important to examine which type of industry benefits the most when using different tools in a positive symbiosis.

The project begins with a study of the current procedures and methods followed at case company, Supplier Quality and Development department (SQ&D) by learning their procedures such as Sourcing, Advanced Product Quality Planning (APQP), Production Part Approval Process (PPAP), Part Production Change Notice (PPCN), Specific Requirements, Safety Management, Production Requirements etc. at the case company for a deeper and clearer understanding of the current processes being followed for managing their suppliers to achieve and maintain a successful working business relationship with case company.

This in depth study forms a basis for designing the questionnaire used during the benchmarking activity. The finalized questions have been formulated together with the stakeholders involved in the project and focused on what methodologies have been implemented and used to manage their suppliers in their respective sector. The interviews have been conducted in a semi structured way with relevant stakeholders at the benchmarked companies. Therefore, the project follows a qualitative research approach, where theory has been generated by interpreting the interviews and constructing analyses and suggestions.

Triangulation involves the use of different methods, especially observation, focus groups and individual interviews that form the major data collection strategies for qualitative research (Shenton, 2004). It begins with the assumption that observations that are verifiable are being subjected to different interpretations and the job of the researcher is establishing how the various claims for truth and reality are being constructed in day to day life i.e. the researcher is the key instrument and the analysis is based on the researcher's interpretation((Easterby-Smith, 2015).

3.2 Data Collection

According to Forker & Mendez (2001, p.207) ‘Benchmarking is to improve one's own operational processes without reinventing the wheel’. The process involves recognizing ideal practices and establishing quantified metrics for institution of these practices and is performed at different levels namely competitive, industry, or best-in-class level (McNair & Leibfried, 1992).

According to Stapenhurst (2009) benchmarking helps in measuring and improving an organization. It usually consists of two aspects:

1. The performance level comparison for ascertaining gaps in the current organization and ascertaining from which organizations the current organization can learn the most.
2. It also involves studying the reasoning behind the best or better performers in achieving their superior performances and adapting their practices.

Referring to Stapenhurst (2009, p.31), a benchmarking methodology as 'Review Benchmarking' was incorporated in this comparative study, where 'we as participants identify relative strengths, weaknesses and best practices to make appropriate recommendations and facilitate improvement activities.' The objectives of the study are typically :

1) To establish performance levels of benchmarking companies
2) To quantify performance gaps between them, depicting best, average and worst performance.
3) To notice differences and practices that lead to these differences
4) To submit individual analysis to benchmarking companies and a combined analyses with the courses of action to the case company.

Another benchmarking methodology stated by Stapenhurst (2009) is 'One-to-One Benchmarking'. In this type of benchmarking, one group of participants is visited by a group of other participants. This is by far one of the most common methods of benchmarking.

The objectives of the study are typically:

1) To find which organization is best at performing the aspect of the business that needs to be improved.
2) To visit them for ascertaining their performance levels and learn how they achieve those levels.
3) Studying the practices followed by them, their necessary adaptation and possible improvements for use in another company
4) The final step is adoption of new practices.

These two methodologies mentioned above have been implemented in tandem and form the basis of the performance analyses in this thesis.

The four benchmarked companies, 'Company B1', 'Company B2', 'Company B3' and 'Company B4' in the thesis have been selected by the SQ&D team's expertise at the case company, with the consideration of different segments. The four benchmarked companies, three from the automotive industry and one from the non-automotive industry are perceived to be segment leaders in their industry as they similarly follow high quality standards. The sampling of the companies is based on the focus of quality aspect in the thesis, resulting in the selection of three benchmarked companies from the automotive industry.

The data collection begins by understanding case company's internal way of working. The case company's Supplier Quality Assurance Manual (SQAM) defines the expectations and working procedure requirements intended to assist suppliers in achieving and maintain a successful working relationship with case company. The tier 1 suppliers shall cascade the requirements further to their suppliers i.e. tier N suppliers of case company (Case company document 1, 2019).

The manual has been developed not for controlling the suppliers but acting as a reference for the compliance of the requirements and agreements with them. A considerable time at initial

stage of the master thesis has been spent on trying to understand the current approach for ensuring supplier quality assurance at case company. Hence, it is important to go through the processes mentioned in the manual for better understanding of the results from the interviews. The processes have been summarized following a chronological order and can be referred in the appendix 1. The processes include sourcing, Advanced Product Quality Planning (APQP), Production Part Approval Process (PPAP) and Product Process Change Notification (PPCN). The underlying terminologies and methods in these four processes such as Special Characteristics, key components, Failure Mode Effective Analysis (FMEA), Design Failure Mode Effective Analysis (DFMEA), Process Failure Mode Effective Analysis (PFMEA) and Control Plan have also been described in appendix 1. These processes and practices in use are also common for the bench marked companies B1, B2 and B4 operating in the automotive industry.

The questionnaire in the thesis has been developed after understanding the manual and reviewed by the internal stakeholders, to conduct a set of interviews. Four semi-structured interview sessions have been conducted with 1-4 representatives from each organization. The representatives work in roles similar to the internal interviewees at the Supplier Quality & Development department of company who work as Supplier Quality Engineer (SQE). In total, 18-20 respondents have participated in the study. The sessions have been carried out during working hours, with each of them spanning up to a couple of days at the most. They reflected around their own way of working with their supply chain along with what they think are 'best practices' for tier N management. Another interview sessions or internal focus group sessions with a similar setup have been conducted within the case company alongside few SQEs from the SQ&D team for a couple of days. They answered the questionnaire by reflecting upon their standard way of working in tier N management at case company. The information gathered from these answers has directed us to find what and how working practices should be compared, alongside identifying best practices from each of the organizations.

3.3 Data Analysis

The data generated from the benchmarking activity has been analyzed by constructing a 'Process Map' and outlining the 'Performance Gap Analyses', wherein performances have been compared, gaps and potential benefits of filling those gaps are highlighted to help mitigate the issues that resulted in this study.

1) Process Map – This is the first part of data analysis. The questionnaire has been divided into different phases of the procurement process. The information in each of these stages has been identified and structured in series, comprising a process map for the case company and the benchmarked companies.

2) Performance Gap Analyses – This is the second part of data analysis. Each phase of the questionnaire has been analyzed from the process map, to depict performance comparisons. As stated by Stapenhurst (2009), a series of bar charts have been plotted

according to these phases, where performance on Y axis shall be the Level of Tier N from 1 to 4; 4 is the technical limit and 3 is the top quartile. The ranking is based on the level of tier N achieved as per the comments given by the interviewees. The author states that the target is 'objective and not dependent on the participants', which is identified as an advantage of using such a limit. X axis shall have bar charts of 4 benchmarked companies. Automotive and Non-Automotive companies shall have separate markings for bar charts. This data analyses have then been utilized to derive conclusions and discuss suggestions for implementation.

3) Bubble diagram – A Bubble Diagram has been constructed in conclusion chapter to provide a brief overview for implementing the best practices and recommended improvement suggestions. This representation is based upon the researchers own judgement and their experience from the interviews. The X- Axis represents the level of effort for implementation, determining how easy or difficult it could be to incorporate these practices and suggestions as a part of the case company's daily working activities. The Y-Axis represents the level of impact, determining high or low influence, following the implementation of suggestions. The size of the bubble determines the level of cost.

3.4 Research Quality

Bryman and Bell (2011) cite the example of the study conducted by Spencer et al (2003) through which a comprehensive list of criteria has been generated to be used for evaluating the quality of qualitative research. These criteria are briefly stated below in Table 2 together with the measures that have been taken to ensure research quality in this study:

Table 2: Criteria and measures for ensuring research quality

Criteria	**Description**	**Measures**
Credibility of Findings	Credibility of Findings is established by ensuring that the research has been carried out in good practice and has been verified by the members who participated in this study.	Credibility has been ensured by seeking corroboration through 'respondent validation', where reports of findings have been exchanged with the stakeholders & their feedback is implemented to consolidate this research.
Profound Knowledge Understanding	Profound knowledge and understanding is gained if the new research is extending the previous research.	The past research on benchmarking was based on single case studies, without comparative analyses, which has been included in this research.

Criteria	Description	Measures
Quality of Data Collection & Analysis Formulation	Quality of Data Collection and Analyses is maintained by evaluating that the aims and objectives of the research have been met.	Quality of Data is maintained by carefully transcribing the interviews to prevent distortion of information used for analysis especially where the focus has been on methods showing performance differences, thus suggesting the need for course of action.
Contexts of Data Sources	Contexts are retained and portrayed by drawing wider influences of the scope.	The data sources have been chosen in a way that the context revolves around the methodology of bench-marking for supplier development communication, which is the essence of our research questions.
Richness of Data	Data Richness is instilled by detailed depth of the content and diversity of perspective.	The depth of this research is set in the form of Process Map and Performance Gap Analysis to visualize the congregated data, following which the best practices developed have been plotted in the Bubble Diagram on the basis of their implementation, impact and cost
Clarity regarding theoretical perspectives and links between data interpretations and conclusions	Clarity in knowledge interpretation throughout all phases of the research.	The theoretical perspectives have been clarified in the literature review, with the benchmarking theory driving the interpretations and conclusions.
Documentation of Research Process	Documentation of data collection and analyses formulation have adequate, clear and coherent links between interpretations and conclusions.	The research process is documented by depicting the outline of the master thesis in figure 1 that indicates the plan.
Defensibility of Research Design	Defensibility of theoretical perspectives and case study design to shape the form and output of evaluation	The authenticity of this research is defended by ensuring there were multiple sources from different industries to prevent a bias.
Attention to Ethical Issues	Following a code of conduct	All ethical aspects have been respected and agreed upon. They have been articulated in the next section.

3.5 Ethics

As stated by Bryman and Bell (2011), the following Ethical Principles have been taken into consideration:

1) No participant has been harmed physically or mentally through any kinds of reprehensible acts.. The code of ethical conduct has been taken care of by explaining the purpose behind this project and sample questions from the questionnaire to the prospective participants, followed by the benefits for both the involved parties. Responsibility has been undertaken to follow this code and to take reasonable precautions not only for interviewees, but also the researchers, whose anonymity cannot be maintained.

2) All participants shall have complete information regarding the implications of the process and there shall be no lack of informed consent. They are introduced with this information at the beginning of the questionnaire sent to them by mail, which has also been described briefly during the commencement of the interview sessions. We ask for consent to record the interviews and also have submitted a version of the analysis report to the participating stakeholders of each of these interview sessions.

3) All participants have their right to provide secluded information, keeping the confidentiality intact to avoid invasion of privacy. The relevant stakeholders have full autonomy over what information they choose to disclose in the interviews as well as the information we are allowed to mention in the public version of the analysis report.

4) No deception has been involved, with the research been represented exactly as meant to be, without jeopardizing human dignity at the cost of personal gains and all clauses have been respected. To ensure the expectations of all stakeholders, the data shared during this research has been described after careful scrutiny, for which Non-Disclosure Agreements have been signed between the stakeholders belonging to each of these exchanging parties to ensure the same.

4. Results

The empirical data derived from observing standard operating procedures and from interview sessions based on the questionnaire, have been outlined in this sub chapter and have been described. The findings from the four benchmarked companies and the internal interviews at case company about the current practices being followed with respect to the tier N management have been described.

The empirical data in the sub section has been categorized under sourcing, APQP, PPAP and PPCN for all the companies, the only exception being bench marked company B3 operating in the non-automotive industry for which in place of APQP, PPAP and PPCN Quality planning, Production Approval and Change Notification has been used for categorization.

4.1 Company B1

Benchmarking company B1 is operating in the automotive industry. In this sub section we will go through the strategies that company B1 have planned or deployed for tier N supplier management with respect to sourcing, APQP, PPAP and PPCN.

4.1.1 Sourcing

When it comes to sourcing for potential supplier, company B1 performs Manufacturing Station Evaluation (MSE). In MSE they go out and perform the first potential analysis of supplier which they call light MSE and later they perform the full MSE. They have stated some requirements for sub-supplier management in full MSE but not in light MSE which they say has to be improved.

"Normally when we go out and do the first potential analysis of the supplier we are doing the light MSE which is about one day work in the supplier side during sourcing. We send out this to the supplier prior to the audit. We have few questions in the light MSE about the sub suppliers but in full MSE we have a full chapter about sub supplier quality management and here we have the system requirements for the sub suppliers. But we feel the questions that we have in the MSE is not sufficient for sub suppliers during the light MSE i.e. too few questions and we need to look into that in a better way"

Company B1 do not have a standardized mapping of tier N suppliers' components but they think the idea is good.

"But I think the idea is good for high impact components at sub suppliers which we need to improve"

They communicate their requirements on components level in the sourcing phase to their tier 1 suppliers who are responsible for cascading the requirements further to tier N suppliers.

"We are communicating requirements to the tier 1 only in Request for Quotation (RFQ) and we are using a documentation called Engineering Work Procedure (EWP) stating how to split work between us and the supplier. The requirements are defined on delivery-unit level and the tier-1 supplier is responsible to cascade requirements to Tier-N suppliers"

About performing Special Process (SP) audits at tier 1 and tier N level, company B1 perform assessments of products at tier 1 level as the interviewees said:

"We perform Product Assessment (PA) at product level for our tier 1 suppliers but only in rare cases we go to the tier N suppliers. However, we should do this more. For example there could be cases where the tier 1 supplier is doing mechanical parts and they suddenly are responsible for electronics where they don't have the competence to do specific audits, then we can help them in that case"

4.1.2 Advanced Product Quality Planning (APQP) and Production Part Approval Process (PPAP)

To ensure an overview of the breakdown and alignment of the time plan of tier 1 suppliers with the tier N suppliers the interviewees described that in contrast to sourcing phase they go deeper on the suppliers' performance during APQP and PPAP.

