Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Economics and Management
Department of Industrial Economics and Technology Management

Aleksander Wermers Nilsen

The role of suppliers in contract product development

A categorization of supplier roles including success factors and information sharing guidelines for supplier involvement in contract product development.

Master's thesis in Master of Technology Management
Supervisor: Erlend Alfnes
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Summary

Purpose

Supplier involvement in new product development requires information sharing between the buyer and supplier. Prior research however usually discusses large companies, with continuous production. Far less research is done for contract development. The objective of this thesis is therefore to investigate the role of the supplier in contract development. As information sharing is an important factor with regard to the success of the supplier performance, this thesis investigates what tools and best-practice exists in the literature. Furthermore, a possible categorization of the different roles of a supplier in a development project is identified. The thesis also discusses if any of the best-practice methods are considered relevant in buyer-supplier cooperation in contract development. Lastly the thesis suggests formal guidelines for buyer-supplier information sharing for contract development.

Structure

The structure of the thesis started by addressing the theory and relevant literature in the fields of contract development, supplier involvement, information sharing and success factors. The theory section is rounded out by discussing a few of the key tools and best-practices in the field of supplier involvement. The empirics section of the thesis starts with a presentation of the survey and the workshop that were conducted. The results of the survey are presented. Following the empirics is the discussion and conclusion. The thesis is concluded with the bibliography.

Theoretical framework

The theory section discussed and defined the key concepts used. It also summarized research done in the field. This thesis discussed contract development and the aspects in which contract development differs from off-line development process (Alderman, Thwaites og Maffin 2001). The concepts of capacity projects and know-how projects are defined as the two types of projects that can be undertaken by a supplier (Wagner og Hoegl 2006). Furthermore, a model for supplier involvement is shown. Supplier involvement consists of two dimensions, the degree of development risk in the project and the degree of responsibility held by the supplier (Wynstra, Wynstra og Pierick 2000). Theory on information sharing is presented, showing that previous research found a link between information sharing and the relationship quality. A link between relationship quality and supplier performance on a development team is also found (Sjoerdsma og van Weele 2015). Success factors for supplier involvement is found to have both long-term and short-term benefits (Echtelt, et al. 2006). Success factors are also found to correlate to decreasing development cost, improving product quality and shorter time to market (Johnsen 2009). Further, success factors can be divided into two groups; relationship structuring factors and asset allocation factors. The relationship structuring factors facilitate the assets allocation factors, while the asset allocation factors correlate with the successful

implementation of suppliers in the new product development processes (Ragatz, Handfield og Scannell 1997).

The tools and best-practices section discussed the Advanced Product Quality Planning (APQP) method. APQP is a process for facilitating communication between all persons and activities in a development team (Stamatis 2018). The APQP process has adopted Failure Mode and Effect Analysis (FMEA), control plans, and checklists among others in order to facilitate communication.

Findings

The survey questioned both companies that currently involve suppliers and companies that did not involve suppliers in development projects. All survey respondents are involved in contract development. The research found that communication is an important factor when choosing to involve a supplier in development. Firms that have not involved suppliers, indicated that communication would be critical if they did decide to involve suppliers in the future. Firms not currently involving suppliers indicated that limitations on their own internal capacity would also be critical if they were to involve suppliers. Firms currently involving suppliers consider the experience of the supplier as well as cost, important when choosing which supplier to use. Based on these survey results and the findings in previous research, this thesis proposes a model for categorizing the role of the supplier in the development team. Firstly, a split of the type of project between capacity and know-how. Secondly, a split between the degree of development risk (low and high) which correspond to arm's-length involvement and strategic involvement. The four roles of the suppliers are:

- "Purchased design capacity" (a capacity project with low degree of development risk)
- "Module design specialist" (know-how project and low degree of development risk)
- "Design team partner" (capacity project with high degree of development risk)
- "Systems architect" (know-how project and high degree of development risk)

Success factors for each of the roles are proposed. The factors are chosen so arm's-length development ("purchased design capacity" and "Module design specialist") have less long-term focus. The success factors also are identified so that the relationship structuring factors are more prevalent in the strategic involvement roles ("Design team member" and "Systems architect"). For all four roles the success factors; "specify functions and performance"," coordinating development activities with suppliers" and "formulate communication and information sharing guidelines" are included. The last one is of special interest as establishing and formulating information sharing guideline directly is connected to the relationship quality between

buyer and supplier. Thereby allowing the successful involvement of a supplier on a development team. The thesis proposes an information sharing guidelines for each of the supplier roles found. The input for these guidelines are based on the survey data. The survey data found that checklist methods and FMEA are considered relevant tools for conveying technical information.

A workshop, consisting of the author and 4 experts in the field of supplier involvement and product development discussed the findings of the survey. The proposed roles of suppliers in development teams and the success factors were also discussed. The workshop group provided feedback on all work done and proposed some additional input. The workshop group considered physical information sharing to be an important tool in development projects. Physical information consists of prototypes, design sketches and mock-ups. The workshop group also suggested a partnership assessment prior to involving any supplier. The goal of a partnership assessment is for both the supplier and buyer to asses if they consider each other compatible as far as project execution, capacity and technological aptitude. The final information sharing guidelines provide a suggested plan for information sharing across the six stages of development, for each of the roles a supplier can have in a development project. The role of the suppliers requires different guidelines for information sharing. The differences reflect the uniqueness of each role and ultimately increase the quality of the relationship and by extension the performance of the supplier in contract development team.

Research Limitations

The survey data only provides results from companies that do contract development, the framework of this thesis is not known to be valid for off-line development when supplier involvement in development is done. Furthermore, the respondents to the survey are all companies based in Norway, therefore geographical preferences may occur if applied to other countries.

Contribution

This thesis provides a new approach to considering the role of a supplier in a development team. The degree of development risk and type of project will identify the role of the supplier. The project also applies supplier involvement in product development theory to contract development. The thesis proposes information sharing guidelines based on the role of the supplier in the development. This provides an approach for information sharing that will increase performance quality of supplier involvement in contract development.

Keywords: Role of the supplier, Supplier involvement, Contract development, Product development, Information sharing, Success factors

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1 Introduction

Working in the field of mechanical product development will inevitably lead to a phase in the development cycle where the idea needs to be realized. Very often the mechanical product needs components like, seals, bolts, parts or modules that are not directly designed by the developments team. These parts and module may be purchased directly from a supplier or developed externally. Suppliers may be included in a development team. One quickly realizes, just by being involved in such a project, that projects are not created equally to one another, no supplier is an exact copy of its competitor and not all manufacturer have the same tools in their workshop. In fact, not all suppliers have knowledge of the same information sharing systems or methods. The role of the supplier in such development project are often very different. One will often hear the names of complex systems such as LEAN, AQP, APQP, DfX, DfM and many others. Many of these systems involve complex organizational structures that are embedded at the very root of the large company's strategy and involve sub routines of a network of methods. However different or similar the methodologies are, they all have an information sharing routine or model. Looking specifically at contract development[1] where a supplier is contracted to develop parts or subsystems, the need for concise information sharing is evident as the supplier and buyer to varying extent both are part of the development team while also being an external partner.

The research field of supplier integration into new product development provide insight into the benefits of integration but they do not discuss the Scandinavian market, and they look largely at large cooperation's with continuous production. This report will focus on technology companies based in Norway that do new product development. The companies in focus have products that are produced in batches, meaning that they do not require continuous on-going production. The products considered in this thesis are engineered to order or contract development.

It is stated in many reports, such as Petersen, Handfield and Ragatz (2005) and Johnsen (2009), that information sharing between supplier and buying firm is one of the key components to involving the suppliers in new product development. Furthermore, reports such as Sjoerdsma and van Weele (2015) conclude that the positive effects of supplier integration are mitigated without proper communication and knowledge sharing. It stands to reason that while involving the suppliers into the development phase is advantageous, information sharing is paramount to the success of the development project. The information however needs to be utilized,

[1] The concept of contract development will be discussed later on in the theory section but put simply: it is development projects where a supplier is paid to develop a subsystem or component for the buying firm.

the how/when/amount should be discussed so that each team member is aware of their role.

The objective of this thesis is therefore to investigate the role of the supplier in contract development. As information sharing is an important factor with regard to the success of the supplier performance, this thesis investigates what tools and best-practice exists in the literature. Furthermore, a possible categorization of the different roles of a supplier in a development project are identified. The thesis will also find out what is perceived useful and important by the people involved in making the decision of involving suppliers. Lastly the thesis suggests formalized guidelines for buyer-supplier information sharing for contract development.

The following question are to be answered in this thesis:

1. What tools and best-practice exist in the literature regarding information sharing in supplier involvement in product development?
2. Is it possible to categorize different roles of the supplier in a development project? And what success factors must be in place?
3. Are any of the best-practice methods considered relevant in buyer-supplier cooperation in contract development?
4. Can buyer-supplier information sharing be formalized in contract development based on the roles of the supplier?

2 Theory

In order to answer the question regarding best practice methods in tools, this thesis will need first to talk about contract development and supplier involvement. This is necessary to define the parameters of this thesis. After that, information sharing, and success factors will be addressed. Once the terminology and parameters are discussed a presentation of the existing tools and best-practice is included. These best-practices and tools are found in literature and talks with experts in the field of new product development and supplier integration. The methods are not methods specific to contract product development, but rather a larger view was taken to find on how information sharing is done in regard to product development is done on a large scale.

2.1 Contract development

In product development, to a large degree most of the literature discusses new product development in context of the large firms developing new products. Fewer reports discuss the alternatives, however reports such as Alderman, Thwaites and Maffin (2001) address the challenges associated with low volume, or one batch productions. This thesis will define conventional product development as Alderman, Thwaites and Maffin (2001), where they call it: off-line development. Off-line development is development following the flow; product planning, initiation, concept development, detail design, prototyping and finally manufacture and market launch. In short development is done first then sale of the final product. Conversely, a contacted development process flows generally speaking as; marketing, development, negotiation, contract design, manufacturing and finally installation. This implies that a sale takes place with where the buyer provides a product specification. The development of the product is done after the buyer has committed to the purchase. The two processes are shown in Figure 1.

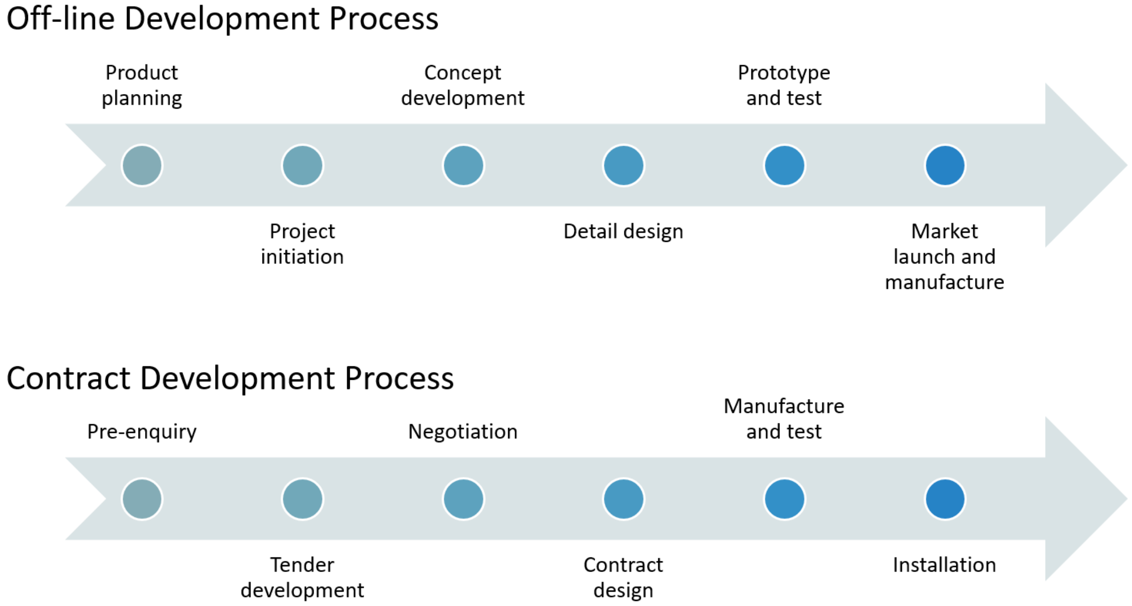

Figure 1: Off-line and contract development process as described by Alderman, Thwaites and Maffin (2001)

The processes shown in Figure 1 are of course simplifications. Several variations and hybrids of contract development process exists and specifically Alderman, Thwaites and Maffin (2001) defines three hybrid groups to capture all the possible variations, as shown in Table 1

Table 1: Hybrids of Contract development.

	Volume	Complexity	Project description
A	LOW	HIGH	Offline development in start. Contract development to finish
B	HIGH	LOW	Contract development in start, offline development after first delivery (to become preferred supplier)
C	LOW	HIGH / LOW	Contract development of first, offline development of product range

Engineered to order projects are examples of pure contract development, they require the buyer to place an order, specifying the product they require. The supplier them designs and manufactures the product. Customized made to order products require that the supplier modifies one of their existing products to meet the buyer's specifications. Both engineered to order and customized made to order products may become hybrids, such as the ones described in group B or C, Table 1. This would happen if an offline development takes place after delivery. It becomes apparent due to the hybrid definition that the division between the offline process and contract process can be unclear. An example is a long-term development cycle where deliveries are expected over the duration of the project, could be considered off-line. For the purpose of this project this example would be considered a contract development if the sales proceeded the initial order. The project is considered finished once the delivery is complete. This thesis considers contract development, the survey was therefore sent out to companies that involved suppliers in contract development.

