MASTER

Early supplier involvement in hightech new product development

a case study at ASML

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Early Supplier Involvement in high-tech New Product Development: A case study at ASML

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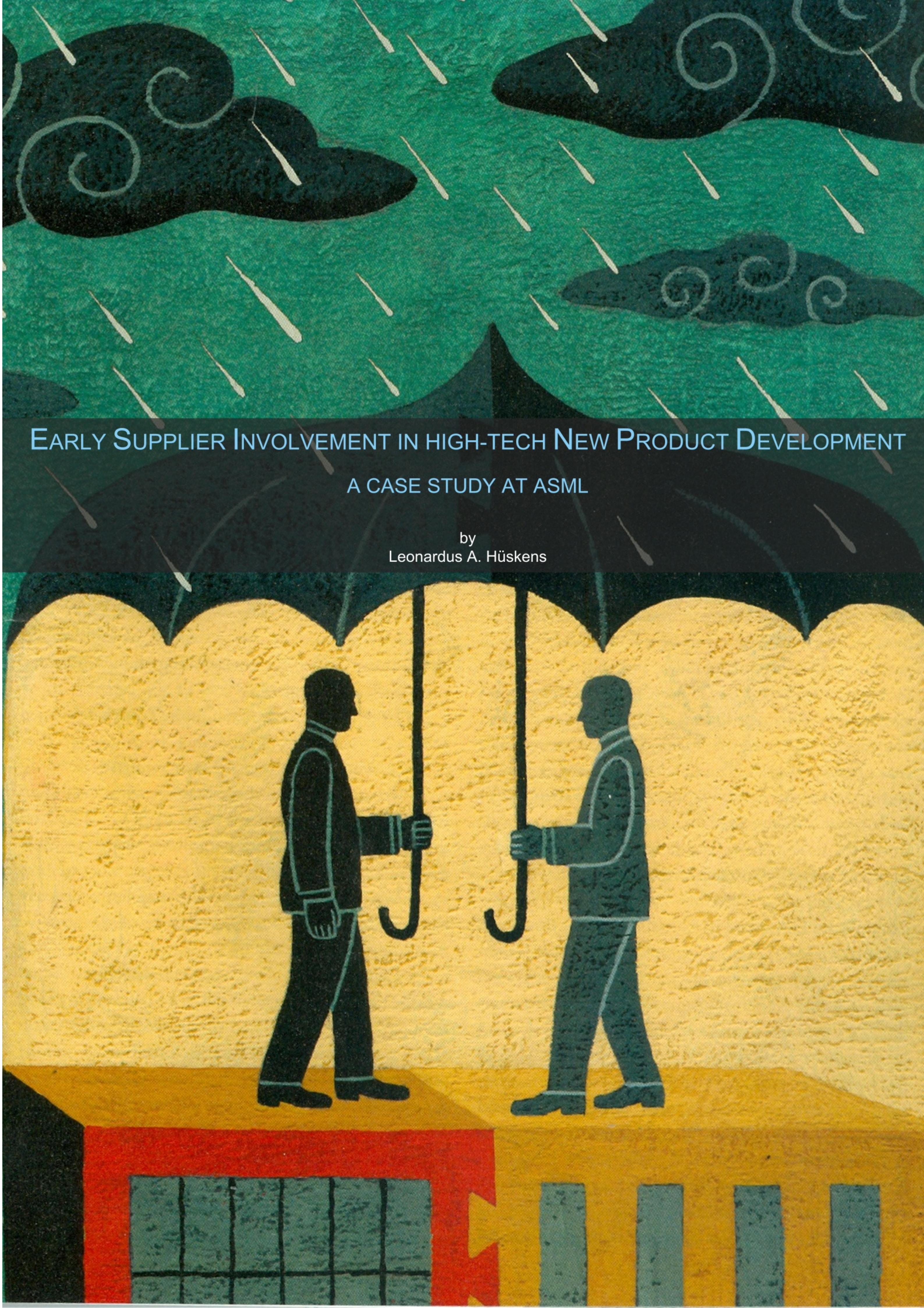

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Abstract

Purpose – Recent literature suggests that early supplier involvement (ESI) can contribute significantly to the competitiveness of companies. However, many companies face difficulties in benefitting from this strategy in new product development (NPD) processes. This thesis examines ESI practices in a high-tech company in the semiconductor industry (i.e. ASML), to understand the causes of these difficulties.
Design/methodology/approach – An in-depth field-based case study of ESI practices within ASML was conducted. We limited the relational set in our observation to one type of interaction (i.e. buyer-supplier) and to one particular occasion (i.e. the development of a new product). The observations were used to distil and analyze problems and issues encountered during ESI practices in four NPD projects. Possible solutions have been explored subsequently.
Findings – The results indicate that the level of modularity of design, technological uncertainty and supply risk are three determinants which have a specific role in ESI practices of companies acting in a high-tech industry. In addition, based on the results of both literature and the case study, a methodology is developed for the management of ESI in order to improve the performances in NPD projects.
Originality/value - This was the first study examining the practical implications of ESI in NPD projects with regard to a high-tech environment. So far, studies of ESI have predominately focused on NPD in low- and medium-tech industries. In addition, we developed a tool to manage ESI successfully in NPD projects, within the high-tech industry.
Keywords - Early Supplier Involvement, New Product Development, Project management