"During the APQP and PPAP we go deeper on how are the suppliers performing.
For having a time plan with the suppliers we have a specific folder with a planning form in APQP for sub components and part planning of sub suppliers. In this section we want the supplier to list all the ingoing parts starting with the high important components and so on and going down the sub supplier name, part name, part number, when they are going to have their first part of the tool. This specific folder is similar to product level time planning and we review it strongly every month"

On being asked about the monitoring of how tier 1 supplier deploy special characteristics at the component level, it could be deduced that company B1 currently have a structured way of doing this through a tool called Special Attributes Approval (SAA) as the interviewees described:

"We have a tool called Special Attributes Approval which is pretty good. It contains everything about the part name, part number, part folder and so on which is then referenced to DFMEA, PFMEA, control plan which we keep track on all the time. It consists of two stages, planning phase and the manufacturing phase and it is mandatory for the suppliers to fill in the details in these phases for PPAP and we check it"

"From my experience this is the best practice here in our company with respect to tier N management and if there is one thing that you should take out from our session is SAA"

When it comes to auditing tier N suppliers (tier 2 and more) the interviewees argued that currently they do not do it but acknowledged it can be done in some circumstances.

"Normally we do it at tier 1. We seldom check audit reports with the tier 2. It can happen in some circumstances that tier 2 suppliers have the majority of value added activities, for example tier-1 only do simple assembly activities. There we can do the audit

4.1.3 Product Process Change Notification (PPCN)

When asked about PPCN submission from the suppliers the interviewees said that at Company B1 Engineering Change Notification (ECN) and Site Change Notification (SCN) are used which is the equivalent of PPCN.

"We have what we call ECN and SCN for PPCN. ECN is managed by R&D and is applicable when an external supplier wants to make a design change after PPAP approval of production-parts or service-unique parts. It is requested online by the supplier. It is matched by R&D and an approved SCN generates a Change Request of Product (CRP) in our system. We are part of the CRP process so the site SQE gets the question, do you approve this CRP or not"

"A SCN is managed by purchasing or site SQE depending on the type and is applicable when an external supplier needs to make a change to a production manufacturing process or site/location after PPAP approval of production-parts /or service-unique parts. We currently work with SCN in excel form but in future it would be good if SCN is also online like ECN as it is easier"

The interviewees further added that ECN and SCN is working well for them for communicating the PPCN requirements from tier 1 to tier N suppliers.

"We are informing our tier 1 that you must use ECN/SCN when you are communicating with us, you have your own change management system. We review that when we audit the suppliers, so we know that that is working as well"

"We have a good picture of how our supplier is working with its sub supplier"

4.2 Company B2

Benchmarking company B2 is operating in the automotive industry but is a small OEM. The company is using a pragmatic approach with respect to tier n supplier management .Similar to the above mentioned companies in this sub section we will go through the strategies that company B2 have planned or deployed for tier N supplier management.

4.2.1 Sourcing

When it comes to sourcing for potential supplier evaluation and mapping tier N components, company B2 consider tier 1 suppliers and only in some cases they go to tier 2 suppliers.

"Most of the time during sourcing and mapping tier N components we are considering only tier 1 suppliers, meaning we are not at all speaking about tier 2 suppliers"

The interviewee added that for cascading the technical requirements to tier n suppliers also it was the responsibility of tier 1 suppliers.

> *"Tier 1 supplier is responsible to understand the technical requirements and to cascade the same method to tier 2 as at company B2 tier 1 is responsible for implementing the same thing with tier 2 and so on. The important thing here is not to force the suppliers because we want them to be fully responsible and be less intrusive"*

The interviewee continued on the reason for not going in depth in the supply chain.

"For me the important thing about Tier N management is how you limit yourself. If you have a complete team of people to monitor it then it is okay but if you do not monitor it properly then it can very quickly become exponential, increasing information that could be redundant. Probably you can achieve it once but how do you maintain it for all the coming years"

About performing Special Process (SP) audits at tier 1 and tier N level, company B2 has a standard requirement for tier 1 supplier to perform the audits on tier 2 level and tier 2 to perform audits tier 3 level as the interviewee said:

"It's a standard requirement that tier 1 is performing all its audit on tier 2 and tier 2 should perform on tier 3. It's like cascading. It's mandatory to perform the audits but it's not only SP audits, it's all the different audits including capacity".

The interviewee added that they do not participate in supplier selection audit but for evaluation audit if risks are identified then they participate in audit along with tier 1 supplier.

"We never participate in supplier selection because it is very important to let commercial discussions remain between tier 1, 2 and so on"

4.2.2 Advanced Product Quality Planning (APQP)

To ensure an overview of the breakdown and alignment of the time plan of tier 1 suppliers with the tier N suppliers the interviewee described that a pragmatic approach is followed at company B2 where monitoring in between milestones is considered.

"*Again I want to highlight the pragmatic approach at company B2 which is really efficient. We can put the milestones for all the products but this does not prevent you for being late. it's not about the milestones, it's how you monitor in between the milestones so that when you are coming to the milestone there is few risk of having any deviation"*

On being asked about the monitoring of how tier 1 supplier deploy special characteristics at the component level, company B2 use APQP as the interviewee described:

"It is covered in the APQP but there are no specific tools outside this. Everything is monitored through one tool, the tool itself is APQP, you have everything in it."

"There are specific items for tier N suppliers in the APQP file and the tier 1 supplier is coming and putting the documents in the shared area and then it is exchanged like this. On the principle it is great but it is not done efficiently and sometimes it is done but not stored systematically"

4.2.3 Production Part Approval Process (PPAP)

The interviewees talked about the PPAP approval at the components level

"The tier 1 suppliers are in charge of sharing information they have of all the milestones of all components, supplier selection, PPAP and everything. We check if the PPAP is validated by tier 1 but not the content. The target is not to do it. It's to let tier 1."

In relation to above the interviewees further added:

"It is not only PPAP but all the major milestones for the tier 1 parts that should be checked for all the components and it is only when you are doing this that you are sure with complex assembly that new part would be fully ready to be validated. . It is very important not to wait because a lot of the reasons of why the component was not ready on time was because of the sub components was not ready and sourced on time"

4.2.4 Product Process Change Notification (PPCN)

Towards the end of the interview, PPCN submission from the suppliers was discussed.

"It is requested that the suppliers inform us of the changes including the PPCN submission so that it is not missed. They have to communicate that's the rule. If they are not doing it, we will not be happy. But sometimes you are having audits and then you can identify the changes"

However, the interviewee talked about the work of site supplier quality engineer (SSQE).

"In company B2 you have the SD(Supplier Development Site) or SSQE who are the supplier quality persons that are in charge of the plant of the supplier and have like 50 plants in their portfolio but they are monitoring the industrial activity of the plant and everything that is happening there. These persons are knowing by heart the plants of the suppliers, so if anything is happening and they are saying it you have more chance to identify here. It's a specific organization of SQ&D, they are dedicated to process all capacity, quality improvements of the tier 1 supplier that helps in getting a lot of information.

The interviewee described that the work of SSQE is one of the best things at company B2 that helps in monitoring the changes proactively in the plants of the suppliers for which the SSQE is in charge of.

"They are spending all their weeks travelling at the different plants of the different suppliers they are in charge of. So this is helping also to identify if something is changing because they cannot modify something on the plant without letting the SSQE know. This is helping a lot. This is one the best thing that happens at company B2 because you can easily monitor and solve quality issues, logistics issues and being able to identify everything in anticipation. This is the process of a big OEM that company B2 has chosen to implement. It is very good and efficient"

4.3 Company B3

Benchmarking Company B3, the sole participant from non-automotive industry has a specifically personalized way of working with their supply chain, including Tier N management.

4.3.1 Sourcing

"We have a standard defining our own way of working, which includes various modules such as compliance, commercial and sustainability aspects that the suppliers are supposed to follow. Our suppliers have the responsibility to ensure that they have communicated our standard to their sub-suppliers."

A tool has been stated, where a database is maintained that displays information about supplier selection, evaluation and inclusion, during the first phase of sourcing.

"The 'B3 Correspondence Portal' is an interface for supplier communication, where suppliers have access to the portal for corresponding with our company. In the 'Supplier Relation Data Base', critical suppliers and their sub-suppliers are mentioned in the system, with a number of checks and procedures associated with them. These are monitored by a council that decides whether we should continue with a supplier in the future."

Requirements are communicated to tier N during sourcing phase by establishing control over processes and by performing tier N mapping according to these processes at component level.

"We use the IBX module from Capgemini to document and collect the commercial specifications from the suppliers. Technical specifications are sent to the suppliers separately on the basis of what is expected from the product. So, the supplier has an opportunity to enter the system and resubmit their bid, if necessary."

Going into detail regarding the auditing of tier N management, the interviewees described:

"*We have 15 special appendices that contain several different processes. We perform a compliance assessment as a pre-audit, for the suppliers to come up to a right level. Although we can say that our suppliers are responsible for auditing our sub suppliers. We confirm there are three levels. First, we check whether all the special appendices are signed. Second, our suppliers' maintenance of log books is followed up, whether they are following the development scheme. Third, is that we check whether our suppliers are going to their sub-suppliers and doing the audits of these special processes. The depth of these levels are decided by the business teams so as to at which level should the supplier be judged. We call them External Audits."*

4.3.2 Quality Planning

The respondents mention the importance of technical expertise in the areas of Lean Management and Six Sigma for improving their supplier assessment. Therefore, during Quality Planning, several tools have also been in place in the various stages of product development, and for deployment of special characteristics.

"We are implementing Design for Six Sigma along with FMEA in risk assessment of products and processes."

Although company B3 do not have a time plan in place, they have been working to follow the flow of tier N supply chain.

"We don't even monitor our suppliers' breakdown time. But, we still believe that project monitoring is a prime thing. We have a supplier planner to check the timing of our product orders. During our assessment, we evaluate how they are going to be working with any breakdown, by themselves. We use Microsoft Office tools as a part of monitoring our progress

with suppliers. We build a buffer and we back calculate till the measurement of our first delivery. We have to do this, since we have a final sales target in our agenda."

The '*B3 Correspondence Portal'*, described in 4.3.1 sourcing, also enables them to register and map their supply chain and monitor processes in project phase.

"Our suppliers are working on the system all the time and here is where most of our communication takes place. The tests are divided into critical, major and minor categories and any deviations with respect to them are prioritized by our specialists, who fix them."

For special characteristics, a lot of specifications need to be communicated to suppliers, so that they have the right incoming components from their sub-suppliers. This is being monitored in the '*B3 Correspondence Portal*'

"We do it at a product level through compliance certifications. We work closely with them regarding these certifications and conduct a number of tests before we give a go ahead for mass production. In our products, 50%-70% is the material price. When we have a good follow up with the sub-suppliers, we can save a lot of money. Our Business Developers are expected to do Program Management, to make sure that with our set of suppliers, we have a good quality launch. If any of these certifications or test reports is absent or outdated, there is a deviation in our system and is simply a No-Go. New reports have to be submitted."

Company B3 makes sure that after conducting the pilot-testing during product development, that the tests on special characteristics which are critical to quality are implemented on the production line.

"All tests have markings, referring to 'critical to quality' in the production line, which are included in the standard operating procedures. Our legal requirements have to be cascaded throughout tier N supply chain.

4.3.3 Production Approval

The third phase of Production approval, where the mass production is regulated with a number of tests, is indistinguishable for this non-automotive company. It is an active part of their second phase of Quality planning and has therefore been covered parallel in the section above.

4.3.4 Change Notification

During the fourth phase of Change Notification, the suppliers have to report any changes on the '*B3 Correspondence Portal*' and make sure that their approval plan for change includes all verification tests.
"We have a section that is named 'New and Modified Product' in our system. Again, it is the responsibility of tier 1 to handle changes in suppliers. What concerns us is that whenever there

is a change of supplier, new internal audit reports and test reports must be submitted. Then they are validated by us. If one supplier changes a process, they repeat the test. Since, there are going to be new ways to produce the same products, there must be new reports"

4.4 Company B4

Benchmarking company B4, a major supplier in the automotive industry has a more detailed system for tier N management.

4.4.1 Sourcing

During potential supplier evaluation for the first phase, sourcing, tier 2 suppliers are audited along with tier 3 and beyond, depending on the business case.

"Planned Supply Chain is requested from suppliers with every feasibility confirmation"

The interviewees mention that Tier N component mapping is also performed during this phase.

"*Component Mapping Chart (CMC) is used for mapping supply chain until raw material supplier"*

The company deploys a tool to communicate requirements in tier N supply chain at a component level.

"We communicate all requirements in sourcing phase, where 'EAL' with specifications and drawings is stated via tool named B4 Correspondence Portal"

4.4.2 Advanced Product Quality Planning (APQP)

In the course of the second phase 'Advanced Product Quality Planning', the alignment of time plan is delegated to the tier 1 suppliers, the fulfilment of which is monitored by the benchmarked company.

"In general, our system-suppliers are responsible for their sub-projects. We check the main milestones and deviations along the respective critical paths and deploy necessary measures to secure the time schedule"

Risk assessment plays an important role in communicating requirements to be deployed from product level and then subsequently to process level.