2.2 Supplier involvement

Developing a new product was mainly considered an in-house expertise. A firm would hire a product development department that would have sufficient knowledge about production methods and the knowledge of how to bring to market the best possible product. In later years however, a focus on keeping in-house the core competencies and using external resources to supplement the in-house activities has emerged. This has been proven to be a viable strategy for companies looking to be financially effective. Involving suppliers and the accompanying academic research into this field has been conducted since the 1980's, see Johnsen (2009). In the 1980's the leading research, led by the automotive industry, focused on the performance gap between US and Japanese manufacturers. This was of interest at the time as US car companies did not, generally speaking, use suppliers in parts of the development while the Japanese auto manufactures increasingly started to include suppliers. The findings showed that the Japanese firms involving suppliers in product development, had a reduced time to market (Clark 1989), resulting in a more economic production, technologically superior products and a sustained competitive advantage. The field evolved, reaching conclusions that by integrating suppliers in new product development, the company would reduce development time and increase success rates. Research by Bonaccorsi and Lipparini (1994) noted that a framework for joint learning must be in place in order for the supplier to be an integral partner in new product development. In the late 1980's and early 1990's the US car manufactures, and their suppliers started to catch up, creating the system known today as APQP (Advanced Product Quality Planning). APQP is a methodology that sets requirements and common goals for auto manufactures and their suppliers, done in an attempt to increase quality of new product development. The system was originally created for large auto manufactures, but many of the tools have been adopted by other sectors since (Carbone 2005).

In the late 90's and early 2000's research into new product development looked at supplier involvement in the early stages of development. Ragatz, Handfield and Petersen (2002) finds that when a supplier is involved early in the development process it is critical that the supplier not only have the technical abilities needed but also have the correct culture in their firm. The article also finds that when the supplier has a high level of responsibility, (termed as "black box" integration) it is beneficial with regards to the outcome, that the supplier is involved in determination of the technical metrics and targets of the project. "Black box" integration means that the supplier has a large responsibility and the decisions concerning the design is primarily the supplier's responsibility. The design is ultimately a product that fulfills the buyer's specifications. The other side of this is "white box" or "grey box" projects were suppliers have lower development responsibilities. "White box" development is used when the buyer consults with a supplier in a project. “Grey box” is when a supplier develops component in cooperation with the buyer. In the 2000’s Wynstra, Wynstra and Pierick (2000) also recognizes that all supplier involvement is not equal, they identify 4 scenarios with different communication setups or categories. Consider a plot with two axes, the y axis is the degree of supplier responsibility, from low to high, and on the x axis the development risk, from low to high. The area is of this split into 4 areas, so one splits the degree of responsibility in to, low and high and the same for development risk, see Figure 2. This report will consider the two categories that have a high degree of responsibility. The lower two segments, critical development and routine development are characterized by little to no supplier involvement, thus the focus is on the buyers needs and less on the buyer-supplier relationship. Development risk refers to the complexity of the project, and indirectly the time and effort need to complete the project. The higher the development risk the earlier a supplier needs to be involved. A high degree of risk requires a strategic decision to involve the suppliers. Wynstra, Wynstra and Pierick (2000) claim that projects in the arms-length group require less information sharing than the strategic development group. In an arm’s- length development project, the supplier requires little direct communication, usually the only communication is centered around status of the project and time to completion. This communication is usually initiated by the supplier. The strategic development group require close collaboration between suppliers and the buying firm, resulting in technical information sharing, in face-2-face meetings and working groups by many individuals across several fields in the two different companies.

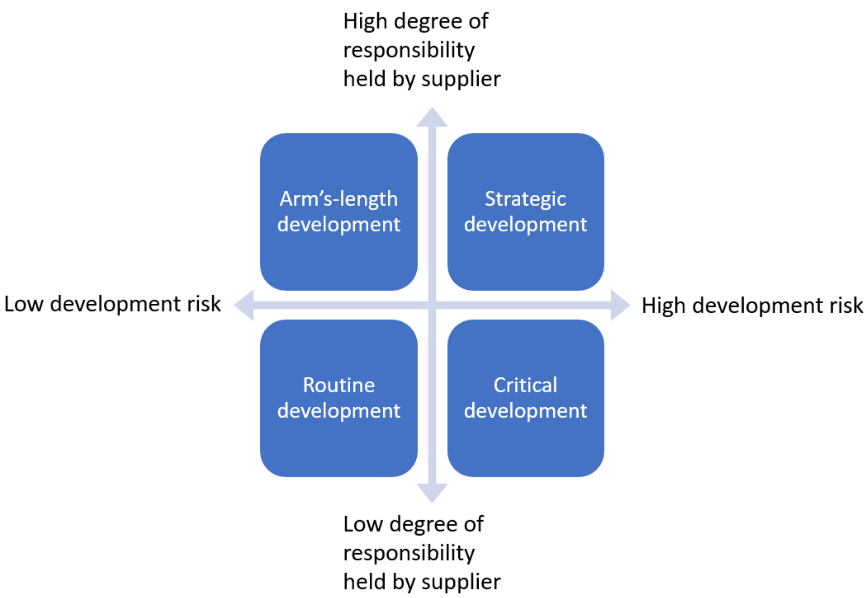

Figure 2: Level of supplier involvement and development risk define the type of development project according to Wynstra, Wynstra and Pierick (2000)

Not all research indicates positive effects of involving suppliers into new product development. Corswant and Tunälv (2002), finds longer development time and development cost related to the involvement of suppliers. Furthermore, Wagner and Hoegl (2006) argue that it is difficult to gain a positive effect from involving suppliers, postulating that two elements must be in place for sufficient supplier involvement, one of which is the management of supplier involvement on the project level. Buyers need to access their supplier's competencies and they need to integrate this information into their own products in order to gain a potential sustainable competitive advantage. Furthermore, Wagner and Hoegl (2006) argue that the project managers ability to manage the supplier's involvement is of great importance. This management of the supplier involvement is done by reducing the coordination gap. The coordination gap is a mismatch between the information required and actual information coordinated about tasks that need to be performed.

While discussing the level of supplier involvement one also needs to consider the type of projects into which a supplier is involved. Wagner and Hoegl (2006) defines to types of projects; know-how projects and capacity projects. The first, know-how projects, are when then supplier has the in-depth knowledge and technical understanding needed to carry out the project. Capacity projects are when the buying firm needs more resources to complete the project. The capacity project buyer has a goal of overcoming the shortages of their own organization, often the supplier takes on less important responsibilities in order for the buyer to focus on the critical elements of the project. The know-how project buyer realizes that they do not poses the knowledge required to perform a task and therefore the supplier is given responsibility that component or part, critical or not.

2.3 Information sharing

Sjoerdsma and van Weele (2015) discusses the buyer-supplier relationships and identifies fourteen factors that affect the result of a new development process. Among these factors are; access to resource and knowledge, information sharing, supplier contribution of new ideas, and quality of relationship. Further Sjoerdsma and van Weele (2015) finds twelve factors that determine the quality of the relationship. Of these twelve factors they discuss five in-depth. The five are considered to be the most powerful with regard to linking relationship quality to performance of supplier integration in product development. The five factors are; trust, communication, information and knowledge sharing, cooperation and coordination, and commitment. Sjoerdsma and van Weele (2015) argue that trust increases open communication and promotes willingness to share information. Communication is key to develop the relationship between buyer and supplier. While information and knowledge sharing increase new idea generation in a project, which in turn increases trust. Cooperation and coordination help align operational parameters and goal setting in a project. Lastly with commitment comes the increase of information and knowledge sharing. More simply put: the five factors are intertwined. The relationship quality and knowledge transfer seem to be positively associated with new product development performance. In their research they find a positive correlation between the relationship quality and knowledge and information sharing.

Jonsson and Myrelid (2016) found that most of the literature does not address the correlation between information shared and actual information usage. In their article information sharing is defined as having four variables; content, frequency, direction, and modality. Thus, information sharing is a combination of factors, consisting of what the content of the information is, how often information is being shared, if it is unidirectional or bidirectional and what medium is being used. The same article also makes a distinction between willingness, ability and intended usage. Willingness is described as the receiver wishing to use the information but cannot do so, while the ability to use information does not directly imply that the receiver wishes to use the information. The combination of high willingness and high ability results in intended information usage. The report concludes that inter-organizational factors affect willingness while intra-organizational factors affect ability. The article also finds that a formal planning process for information utilization is significant. In fact, they find that the direct interaction between personnel that were involved in the planning process affected the information usage greatly. Willingness is for the purpose of this thesis assumed, as all surveyed persons are assumed to be willing and able to use the information they received. This is done as the survey persons are involved as the buying part in a contract development project, therefore this report assumes that it is in their best interest to be willing to use any information concerning their project

2.4 Success factors

In order to successfully involve supplier in the development process several reports have assessed what factors need to be in place for such an endeavor to be deemed successful. Johnsen (2009) suggests, there are three main factors that influence the success of supplier involvement; supplier selection, supplier relationship development and adaptation and Internal customer capabilities. Selection of supplier as discussed in the article, concerns which suppliers to use in the development process and which to involve early. The second factor is of interest for the purpose of this thesis, supplier relationship development and adaptation, which Johnsen (2009) finds to be frequently overlooked by managers. Supplier relationship development and adaptation is achieved by looking at mutual trust, commitment and mutual understanding of performance targets. Another way to build supplier relationship is by including suppliers' employees on the development team as discussed by Ragatz, Handfield and Petersen (2002). The third factor found in Johnsen (2009), is about the buyer's internal capabilities, such as the ability to manage internal cross-discipline teams, which they argue is linked to the ability to manage intra-firm supplier involved teams. See Figure 3 for a visualization of the factors.

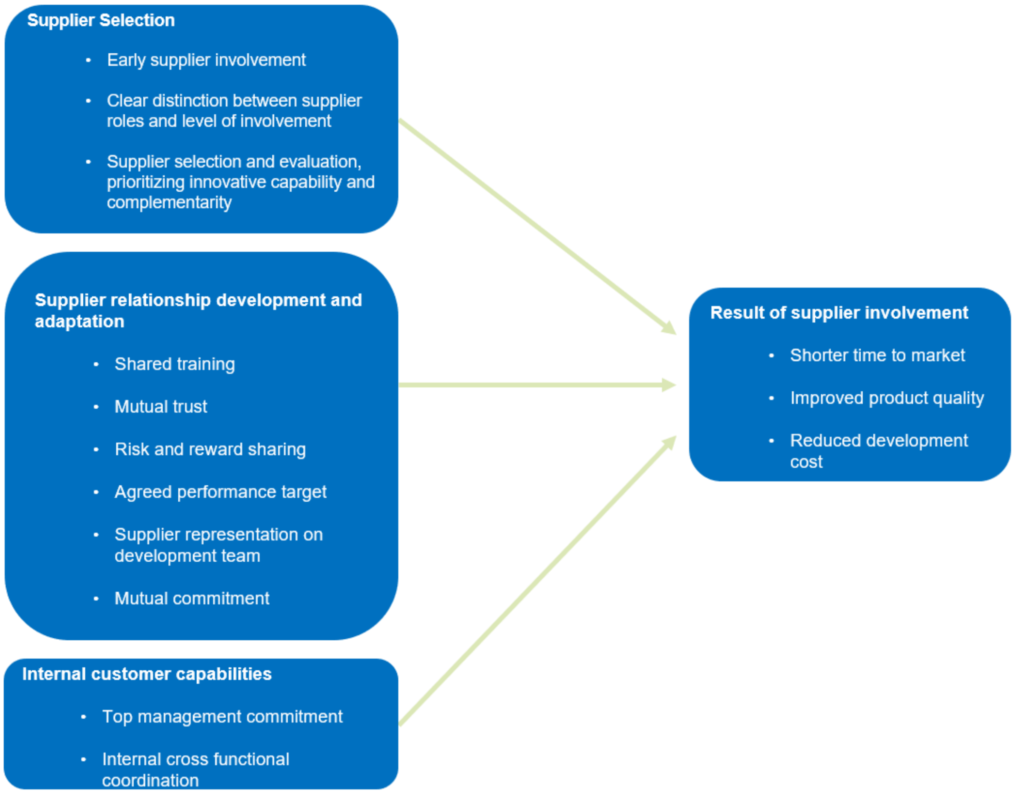

Figure 3: Factors affecting supplier involvement success according to Johnsen (2009)

Ragatz, Handfield and Scannell (1997) also find that these same three factors are among the factors that promote successful supplier involvement. However, Ragatz, Handfield and Scannell (1997) goes into greater depth, finding that supplier membership on the buyer's development team is the greatest success factor. They found that open and direct intra-company communication most often resulted in a rapid fix of most problems. Co-location was found to be more relevant with highly technologically complex projects, or in long term development projects. Furthermore, factors such as formal trust, customer requirements sharing, technology information sharing, and shared physical assets provide successful supplier integration. The article by Ragatz, Handfield and Scannell (1997), finds two groups of factors that lead to successful supplier integration, relationship structuring factors and asset allocation factors. They find that the asset allocation factors directly influence the new product development, while the relationship factors are what they describe as facilitating factors, by that they mean the relationship structuring factors facilitate the sharing of assets. The Asset allocation factors are split into three sub groups, intellectual, human and physical assets, see Figure 4.