"Controls are in place for incoming components, which along with the whole APQP process, are executed based on part risk"

"Tier 3 audits and co-audits are a part of risk based audit program."

Essential Attributes List is used as a basis to monitor and investigate key components.

"The EAL is followed up with the suppliers for its presence in FMEA, CP, Work Instructions, etc. We follow the flow of items in the EAL and during audits, it is checked that the drawings for Tier N contain those items as well."

"During APQP, we particularly look for safeguarding the EAL. Measures have been defined and during process release, we check if those measures are in place"

This ensures that tier 1 suppliers are communicating these requirements to tier N suppliers, which are being monitored by tier 1.

4.4.3 Production Part Approval Process (PPAP)

In the third phase, Production Part Approval Process (PPAP), the notified requirements must be rightly incorporated by the tier N supply chain. Therefore, it is important to understand the complete supply chain. The company establishes this knowledge, by filling out a map.

"Our suppliers have to fill out the CMC which has information indicating down to the sources of raw materials. This chart is a part of PPAP"

The company states that the investigation of PPAP components through risk assessment is performed on a random basis to ensure OEM requirements have been cascaded to Tier N suppliers.

"Requirements are cascaded according to the EAL. Depth of checks depends upon the risk rating of the purchased component. The risk rating is developed by our suppliers for their sub components and is mainly done on a random basis."

Tier N requirements according to PPAP are registered and documented by the company to make sure that tier 1 supplier has approved all components of PPAP.

"During PPAP, we check that all Cover Sheets of sub-components are available at the correct level"

4.4.4 Product Process Change Notification (PPCN)

In the fourth phase, Product Process Change Notification (PPCN), it is critical that the changes are notified throughout the tier N supply chain. The company guarantees communication of changes to their tier N supply chain, by securing submission of changes from them. They also

monitor that the tier 1 suppliers have their own approval plan for all changes, including the designs and verification tests. Some of the activities are:

"*CMC is mapped till the lowest level and referred for new part drawings and changes in supply chain",*

"Frequent on-site visits, audits, re-qualification, re-certifications are parts of the change process",

"The process is described in Quality Assurance Agreement. There shall be a notification before initiation of change and before approval of change."

In this way, the company ensures that tier 1 suppliers have an effective control on all changes in their supply chain.

4.5 Case Company

4.5.1 Sourcing

When it comes to potential supplier evaluation, the case company performs Supplier Assessment Protocol (SAP) audit, SP audit and onsite visits to the tier 1 suppliers but not the tier N suppliers. There is a tool for evaluating risks in sourcing called Risk Estimation in Sourcing (RES) where the stakeholders from case company go through the scorecards with the cross-functional sourcing team and identify potential risks for the sourcing case of potential suppliers and identify whether the suppliers are of higher risk. The stakeholders then assess the recommendations towards each supplier to be included in the RFQ (Case company document 1, 2019).

SAP and RES are the tools for the selections of suppliers to be tier 1 suppliers to case company. The case company communicate the requirements to the tier 1 suppliers through Technical Review Requirement (TRR) but the case company does not have any method to validate whether the requirements which are being communicated to tier 1 suppliers are further cascaded(if tier N suppliers are involved).

"There are few questions related to sub supplier management in SAP, RES but is it good enough? We could check if we could include a chapter in SAP, RES for sub-supplier management including supplier selection and making sure not missing the finance related questions as well in SAP for tier N management"
At present in case company there is no standardized way regarding on which level tier N suppliers' components is mapped and considered in sourcing. The supply chain should be mapped in sourcing as the interviewees explained:

"A mapping tool document consisting of a standards template should be developed for the Tier 1 suppliers to share their plan. It could consist the bill of material (BOM) list with the potential sub-suppliers, at least for the key components, including qualification of the potential suppliers, location of the sub-suppliers"

When asked about performing SP audits by tier 1 suppliers at tier N level the interviewees said the following:

"In the mapping tool that we discussed, we could add a column if the tier 1 supplier does or will do SP audit of tier N suppliers' processes"

"We need to check if possible we could share our SP audit requirements with Tier 1 suppliers and vice versa. The Tier 1 supplier could have its own questionnaire of SP audit requirements with its suppliers"

4.5.2 Advanced Product Quality Planning (APQP) and Production Part Approval Process (PPAP)

To ensure an overview of the breakdown and alignment of the time plan of tier 1 suppliers with the tier N suppliers the interviewees described:

"*We could ask for more details and time plan for component level during APQP. For example I ask the Tier 1 suppliers if they do APQP with the sub-suppliers and I add that information in APQP"*

Following the above discussion the interviewees came up with few proposals with regard to time plan:

"We could add a sheet for sub components in APQP including time plan in alignment with product time plan as it is good to find a structured and simple way to follow up, resulting in more integration at case company. Also we could have the APQP report online which could be updated and reviewed regularly or monthly"

On being asked about the monitoring of how tier 1 supplier deploy special characteristics at the component level, it could be deduced that case company currently does not have a structured way of doing this:

"*We are not very structured at doing this. Special characteristics list should be one the most important handovers and should be worked in a cross functional team"*
At this point the interviewers conveyed the interviewees about a specific tool being used at benchmarked company B1 which is covered earlier in the empirical data. The interviewees acknowledged the need to perform some improvements and development of a tool like the benchmarked company B1:

"*We need to develop a special characteristics tool similar to benchmarked company B1 which could consist of the characteristics description, specification, and criticality of the components. How deep in the supply chain we should go could be discussed later upon development of the tool but we should make it mandatory to tier 1 suppliers to use the tool for components PPAP. It means we make sure all special characteristics would be identified. The sheet in APQP in the component level could be marked if the component is a critical component"*

The interviewees further argued about ensuring a better monitoring of the requirements communicated to tier 1 suppliers, to ensure that they are being communicated to tier N suppliers with further suggestions:

"We could develop a one page document with few requirements such as requirements for PPCN, capability requirements for special characteristics etc. We could send this document along with the supplier quality assurance manual (SQAM) to all the tier 1 suppliers and ask them to cascade it to their tier N suppliers. But the name of this document should be chosen carefully so that the suppliers do not skip the SQAM and think of the requirements in this document as the most important requirements"

When it comes to auditing tier N suppliers (tier 2 and more) the interviewees argued it depends upon the processes, their criticality and the number of sub-suppliers of tier 1:

"*Process audits at the tier N could be performed if the majority of the value added activities are performed at tier N level and tier 1 suppliers only do simple assembly activities. It could be done in cases for example when a problem from tier 2 supplier is identified. Also for big tier 1 suppliers with many tier N suppliers, it is good to be done sometimes*"

However one of the interviewees argued that responsibility of approval should still be at tier 1 supplier which the other interviewees agreed.

"*I do not think we should have any restriction from tier 1 suppliers but we should make sure that we never take responsibility of approval when we do this"*

The interviewee further talked about the PPAP approval at the components level which is interviewee's own way of working but could be insightful for improvements for the investigation of components PPAP and process audits in future.

"For PPAP approval when I visit the tier 1 supplier I randomly select two components. Normally I try to pick one critical component or special component and one standard component. Then I ask the supplier which I do not select in advance, to bring the supplier quality engineer (SQE) who approved that PPAP and then we review that together asking them what is the capability here, why this is not a special characteristics etc."

In relation to above and the special characteristics and mapping tool proposed earlier the interviewees argued for the requirement of a data base for supporting the tools.

"For all PPAP documents and special characteristics tool and mapping tool, we need a data base that the supplier can use to upload the document there. The SQE and others should get an automatic mail that the documents are updated or uploaded"

4.5.3 Product Process Change Notification (PPCN)

Towards the end of the interview for tier N management with the interviewees at case company, PPCN submission from the suppliers was discussed. Case company is facing some difficulties with regard to PPCN submission. They described the current reasons as to why PPCN submission is missed.

"PPCN is missed if the tier N suppliers do not inform the tier 1 suppliers of the changes or if the tier 1 suppliers do not inform us of the changes. It is also missed if tier1 suppliers do not communicate PPCN requirements with tier N suppliers"

The interviewers gave inputs about the systems being followed at the benchmarked company B1 for PPCN. The interviewees came to a consensus that a system is required at case company for PPCN in order to make sure that tier 1 supplier can ensure that PPCN process is communicated to tier N suppliers, and guarantee that they will submit PPCN Changes.

"*For PPCN documentation we need a system where the PPCN could be uploaded by supplier which would also show our team"*

"The mapping tool document is a living document. In that document if there is any change in tier N supplier for example supplier switch or location change of the supplier, the mapping should be updated and our team should receive a notification that the supplier should submit PPCN. This could be a type of automatic process"

5. Analysis

From the empirical findings it is clear that the case company and the benchmarked companies have some similarities and dissimilarities with respect to tier N management and communication of requirements to suppliers. The empirical findings form the input for the analysis. In this chapter the empirical findings from the interviews at the case company and the benchmarked companies within sourcing, APQP, PPAP and PPCN have been compared.

5.1 Process Map

The process map is constructed (Table 3) to give a summary of the input. It is structured following the phases in the questionnaire. It gives an overview of tools, communication methods and ideas suggested during the interviews by the benchmarked companies and the case company. Abbreviations of these tools and ideas have been stated alongside their names. For ease of the researchers, these tools and ideas have been abbreviated in the latter part of this report. The readers shall take a note of this and refer to the following table for the same.

Table 3: Process Map

	Company B1	**Company B2**	**Company B3**	**Company B4**	**Case Company**
Sourcing	Manufacturing Station Evaluation (MSE)	Consideration of only Tier 1 suppliers for supplier evaluation	B3 Correspondence Portal	B4 Correspondence Portal	Supplier Assessment Protocol(SAP), Special Process(SP) audit, Technical Review Requirement(TRR, Risk Estimation in Sourcing(RES)
	Engineering Work Procedure (EWP)	Responsibility of tier 1 suppliers for cascading the requirements to tier N suppliers	Purchase Manual, 15 Special Appendices, Supplier Relation Data base (Mapping), IBX software from Capgemini (Mapping)	Component Mapping Chart (CMC) for raw materials mapping	Idea of mapping of supply chain of tier components through a mapping tool
	Product Assessment (PA)	Cascading requirement for performing	Compliance Assessment (Pre	Special Process Audits according to internationally	Idea of adding a column for Special Process(SP) audits

	Company B1	Company B2	Company B3	Company B4	Case Company
		audits with tier 1 supplier performing on tier 2, tier 2 on tier 3. Capacity audit in tier N	Audit/Announced Audit) Unannounced Audits External Audits Internal Audits	recognized standards Risk based audit programs	by tier 1 supplier on tier N supplier in the mapping tool
APQP	Specific Folder with a planning form	Pragmatic approach of monitoring in between milestones	Program Management, Supply Planner (Project Monitoring)	Supply Chain Plan Critical Path and Main Milestone deviations	Idea for breakdown and alignment of the time plan of tier 1 suppliers with the tier N suppliers
	Special Attributes Approval (SAA)	Special characteristics covered in APQP	Design for Six Sigma DFMEA (Design Failure Mode Effective Analysis to be implemented) PFMEA (Process Failure Mode Effective Analysis for Risk Assessment) Legal Requirements	Part Risk Assessment Essential Attribute List (EAL) for monitoring and investigating key components	Need for development of a special characteristics tool similar to Company B1
	Idea of suppliers working more with their sub suppliers for critical components.		5 No-Go Gates Marking of Critical Processes in Production		Ideas for better monitoring of the requirements that are communicated down the supply chain Idea for performing process audits at tier N suppliers
PPAP	Specific Folder with a planning form	Responsibility of Tier 1 suppliers for PPAP approval at components level	Categories of Tests (Critical, Major, Minor)	Component Mapping Chart for verification of approvals from tier N supply chain	Idea for performing PPAP approval at the components level

	Company B1	Company B2	Company B3	Company B4	Case Company
				Re-verification of Sub-Component Cover Sheets	
	Special Attributes Approval (SAA)		Validations Test Reports	Risk Rating of the purchased component as stated in the Essential Attribute List (EAL)	Idea for requirement of a data base
PPCN	Engineering change notification(ECN) and Site Change Notification(SCN)	Site Supplier Quality engineers(SSQE	B3 correspondence portal for new and modified product, for warning level for test report expiration	Notifications before initiation of change and before approval of change New product development, Re-Audit, Re-qualifications, Re-certifications, On-site visits	Idea for mapping tool document to be updated upon any change at tier N supplier

5.2 Performance Gap Analysis

In the performance gap analysis the process map is followed by phase-wise bar charts depicting the level of tier N performance of the benchmarked companies and the case company where the process map has been elaborated on. The process of analyzing the benchmarking data begins with identifying the relationships between information to compare performance levels of participants, where several aspects have been taken into consideration in the latter part of the analyses. The Performance Analysis has been depicted for every stage of the questionnaire and is stated in the form of graphical data as mentioned

5.2.1 Sourcing

Company B1

Company B1 perform MSE while sourcing for potential supplier evaluation. For the first potential analysis of the supplier company B1 perform light MSE where they have few questions about the sub supplier management as compared to their full MSE where they have a full chapter about sub supplier quality management. Hence, company B1 acknowledged that they need to improve their light MSE by including more questions about the sub supplier management. They agreed to the idea of the standardized mapping of tier N suppliers' components which they currently do not have and thought it was a good idea.

When it comes to communication of requirements to tier N suppliers, company B1 communicate their requirements to their tier 1 suppliers only during RFQ and they are using a document called EWP for splitting the work between them and the tier 1 supplier. The tier 1 supplier is then responsible for cascading the requirements to tier N suppliers.