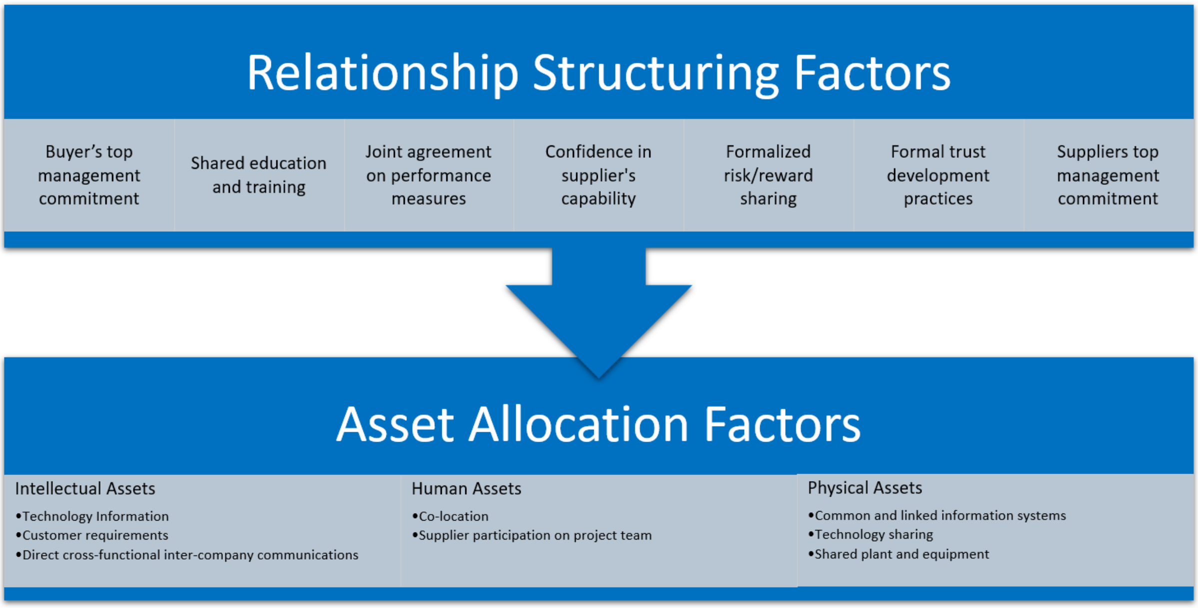

Figure 4: Model for successful integration of supplier into new product development (Ragatz, Handfield and Scannell 1997).

In another report Echtelt, et al. (2006) conclude that the success of supplier involvement as a firm's strategy is contingent on the ability to gain short-term and long-term benefits. To this end they suggest a model consisting of two arenas; the strategic management arena and the operational project management arena. The strategic management arena consists of among others, activities such as; formulating communication guidelines, pre-selecting suppliers, exploiting suppliers' skills and capabilities, and motivating suppliers to develop specific knowledge. The operational project management arena consists of activities such as; determining operational targets, coordinating development activities with suppliers, and evaluating supplier's performance. While the short-term result such as cost, development time and technical performance are mainly captured by the operational project management arena, long-term benefits are captured in the strategic management arena. Long term results are access to supplier's technology, future effective collaboration and the reuse of technical solutions. The success according to Echtelt, et al. (2006), is to not focus solely on short-term benefits as this hinders long-term planning, while solely focusing on long-term benefits will overlook the short-term benefits.

2.5 Tool and Best practices

There are many theories and methodologies regarding new product development, among them we find Design for Manufacturing (DfM), Design for eXelence (DfX), Advanced Quality Planning (APQ), Advanced Product Quality Planning (APQP) and many others. The Japanese model is considered the starting point for a large-scale supplier involvement in product development. In their book Imai, Nonaka and Takeuchi (1985) discusses the differences between US firms and Japanese firms, regarding new product development. The Japanese firms to a large extent, allow for multi-disciplinary self-managing teams and networks. Information exchange was built on mutual support to reach the common goal. The many sub-contractors would exchange information directly with each other (vertically in the development team hierarchy) and with the primary buyer (horizontally in the development team hierarchy). Thus, the information flows freely in a self-governing team. The team has received and overarching common goal for the project from the top management. This goal was presented early on, prior to development start. The development network proceeded to execute the project though information exchange between engineers, technical professionals and suppliers. This Japanese model was not a formally defined model, the term was attached to the observations made by researchers. There existed many variations based on the project and firms involved. The Japanese model is a generalization of the practices found in Japan at the time. The model did however pave the way for new tools and practices to be developed, refining and created models that where not company or project specific. The US car industry adopted Advanced Product Quality Planning (APQP), which has proven to be a useful method with regards to production and supplier involvement in new product planning. Other industries have benefited as well from the APQP model (Carbone 2005, Mittal, Khanduja and Kaushik 2011, Wang 2010). In this section an outline of common best practice and tools will be presented.

2.5.1 APQP

AQP (Advanced Quality Planning) is a methodology for the developing the suppliers manufacturing process so that it meets the capacity required by the buyer. APQP is a method for defining and executing actions needed so that the product meets the buyer's requirements. Thus, APQP described by Stamatis (2018) is a process to facilitate communication between all persons and activities involved in the program. APQP sets common expectations for internal and external supplier to minimize risk and increase profitability for all parts. APQP uses a common and standardized reporting format to ensure quality products that are delivered on time. APQP also specifies a feedback phase so that future development project can learn and improve on the knowledge of the previous projects. The first step in the APQP process is a "product planning and quality program definition", in this phase the goal is to clearly define the project in terms of goals and expectations. The second phase is the product design phase where feasibility studies, FMEA, design reviews and checklists tools are used to ensure the highest possible quality. Following the design phase is the process design phase, the validation phase and finally product launch and project assessment phase. Figure 5 shows the board outline of the APQP process, which clearly shows the feedback assessment and corrective actions phase as active throughout the entire project.

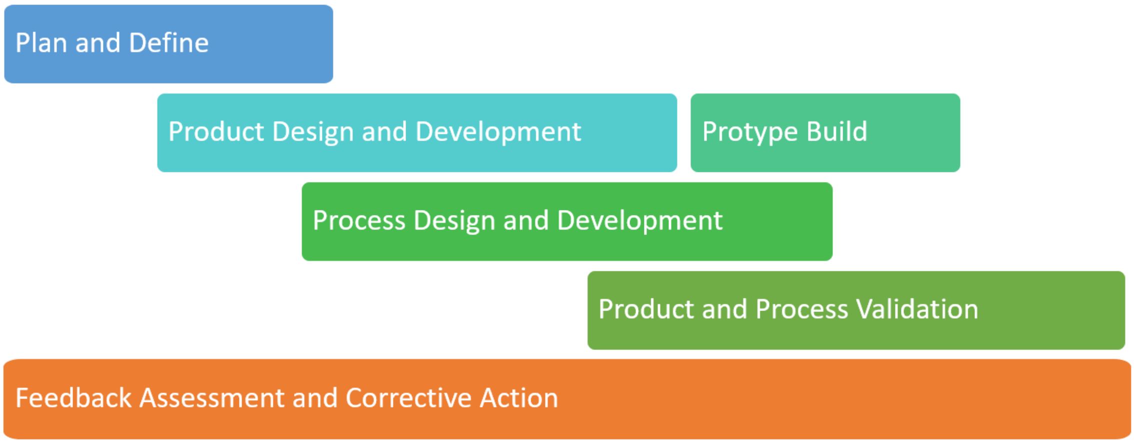

Figure 5: The APQP process as shown in Stamatis (2018)

This thesis will recognise the importance of the feedback assessment phase of the APQP and its importance in the methodology. This thesis will not address the methods used individually, for information on the 8D method, Six Sigma, 5 Whys and statistical process control see (Stamatis 2018). In the following sections this thesis, we will discuss the key information sharing methods of APQP. They are known through other methods also, but they are central in the APQP process. These key concepts are FMEA, Control plan and checklists. There are of course other concepts, but for they are disregarded in this thesis.

FMEA

Failure Mode and Effects Analysis, FMEA, has been around since the 1950's and its main purpose is to evaluate all possible failure modes and the effects of the corresponding failures. The general method is done by assembling a team. The team members have the authority to take action. Once the team, is assembled, the group then asses every possible safety concern, characteristic and function of the product and manufacturing process. Each concern is assessed with regard to severity and possible effects. A corrective action is assigned along with a detection method. All failure possibilities are put into the FMEA form, along with the potential severity, detection method and corrective actions. S. G. Teng, et al. (2006) discusses a system using FMEA. They argue in detail that an integrated FMEA approach with a detailed analysis of failure modes at all stages of the design and manufacturing phase will provide knowledge of the failure modes and the consequences of failures to all members of the team. This in turn will result in personnel in all stages of design and production to make the correct decisions, when failures accrue. S. G. Teng, et al. (2006) also notes that often FMEA information is to general, the vague information may be confusing or misleading. This may cause wrong actions to be taken or failures to be over looked. Another short coming of FMEA is the inconsistency for rating scales and formats. One designer may rate the severity of a potential failure different than another designer. These problems cascade down the supply chain, therefore a project specific (standardized for all stages of the design) FMEA, with detailed and clear information, rating and formatting will ensure that all members can communicate clearly on actions taken. The main issue is however that all members must see the inherent value in the system, as one stage failing to report or update the FMEA will cause the other group members to miss information.

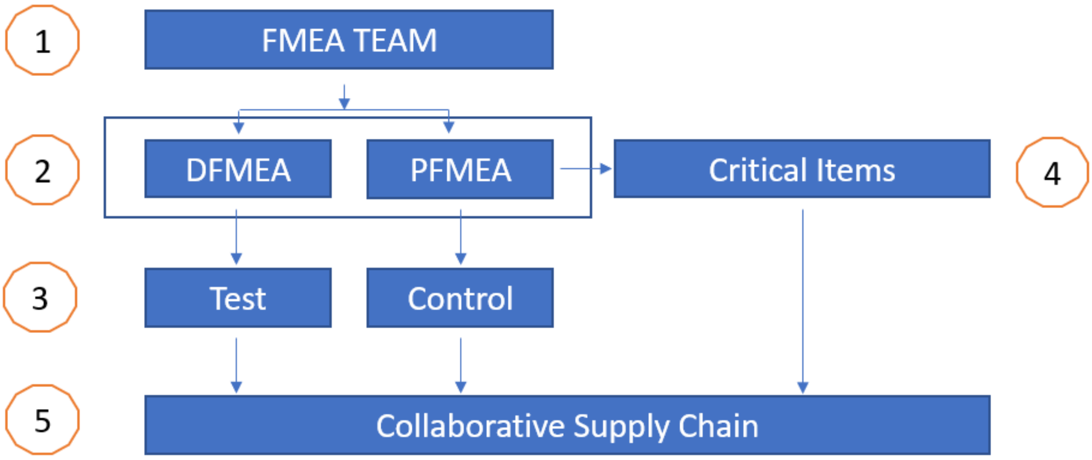

Figure 6: FMEA process (S. G. Teng, et al. 2006)

In Figure 6 a FMEA process is shown. The method includes deriving a link between PFMEA (the process FMEA) and DFMEA (design FMEA). The DFMEA and PFMEA provide a critical items list. Once a FMEA is in place a testing protocol can be designed.

Control plan

A control plan according to Stamatis (2018), is a tool that identifies all processes and operations in the manufacturing process. This includes material flow and equipment. Based on the PFMEA one will identify the characteristics of the product at each specific point in the manufacturing process. The control plan is a living document that should include frequency of testing and the required results of each test. The control plan is an extensive document that requires a lot of work and experience to put together. Also, due to the nature of it being a living document, it requires that all information is up to date and accurate. The benefits of the control plan are that anyone in the development team has access to up to date information on the manufacturing status. Another benefit is that errors in the production can be discovered early and at the exact location in the process. The error can be concisely be communicated to all members of the development team momentarily.

Checklist methods

Stamatis (1998), discusses the AQP feasibility checklists. These checklists are a formal way of sharing information. The information shared ensures that the product meets the requirements set by the buyer. The checklists make sure that all parts have been checked to ensure that the drawing contain the correct information and that the manufacturer are physically able to manufacture the parts. Three checklists are included in this thesis: checklist for engineering drawings checklist for materials, and checklist for manufacturing feasibility.

The checklist for engineering drawing asks the supplier the following questions; do the part tolerances fit with each other, are all dimensions required to manufacture the part on the drawing, are the inspection dimensions clearly labeled, and are the interfaces correct. This checklist can be filled out by the supplier, or buyer and supplier together. Alternatively, including a mechanic or production worker to verify that the information is correct and usable is possible. This check may save production time as an erroneous drawing, that is uncovered in the production phase, may require a back and forth with the design team and at worst require a redesign.

The checklist for materials asks the design team if the considered materials are approved with regard to the design standard and if the materials have a certificate. Also, if the required heat and surface treatments are applied and are the other materials in the part or components compatible. Different materials behave significantly different when exposed to heat or loading. This checklist identifies the risks correlated with the materials. As with the checklist for engineering drawing this checklist will uncover any issues before the production starts.

The checklist for manufacturing feasibility not only requires the design team to investigate whether the manufacturer has the machines and tools required to produce the parts, it also ensures the manufacturer can meet the quality and quantity needed. The list will also provide assurance that the tests and dimension verification process is in place. The list also can make sure production methods meet the applicable standards and that additional costs to avoided. When filling out this checklist representatives from the design team and manufacturer should be cooperating in order to secure that all aspects of the list are a sufficiently checked.

2.5.2 LEAN

LEAN Manufacturing is at its simplest a method of minimizing waste and is derived from the Toyota Production system (Melton 2005). The waste which shall be eliminated is, non-value-added work, uneven work flow and overburden. The LEAN systems is complex. The system has a long list of tools that may be used depending on the project. At the heart of the method one finds Kaizen, where no process is never considered perfect (there is always room for improvement). The LEAN system has roots in the Japanese model of the 1980’s so it naturally includes suppliers’ involvement. Supplier involvement consists of feedback focusing on incremental change. As there is a constant focus on improvement the method is best suited for long-term mass production.

3 Methodology

Data will be collected via a survey from firms which recently had one or more projects that included supplier integration as well as firms that have not integrated suppliers. The companies selected are involved with the authors firm, therefore some prior knowledge about their business is known. A third group is also surveyed. This groups consist of consultant, project managers and professionals that are not employed by the supplier or the buyer. These professionals work with coordinating development project that involve suppliers. This survey attempts to discover to what extent information sharing factors in to the decision for firms to seek supplier involvement in product development. The survey also tries to uncover if there are any best practice tools or methodology that are considered relevant in buyer-supplier cooperation in contract development. The report will focus on technology companies based in Norway that do product development. The companies in focus have products that have batch production, meaning that they firmly are positioned as contract development projects. Once the data from the survey has been analyzed, a workshop group will evaluate the model and provide insight into their thoughts on the findings.