Also in place of SP audits which is performed only at process level at case company, company B1 perform PA at product level for their tier 1 suppliers but only in rare cases they perform PA at tier N suppliers.

Company B2

At Company B2 while sourcing for potential supplier evaluations are only considered for tier 1 suppliers with the occasional inclusion of tier 2 if there is any complex assembly involved but tier 3 is never considered. Company B2 is going up to only tier 1 level for monitoring the communication of requirements during sourcing, as for the communication of the technical requirements at the company B2, it is the responsibility of tier 1 suppliers if tier N suppliers are present. The reason for tier 1 responsibility is that company B2 wants to be less intrusive with their tier 1 suppliers, as in order to go in depth of the supply chain there should be a complete team to monitor it. Otherwise, it can quickly become exponential with lots of information that can become redundant. Hence, one of the big challenges for an OEM is where to put the limit in tier N management.

Company B2 have a standard cascading requirement when it comes to audits including capacity i.e. tier 1 supplier should perform audits on tier 2 supplier, tier 2 with tier 3 and so on. Company B2 does not participate in supplier selection audits as for them it is important to let the commercial discussions remain between tier 1 supplier and tier 2 supplier and so on. This is in line with the reason stated above for being less intrusive while communicating the technical requirements. However, company B2 acknowledge that, if there are risks identified at tier N level, it is possible to participate in the evaluation together with the tier 1 supplier.

Company B3

During the Sourcing Phase, company B3 in their own standard way of working maintains supplier relationship by highlighting various modules about compliance, finance and sustainability in the initial phase and monitors the way they are being carried out by their tier N supply chain. The supplier data base they have in their system has several numbers of checks and procedures associated with them, the completion of which is marked in the system. Thus, facilitation of information transfer has been taken care of since the beginning by mapping the tier N supply chain at a component level, to collect all technical and commercial aspects and to know where the critical components are being sourced from and capture it on the system.
These aspects are then communicated to the tier 1 suppliers and supervised production of these components is performed by conducting compliance audits as a pre audit, alongside internal, external and No-Go Audits. Although the responsibility is primarily handled by tier 1 suppliers,

the company checks whether they are visiting their tier 2 sub-suppliers. Hence, company B3 communicates their requirements at tier 2 level as they monitor in their online system, whether their requirements are being positively incorporated by the tier N supply chain.

Company B4

During the sourcing phase, company B4 comprehensively follows their system in place. Their planned supply chain including its feasibility, is mapped on the 'CMC' until the raw materials, which leverages their depth of communication. This is operated on a tool named 'B4 Correspondence Portal'. To continue strengthening and refining their tier N supply chain, they engage up to tier 3 in the supplier selection process.

The company audits their tier 2 suppliers based on internationally recognized standards along with tier 3 suppliers, depending on the business case. Thus, company B4 monitors their communication of requirements at tier 3 level, where self-assessments are also accepted, similar to company B3.

Case company

During the sourcing phase case company uses the SAP, perform SP audits and onsite visits to tier 1 suppliers but not on the tier N suppliers. The technical requirements are communicated to tier 1 suppliers through the TRR but there is no mechanism to validate that the requirements which are being communicated to tier 1 suppliers are cascaded upstream if tier n suppliers are involved. There are currently limited questions about sub supplier management in SAP. Therefore, a proposal was made by the interviewees to include a chapter about sub supplier management including supplier selection and finance related questions in SAP. The questions in the RES for sub supplier management also need to be revisited and updated if those are not good enough.

Presently at the case company there is no standardized way on which level tier N suppliers' components are mapped and considered, during the sourcing phase. Hence, the development of a mapping tool document during sourcing was proposed that would consist of a standard template for tier 1 suppliers to share their plan such as discussion of key components with sub suppliers and asking the tier 1 suppliers if they perform SP audits of their tier n processes with the addition of a column in the proposed mapping tool. Also, it was suggested by the interviewees whether the SP audit requirements could be shared with tier 1 suppliers and vice versa. Figure 2 below depicts up to which level in tier N the companies are monitoring their communication during sourcing.

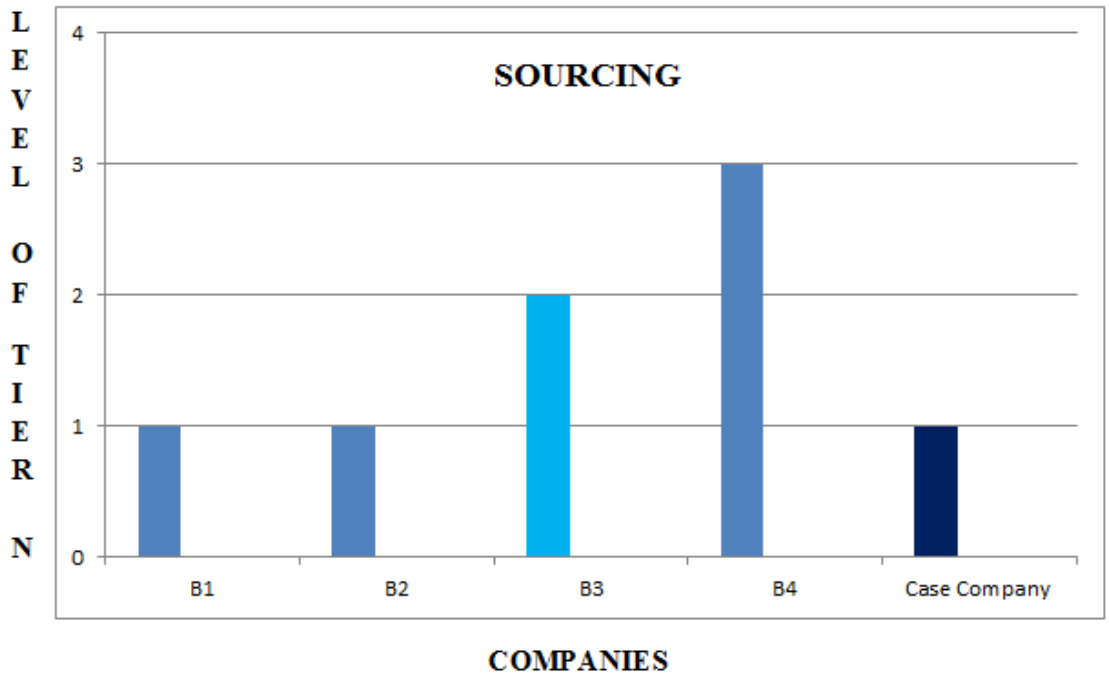

Figure 2: Level of tier N communication monitored during Sourcing

5.2.2 Advanced Product Quality Planning (APQP)

Company B1

For ensuring breakdown and alignment of time plan of tier 1 suppliers with the tier N suppliers company B1 has a specific folder with a planning form in APQP for sub components and part planning of sub suppliers. The folder is similar to product level part planning and they review it every month.

Company B1 also has a structured way for the deployment of special characteristics at the components level. They have a tool called Special Attributes Approval (SAA) that contains everything about the part name, part number which is then referenced to PFMEA, DFMEA and control plan, and they keep track of it every time. According to interviewees at company B1, this is the best practice there with respect to tier N management and if there is one thing the case company should take from the interview it should be SAA.

When it comes to performing audits at tier N level, company B1 perform the audits at tier 1 level only and rarely audit reports at tier 2 level are checked. But they acknowledge it can happen in some circumstances such as tier 1 supplier perform only simple assembly activities and majority of the value added activities are performed at tier 2 level. But at present they are performing audits up to tier 1 level in the supply chain.

With regard to the above an idea was proposed by the interviewees that suppliers could work more with their sub suppliers for critical components. There is an APQP status review of each component at different phases with tier 1 suppliers where they could mark the component to be a crucial part for sub suppliers. Following this questions could be asked regarding the type of audits that the tier 1 supplier has made for those critical parts.

Company B2

A pragmatic approach of monitoring in between milestones in APQP is followed for ensuring breakdown and alignment of time plan of tier 1 suppliers with the tier N suppliers at company B2. They acknowledge that if a sub component is really sensitive or crucial there is a specific time plan to follow it, even if it is at tier 2 supplier. But at present they are monitoring in between milestones in APQP with their tier 1 suppliers. The interviewee add that it is important to monitor in between milestones so that upon reaching the milestone there is few risk of having any deviation.

However, company B2 do not have a specific tool for the deployment of the special characteristics at components as it is covered in APQP. They have specific folders for tier N suppliers in APQP as the tier 1 suppliers come and put the documents in the shared area, which on principle is great, as it is done sometimes by tier 1 suppliers but is not stored systematically and hence currently is inefficient.

Company B3

During the Quality Planning phase, company B3 actively utilizes several tools in the product development phase, namely Microsoft Office, Product-FMEA and have been implementing Design for Six Sigma as a model for evaluation, for improving their supplier assessment. The role of ‘Supply Planner’ is enacted to instill the communication aspect for back calculating measurement of their time plan from the first delivery. ‘Business Developers’ are expected to do Program Management to fortify this communication aspect and ensure that the special characteristics are adopted at a product level by maintaining latest test reports and right level of compliance certifications.

The test reports are categorized into critical, major and minor tests, with warning levels associated with them at the time of expiration. Regional legal requirements are taken into consideration while carrying out standard operating procedures and deploying requirements from product level to process level. Financial aspect plays an important role in tier N management for company B3, since more than 50% is the material price and a good follow-up with the tier 2 suppliers saves a lot of money which they are currently following.

Company B4

Company B4's time plan includes scheduled checks of milestones and deviations along the critical path, which is the shortest possible path for completion of the project. The fulfillment of this path and deployment of required actions is monitored by the company.

Risk assessment is an important part of the product development process, where 3 audits and co-audits tier are included in forming the assessment and incoming inspection is meticulously controlled. This is because some of their products are under design responsibility of tier 1 suppliers and the company believes that a maximum level of participation is necessary for knowledge expansion. Special characteristics are drafted in the Essential Attribute List (EAL), which is referred during the complete phase of APQP, notably to monitor and investigate these key components. This ensures that requirements are communicated to all the participants in their tier N supply chain, throughout the APQP phase and also are monitored by their tier 1 suppliers up to tier 3 level.

Case Company

Currently at the case company, tier 1 suppliers are responsible for the development of detailed APQP. But they see that they have issues for ensuring breakdown and alignment of time plan of tier 1 suppliers with the tier n suppliers. To tackle this, the interviewees came up with ideas such as asking for more details and time plan for component level during APQP. A sheet could be added for sub components in APQP for ensuring that the product time plan is in alignment from OEM to tier N level, which would make it easy to follow up in a structured manner.

For the deployment of the special characteristics at the components level it was deduced by the interviewees that case company presently do not have a structured way of doing this. Hence a proposal was made by the interviewees to develop a tool similar to company B1's SCA that would consist of characteristics description, specification and criticality of the components as the sheet in the APQP would be marked if it is a critical component.

For better monitoring of the requirements that are communicated down the supply chain an idea was proposed by the interviewees for developing a one page document with fewer requirements such as requirements for PPCN, capability requirements for special characteristics. This document could be sent along with SQAM to the tier 1 suppliers who would be asked to cascade it further down the supply chain. But it is important to make sure that the suppliers do not consider the requirements in this document as the most important requirements and they do not go through the SQAM.

For performing the process audits at tier N level it was suggested that it depends upon the criticality of the processes and the number of sub suppliers of OEM's tier 1 supplier. If the majority of the value added activities are performed at tier n level and tier 1 suppliers only perform the assembly activity, the idea was proposed that process audits could be performed.

Likewise it was proposed that for big tier 1 supplier with many tier N suppliers process audit could be performed. However, it is to be ensured that when these audits are performed by the OEM, the responsibility of approval still remains at tier 1 supplier without bypassing them. This would ensure training of tier 1 suppliers by the OEM and with the passage of time it is expected that the tier 1 supplier do these audits independently. Figure 3 below depicts up to which level in tier N, the companies are monitoring their communication during APQP.