3.1 Survey and Data

The data collected was entered into IBM SPSS. IBM SPSS can in addition to plotting the data calculate correlations. As the data collected in the survey is either ordinal or interval based, the correlations are found using the Spearman Rho method. An ordinal variable is one that can be ranked. Ordinal variable can easily put the categories in an order that would make sense. According to Bryman and Bell (2015), Spearman Rho values lie between 0 and 1. A value of zero indicates no relationship while a value of 1 indicates a perfect relationship. Using a scatter diagram can also show the relationship. If the data points lie on a perfectly straight line and increases in value, the relationship is 1. If a value is negative it indicates that the relationship is such that an increase of one variable decreases the other.

The amount of data found is quite low so any correlations should not be considered absolute. The data will however indicate tendencies on which the model can be created. While the data itself may be limited, the experience of the workshop group will account for a large number of projects in which suppliers are involved. The input of the focus group is therefore paramount with regards to verifying the findings of the survey.

The names of the respondents and their current employers are omitted for the survey in order to ensure anonymity. This was a prerequisite for several of the respondents.

3.1.1 Firms involving suppliers and professionals

Table 2 shows the questions and related variable names. All data found in this survey is labeled with “S” in front of the question number. The variable names will be used further in the empirics’ selection as part of the analysis of survey data.

Table 2: Questions and variable names for survey sent to firm involving suppliers and professionals.

Question	Variable name	Question	Scale
1	S1	Did the quality of your project meet your expectations?	Yes / No
2	S2	Did the final price meet your expectations?	Yes / No
3	S3	Did you meet the scheduled delivery date?	Yes / No
4	S4	Did the experience communication between you and the supplier as satisfactory?	Yes / No
6	S6	Do you consider supplier firm X as?	0= Poor, 5 = preferred supplier
8		Rate the importance of following categories	1=Not, 5=Most
	S8A	Support in structural design	
	S8B	Support in process design	
	S8C	Design Revision Time	
	S8D	Prototyping time	
	S8E	Quality performance	
	S8F	Ease of communication	
	S8G	Cost	
9		When choosing to involve suppliers, rate the importance of these factors	1=Not, 5=Most
	S9A	Relationship with supplier	
	S9B	Experience of supplier	
	S9C	Experience of work with supplier	
	S9D	Reduced delivery time	
	S9E	Your capacity	
	S9F	Reduced design time	
	S9G	Ease of communication	
10		Do you know of the following standards and methods, do you consider them relevant?	0= No knowledge, 1=Not Relevant, 4=Very Relevant
	S10A	ISO 9001-2015	
	S10B	APQP	
	S10C	DfM	
	S10D	DfX	
	S10E	LEAN	
11	S11	Communication with supplier is?	1=Not regarded, 4= Very important
12		Would any of the following reporting and control methods be relevant?	0= No knowledge, 1=No Relevance, 3= Relevant
	S12A	Statistical process control	
	S12B	Checklist for materials	
	S12C	Checklist for engineering drawings	
	S12D	Checklist for manufacturing feasibility	
	S12E	FMEA	
	S12F	Dynamic Control Plan	

Surveyed persons from firms involving suppliers are purchasing professionals and decision makers in companies that have involved suppliers in the development phase of a project. The firm has also used the same supplier for manufacturing. All companies in this group are based in Norway. The companies have done mechanical development. The final product was always a physical mechanical product, often containing electronics that where purchased from a third party.
Surveyed professional are individuals that either work with the supplier, manufacturer or closely work in the team. This group is considered to have the day to day

experience of working in intra firm projects. All survey participants from this group three have a mechanical engineering degree and experience working with manufacturing, product development and have high technical understanding.

3.1.2 Firms not involving suppliers

Table 3 shows the questions and related variable names. All data found in this survey is labeled with "PS" in front of the question number. The variable names will be used further in the empirics' selection as part of the analysis of survey data. Note that PS5X is equal to S8X, PS6X is equal to S9X, PS7X is equal to S10X, PS8 equal to S11, and PS9X equal to S12X.

Table 3: Questions and variable names for survey sent firms not involving suppliers

Question	Variable name	Question	Scale
1	PS1	Did you, prior to the survey, know about the services of firm X	Yes / No
2	PS2	Which of the following would a supplier have to excel at in order for you to consider involving the supplier in development	Check all that apply: Price, Quality, Delivery time, Communication, Support
4	PS4	Do you consider involvement of manufacturing to be	1=not important, 3=important (but in house)
5		Rate the importance of following categories	1=Not, 5=Most
	PS5A	Support in structural design	
	PS5B	Support in process design	
	PS5C	Design Revision Time	
	PS5D	Prototyping time	
	PS5E	Quality performance	
	PS5F	Ease of communication	
	PS5G	Cost	
6		When choosing to involve suppliers, rate the importance of these factors	1=Not, 5=Most
	PS6A	Relationship with supplier	
	PS6B	Experience of supplier	
	PS6C	Experience of work with supplier	
	PS6D	Reduced delivery time	
	PS6E	Your capacity	
	PS6G	Reduced design time	
	PS6G	Ease of communication	
7		Do you know of the following standards and methods, do you consider them relevant?	0= No knowledge, 1=Not Relevant, 4=Very Relevant
	PS7A	ISO 9001-2015	
	PS7B	APQP	
	PS7C	DfM	
	PS7D	DfX	
	PS7E	LEAN	
8	PS8	Communication with supplier is?	1=Not regarded, 4= Very important
9		Would any of the following reporting and control methods be relevant?	0= No knowledge, 1=No Relevance, 3= Relevant
	PS9A	Statistical process control	
	PS9B	Checklist for materials	
	PS9C	Checklist for engineering drawings	
	PS9D	Checklist for manufacturing feasibility	
	PS9E	FMEA	
	PS9F	Dynamic Control Plan	

Survey persons from firms that have not involved suppliers consists of purchasing professionals and decision makers in companies that have not engaged suppliers in development project. These companies develop their product in house then fully outsource the production to another company. It should be noted that this group was less responsive to the survey than the other groups. This may because they are more concerned about intellectual property than the other groups, a formal NDA was not signed with any survey respondent. The respondents were in large part not familiar with the author of the report, which also may have reduced willingness to participate in the survey.

3.2 Workshop

A workshop was conducted with 4 participants. The workshop discussed the findings of the survey and found a suggestion to further develop the purposed model for information sharing and reporting. The participants are professionals that work closely with companies in product development. They all have experience regarding supplier involvement and all participants have technical degrees within mechanical engineering.

4 Empirics

4.1 Survey and Data collection

The survey data collected was from three sources, as summarized in Table 4.

Table 4: Summary of the surveyed groups.

Group id. nr.	Groupe name	Surveys sent	Surveys answered	Group characteristics
1	Firms involving suppliers	22	14	Have been involved suppliers in product development.
2	Firms not involving suppliers	18	6	Have used external sources for product development but not integrated suppliers into product development projects
3	Professionals	18	11	Work with product development, often work as the contact point between suppliers and buying firms. Not employed in the buying firm or the supplier.

In order to attract as many responses as possible the surveys where kept short. The survey for group 1 and 3 were identical while group 2 was modified in order to account for the fact that the group have not engaged suppliers in development projects. The survey for firms involving suppliers was added to a customer survey, therefor some questions where not related to this thesis, these questions are excluded from the analysis in this report as they were for company feedback and marketing purposes only.

4.1.1 Firms involving suppliers

Presented in Figure 7 to Figure 11 are the results of the survey for group 1, the firms that have involved suppliers in development projects. The mean is presented as a tool to understand the trend among the respondents.

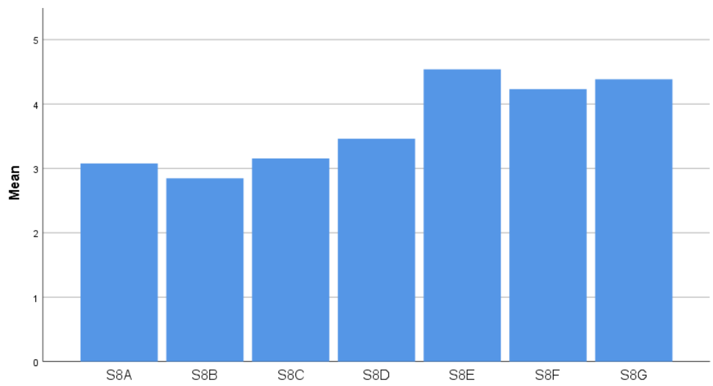

Figure 7: Mean result S8A – S8G, 1 = no importance, 5= very important

Figure 7 shows a clear tendency that S8E (quality performance), S8G (ease of communication) and S8F(cost) are more important to the respondents than the other categories. S8B (support in process design) is the only category with a mean below

3, which is the average marker. S8A (support in product structural design) and S8C (design revision time) show results marginally above average importance.

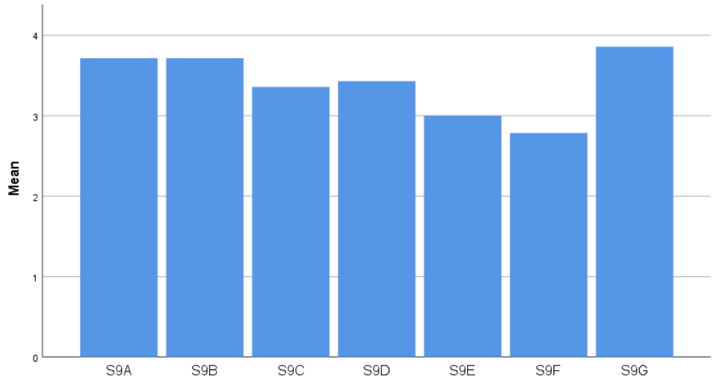

Figure 8: Mean result S9A – S9G, 1 = no importance, 5= very important

Figure 8 shows a tendency that S9G (ease of communication), S9A (relationship with supplier) and S9B (experience of supplier) are more important to the respondents than the other categories when choosing to involve suppliers. S9F (reduced design time) is the only category with a mean below 3, which is the average marker, while S9E (capacity) is at 3. Communication (S9G) is the most important factor when choosing a supplier, narrowly ahead of the relationship with the supplier (S9A) and the perceived experience of the supplier (S9B). The least important factor on average is the factor of reducing the design revision time (S9F).

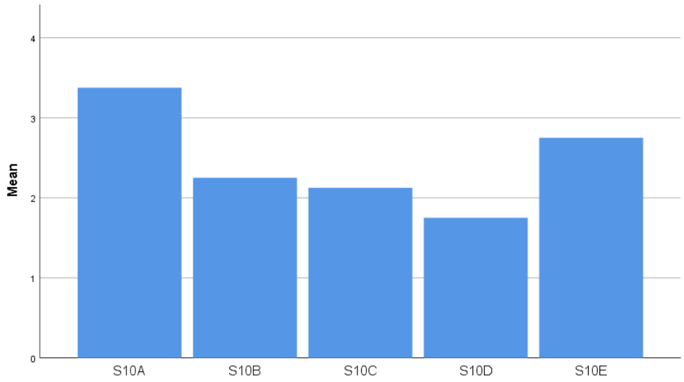

Figure 9: Mean result S10A – S10G, 1 = no relevance, 4= very relevant

According to Figure 9 the respondents find on average S10A (ISO 9001:2015) more relevant than other factors in question 10, which asked to what degree the different standards and methods are relevant for their company.

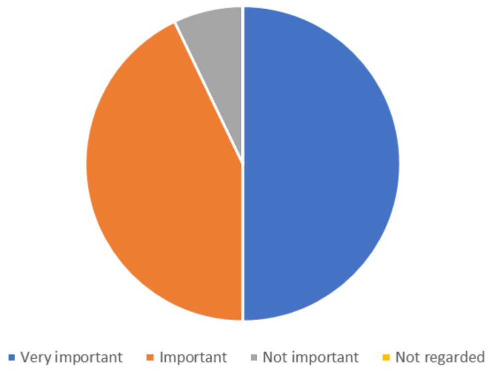

Figure 10: The responses to question S11 by answer category.

Figure 10 shows one respondent did not considered communication as an important factor when choosing which supplier to involve in a development project. Six respondents, answer that it was important but not crucial. Seven of the surveyed replied that it was important and strongly considered when choosing suppliers to involve in development projects.

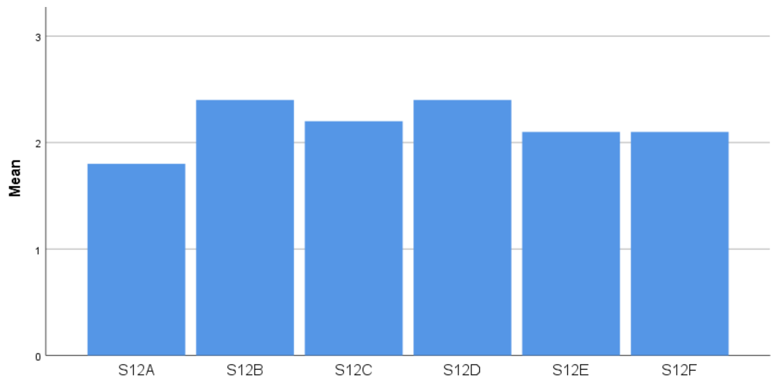

Figure 11: Mean result S12A – S12F, 0=No Knowledge 1 = no relevance, 3= Relevant

In Figure 11 it seems clear that S12B- S12F (checklist for materials, checklist for engineering drawings, checklist for manufacturing feasibility, FMEA, and dynamic control plan) are marginally different. All score as nice to have but not key in decision making. S12A (statistical process control) is a little bellow the mean of 2, which implies that on average most customers see little or no relevance of the Statistical process control methodology.

Correlations for the satisfied customer is done using spearman's rho method, correlating S4 to S8, S9, S10 and S12.

Table 5: Correlation between S4, which asks if the respondent was satisfied with the communication with the supplier, and the importance of S8A- S8G.

	S8A	S8B	S8C	S8D	S8E	S8F	S8G
S4	**0,387**	-0,198	0,082	**0,624**	0,264	0,298	**0,425**

Remembering that a correlation of 1.00 is a perfect correlation, and a factor equal to 0 implies no correlation, we find a weak correlation between existing satisfied respondent and the support in structural design (S8A), cost (S8G) and prototyping time (S8D). Quality Performance (S8E) and ease of communication (S8F) have a weaker correlation. The strongest correlation is with prototyping time. This indicates that customers satisfied with the information sharing in their development project also considered prototyping time important, also that customers that where not satisfied consider prototyping time less important.

Table 6: Correlation between S4 and the importance of a factor when choosing a supplier, S9A- S9G

	S9A	S9B	S9C	S9D	S9E	S9F	S9G
S4	-0,442	0,112	-0,145	-0,184	0,216	0,108	**0,408**

We find a weak correlation between satisfied existing customers and the importance of easy communication (S9G) with suppliers. We also find a weak negative correlation with regard to the existing relationship with the supplier (S9A). This indicates to a lesser extent that customers satisfied with the information sharing in their development project also considered communication important, also that customers that where not satisfied consider communication less important.

Table 7: Correlation between S4 and commination and reporting methods, S12A- S12F

	S12A	S12B	S12C	S12D	S12E	S12F
S4	0,037	-0,240	**0,477**	**0,433**	0,0	**0,441**

Existing satisfied customers did indicate showed a weak correlation that checklist for engineering drawing (S12C), checklists for manufacturing feasibility (S12D) and dynamic control plans (S12F).

4.1.2 Firms not involving suppliers

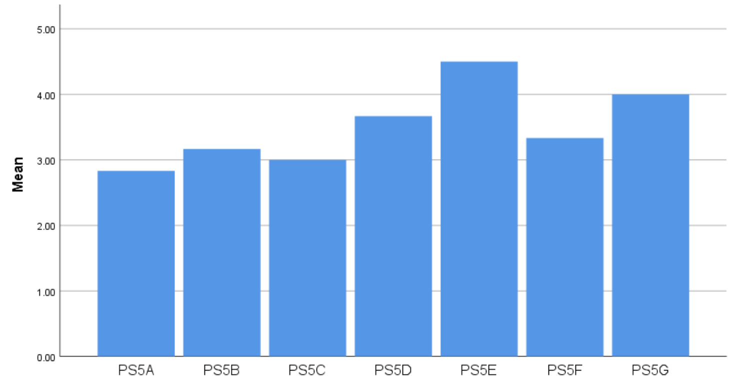

Figure 12: Mean result PS5A – PS5G, 1 = not important, 5= Most important

Figure 12 shows that the firms not involving supplier on average indicated that Quality performance (PS5E) was most important, followed by the cost (PS5G). Least important, support in structural design work (PS5A).

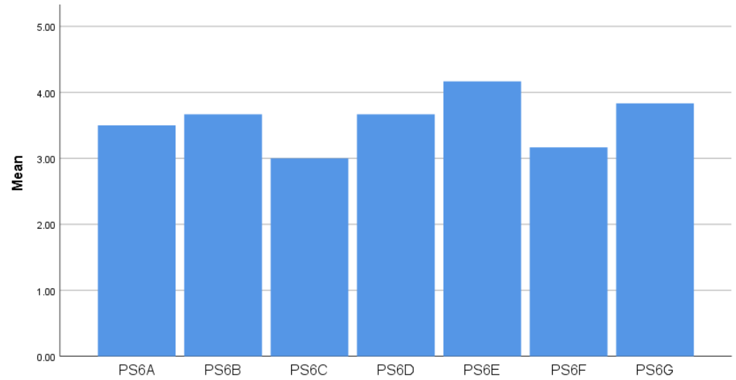

Figure 13: Mean result PS6A – PS6G, 1 = not important, 5= Most important

Figure 13 finds that the firms not involving supplier would rate their own capacity (PS6E) on average as the most important factor if they should choose to involve a supplier, if they choose to involve supplier in development projects. Least important is the experience of the supplier (PS6C).

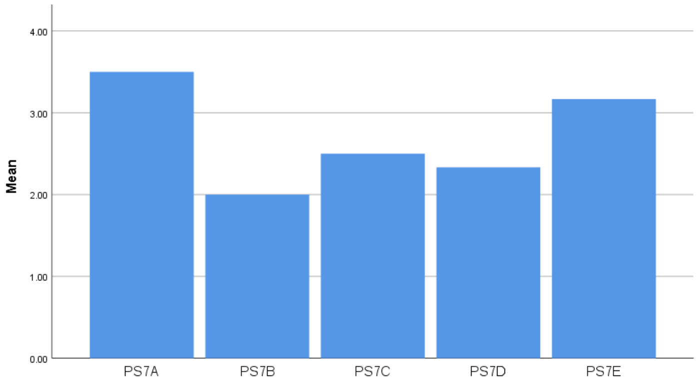

Figure 14: Mean result PS7A – PS7E, 0=No Knowledge 1 = no relevance, 4= Very relevant

In Figure 14, we find the different methodologies, where on average the ISO 9001-2015 (PS7A) is the most relevant, with lean (PS7E) being the only other method to be over an average of 3.

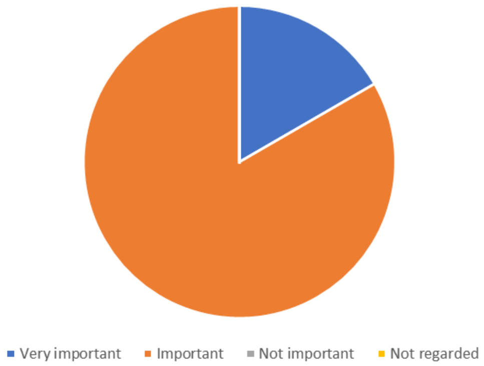

Figure 15: The responses to question PS8 by answer category.

Figure 15 shows one respondent considered communication as a very important factor when choosing which supplier to involve in a development project. Five respondents, answer that it was important but not crucial when choosing a supplier.

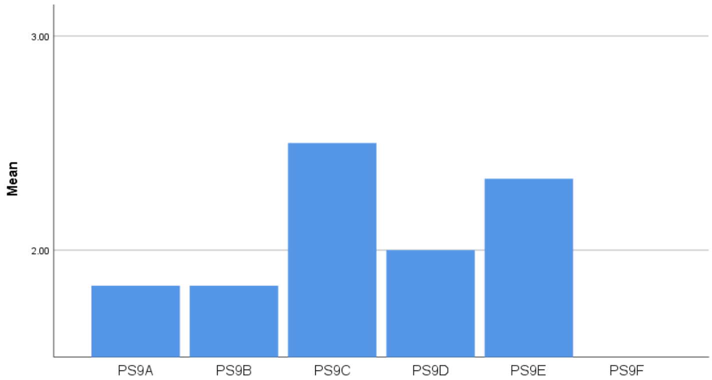

Figure 16: Mean result PS9A – PS9F, 0=No Knowledge 1 = no relevance, 3= Relevant

Figure 16 Shows a clear result, FMEA (PS9E) and checklists for engineering drawings (PS9C) to be relevant.

Table 8: Correlation between PS8– importance of communication in new product development and communication and reporting methods, PS9A - PS9F

	PS9A	**PS9B**	**PS9C**	PS9D	PS9E	PS9F
PS8	-0,566	**0,775**	**0,447**	-0,707	-0,316	-0,447

The correlations Table 8 show PS9C with a weak correlation and PS9B to have a strong correlation. PS9A and PS9D have a strong negative correlation. This mean that firms that consider communication important also consider checklist for materials important, and that firm that consider communication less important also do not consider checklists for material important. The opposite hold true for checklist for manufacturing feasibility: if the firm considers communication less important than they consider checklist for manufacturing feasibility important.

4.1.3 Professionals

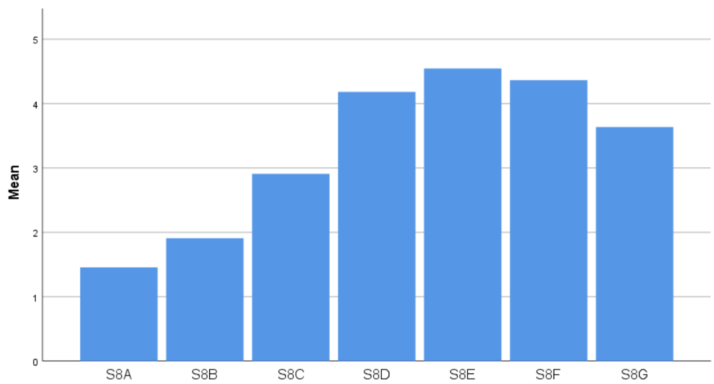

Figure 17: Mean result S8A – S8G, 1 = no importance, 5= very important

Figure 17 shows that the professionals consider quality (S8E), Ease of communication (S8F) and prototyping time (S8D) on average the most important categories. Support in structural design (S8A) and support in prosses design (S8B) are on average the least important.

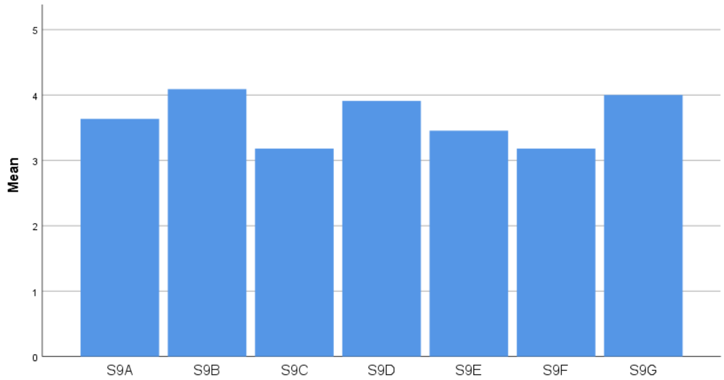

Figure 18: Mean result S9A – S9G, 1 = no importance, 5= very important

For the question related to factors of importance when choosing to involve a supplier Figure 18 shows that the professionals consider all the factors quite important, with the experience of the supplier (S9B) being marginally the most important.

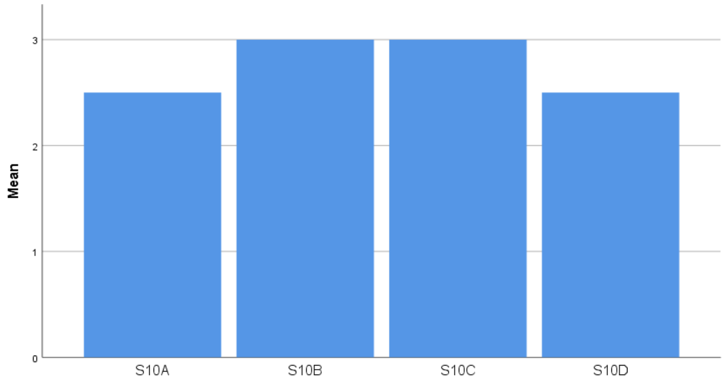

Figure 19: Mean result S10A – S10G, 1 = no relevance, 4= very relevant

In Figure 19 the professionals on average consider APQP (S10B) and DfM (S10C) to be more relevant than ISO 9001 (S10A) and Lean (S10D).

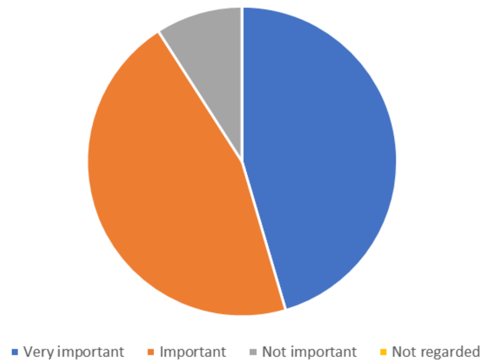

Figure 20: The responses to question S11 by answer category.

Figure 20 show one respondent considered communication as a factor that is not considered important when choosing which supplier to involve in a development project. Five responded that it was important but not crucial when choosing a supplier. Five of the surveyed replied that it was important and strongly considered when choosing suppliers to involve in development projects.

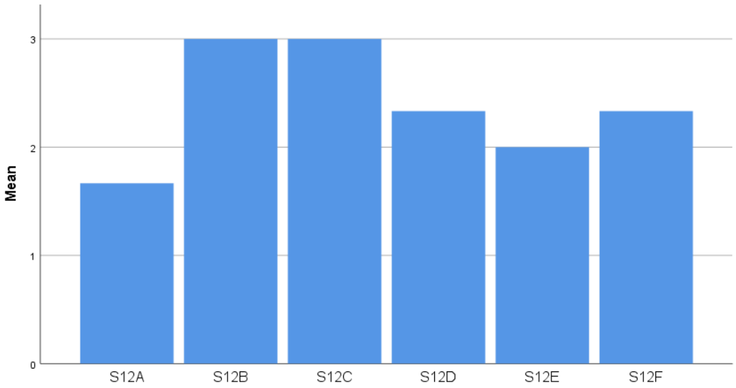

Figure 21: Mean result S12A – S12F, 0=No Knowledge 1 = no relevance, 3= Relevant

Figure 21 shows that Checklists for material (S12B) and for engineering drawing (S12C) are considered more relevant than the other communication and reporting systems. Statistical process control (S12A) is the least relevant according to this survey.

No significant correlations were found for the professionals' group.

5 Discussion

The results for the survey groups showed different priorities with regard to what was considered important. However, all three groups answered that the information sharing is an important factor in a product development project. This indicates that any company aspiring to involve suppliers into development projects need to set up proper information sharing channels. They need to ensure proper reporting systems across the entire development team. This is also reported in Wynstra, Wynstra and Pierick (2000). They claim that information sharing need to be differentiated for different levels of supplier integration, recall arm's-length and strategic involvement of suppliers. The different responses between the survey groups may be the result of some underlying factor regarding why some companies choose not to involve suppliers in development projects. These differences may be because the surveyed firms are not representative enough of the entire population. However, this analyzes the responses in an attempt to find a correlation to the theory behind different levels of supplier involvement.