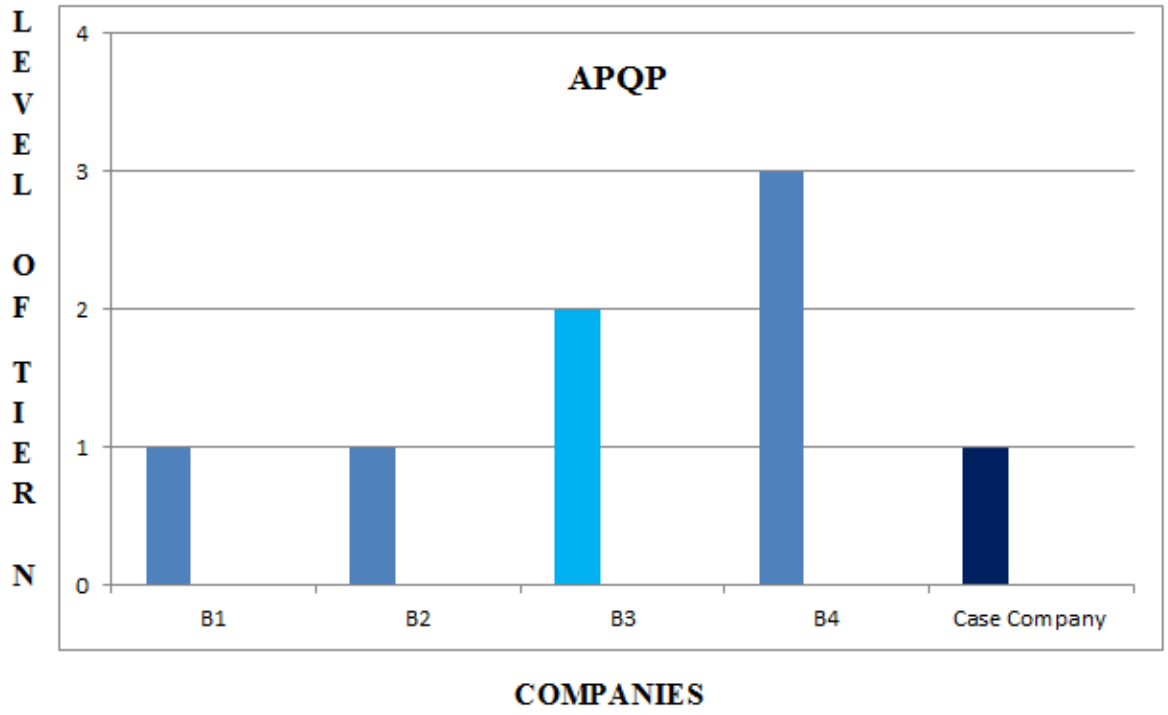

Figure 3: Level of tier N communication monitored during APQP

5.2.3 Production Part Approval Process (PPAP)

Company B1

For PPAP at company B1 the specific folder with the planning form is used similar to their APQP with a PPAP check list. It is the responsibility of tier 1 supplier to fill the checklist.
In their SAA they have two phases, planning phase and the manufacturing phase. It is mandatory for the tier 1 suppliers to fill in the details for PPAP in these phases which is then checked by them.

Company B2

At company B2 it is the responsibility of tier 1 suppliers for PPAP approval at components level i.e. upstream in the supply chain. They have set milestones in APQP and the tier 1 suppliers are responsible for sharing the information for the milestones of all the components including supplier selection and PPAP. Company B1 check if the PPAP is validated by tier 1 but not its content.

Company B3

During the Production Approval phase, company B3 monitors the timely submission of approved test reports from their tier 1 suppliers. It is self-explanatory to the suppliers through their correspondence portal system that for Production Part Approval, if new test reports are not refurbished before their date of expiry, it is a No-Go. The company very much welcomes the idea of Poka-Yoke to be carried out by their tier N supply chain to reject non-conformities in the system, with some of their suppliers working on it.

Company B4

To ensure integration of notified requirements, the tier N supply chain of company B4 is required to fill the 'CMC', which is an active part of PPAP phase. This renders their involvement to tier 3 and beyond. Risk ratings of incoming components are developed, observed and noted across the cross functional teams, which are also cascaded up to tier N level. Following this, the cover-sheets of all sub-components are checked for their availability at an optimum level.

Case Company

Case company expect that for PPAP approval from them to their tier 1 suppliers, the manufacturing process used to produce parts is fully developed, thoroughly tested, and capable of serial production of parts conforming to the technical specifications. But this process is only done for tier 1 suppliers. There is no standardized way of PPAP approval at components level for parts coming from tier n suppliers. Hence, an idea of random selection of two components by SQE from case company when visiting the tier 1 supplier was proposed by an interviewee for performing the PPAP approval at the components level. The idea is to pick one critical and one standard component at tier 1 supplier which is coming from tier n suppliers and review the PPAP of those components with the SQE from tier 1 supplier who approved the PPAP. The review could include capability requirements, presence of special characteristics etc.

In relation to above, a proposal was made by the interviewees for the requirement of a database which the supplier can use for uploading the documents triggering an automatic mail to the SQE at case company whether the documents are uploaded or updated. Figure 4 below depicts up to which level in tier N, the companies are monitoring their communication during PPAP.

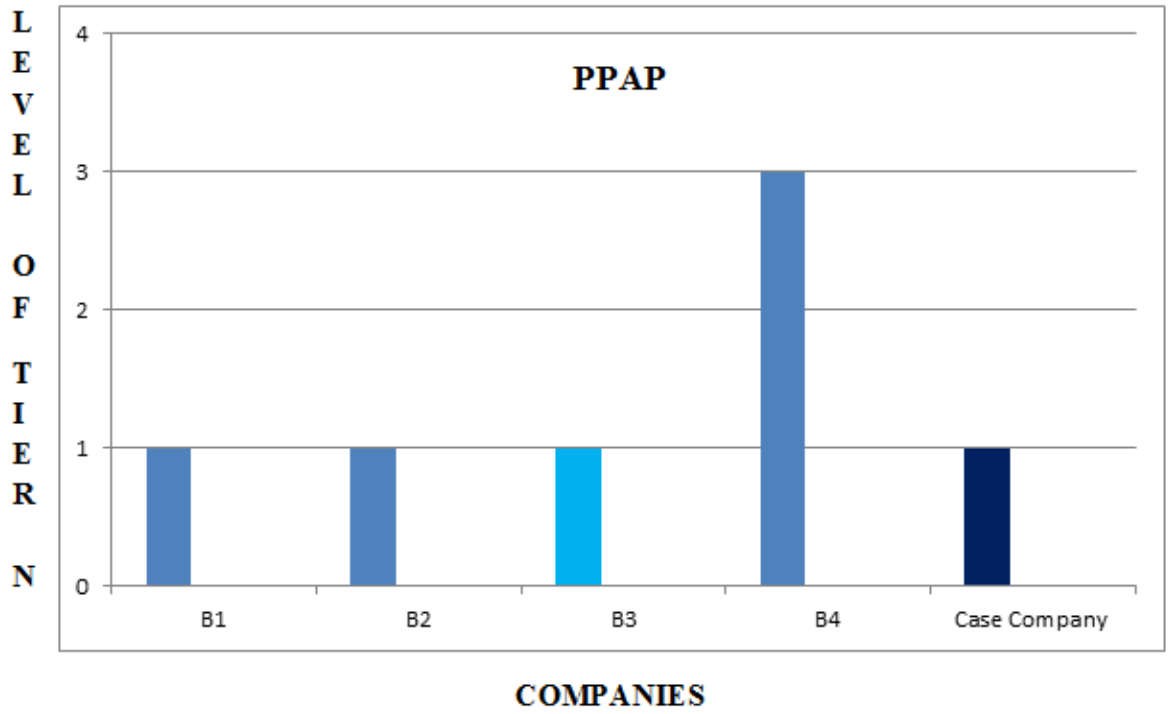

Figure 4: Level of tier N communication monitored during PPAP

5.2.4 Product Process Change Notification (PPCN)

Company B1

For PPCN company B1 use Engineering Change Notification (ECN) and Site Change Notification (SCN). ECN at company B1 is managed by R&D and is applicable when the tier 1 suppliers want to make any engineering change after the PPAP approval of the produced parts. ECN is requested online by the supplier that generates a Product Change Request (PCR) in the online system for approval by company B1.

SCN on the other hand is managed by purchasing and is applicable when the tier 1 suppliers want to make a change in the production manufacturing process or location after the PPAP approval of produced parts. Currently, SCN is done offline in an excel sheet but company B1 see that in future it would be a good idea to do SCN also online like ECN as it would make the process easier.

For company B1 ECN and SCN are working good for them for communication of the PPCN requirements from tier 1 to tier N suppliers. It is a requirement for their tier 1 suppliers to have their own change management system when they are using ECN and SCN. When company B1 audit the tier 1 suppliers, they know if it is working well or not. Hence, they have a good picture of how their tier 1 suppliers are working with their sub suppliers.

Company B2

For PPCN submission at company B2, it is a general requirement that the tier 1 suppliers inform them of the changes and it is not missed but there is no specific mechanism to ensure that it is not missed. Sometimes they perform audits where they can identify the changes coming from upstream in the supply chain.

However, in relation to above they have Site Supplier Quality Engineer (SSQE), whose work is one of the best things at company B2 for monitoring the changes proactively. The SSQEs at company B2 are in charge of the plant of the suppliers and monitor the industrial activity of the plant. The activity includes capacity and quality improvements of tier 1 suppliers that helps in getting a lot of information. Hence, there are more chances of identifying any changes in anticipation resulting in easy monitoring of quality and logistics issues.

Company B3

During the Change Notification phase, company B3 expect their tier 1 suppliers to handle all the changes in sub suppliers and note those changes in the 'New and Modified Product' section. Changes also call for the submission of new audit reports and test reports.

Company B4

During PPCN phase, company B4 expects timely communication of changes from tier 3 suppliers and beyond for which they monitor the approval plan containing new design and verification tests. New sets of on-site visits, audits, re-qualification and re-certification form a central part of the change process and are explained in 'Quality Assurance Agreement'. The company expects to be notified before the initiation and approval of change from their tier 1 suppliers. They also monitor that the tier 1 suppliers have their own approval plan for all changes, including the designs and verification tests.

Case Company

For PPCN, case company has the requirement that their tier 1 supplier must submit all the proposed changes to the product, production process, materials or suppliers prior to the introduction of the change after the successful PPAP given to the supplier by case company.
Case company is facing some difficulties with regard to PPCN submission by tier 1 suppliers. The reasons for missing the PPCN submission are tier N suppliers not informing the tier 1 suppliers of the changes and tier 1 suppliers not communicating the PPCN requirements with their tier N suppliers.

Hence in relation to above an idea was proposed by the interviewees for having a system where the PPCN could be uploaded by the supplier. The mapping tool document proposed earlier in sourcing is a living document. Hence the interviewees proposed to update the mapping tool document by the tier 1 supplier if there is any change at the tier N supplier. As a result of this

update the team at case company should receive a notification that the supplier should submit PPCN. Figure 5 below depicts up to which level in tier N, the companies are monitoring their communication during PPCN.

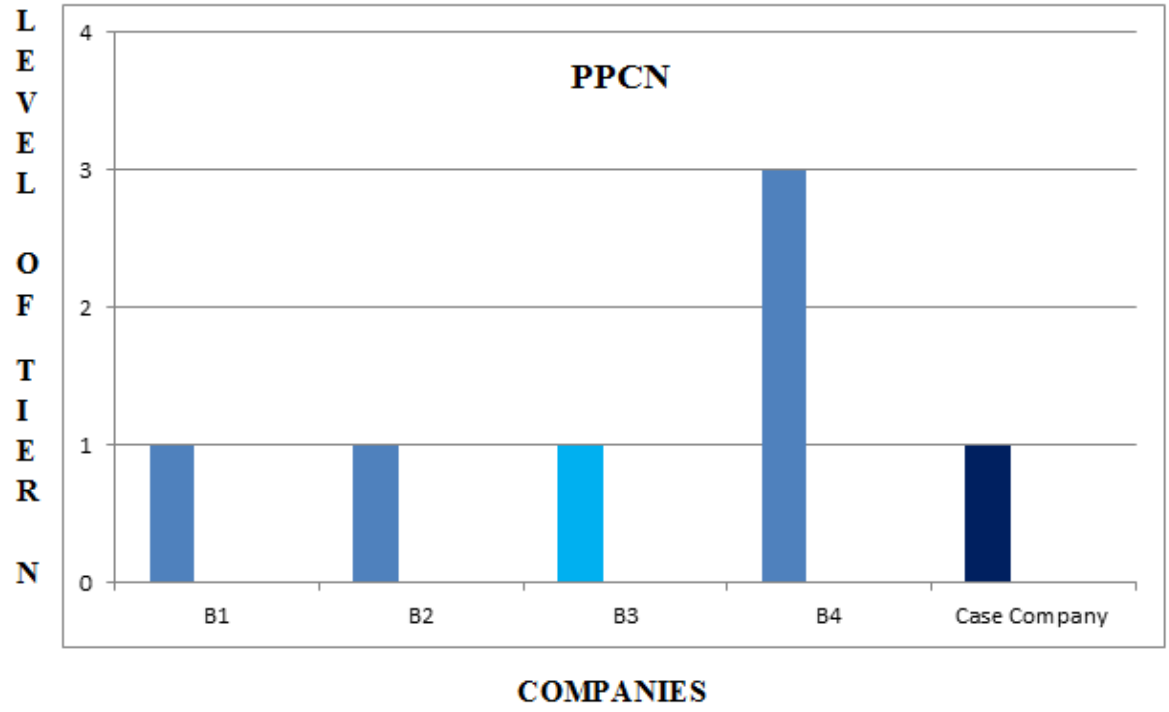

Figure 5: Level of tier N communication monitored during PPCN

6. Discussion

In this section, the analysis from the previous section are discussed. It is divided into two sub sections:

In the first sub section the common methods of communication of the requirements from the OEM to tier 1 suppliers and from tier 1 suppliers to tier N suppliers are discussed.

In the second sub section the best practices and improvement suggestions based on the analysis and discussion of the first subsection, for the improved supplier quality in tier N supply chain management are discussed.

6.1 Communication of requirements from OEM to tier 1 suppliers and from tier 1 suppliers to tier N suppliers

This subsection is further divided into sourcing, APQP, PPAP, PPCN following the same chronology, as in the empirical data and analysis. In each of the above phases the practices used by the OEMs for communication to their upstream supply chain that are followed are discussed and are compared with each other. If there are challenges faced by them for the communication, they are discussed along with the improvement suggestions by them for mitigating those challenges.

6.1.1 Sourcing

When it comes to sourcing the case company, benchmarked companies B1 and B2 communicate their requirements to their tier 1 supplier who are responsible for communicating the requirements upstream in the supply chain.