Table 9: Comparison of results from survey groups.

Question	Sorting levels		Firms involving suppliers	In-House Professionals	Firms not involving suppliers
S8 / PS5	Low	< 3	B	A, B, C	A
	High	> 4	E, F, G	D, E, F	E, G
S9 / PS6	Low	< 3	F		C
	High	> 4		B, G	E
S10 / PS7	Low	< 2	D		B
	High	> 3	A	B, C	A, E
S12 / PS9	Low	< 2	A	A, E	A, B, D
	High	> 3		B, C	

Table 9 show four of the questions from the survey, filtered so that one can find the answers that are lower than the average and higher than the average. The sorting levels column shows the cut-offs for the filter and the three last columns show which answers remained after the sorting. Using Table 9 one can see that there are different priorities for the different groups.

The data for firms involving supplier, shows that they do not consider process design important while their focus is the combined efforts of reducing costs, increasing quality. The group considers communication to be important when trying to reduce cost and increase quality. Reducing the design time is not a consideration. The ISO

9001-2015 standard is considered an important tool while statistical process in not key.

Doing the same exploration of the data for firms not involving suppliers show that they do not consider the support in structural design to be important. They do consider cost and quality to be important. Any previous experience with a supplier does not affect the decision to involve suppliers, but their own internal capacity is a more important factor. APQP methodology is not believed to quite as relevant as ISO 9001-2015 and LEAN. The firms not involving suppliers consider the statistical process control method, checklist for materials and checklist for feasibility to be less relevant than the other methods.

The professionals group data show that support in structural and process design, and revision time are less important than cost, quality and prototyping time. The experience of the supplier along with ease of communication is regarded as important when including suppliers into development projects. The APQP and DfM methodologies are considered relevant. Statistical process control and control plans are less relevant, while checklists from materials and drawings are more relevant.

The data used in this report from the survey phase is not plentiful, and therefore this report is careful in using the data and the above interpretation. Earlier research done by Wagner and Hoegl (2006), identified two different types of supplier integration projects; know-how projects and capacity projects. The findings of the survey identified a trend, namely that the firms currently not involving suppliers indicated that they would, on average, consider capacity to be a more important motive for supplier integration. Conversely the firms involving suppliers considered performance quality, reduced cost and the experience of the supplier be their motivation. Thus, a parallel to Wagner and Hoegl (2006) can be drawn, two project types for supplier involvement. This thesis will use this distinction between project types going forward. The theory also presented a distinction between degrees of development risk involved: arm's length and strategic involvement, according to Wynstra, Wynstra and Pierick (2000). We disregard the low level of supplier responsibility groups for the purpose of this thesis, as discussed earlier. Thereby, leaving the two degrees of development risk. The development risk as discussed in the theory section, concerns the complexity of the project, and thereby the degree of involvement. High risk implies long development time and high degree of supplier involvement, leading to the buyer's firm needing to strategically choose their collaboration partners wisely. Combining the type of project and the degree of risk, a matrix can be devised as shown in Figure 22. This figure shows the suppliers role in a development project, specifically for contracted development as the data found concerns firms doing contracted development.

Supplier involvement / Type of project	Arm's length • Low degree of development risk	Strategic • High degree of development risk
Capacity • Supplier takes responsibility for less critical components	Purchased design capacity	Design team partner
Know-how • Supplier takes responsibility for critical modules or systems	Module design specialist	Systems architect

Figure 22: Supplier role for contract development projects.

The matrix indicates four combinations of supplier involvement and project types. These relationships are

- Purchased design capacity: capacity project with low development risk
- Module design specialist: know-how project with low development risk
- Design team partner: capacity project with high development risk
- Systems architect: know-how project with high development risk

The first group, “purchased design capacity”, contains projects where the suppliers have responsibility for less critical components and the supplier has a low development risk. The project is firmly inside the supplier’s main core working area and they are considered competent in their field. The buyer typically asks for a solution to their problem, the supplier delivers the component with minimal interaction after the first inquiry. While the component is question is designed by the supplier, it may actually be a standard solution, but looking from the buyer side, this is in effect a component developed by the supplier.

The second relationship, “module design specialist”, is somewhat similar in that the supplier-buyer interaction is limited, but “module design specialist requires more information sharing as the supplier provides a custom product that meets the specifications of the buyer. This may often be a customized made-to-order development. Often the supplier will customize one of their standard products to meet the buyer’s needs. The supplier is considered an expert in the field and has been selected by the buyer for precisely this reason.

The “design team partner” role requires quite a bit of information sharing. The supplier is involved in development of a complex system, the supplier responsibility is not on the critical components, but the complex nature of the development requires coordination of information such as product specifications, interfaces and other non-trivial information. The supplier is considered part of the development team but does not take the lead role in specification of the entire system. The buyer requires the capacity of the supplier in order to complete the project.

The last group is “systems architect”, here the supplier has special knowledge of the critical sub systems of the project. The supplier is included in the development team. Information sharing is critical to the success of the product. Product specification, interfaces, production methods and most of the key decisions concerning the development is done in coordination with the buyer. Often the supplier and buyer will co-locate in order to maximize the coordination and allow for informal information sharing. The supplier is considered an expert in the field. The supplier, as the expert, will design critical component and make technical decisions concerning the development.

For firms not involving supplier (from the survey), we can infer from the survey data and from the Figure 22 relationship groups that they would consider involving suppliers using the “purchased design capacity” or “design team partner” roles. The respondents in general want to supplement their current activities by outsourcing some of the development of less complex tasks, this is done to free up internal capacity or general lack of project engineers. Costs and quality are important but previous experience with a supplier is not. While they could have involved suppliers, they have chosen to do the development in-house, as they most likely have the competency to do so.

For the firms involving suppliers (from the survey), the respondent on average correlate to the know-how projects. They want to reduce cost and increase quality by having a specialist perform the development in less time than it would by learning the knowledge in-house. It is not evident how the respondents are distributed between the “module design specialist” and “systems architect” roles.

The professionals show no clear signs of belonging to either the capacity or know how projects, which is natural as they have worked in a wide variety of projects, leading to no clearly defined position. However, this report assumes that they were involved in the high degree of development risk roles, “design team partner” or “systems architect”. This is because the professionals are hired to lead projects that have a high degree of technical complexity.

In order to maximize the effect of involving suppliers into contract develop projects in each group, this thesis will propose success factors, for each of the supplier's roles. This will improve the information sharing for projects. This will be done based on the finding of Ragatz, Handfield and Scannell (1997), Johnsen (2009) and Echtelt, et al. (2006). Not all the factors in the literature are applicable for contract development. For example, risk reward sharing, in contract development the sale is made prior to development, therefore a price has most likely already been set. Therefor a supplier will usually submit a project price offer, which the buyer will either accept, decline or negotiate. Furthermore, factors regarding shared training, shared education and, shared plant and equipment, are also neglected in this model. The contract development model often requires the project to start immediately, therefore a supplier with the correct equipment, and qualification must be selected. That said, there is an inherent motivation for shared training and equipment that may be negotiated so that future collaboration may be even more effective. This may be part of any feedback and/or evaluation of the supplier. Figure 23 show the success factors for each of the suppliers' roles. The figure is structured so that each role also includes the factors of the level below (with a few exceptions). The "purchased design capacity" role has the fewest factors, while the "systems architect" has the most factors. The figure is also structure so that, "systems architect" and "design team partner" included success factors that pertain to long-term relationship, as discussed by Echtelt, et al. (2006). The model also attempts to follow the findings of Ragatz, Handfield and Scannell (1997), here relationship structuring factors facilitate the asset allocation factors, thus the two know-how levels, "module design specialist" and "systems architect", include some relationship structuring factors.

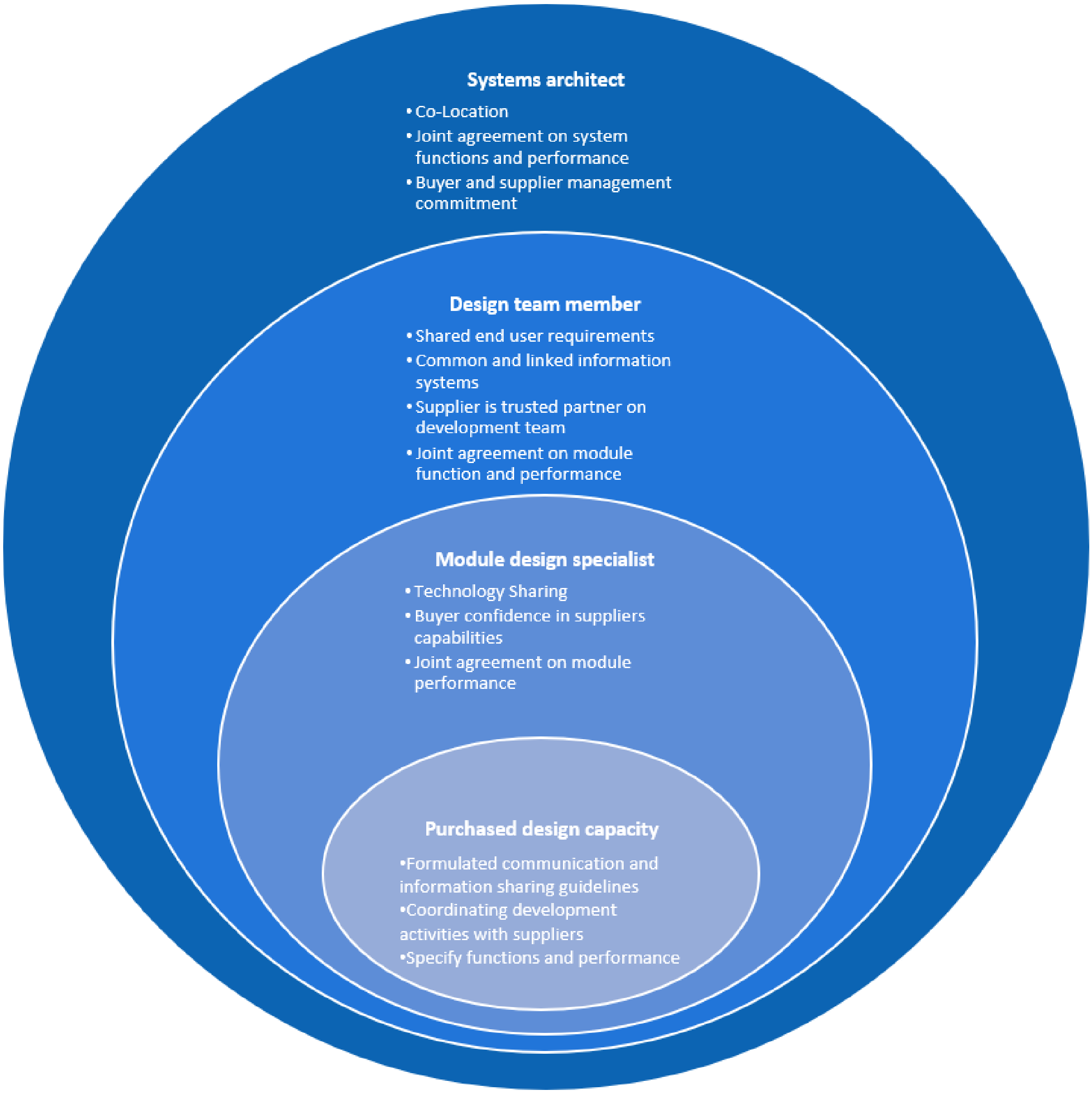

Figure 23: Success factors for the supplier roles in contracted development.

The success factors proposed in Figure 23 are:

- Purchased design capacity
    - **Specify functions and performance**: the buyer specifies the functions and performance of the product. The buyer must be clear on the specifications of the product they require.
    - **Coordinating development activities with suppliers:** the buyer and supplier have a clearly divided the tasks required of each other. There is no ambiguity on who does what.
    - **Formulated communication and information sharing guidelines**: the buyer and supplier have agreed on reporting methods. There is a formal understanding of how often status updates are required. The
    - buyer and supplier have agreed who shares information within the development team. Meeting and meeting protocols are agreed to.

- Module design specialist
    - **Technology sharing**: the supplier has access to technological knowledge and equipment required to complete the project. The supplier must be willing to share their technology.
    - **Buyer confident in supplier capabilities**: the supplier is an expert. The buyer must recognize this fact and allow the supplier to complete their work.
    - **Joint agreement on module performance**: the buyer and supplier agree on the performance requirement of the part /module. The supplier's expertise is considered superior to the buyer knowledge; therefore, the supplier may suggest performance measures.

- Design team member
    - **Shared end user's requirements**: the buyer shares the end user's requirements. The previous two roles did not receive the requirements as they may contain information that a competitor should not have. The strategic nature to the collaboration allows for the supplier to gain access to these end user requirements.
    - **Common and linked information systems**: linking information sharing systems allows for the supplier to gain better access to documents and files pertaining to the project.
    - **Supplier is a trusted partner on the development team**: the supplier is a trusted partner of the development team. The supplier's input and work are recognized. Informal information sharing is encouraged.
    - **Joint agreement on module function and performance**: The technical complexity of the part/module requires that both buyer and agree together on function and performance measures.

- Systems architect
    - **Co-location**: the member on the development team work in close proximity. Preferably in the same work space so that informal information sharing occurs daily.
    - **Joint agreement on systems function and performance**: The technical complexity of the system requires that both buyer and agree together on function and performance measures. The supplier, as the expert will lead these decisions.
    - **Buyer and supplier management commitment**: the management at both the supplier and buyer see the benefit of the collaboration. Both firms have committed adequate personnel and assets in the project.

Note the factors the pertain to "joint agreement on module/system functions and/or performance" replace each other in the different suppliers' roles.