Company B3 have a supplier data base in their system and the requirements that are communicated to their tier 1 suppliers are supervised by conducting compliance audits. Although the communication of requirements from tier 1 to tier N level is primarily handled by tier 1 suppliers, company B3 supervises their tier 1 supplier whether they are visiting their sub suppliers and the requirements are inculcated at the tier N level. This tangents with Krause et al.'s (1998) description about buyers engaging in supplier development activities for improving supplier's quality and delivery performance. Company B4 also engage in supplier development activities, and are the best in class for sourcing among the five companies as they engage up to tier 3 level in their supplier selection process as well as performing audits. They have a comprehensive system in place in the form of a tool named 'B4 correspondence portal' where their planned supply chain is mapped on the 'CMC' until the raw materials. This is in line with Juran et al. (1974) argument that for ensuring materials are of highest quality possible,

organizations should work directly with raw materials suppliers from the beginning. It is reiterated by Kaynak (2002) who argues that the usage of high quality materials and parts would positively affect the quality of the buying firm's products.

As there is no mechanism of validating the communication of requirements to tier N suppliers at case company, a proposal was made by the interviewees to include a chapter about sub supplier management in their SAP and RES including questions for supplier selection and finance related questions. Company B1 also acknowledged that they need to improve their light MSE during sourcing with the inclusion of more questions about sub supplier management. The above proposal is in line with Amelia & Hale's (2007) suggestion as it would help in improving firm performance as it involves emergence of information sharing between firms which is directly related to product quality improvement and indirectly related to financial performance through product quality improvement.

Similarly, for standardized mapping of tier N suppliers' components, a mapping tool document during sourcing was proposed by the interviewees at the case company consisting of a standard template for tier 1 suppliers to share their plan such as discussion of key components with sub suppliers and performing SP audits of tier N processes. This would help in building trust and consensus as it tangents to Heher & Chen's (2017) argument that process mapping is a product of collective intelligence, requiring brainstorming sessions involving the relevant stakeholders from the involved areas. Following this plans for targeted quality improvements can be made.

Also, it was proposed by the interviewees at the case company that the case company could share their SP audit requirements with their tier 1 suppliers and vice versa. This is in line with Krause et al.'s (1998) argument of knowledge sharing as an important factor for supplier development activities offering mutual benefits for the buying firm and the supplier. This support activity in turn would result in improved buyer-supplier performance (Humphreys et al., 2004) and improved relationship between the buyer and the supplier (Krause, 1999 and Sriram & Stump, 2004).

Although company B1 perform SP audit at tier 1 level which they call product assessment (PA) there is a learning here for the case company who perform SP audit only at the process level. Company B1 perform SP audit at product level in addition to the process level. Hence it could be deduced that the benchmarking of company B1 has helped the case company to learn another aspect of SP audit which is in line with Bagchi's (1997) argument that the ultimate aim of benchmarking is to learn from each other.

At company B2, the responsibility for communication of requirements to sub suppliers including capacity requirements is put on the tier 1 suppliers including performing audits at sub suppliers as they want to be less intrusive with their tier 1 suppliers' commercial discussions with their sub suppliers. The learning for the case company here is that from the quality point of view capacity also needs to be considered and OEM can be hurt by capacity as well. Company B2 mention that as an OEM the challenge is where to limit oneself in tier N management as going upstream in the supply chain increases the amount of information for

which there should be a complete team to monitor. This supports Dean & Bowen's (1994) argument that continuous improvement is built on teamwork and Bardi et al. (1994) and Narasimhan & Kim's (2001) argument that organizations should strengthen their internal integration prior to integrating themselves with the suppliers.

6.1.2 Advanced Product Quality Planning (APQP)

Bergman & Klefsjö (2010), explain the importance of making complex processes simple to improve productivity. Also, it is reiterated by Heher & Chen's (2017) argument that knowing workflows of other organizations is also important for achieving common goals in the supply chain. Therefore, the Quality Planning phase essentially begins with the alignment of time plan, followed after the communication of commercial and technical requirements during the sourcing phase.

Company B1 has a time plan for all tier 1 suppliers, maintained and reviewed by them every month. A suggestion was also made by the interviewees during the interview that in the APQP status review with tier 1 suppliers they could mark crucial parts for sub suppliers. Company B2 state that it is more realistic to have a time plan only for critical components from the tier 2 suppliers and focus more on how tier 1 manages this responsibility. They strongly agree that it is important to have a pragmatic approach of monitoring in between milestones, which they currently follow. This could be a learning for the case company. Company B3 employs the role of a 'Supply Planner' who prepares the plan for tier 2 suppliers according to the launch of the products, with the inclusion of buffer time.

Company B4 has the most structured time plan, ranging till tier 3 suppliers, where the material flow is verified at different stage gate, so that it follows the least path of completion. This supports Bergman & Klefsjö's (2010) and Heher & Chen's(2017) earlier statement of ensuring the right follow up of the workflow information has taken place, before formulation of time plan. At the case company for ensuring breakdown and alignment of time plan of tier 1 suppliers with the tier N suppliers a similar proposal was made by the interviewees for addition of a sheet for sub components in APQP.

Krause et al (1998) focus on the improvement in supplier relationship with the effective sharing of product and process requirements. For the 'Product Development' phase, the benchmarked companies have ways to set out special characteristics for their respective products. Company B1 deploys a tool in the form of SAA, which has all the stages of product development in the tier 1 supply chain and is monitored by them. The company self attests and acknowledges that this is their best practice and can be directly incorporated by the case company in their work structure. Hence, the case company could have a tool similar to the SAA used by company B1. However, company B2 share all development stages in a commonly accessible document, the completion responsibility of which is delegated to the tier 1 suppliers. Company B3 also perform FMEA similar to the automobile industry and further ensure enactment and implementation of special characteristics. This is done by ensuring regional laws are complied right from the beginning along with the presence of current test reports. The company believes

that since material price is majority of the product cost, continuous monitoring and feedback from tier 2 suppliers shall recoup more saving. With audits, co-audits and risk assessments performed at a tier 3 level, Company B4 is aware that the extent of knowledge is directly dependent upon the level of participation. The important characteristics have been emulated right from component mapping in sourcing, with company B4 not only monitoring tier N supply chain, but also tracking the monitoring process of tier 1 suppliers on tier 2 suppliers. This has been agreed upon by Matook et al (2009) that risk management in purchasing is important because of its role in financial performance. Also, Hartley & Choi (1996) are in line with company B4 as they mention that long term relationship with suppliers having a low risk rating shall be a deciding factor in the dynamic business environment.

6.1.3 Production Part Approval Process (PPAP)

When it comes to PPAP and production approval at components level for the case company, benchmarked companies B2 and B3, the responsibility is put on their tier 1 suppliers.

Company B1 on the other hand have a specific folder with their planning form or checklist for components level PPAP similar to their APQP and PPAP checklist. They put the responsibility on tier 1 supplier to fill the checklist. Also in their SAA at the planning and manufacturing phase, it is mandatory for the tier 1 supplier to fill in the details for PPAP which is checked by them.

Company B4 is the best in class among the five companies for components PPAP. For ensuring integration of notified components, the tier N supply chain of company B4 is required to fill the CMC as an active part of PPAP phase. For components PPAP the involvement of company B4 is up to tier 3 level and beyond.

There is a learning for the case company here for the inclusion of a specific folder with the checklist for components PPAP similar to company B1 or having a components mapping chart similar to company B4. This is line with Dattakumar & Jagadeesh (2003) as the benchmarking approach here through the benchmarking of companies B1 & B4 is helping the case company as a tool for continuous improvement.

Presently at case company there is no standardized method of PPAP approval at components level for tier N suppliers' parts. Hence a proposal for the inclusion of a data base which the supplier could use for uploading and updating the documents related to PPAP approval was suggested by the interviewees. In addition an idea was proposed during the interview that while visiting the tier 1 supplier, the SQE could select one critical and one standard component coming from the tier N suppliers and review the PPAP approval of those components with the SQE of tier 1 supplier who approved it. This support would help in reducing the case company's transactional costs through improved supplier performance (Krause, 1999). The support also would help in developing the suppliers' capabilities and thus in turn would help in meeting the challenge of suppliers already organized to meet the case company's

requirement for quality, delivery, flexibility and cost reductions (Hartley & Choi, 1996; Krause et al., 1998).

6.1.4 Product Process Change Notification (PPCN)

For PPCN submission or change notification of the approved products or suppliers, the case company, benchmarked companies B2 and B3 expect that the tier 1 suppliers inform them of all the proposed changes to the product, materials or suppliers after the successful product approval phase. But currently there is no mechanism present in the companies to validate that change notification would not be missed.

However, company B2 have SSQEs who are in charge of the plant of the tier 1 suppliers who make regular visits to plants. Their work is described by the interviewee as one of the best practices for proactive monitoring of the changes as they monitor the changes in the industrial activity in the plant such as capacity and quality improvements. This technical support provided to the suppliers is helping in the development of company B2's suppliers and is in line with Hartley & Choi (1996); Krause (1997) and Krause et al.'s (1998) argument of evaluation of supplier performance and sharing feedback on the evaluation of suppliers' performance, alongside visiting suppliers' plants.

Company B1 have divided the PPCN submission from their tier 1 suppliers into two parts: Engineering Change Notification (ECN) and Site Change Notification (SCN). ECN is requested online by the tier 1 supplier to the company B1 for any engineering changes while SCN is requested offline for any changes to production manufacturing process or location of their sub suppliers. They plan to make the SCN also online in future. For them ECN and SCN are working very well and they have a good picture of how their tier 1 supplier is working with their sub suppliers. The learning for the case company here is to make their PPCN process online which is currently offline for efficient monitoring of the PPCN submission from their tier 1 suppliers**.** This tangents with Stapenhurst's (2009) argument as benchmarking of company B1 could act as a driver for process improvement for PPCN submission for the case company.

The case company could also take inputs from company B4 whose new sets of on-site visits, audits, re-qualification and re-certification form a central part of the change process which they explain in their 'Quality Assurance Agreement'. The expectation is to be notified before the initiation and approval of change from their tier 1 suppliers. They also monitor that the tier 1 suppliers have their own approval plan for all changes, including the designs and verification tests and just like the components PPAP their involvement for PPCN submission is up to tier 3 level and beyond.

For the case company there is a requirement of a structured system for PPCN submission by the suppliers. Hence a proposal was made by the interviewees for updating the mapping tool document by the tier 1 supplier if there is any change at the tier n supplier. This would result in sending a notification to the case company for PPCN submission by the supplier. This

tangents with Heher & Chen's(2017) argument that process mapping is better than standard operating procedure(SOP) as process maps act as a tool provider for efficient understanding of the processes.

6.2 Best practices and improvement suggestions for improved supplier quality in Tier N supply chain management

Matook et al. (2009) argue that benchmarking approach is useful for the identification of high performers who may have achieved 'best practice' (Camp, 1995) for supplier development presenting an action plan for performing the improvement steps. In this sub section the best practices from the benchmarked companies B1, B2, B3 and B4 have been discussed in this sub section. Bergman & Klefsjö (2010) argue that the popular motto 'Do it right the first time' must be interpreted carefully, the important thing is to learn from the processes and increase the opportunities for improvement. From the internal interviews with the case company the current processes in place was discussed by the interviewees and improvement suggestions were made. The best suggestions for improvement from these interviews have also been discussed in this sub section.

In the final conclusion chapter, the best practices and improvement suggestions have been depicted in a bubble diagram in terms of investment required versus their impact.

Beginning with company B1, the best practice that could be taken by the case company, validated by the interviewees at the company B1 is Special Attributes Approval (SAA) tool which company B1 are using for structured deployment of special characteristics at the components level. Company B1 make it mandatory for their tier 1 suppliers to fill in details for PPAP in the planning and manufacturing phases of SAA which is then checked by them. Hence, SAA could be incorporated by the case company in their work structure

Company B1 has an APQP status review meeting with the tier 1 suppliers every month where they maintain and review the time plan with their tier 1 suppliers. In relation to this, a suggestion was brainstormed by the company B1 interviewees that their tier 1 suppliers could also mark the crucial parts coming from their sub suppliers. These markings of crucial parts by the tier 1 suppliers then could be reviewed by company B1 during their monthly APQP status review meeting. The case company could utilize this brainstormed suggestion as it can be deduced from this suggestion that if there is a project time plan, the supplier time plan could be even before PPAP approval. For PPAP at company B1 a specific folder with a planning form used which could also be a learning for the case company. The case company could make their PPCN process online similar to the Engineering Change Notification (ECN) by the benchmarked company B1 for efficient monitoring of PPCN submission from their tier 1 suppliers.

From company B2 an important learning for the case company could be inclusion of capacity requirements when the sub suppliers' audits are performed by the tier 1 suppliers, as from the quality point of view capacity requirements also need be considered. At company B2 the pragmatic approach of monitoring in between milestones in APQP is considered more important than just having milestones at different stages of APQP review, which could be another learning for the case company. The best practice at company B2, which the interviewee acknowledged during the interview is the work of Site Supplier Quality Engineers (SSQE) responsible for manufacturing plants of their tier 1 suppliers. Any change in the industrial activity in the plant such as capacity and quality improvements has to go through SSQE as the tier 1 suppliers must inform the SSQE in charge of the plant. This results in proactive monitoring of changes upstream in the supply chain.

The 'online system – B3 correspondence portal' at company B3 includes different modules that give their stakeholders a comprehensive visualization of the supply chain. The module- 'Supplier Relation database' includes several instructions and checklists for the tier 1 suppliers and tier N sub-suppliers as well as special appendices for critical components. The communication of information is expedited by capturing and mapping the technical and commercial aspects on the system followed by monitoring the progressive integration of these aspects in their tier N supply chain.

The cross functional team of company B3 also performs 'Program Management' during their active participation in the system, further strengthening communication between tier 1 and tier N and assuring the expected implementation of special characteristics. With a focus on territorial legal requirements it is compulsory to perform a number of tests at different levels, accompanied by timely refurbishment. An automated warning system assisting them in this case, the internal stakeholders have enough buffer time to begin monitoring the tier N supply chain for submission of new test reports.

It could be deduced that company B3 works effectively well on this online system as it provides a financial benefit for them, due to which it has been the best practice for them. The case company can formulate and implement an ingenious online system similar to company B3 as a mode of correspondence for product and process quality planning, to keep all internal and external stakeholders in the loop.

Company B4 being fastidious in their chain of processes, have been making sure that their system is in line with each and every part of their process, since the beginning. Their Component Mapping Chart (CMC) forms the basis of their time plan and depicts the practicability, right from sourcing. As a result of this, they have been able to perform audits till tier 3 suppliers and beyond in certain cases to ensure that this type of component mapping leverages their time plan and keeps them primed and flexible to any changes in their supply chain alongside securing all milestones traversing the critical path.

The chart consists of Essential Attributes List (EAL) that includes special characteristics for every tier, utilizing which the company stakeholders perform risk analysis during product

development also based on their audits, co-audits and self-assessments. Delegation of design responsibility has been perceived as a learning opportunity to have a maximum know-how from the matured performers in the industry and deployment of this responsibility is monitored by the company B4, with tier 1 suppliers also monitoring their tier N suppliers and keeping OEM in the loop.

The CMC also assimilates changes in design or process requirements across cross functional teams which are verified by checking completion of the cover sheet of all components. This map is a form of an active document and is an important reference for part production approval and change notifications. Due to several advantages for the internal and external stakeholders from this mapping, it has been considered as the best practice at company B4. Incorporating and emulating this mapping can assist the case company in visualizing supply chain to their lowest tier and in monitoring the effective integration of all special characteristics, helping to build the quality right from the start of the procurement process.

For the case company the proposal made by interviewees for the inclusion of a chapter about sub supplier management in their SAP and RES including supplier selection and finance related questions would help in validating the communication of requirements in sourcing to tier N suppliers. Also, the idea of inclusion of the mapping tool document during sourcing by the interviewees for the tier 1 suppliers, to share their time plan in the standard template of the mapping tool document would help in the standardized mapping of the tier N suppliers' components. Likewise, a sheet for sub components in APQP would help the case company for ensuring breakdown and alignment of time plan of tier 1 suppliers with the tier N suppliers. During the PPAP approval at components level the case company could increase their tier 1 supplier's capabilities and knowledge by making their SQEs more involved during the visit to tier 1 suppliers. The proposal is that the case company could jointly review the PPAP approval at the components level of one critical and one standard component with the tier 1 suppliers' SQE who approved the PPAP. If it is a critical component coming from sub suppliers, then the case company could also perform joint audits of sub suppliers with their tier 1 suppliers. But the case company should ensure that they communicate their views on these audits to only tier 1 suppliers. The responsibility should still remain at tier 1 supplier, as the communication with their tier 1 sub suppliers might result in misinterpretation to the sub suppliers that the case company is responsible for the sub components approval instead of the tier 1 supplier.

7. Conclusion

Answers to the first two research questions have been answered in 6.1 covering the processes in sourcing, APQP, PPAP and PPCN based on the analysis from 5.

The companies cascade the requirements in the supply chain to their tier 1 suppliers and the responsibility of cascading the requirements further lies with the tier 1 suppliers if tier N suppliers are involved. But this does not imply that the OEMs are not monitoring the activities upstream in the supply chain. The OEMs do provide support activities at different stages of the processes in sourcing, APQP, PPAP and PPCN to their suppliers, if not at every stage. This ensures development, learning and better communication of requirements from the OEM to their sub suppliers, in the process building trust and consensus between the OEM and the tier 1 supplier. This in turn results in the better quality of work and spending of time and resources where it really matters with respect to tier N management. The best practices and the improvement suggestions therefore, from the OEMs for improved supplier quality in tier N supply chain management have been answered in 6.2 based on the discussion from 6.1. Five of those best practices and improvement suggestions recommended for the case company are as following:

- SAA tool from company B1
- The work of SSQEs and pragmatic approach of monitoring in between milestones including consideration of capacity requirements from company B2
- The online system – 'B3 correspondence portal' from company B3
- Components Mapping Chart(CMC) from company B4
- Proposal for the development of a mapping tool document from internal interviews at the case company

Figure 7 depicts the bubble diagram to represent the ranking for implementing the five best practices that have been recommended above, based on the level of effort for implementation, the level of impact and the level of cost. These practices shall now be discussed in order of an increasing level of cost.

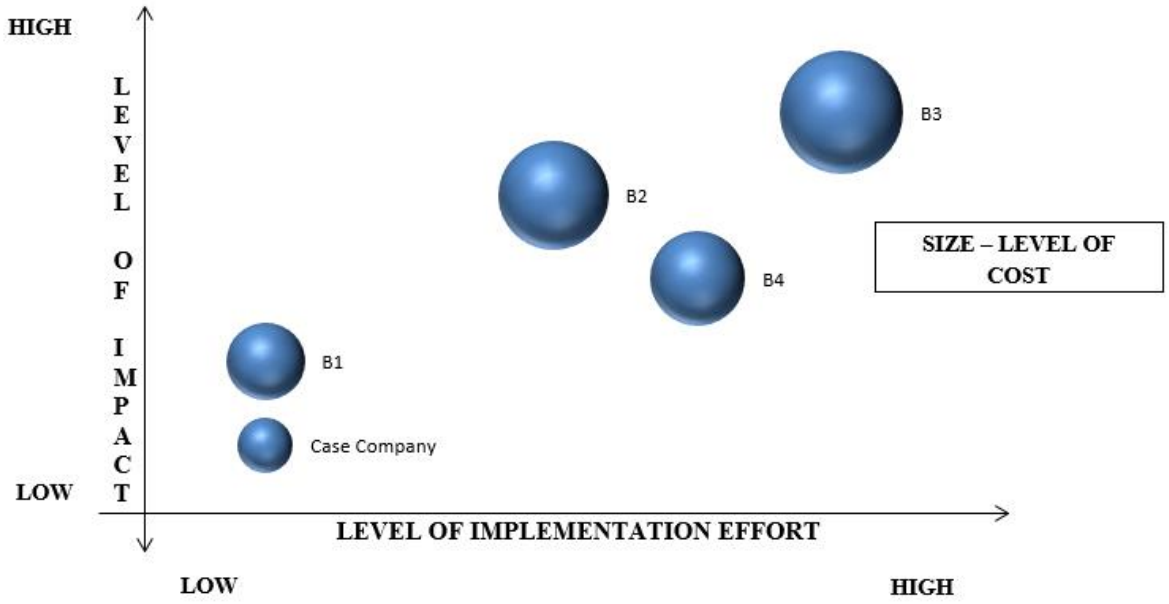

Figure 7: Bubble diagram

By drawing comparisons between the best practices suggestions that have been derived from analyzing the interviews, the suggestions from the case company and company B1 have been suggested as 'low hanging fruits', by the researchers. They can be implemented by preparing a template for each of them. Since these tools will assist the case company only with respect to tier 1 supplier communication, they are considered to have a lower level of impact than the other suggestions and shall be easy to implement with the least investments.

The best practice from B2 has a high level of impact, with a higher level of implementation and cost, than the former two practices, as it requires thorough knowledge expansion for a more improved communication with the tier 1 suppliers. This will require more frequent visits at the tier 1 supplier plants and more detailed handling of the standard operating procedures. The best practice at B4, although similar to the one suggested by the case company, has a higher level of implementation effort and impact, since the mapping is performed up to tier 3 and therefore has been assumed to be more detailed and complex than the mapping suggested by case company, which shall also contribute to the higher cost. The best practice at B3, are considered to be the costliest and most difficult to implement as it involves reforming the old system to a completely new system. Although tedious, it has been expected to have the highest impact, as all activities under tier N management shall be a part of this loop.

The thesis has resulted in a lot of insights about the benchmarked companies' way of working with tier N management. However, in the benchmarking performed for the companies, three companies were from the automobile industry and one company from the non-automotive industry. Hence, it would be interesting to look into how other companies from the non-automotive sector are working with respect to tier N management in future. Also all the companies benchmarked were OEMs. Therefore, it would be interesting to investigate the problems the suppliers and their sub suppliers of OEMs are facing and getting their perspective

as to where the communication of requirements fail. Lastly, it was highlighted in one of the interviews that as an OEM, the challenge is where to limit oneself in tier N management when going upstream in the supply chain. This brings too many tiers in the picture and increases the amount of information which could be difficult to monitor without extensive teamwork. Hence, future research in this area is also encouraged.

‘

References:

Amelia S. Carr, Hale Kaynak, (2007) "Communication methods, information sharing, supplier development

B. Forker, L. and Mendez, D. (2001). An analytical method for benchmarking best peer suppliers. International Journal of Operations & Production Management, 21(1/2), pp.195-209.

Bagchi, P. (1997). Logistics benchmarking as a competitive strategy: some insights. Logistics Information Management, 10(1), pp.28-39.

Bardi, E.J., Raghunathan, T.S. and Bagchi, P.K. (1994), "Logistics information systems: the strategic role of top management", Journal of Business Logistics, Vol. 15 No. 1, pp. 71-85.

Bell, E., Bryman, A. and Harley, B. (2011). Business research methods. United Kingdom: Oxford University Press

Bergman, B. and Klefsjo, B. (2010). *Quality*. Sweden: McGraw-Hill..

Bhatt, G.D. (2000), "An empirical examination of the effects of information systems integration on business process improvement", International Journal of Operations & Production Management, Vol. 20 No. 11, pp. 1331-59.

Burt, D.N. (1989), "Managing suppliers up to speed", Harvard Business Review, Vol. 67 No. 4,pp. 127-35.

Camp, R. (1995), Business Process Benchmarking: Finding and Implementing Best Practices, ASQC Quality Press, Milwaukee, Wisconsin.

Childerhouse, P., Hermiz, R., Mason-Jones, R., Popp, A. and Towill, D.R. (2003), "Information flow in automotive supply chains - present industrial practice", Industrial Management & Data Systems, Vol. 103 No.3, pp. 137-149.

Crocitto, M. and Youssef, M. (2003), "The human side of organizational agility", Industrial Management & Data Systems, Vol. 103 No. 6, pp. 388-97.

Dattakumar, R. and Jagadeesh R. (2003), "A review of literature on benchmarking", Benchmarking: An International Journal, Vol. 10 No. 3, pp. 176-209.

Dean, J. and Bowen, D. (1994). Management Theory and Total Quality: Improving Research and Practice through Theory Development. The Academy of Management Review, 19(3), p.392.

Deming, W. Edwards 1986 Out of the Crisis, Cambridge. MA: MIT Center for Advanced Engineering Study

Dewett, T. and Jones, G.R. (2001), "The role of information technology in the organization: a review, model, and assessment", Journal of Management, Vol. 27, pp. 313-46.

Easterby-Smith, M., Thorpe, R., and Jackson, P. (2015) Management and Business Research ,SAGE, Thousand Oaks, California, 5th edition.

Flynn, B.B., Schroeder, R.G. and Sakakibara, S. (1995), "The impact of quality management practices on performance and competitive advantage", Decision Sciences, Vol. 26, pp. 659-91.

Fong, S.W., Cheng E.W.L. and Ho, D.C.K. (1998), "Benchmarking a general reading for management practitioners", Management Decision, Vol. 36 No. 6, pp. 407-418.

Forza, C. and Flippini, R. (1998), "TQM impact on quality conformance and customer satisfaction: a causal model", International Journal of Production Economics, Vol. 55, pp. 1-20.

Fynes, B., Voss, C. and de Búrca, S. (2005), "The impact of supply chain relationship quality on quality performance", International Journal of Production Economics, Vol. 96 No. 3, pp. 339-54.

Hackman, J. and Wageman, R. (1995). Total Quality Management: Empirical, Conceptual, and Practical Issues. Administrative Science Quarterly, 40(2), p.309.

Hartley, J.L. and Choi, T.Y. (1996), "Supplier development: customers as a catalyst of process change", Business Horizons, Vol. 39 No. 4, pp. 37-44

Heher, Y. and Chen, Y. (2017). Process mapping: A cornerstone of quality improvement. Cancer Cytopathology, 125(12), pp.887-890.

Humphreys, P.K., Li, W.L. and Chan, L.Y. (2004), "The impact of supplier development on buyer – supplier performance", Omega: The International Journal of Management Science, Vol. 32, pp. 131-43

Ishikawa, Kaoru 1985 What is Total Quality Control? The Japanese Way, Englewood Cliffs, NJ: Prentice-Hall

Juran, Joseph M. 1974 The Quality Control Handbook, 3rd ed. New York: McGraw-Hill

Kaynak, H. (2002), "The relationship between just-in-time purchasing techniques and firm performance", IEEE Transactions on Engineering Management, Vol. 49 No. 3, pp. 205-17.

Krajewski, L.J. and Ritzman, L.P. (2004), Operations Management: Processes and Value Chains, 7th ed., Prentice-Hall, Upper Saddle River, NJ.