The research done by Sjoerdsma and van Weele (2015) indicated that relationship quality with the supplier affects product development performance. The goal is to increase trust, commitment, information sharing and cooperation so that the supplier's role can maximize the development performance. The "purchased design capacity" role for example is not as concerned with the long-term benefits as the short-term. The survey backed by the theory in the literature, suggest that all firms consider communication essential in supplier involvement projects. To this end, “formulated communication and information sharing guidelines” are placed so that it is valid for all the supplier’s roles.

This report proposes a formal and information sharing guideline between supplier and buying firm based on the four roles. The APQP methodology demonstrate how large-scale restructuring can have positive effects on the firm, but it requires a good deal of reorganizing and coordination with suppliers. The APQP method is intended for large companies, with off-line development and continuous production. The guidelines proposed later in this paper, would replace these processes by implementing a pre-project discussion on what information will be shared and who will share it, thus bettering coordination and cooperation in contract development.

5.1 Workshop Discussion

The workshop consisted of four professionals, with working experience within product development and supplier involvement. The author of this thesis started by presenting the parameters of the thesis, emphasizing contract development and information sharing in new product development. After the theoretical parameters the findings of the survey were presented. The workshop group quickly were able to identify projects that fell into the roles of supplier categories. They could not recall any project they had worked on that fell outside all the categories. The workshop group therefore concluded that the roles presented in Figure 22 to be valid. The success factors proposed in Figure 23, also were deemed satisfactory. No further comments were added to these finding.

The bulk of the workshop group discussion centered around the information sharing guidelines. The discussion uncovered some phases and modes of information sharing that the author had not considered prior to the workshop. The main contribution from the workshop where, partnership assessment, regulatory information, physical information exchange, quality assurance and post development hand off, as part of the information sharing guidelines.

Partnership assessments were proposed as the first improvement. The workshop group suggested an evaluation of the partnership at the very start of the project. In practice this is usually done informally but the group felt that a formal assessment could be advantageous. The goal is to assess the jobs that needs to be done and evaluate if both partners believe that they are compatible. The question whether the supplier has experience and know-how to complete the delivery, does the buyer poses the correct in-house competency to communicate on a technical level with the supplier are among the questions that should be answered during this assessment. This is considered even more important in contract development as a time constraint for delivery might be a factor. In effect the supplier and buyer are on which of the four roles the supplier will have. The partnership assessment ties directly to what Ragatz, Handfield and Petersen (2002) discusses, that when a supplier is involved early in the development process it is critical that the supplier not only have the technical abilities needed but also have the correct culture. While the concept of business assessment isn't new, the Japanese automotive industry visits key supplier prior to development to assess the supplier ability to deliver quality product and the correct price. A partnership assessment also should consider the opposite, a supplier's assessment of the buyer, asking if the buyers technical understanding and requests meet their requirements. The workshop group highlighted the difficulties in working with buyers that don't understand the implications or difficulties associated with their requests. Furthermore, a risk assessment of the buyer of the supplier or vice versa may be in order if no previous cooperation exists. The risks that potentially should be evaluated are the buyer's finances, the degree of repeat business to cover development costs. The buyer needs to evaluate the degree to which they believe the supplier can supply quantity and quality needed, this is discussed in the core of APQP.

Regulatory standards as brought forward by the workshop group was proposed to be added to the predevelopment phase. The buyer and supplier need to agree on which standards should be utilized in the project. It is simple enough to do but has great importance. The information exchange is critical as a buyer may be familiar with industry standards in their field, while the supplier may be familiar with another. For example, a chair manufacturer needing a bearing would be familiar with industry standards pertaining to furniture, while the bearing supplier may be under the assumption that an ISO standard for bearings is enough, as it may well not be.

The workshop group felt that the model lacked a phase where physical information was exchanged. By physical information they meant mock ups, prototypes and design sketches. One often considers the product development cycle as a circular process inside-of the linear overarching main process. The group was therefore adamant about the need for physical information exchange. Physical information sharing introduces an interesting component. Digital information is increasingly important however, in the field of product design a lot of concepts are prototyped. Mechanisms often require visual proof of the concept. Furthermore, the workshop group considers prototypes one of the most efficient way to share technical knowledge. Design thinking by Kelley and Kelley (2015) is a product development methodology that heavily used mock up and prototypes as a way of investigating the solution space, the knowledge is easily transferred.

Quality Assurance and Post development sign off where also a point of interest for the workshop group. There is a need for accountability and cross checking to assure that quality of the product meets the specifications. The main information shared is who performed the action, who cross checked and if the buyer is satisfied with the development phase so that production can commence.

The workshop group had thoughts regarding the information sharing guideline that where was presented, the group liked feedback phase as the saw an inherent value in being able to process potential improvements. The group also liked the checklists and interface documents, though not all are applicable in all projects. There will be a need to be determined which to use on a project-to-project basis.

The last point the workshop group talked about was the phase structure, they felt that the contract design process and the APQP process did not capture the important information sharing phases. The workshop group purposed a structure that resembles work flow stages. Splitting development into 3 phases, pre-development, development and post development.

5.2 Proposed guidelines

In Wynstra, Wynstra and Pierick (2000) they report that over-communication may inhibit the potential benefits, and adjustments must be made project by project. In creating the guidelines for information sharing, one must consider Jonsson and Myrelid (2016). Information sharing is described in the theory as a sum of the factors; frequency, direction, modality and content. The guidelines should describe how the communication should occur, if it should be unidirectional or bi directional, what kind of medium should be used and what kind of information should be shared. The data collected from the survey and workshop along with the four purposed supplier roles form the parameters of the guidelines. The information sharing strategies should different for each of the supplier roles. The different phases of a project may also require different communication set ups. For example: “purchased design capacity” in the start-up phase may require bi directional communication while during the development phase unidirectional, weekly status reports, from supplier to buyer, may be all that is needed.

The project phases in APQP are designed for continuous, large scale production where the phases overlap. The feedback and corrective actions are included throughout the entire project life, this is significant in the APQP methodology as constant feedback for improvement is considered highly important. The APQP model, with its phases does not correlate well with the parameters of this thesis, as discussed earlier. The contract development process, with the linear flow is consider a better fit for the purpose of this thesis. The workshop group also suggested splitting the development phase in three to capture information sharing stages. This thesis uses therefore the following project phase structure:

- Pre-development:

- Development
- Post development
- Production
- Post production
- Market

The pre-development phase is the part of the project where sales, orders, specifications and other development input is discussed. The development phase follows and may include several iterations or cycles as product development is generally not a linear process. There may be some overlap between the phases. Following the development, comes the post development, here information pertaining to quality assurance. Post development hand off meetings are included. Then the production and post production phases take over. The production phase consists of information related to status and delivery time. The post production would contain information about quality. Again, some overlap of the phases may occur as long lead times for materials or manufacturing may require the production to start before the post development phase is over. This is one of the benefits of involving supplier in the development team. The supplier can contribute in the development phase, thereby reducing lead times. Lastly the market phase, where the product is installed and in use. The reason for including the market phase is so that the buyer and supplier can exchange information regarding the process and evaluate their cooperation. The added effect of this phase definition is that team members should refrain from sharing information in the wrong phases thereby reducing irrelevant oversharing of information.

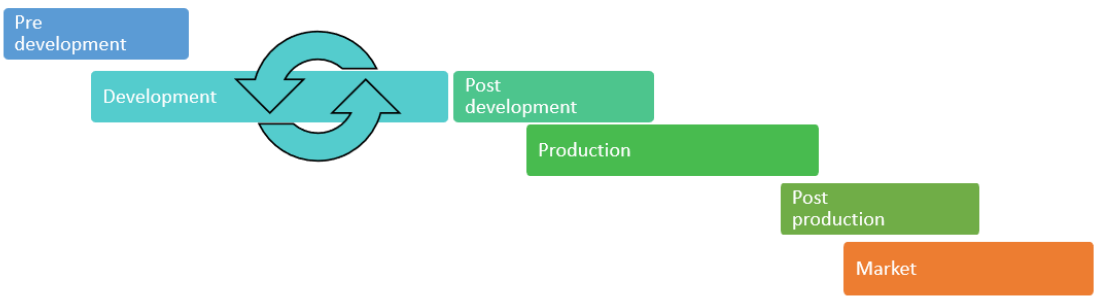

Figure 24: Project flow for contract development, as regarded in this thesis.

Managing the amount of knowledge sharing in a project, as well as the managing which individuals receive the information is the project leader's responsibility. Careful planning of a project should include an outline of the general frequency, direction, modality and content of knowledge sharing. This report suggests that such a plan should be created in the start-up phase or pre-project meetings. An outline of the type of communication should be established. Conversely lack of such information sharing guidelines, may have led to firms to abandon future supplier involvement as previous experience lead to dissatisfaction on the buyer's side. The information sharing guidelines should improve communication and information sharing though coordination and cooperation, thereby building trust and commitment to the supplier. The information sharing guidelines will help coordinate expectations. Information sharing guidelines should also be viewed itself as one of the critical tools to use in supplier involvement for contract development. The suggested information sharing guidelines for the different levels of supplier involvement in contract development are shown below. The modality, frequency and content can be adjusted on a project to project basis.

PURCHASED DESIGN CAPACITY

	Pre Development	Development	Post Development	Production	Post Production	Market
Frequency	Once	Weekly	Once	Weekly	Once	As needed
Direction	Bidirectional	Unidirectional	Unidirectional	Unidirectional	Unidirectional	
Modality	Face-2-Face	Email	Face-2-Face	Email	Email	Email
Content	Scheduling	Status reports	Quality Assurance	Status reports	Material certificates	Product performance
	Deliverables					Future improvements
	Regulatory standards					
	Requirements					

Figure 25: Suggested information sharing guideline for "purchased design capacity".

The first information sharing guide is for "purchased design capacity", see Figure 25. The information sharing required is minimal and mainly centered around the pre-development phase. The pre-development phase information sharing consists of scheduling, agreeing on the deliverables, technical requirements and the regulatory standards. For efficiency, a face-2-face meeting is suggested, so that each partner can effectively communicate their needs. Scheduling is somewhat self-explanatory; the buyer and supplier agree upon a delivery date for the product along with any on-site visits. The scheduling can also set dates for the rest of the in-person meetings and when documentation should be handed over. The deliverables content refers to an information exchange regarding what exactly need to be delivered, it may be closely associated with the regulatory standards and technical requirements. If the development phase is long, weekly updates are suggested so that the buyer is sure that the supplier will meet the delivery date. Post development, a face-2-face meeting could be carried out if the product is complex. Here the buyer should confirm that the developed part meets the quality and performance requirements. During production, weekly status reports should be provided as for the development phase. Once production is complete and the product is delivered, material certificate should be emailed to the buyer. When the product is in place, installed or in use, in the market phase, information regarding future improvements and product performance should be shared in order to improve future buyer-supplier relations.

MODULE DESIGN SPECIALIST						
	Pre Development	**Development**	**Post Development**	**Production**	**Post Production**	**Market**
Frequency	Once	Weekly	Once	Weekly	Once	As needed
Direction	Bidirectional	Unidirectional	Unidirectional	Unidirectional	Unidirectional	
Modality	Face-2-Face	Email	Face-2-Face	Email	Email	Email
Content	Scheduling	Status reports	Quality Assurance	Status reports	Material certificates	Product performance
	Deliverables		Post development hand off			Future improvements
	Regulatory standards					
	Requirements and Interface document					

Figure 26: Suggested information sharing guideline for "module design specialist"

The information sharing guide for "module design specialist" is shown in Figure 26. It is similar to the "purchased design capacity". This is due to the arm's length nature of the involvement. The supplier is considered to have the know-how, and the buyer needs the technical expertise of the supplier to develop the products. The pre-development phase has added technical interface to the content, as the part or module is considered a critical component. Extra care is taken to ensure the interface and technical requirements are agreed on. A post development hand off meeting (often referred to as a stage gate or design review) should be conducted as the buyer and supplier should both ensure that the product meets the specifications.

DESIGN TEAM PARTNER						
	Pre Development	**Development**	**Post Development**	**Production**	**Post Production**	**Market**
Frequency	Once	Weekly	Once	Weekly	Once	As needed
Direction	Bidirectional	Unidirectional	Bidirectional	Unidirectional	Unidirectional	
Modality	Face-2-Face	Email	Face-2-Face	Email	Email	Email
Content	Scheduling	Status reports	Quality Assurance	Status reports	Reporting forms	Product performance
	Reporting forms	Updated reporting forms	Post development hand off		Material certificates	Future improvements
	End user requirements	CAD Model				
	Regulatory standards	Prototypes				
	Requirements and Interface document					

Figure 27: Suggested information sharing guideline for "design team partner".

The information sharing guide for the "design team partner", see Figure 27, requires more information sharing. The supplier has a high degree development risk. The supplier is part of a strategic decision by the buyer. While the supplier is responsible for less critical systems, the product is complex and requires a substantial amount of information sharing. The pre-development phase is like the "module design specialist", however the supplier and buyer must agree on module functions and performance. Reporting forms such as checklists and or FMEA need to be agreed upon. The inclusion of the three checklists; engineering drawing, materials and manufacturing feasibility are suggested, as they provide a high level of confidence without the large commitment of a FMEA. The product being developed is not part of the critical system of the project, therefore the FMEA may be neglected at this level. The development phase consists of more information sharing, CAD models, prototypes and updated reporting forms could be attached in the weekly status reports. If prototypes are used a face-2-face meeting may be better suited than an email. The post production phase requires that the final reporting documents be handed over to ensure that they are filled out and that they meet the agreed specifications.