Krause, D.R. (1997), "Supplier development: current practices and outcomes", International Journal of Purchasing & Materials Management, Vol. 33 No. 2, pp. 12-19.

Krause, D.R. (1999), "The antecedents of buying firms' efforts to improve suppliers", Journal of Operations Management, Vol. 17, pp. 205-24.

Krause, D.R., Handfield, R.B. and Tyler, B.B. (2007), "The relationship between supplier development, commitment, social capital accumulation and performance improvement", Journal of Operations Management, Vol. 25 No. 2, pp. 528-544.

Krause, D.R., Scannell, T.V. and Calantone, R.J. (2000), "A structural analysis of the effectiveness of buying firms' strategies to improve supplier performance", Decision Sciences, Vol. 31, pp. 33-55.

Krause, D.R., Handfield, R.B. and Scannell, T.V. (1998), "An empirical investigation of supplier development: reactive and strategic processes", Journal of Operations Management, Vol. 17, pp. 39-58.

Lawler, Edward E., Ill, Susan Albers Mohrman, and Gerald E. Ledford, Jr. 1992 Employee Involvement and Total Quality Management: Practices and Results in Fortune 1000 Companies, San Francisco: Jossey-Bass

Malcolm Baldridge National Quality Award Consortium 1990 Malcolm Baldrige National Quality Award Application Guidelines, Milwaukee: Malcolm Baldrige National Quality Award Consortium

Matook, S., Lasch, R. and Tamaschke, R. (2009). Supplier development with benchmarking as part of a comprehensive supplier risk management framework. International Journal of Operations & Production Management, 29(3), pp.241-267.

Maxwell, J.A. (2005) Qualitative Research Design: An Interactive Approach. 2nd Edition, Sage, Thousand Oaks

McNair, C.J. and Leibfried, K.H.J. (1992), Benchmarking: A Tool for Continuous Improvement, HarperCollins Publishers, New York, NY.

Narasimhan, R. and Kim, S.W. (2001), "Information system utilization strategy for supply chain integration", Journal of Business Logistics, Vol. 22 No. 2, pp. 51-75.

Ritchie B. and Brindley C. (2007a), "Supply chain risk management and performance - A guiding framework for future development", International Journal of Operations & Production Management, Vol. 27 No. 3, pp. 303-322

Sashkin, Marshall, and Kenneth J. Kiser 1993 Putting Total Quality Management to Work, San Francisco: Berrett-Koehler

Shin, H., Collier, D.A. and Wilson, D.D. (2000), "Supply management orientation and supplier/buyer performance", Journal of Operations Management, Vol. 18, pp. 317-33.

Shenton, A.K. (2004). Strategies for Ensuring Trustworthiness in Qualitative Research Projects. Education for Information, 22, 63-75

Spencer, L., Ritchie, J., Lewis, J., and Dillon, L. (2003). Quality in Qualitative Evaluation: A Framework for Assessing Research Evidence. London: Government Chief Social Researcher's Office : www.policyhub.gov.uk/docs/qqe_rep.pdf

Sriram, V. and Stump, R. (2004), "Information technology investments in purchasing: an empirical investigation of communications, relationship and performance outcomes", Omega: The International Journal of Management Science, Vol. 32, pp. 41-55.

Stapenhurst, T. (2009). The benchmarking book. Amsterdam: Elsevier /Butterworth - Heinemann.

Trent, R.J. and Monczka, R.M. (1999), “Achieving world-class supplier quality”, Total Quality Management, Vol. 10, pp. 927-38.

Ulrika Hellsten, Bengt Klefsjö, (2000) "TQM as a management system consisting of values, techniques and tools", The TQM Magazine, Vol. 12 Issue: 4, pp.238-244, https://doi.org/10.1108/09544780010325822

Internal document

Case company document 1: Supplier Quality Assurance Manual of case company (2019)

Appendix 1: Processes in SQAM

- ## Sourcing

Before awarding of business or contractual agreement is done with the suppliers, the suppliers have to go through the selection process of case company, required to become the case company supplier. This is done to ensure that the suppliers actively participate in evaluation audits performed by case company, demonstrate capability to achieve future quality results and respond to action plans to reach the requested levels of quality. The quality requirements and targets are highlighted in the quality section of the Request for Quotation (RFQ). Suppliers are expected to be able to fulfill all quality requirements. Case company may audit their statements in RFQ related to the fulfillment of these requirements

Also case company primarily uses a module for selection and evaluation of suppliers called Supplier Assessment Protocol (SAP). This assessment is designed to provide a broad, overview of the supplier's organization and an on-site face to face evaluation of a supplier's capabilities and preparedness.

Special Process (SP) audits are used for focusing on production processes that use technology considered critical to the function of the products. For suppliers in those specific technology areas, these audits are a requirement for awarding business and may also be used as a part of process improvement activity or to investigate severe quality problems.

Case company has developed a module Technical Review Requirement (TRR) to assist suppliers in the review of the technical requirements of the part or product that would be supplied. The objective is to ensure that suppliers have identified and thoroughly reviewed, and capable of fulfilling the technical requirements of all of the technical documents, standards, and specifications defining the product.

- ## Advanced Product Quality Planning (APQP)

Suppliers are expected to develop a detailed APQP for the development and prove-out of the processes used to produce case company products. It identifies the tasks to be completed, the expected timing, assigned responsibility for completion and critical path.

- # Production Part Approval Process (PPAP)

PPAP demonstrates that the manufacturing process used to produce parts for case company is fully developed, thoroughly tested, and capable of serial production of parts conforming to the technical specifications.

- # Product Process Change Notification (PPCN)

All proposed changes to the product, production process, material or suppliers after PPAP must be submitted to case company for approval using the PPCN process. Requests for change must be submitted at least 12 weeks prior to the introduction of the change. After successful PPAP no change could be made to the suppliers' product or process without the written approval from case company.

- # Special Characteristics

Special Characteristics are identified using the symbols SC for significant characteristics and CC for critical characteristics. SC specify the features of the product that are essential for its safe and proper use affecting the compliance with regulations, form, fit, function and performance or subsequent manufacturing-process steps. CC is any feature throughout the life cycle of a Critical Safety Item, such as dimension, tolerance, finish, material or assembly, manufacturing or inspection process, operation, field maintenance, or depot overhaul requirement that if nonconforming, missing or degraded may cause the failure or malfunction of a Critical Safety Item.

- # Key Components

Key components are components that are supposed to have Special Characteristics.
For purchased component that are designated as Key Components, the APQP is monitored by the case company, for Non Key Components, APQP is monitored by the supplier.

- # Failure Mode Effective Analysis (FMEA)

It is an analytical tool/methodology used to ensure all potential problems have been considered and addressed throughout the product and process development process.
A part of the evaluation and analysis in FMEA is risk assessment. Each FMEA should ensure attention given to every component within product/assembly, with critical & safety related components to be given a higher priority. One of the most important factors for the successful implementation of an FMEA program is timeliness. It is meant to be a "before-the-event" action, not an "after-the-fact" exercise.

- **Design Failure Mode Effective Analysis (DFMEA)**

DFMEA is the method used to identify the risk at the product level like having the right plan, tolerance. The DFMEA is a living document that is initiated before or at design concept and is continually updated as changes occur or additional information is obtained throughout the phases of product development. An updated list of product special characteristics is the major output of the DFMEA and these characteristics are highlighted in the control plan.

- **Process Failure Mode Effective Analysis (PFMEA)**

PFMEA is the systematic tool to find the risk in production with the processes and make it more stable with low risks. The purpose of PFMEA is to assure that potential failure modes of the process have been considered and addressed. The suppliers to case company shall have a process FMEA developed. One of the important factors for the successful implementation of a PFMEA program is timeliness. It is meant to be a “before-the-event” action, not an “after-the-fact” exercise.

- **Control Plan**

Supplier shall provide a control plan that defines the implementation of value-added control methods for controlling the part and the processes used to manufacture the parts. The control plan is an integral part of an overall quality process and is to be utilized as a living document.

Appendix 2: Interview Questions

- **Sourcing**

Q-1 In sourcing for potential supplier evaluation (in addition to SAP audit, SP audit and SQE visit) do you consider Tier N suppliers and include it.

Note: Please refer to Appendix 1 for RFQ and SAP audit.

Do you think the process is very good?

1-Strongly Disagree	2- Disagree	3- Neither Agree nor Disagree	4- Agree	5- Strongly Agree

Do you use the process efficiently?

1-Strongly Disagree	2- Disagree	3- Neither Agree nor Disagree	4- Agree	5- Strongly Agree

Q-2 On which level tier N component is mapped and considered in sourcing?
- For example for EHPS (Electro Hydraulic Pump Systems) unit electrical motor could be tier-2 supplier
- In steering gear safety components like piston housing, sector shaft etc.

Could you provide an example?

Q-3 In sourcing phase do you communicate requirements in components level and in tier N levels with tier 1?

-Which tools do you use?

Note: Please refer to appendix 1 for key components, special characteristics, and critical characteristics.

Q-4 Do you perform SP audits on special process and in which level (tier 1 + tier N)

Q-5 Do you make it mandatory requirement for tier 1 to perform SP audits on tier N processes? How do you monitor?

Q-6 Do you investigate how is supplier selection process in Tier 1 and how?

Q-7 Do you participate in any supplier selection and evaluation audit?
To what extent (Tier N).

Q-8 During the sourcing (RFQ) which tools do you use to communicate requirements (In case company TRR is used) with your suppliers.

Note: Please refer to Appendix 1 for RFQ and TRR.

- **Advanced Product Quality Planning (APQP)**

Q-9 You have tier 1 suppliers and you would be having a time plan with them. How do you make sure that your tier 1 supplier have the breakdown time plan with their tier 2, tier 3 suppliers and how do you monitor it to make sure it is aligned?
-What methodologies are being used for aligning the time plans and in what cases?

Q-10 How do you monitor that how tier 1 supplier deploy special characteristics (SC) at the component level?
- Which tool do you use to deploy SC?

Q-11 What tools do you use to deploy requirements (For e.g. SC) from product level to component and then subsequently to process level.
(For e.g. QFD or maybe just DFMEA, PFMEA, control plan)
- Do you consider incoming components (key components) in risk analysis in your development process (APQP and PPAP)?

Note - Please refer to Appendix 1 for QFD, DFMEA, PFMEA, Control Plan and PPAP

Q-12 Do you monitor and investigate key components (raw materials included) at the lowest level in Tier N and how?

Q-13 How do you register and map the supply chain i.e.
In sourcing (Q2) and when do you monitor and control Special Characteristics at the component level in the project phase?

Q-14 How do you make sure and monitor that the requirements which is being communicated to tier 1 supplier, is being communicated by them to the tier 2 and tier N suppliers?

Q-15 How do you put systematically lessons learnt of tier N Management in the white book after the conclusion of the project?

Note: Please refer to appendix 1 for white book.

Q-16 For development suppliers, are they fully responsible for design in product and component levels or they can delegate a part of that to Tier N supplier? In which condition?
- If Tier N takes a part of the design responsibility in front of Tier 1, do you investigate, monitor how(DFMEA, Design Risk Analysis of Tier N)

Note: Please refer to appendix 2 for development and non-development suppliers

Q-17 Do you expect and monitor if Tier 1 supplier having a Poka Yoke system, to reject non conformities in special characteristics of incoming components in Tier 1 manufacturing process?

- **Production Part Approval Process (PPAP)**

Q-18 Do you do any audit of your Tier N suppliers (Tier 2 and more).
If yes on what basis and when? (Random based, special processes, key components)

Q-19 How do you document tier N requirements and approvals in PPAP Document and investigation?
Q-20 When you approve PPAP (Approval of part to be launched), how do you make sure that tier 1 supplier has approved all components of PPAP.

Q-21 Do you investigate (documentation review, process audit etc.) components PPAP? What is the basis for the same (e.g. Random, key components or what)?

Q-22 In which level should your requirements be cascaded to your Tier N supplier (e.g. Hardness in Tier 4 suppliers for pump shaft)?

- **Product Process Change Notification (PPCN)**

Q-23 As a PPCN process how you monitor that the tier 1 supplier has its own approval plan for the change including verification tests?

Q-24 What mechanism do you use to make sure that tier 1 supplier has control on all changes in its supply chain (Tier N change including supplier chain) and PPCN submission is not missed?

Q-25 What is your requirement for PPCN Submission? When should it be submitted?

Q-26 What is your requirement for PPCN approval if the change is in Tier N process or component?

Q-27 Which mechanism do you use to make sure that tier 1 supplier can guarantee that PPCN Process is communicated to tier N suppliers and guarantee that they will submit PPCN Changes?

Q-28 How do you work in zero mileage (IR) claims if the root cause of the problem is in Tier N process?

Q-29 How do you work in warranty or field claims if the root cause of the problem is in Tier N process?

- **Tooling Management in Tier N including mainly customer owned**

Q-30 How do you monitor the lifetime of the customer owned tools in Tier 1 and Tier N. If any?

- **Certifications**

Q 31- What is the minimum level of quality system compliance required for all your potential and current tier 1 suppliers (IATF 16949, ISO 9001, and ISO 14001)?
What is Quality Management System requirement (ISO) to tier N suppliers?
Is the same requirement for all tier N suppliers or it can vary from one supplier to another? -How do you control it?

General questions (Optional)

Q-I – What are the key challenges you see for Supplier Quality and Development (SQ&D)?
Q-II – What do you see the three quality aspects that are most important for Supplier Quality and Development (SQ&D)?