SYSTEMS ARCHITECT						
	Pre Development	Development	Post Development	Production	Post Production	Market
Frequency	Once	Daily	Once	Weekly	Once	As needed
Direction	Bidirectional	Bidirectional	Bidirectional	Unidirectional	Unidirectional	
Modality	Face-2-Face	Email	Face-2-Face	Email	Email	Email
Content	Partnership assesment	Status reports	Quality Assurance	Status reports	Reporting forms	Product performance
	Scheduling	Updated reporting forms	Post development hand off	Updated control plan	Material certificates	Future improvements
	Reporting forms	CAD Model	Control plan	FMEA		
	FMEA	FMEA	FMEA			
	End user requirements	Prototypes				
	Team members					
	Regulatory standards					
	Requirements and Interface document					

Figure 28: Suggested information sharing guide for “systems architect”.

The “systems architect” information sharing guide, see Figure 28, is the most comprehensive. This is due the strategic decision of the buyer to involve the supplier’s know-how specialities into the project. During the pre-development phase the buyer and supplier should conduct a partnership assessment, both parties should asses their own abilities, priorities and business needs as well as the other parts ability to collaborate. Once the teams have established that a partnership is possible, team members for the development project should be considered, who is involve, what capacity, which roles and which phases they should contribute in. A FMEA team should be erected and a full FMEA (PFMEA and DFMEA) should be scheduled and carried out. The supplier and buyer may decide to have the development team in a common location so that the information may flow informally daily during the development phase. A control plan for the production phase should be planed as well.

A provision not discussed is the role of project leader, which is a research subject on to its own. This thesis will not delve deeper into the role of the project leader. However, the need for a project leader to monitor and make sure reporting documents are up to date is imperative, the documents including the information sharing guide needs an owner.

There may be many sources of error. The data may misrepresent the population. Firms that involve suppliers that also answered the survey may only be one subset of the population. Meaning that firms that involve supplier and choose not to reply to the survey may have the exact opposite opinion of the ones gathered. Furthermore, when handling data, one must cannot be certain that one is observing correlation or causation. Say we observe two events; A and B. We can plot these against each other in a scatter plot and find that there is a correlation. We cannot say however that because event A happened event B will happen or that event A is linked to event B directly. Underly factors may be in play, like a third event that is the root cause of A and B. The workshop group consisted of members with significant experience in development and supplier integration, but their projects are most likely run with a certain degree of uniformity, which also may lead to an overestimation of their input.

6 Conclusion

The survey questioned both companies that currently include suppliers and companies that did not involve suppliers. All survey respondents are involved in contract development. The research found that communication is an important factor when choosing to involve a supplier in development. Firms that have not involved suppliers, indicated that communication would be critical if they did decide to involve suppliers in the future. Firms not currently involving suppliers indicated that limitations on their own internal capacity would also be critical if they were to involve suppliers. Firms currently involving suppliers consider the experience of the supplier as well as cost important when choosing a which supplier to use. Based on these survey results and the findings in previous research, this thesis proposes a model for categorizing the role of the supplier in the development team. The categorization splits the role of the supplier into four groups. Firstly, a split of the type of project, between capacity and know-how. Secondly a split between the degree of development risk (low and high) which correspond to arm's-length involvement and strategic involvement. The four roles of the suppliers are (presented in Figure 22):

- "Purchased design capacity" (a capacity project with low degree of development risk),
- "Module design specialist" (know-how project and low degree of development risk),
- "Design team partner" (capacity project with high degree of development risk) and
- "Systems architect" (know-how project and high degree of development risk).

Research by Echtelt (2006) argues that the long term and short-term benefits must be considered to achieve a successful development process. Ragatz, Handfield og Scannell (1997) found a correlation between relationship structuring factors and asset allocation factors. The asset allocation factors are directly linked to the successful involvement of suppliers on the development team. While the relationship structuring factors improve the effect of the asset allocation factors. The factors are shown in Figure 23 for each categorization of supplier roles. They factors are organized so arm'-length development ("purchased design capacity" and "Module design specialist") have less long-term focus. The success factors also are organized in a way that the relationship structuring factors are more prevalent in the strategic involvement roles ("Design team member" and "Systems architect"). For all four roles the success factors; "specify functions and performance"," Coordinating development activities with suppliers" and "Formulate communication and information sharing guidelines" are included. The last one is of special interest as establishing and formulating information sharing guideline directly is connected to the relationship quality between buyer and supplier.

The theory in the literature found several tools and best-practice methods for involving suppliers in new product development. The Japanese model was the foundation, even though it wasn't formalized specifically. APQP formalized the American automaker's approach to the field, by including FMEA, checklist methods and control plans. The survey data showed mixed results as far as what best practice methods were considered relevant, however the tools of APQP were found to be considered relevant, especially the checklist methods and FMEA. This shows that although firms involving suppliers did not consider APQP relevant, the methods employed inside APQP were. The thesis proposes an information sharing guidelines for each of the supplier roles found. The input for these guidelines is based on the survey data. The guidelines are shown in Figure 25 to Figure 28.

A workshop, consisting of the author and 4 experts in the field of supplier involvement and product development discussed the findings of the survey, the proposed roles of suppliers in development teams and the success factors. The workshop group provided feedback on all work done and proposed some additional input. The workshop group considered physical information sharing to be an important tool in development projects. Physical information consists of prototypes, design sketches and mock-ups. The workshop group also suggested a partnership assessment prior to involving any supplier. The goal of a partnership assessment is for both the supplier and buyer to asses if they consider the each other to compatible as far as project execution, capacity and technological aptitude. The information sharing guidelines provide a suggested plan for information sharing across the six stages of development (Figure 24), for each of the roles a supplier can have a development project. This will formalize the expectations between buyer and supplier, which will increase trust and commitment between the buyer and supplier. The formalization will also minimize oversharing of information and lead to better coordination.

This thesis provides a new approach to considering the role of a supplier in a development team. The degree of development risk and type of project will identify the role of the supplier. The project also applies supplier involvement in product development theory to contract development. The thesis proposes information sharing guidelines based on the role of the supplier in the development. This provides an approach for information sharing along with success factors that will increase the performance of supplier involvement in contract development.

6.1 Limitations

The survey data only provides results from companies that do contract development, the framework of this thesis is not known to be valid for off-line development when supplier involvement in development is done. Furthermore, the respondents to the survey are all companies based in Norway, therefore geographical preferences may occur if applied to other countries.

6.2 Further work

Further work in the subject should be done to ascertain if the results of are valid worldwide. A larger survey, with a more diverse respondent group across several sectors and in different geographical locations is also suggested. Furthermore, case studies of the four supplier-buyer relationships would give a greater insight into the success factors of each level shown in Figure 23.

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8 Bibliography

Alderman, Neil, Alfred Thwaites, og David Maffin. 2001. «PROJECT-LEVEL INFLUENCES ON THE MANAGEMENT AND ORGANISATION OF PRODUCT DEVELOPMENT IN ENGINEERING.» *International Journal of Innovation Management* 05 (04): 517-542. Funnet 1 5, 2019. http://worldscientific.com/doi/abs/10.1142/s1363919601000476.

Araz, Ceyhun , og Irem Ozkarahan. 2005. «Supplier evaluation and management system for strategic sourcing based on a new multicriteria sorting procedure.» *International Journal of Production Economics*, April: 585-606.

Bidault, Francis, Charles Despres, og Christina Butler. 1998. «The drivers of cooperation between buyers and suppliers for product innovation.» *Research Policy* 26 (7): 719-732. Funnet 12 17, 2018. https://sciencedirect.com/science/article/pii/s0048733397000346.

Bonaccorsi, Andrea, og Andrea Lipparini. 1994. «Strategic Partnerships in New Product Development: an Italian Case Study.» *Journal of Product Innovation Management* 11 (2): 134-145. Funnet 12 17, 2018. https://sciencedirect.com/science/article/pii/0737678294900612.

Bryman, Alan, og Emma Bell. 2015. *Business research methods.* Fourth. Oxford: Oxford University Press. Funnet 12 17, 2018. https://www.worldcat.org/oclc/746155102.

Carbone, Thomas A. 2005. «Integrating operations and product development methodologies for improved product success using advanced product quality planning.» Munich, Germany: Advanced Semicondutor Manufacturing Conference and Workshop.

Clark, Kim B. 1989. «Project scope and project performance: the effect of parts strategy and supplier involvement on product development.» *Management Science* 35 (10): 1247-1263. Funnet 12 17, 2018. https://pubsonline.informs.org/doi/abs/10.1287/mnsc.35.10.1247.

Corswant, Fredrik von, og Claes Tunälv. 2002. «Coordinating customers and proactive suppliers A case study of supplier collaboration in product development.» *Journal of Engineering and Technology Management* 19 (3): 249-261. Funnet 12 21, 2018. https://sciencedirect.com/science/article/pii/s0923474802000206.

Echtelt, Ferrie van, Finn Wynstra, Arjan A.J. van Weele, og Geert Duysters. 2006. «Managing Supplier Involvement in New Product Development: A Multiple-Case Study.» *ERIM report series research in management Erasmus Research Institute of Management.* Funnet 1 22, 2019. http://arjanvanweele.com/42/records/4/echtelt.wijnstra.vanweele.early supplier involvement.jpim.published version.doc.26022008.pdf.

Imai, Ken-ichi, Ikujiro Nonaka, og Hirotaka Takeuchi. 1985. *Managing the New Product Development Process: How Japanese Companies Learn and Unlearn.* Funnet 1 19, 2019. https://hbs.edu/faculty/pages/item.aspx?num=38735.

Johnsen, Thomas. 2009. «Supplier involvement in new product development and innovation: Taking stock and looking to the future.» *Journal of Purchasing and Supply Management* 15 (3): 187-197. Funnet 12 3, 2018. https://sciencedirect.com/science/article/pii/s1478409209000247.

Jonsson, Patrik, og Paulina Myrelid. 2016. «Supply chain information utilisation: conceptualisation and antecedents.» *International Journal of Operations & Production Management* 36 (12): 1769-1799. Funnet 12 30, 2018. http://emeraldinsight.com/doi/ref/10.1108/ijopm-11-2014-0554.

Kelley, David, og Tom Kelley. 2015. *Creative Confidence.* Crown Business. Funnet 1 12, 2019.

Melton, T. 2005. «The Benefits of Lean Manufacturing: What Lean Thinking has to Offer the Process Industries.» *Chemical Engineering Research & Design* 83 (6): 662-673. Funnet 1 31, 2019. https://sciencedirect.com/science/article/pii/s0263876205727465.

Mittal, Kapil, Dinesh Khanduja, og Prabhakar Kaushik. 2011. «Leveraging APQP methodology to drive improvement in SME: A case study.» *International journal of contemporary practices*, 38-51.

Petersen, Kenneth J., Robert B. Handfield, and Gary L. Ragatz. 2005. "Supplier integration into new product development: coordinating product, process and supply chain design." *Journal of Operations Management* 23 (3): 371-388. Accessed 12 17, 2018. https://sciencedirect.com/science/article/pii/s0272696304001056.

Ragatz, Gary L., Robert B. Handfield, og Kenneth J. Petersen. 2002. «Benefits associated with supplier integration into new product development under conditions of technology uncertainty.» *Journal of Business Research* 55 (5): 389-400. Funnet 12 17, 2018. https://sciencedirect.com/science/article/pii/s0148296300001582.

Ragatz, Gary L., Robert B. Handfield, og Thomas V. Scannell. 1997. «Success factors for integrating suppliers into new product development.» *Journal of Product Innovation Management* 14 (3): 190-202. Funnet 1 22, 2019. https://onlinelibrary.wiley.com/doi/abs/10.1111/1540-5885.1430190.

Schiele, Holger. 2010. «Early Supplier Integration: The Dual Role of Purchasing in New Product Development.» *R & D Management* 40 (2): 138-153. Funnet 12 3, 2018. http://onlinelibrary.wiley.com/doi/10.1111/j.1467-9310.2010.00602.x/abstract.

Sjoerdsma, Maarten, og Arjan J van Weele. 2015. «Managing supplier relationships in a new product development context.» *Journal of Purchasing and Supply Management*, 21.3. utg.: 192-203.

Stamatis, D H. 2018. *Advanced Product Quality Planning: The Road to Success.* CRC Press.

—. 1998. *Advanced Quality Planning: A Commonsense Guide to AQP and APQP.* New York: Productivity Press.

Staudenmayer, Nancy, Mary Tripsas, og Christoffer L Tucci. 2005. «Interfirm modularity and its implications for product development.» *Journal of Product Innovation Managment*, 303-321.

Teng, S. Gary, S. Michael Ho, Debra Shumar, og Paul C. Liu. 2006. «Implementing FMEA in a collaborative supply chain environment.» *International Journal of Quality & Reliability Management* 23 (2): 179-196. Funnet 12 17, 2018. https://emeraldinsight.com/doi/abs/10.1108/02656710610640943.

Teng, Sheng-Hsien, og Shin-Yann Ho. 1996. «Failure mode and effects analysis: an integrated approach for product design and process control.» *International journal of quality & reliability managment*, 8-26.

Thiam-Soon, Gan, and Martin Grunow. 2016. “Concurrent product and supply chain design: a literature review, an exploratory research framework and a process for modularity design.” *International Journal of computer Integrated Manufacturing*, 29 12: 1255-1271.

2018. *Trading economics.* 27 12. Funnet 2018. https://tradingeconomics.com/norway/labour-costs.

Wagner, Stephan M., og Martin Hoegl. 2006. «Involving suppliers in product development: Insights from R&D directors and project managers.» *Industrial Marketing Management* 35 (8): 936-943. Funnet 12 21, 2018. https://sciencedirect.com/science/article/pii/s0019850106000861.

Wang, Kung-Jeng. 2010. «Agent-based knowledge management system with APQP: implementation of semiconductor manufacturing services industry.» *International journal of Production Research*, 2913-2936.

Wynstra, Finn, Finn Wynstra, og Eric ten Pierick. 2000. «Managing supplier involvement in new product development : a portfolio approach.» *European Journal of Purchasing & Supply Management* 6 (1): 49-57. Funnet 12 21, 2018. https://sciencedirect.com/science/article/pii/s0969701299000350.

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