Preface

This thesis is the final deliverable of my study Innovation Management at Eindhoven University of Technology. The project took place at ASML Holding N.V. in Veldhoven, the Netherlands. Performing my graduation project at ASML placed me in the convenient position of conducting scientific research in a business environment.

The rapid rate of technological changes and the globalization of markets within the last decades have resulted in a renewed focus of companies on New Product Development (NPD) processes. Besides that, companies within technology-intensive industries, such as ASML, turn towards other companies in order to gain necessary technological know-how to compete, nowadays. Thereby, ASML creates a unique technology network of close partner companies, private research companies, universities and research institutions. Since NPD is the key element of ASML in obtaining and maintaining of a strong position in a growing competitive arena, the choice of conducting my master thesis at ASML regarding inter-company networks and collaborative relationships in NPD, follows consequently. The high standards and innovative technology of ASML result in unique situations, which are interesting to study, to say at least. During this project I developed a framework to analyze these unique situations. I also observed how companies like ASML face them, and simultaneously maintain their technological advantage in comparison to the competition.

This project could not have been completed without the help of certain people and therefore I would like to take this opportunity to thank those who have contributed, directly or indirectly, to this report, and made this period to an unforgettable and fulfilling experience. First, I would like to express my sincere gratitude to my primary supervisor at ASML ir. W. van Reeuwijk. You provided me with a wonderful environment to conduct this study and were always interested in the results. Furthermore, you gave me the freedom to follow my own path, which was sometimes not the one of most relevance for you. In addition, I would like to thank my primary supervisor dr. M.M.A.H. Cloodt, for all the time she spent on helping me, but also for her critics and comments. I also would like to thank dr.ir. K.E. van Oorschot for her advice in completing my internship. Your knowledge and experience, together with your advice and fresh ideas during our meetings inspired me to continue my research successfully. Furthermore, this study would not have been possible without the cooperation of the people and suppliers of ASML, who allowed me to collect the necessary data. In addition, the friendly employees of the ASML Supplier Engineering & Outsourcing department showed interest in my progress all the time. Your world of nanometric precision is absolutely amazing and fascinating, thank you for showing it to me. Moreover, I am grateful to my parents. Their vision, unlimited support and trust during the past have made me the person who I am right now. Last but not least, I want to thank my girlfriend Lindy for her general comments, recommendations, stimulating words and for just listening to me in stressful periods.

I had a great time and hopefully I can continue my professional career in the high-tech industry after completing my Master Degree. One thing that remains is to thank you for your interest in this report and to wish you a pleasant reading experience!

Niels Hüskens
Veldhoven, August 2010

Executive summary

INTRODUCTION - Within the last three decades, the rapid rate of technological change, shortened product lifecycles, and globalization of markets have resulted in renewed focus of companies on New Product Development (NPD) processes. Prior research has indicated that suppliers are an increasingly important resource for Original Equipment Manufacturers (OEMs) in these competitive markets. ASML cooperates with about 500 suppliers in developing its lithography systems, and that takes around 90% of the costs of a lithography system, leaving ASML with the task of integrating these modules and parts into the final tool. It became apparent that with the evolving customer requirements and the more complex lithography systems as a result, ASML is involving suppliers earlier (ESI) in the NPD process. Integrating suppliers early in NPD of ASML, enables the supplier to provide design suggestions or even be responsible for the design, engineering and development of the new product. This study is based on the premise that the actual results of ESI in NPD projects within ASML have been mixed and require a deeper understanding to the organizational and managerial aspects of this phenomenon in order to manage ESI in NPD projects successfully in the near future. Therefore, we investigated the following research question:

> *How can ASML improve its organization in order to manage early supplier involvement in NPD projects successfully?*

LITERATURE REVIEW – By an extensive review of literature, we obtained an overview of existing knowledge in terms of drivers, risks and key success determinants that influence effective ESI management between buyer and supplier. Two general drivers of ESI for short-and long-term benefits were identified. In addition, five risk factors and thirteen success factors of ESI were recognized (chapter 2). We highlighted work by Wynstra (1998), Monzcka *et al.* (2000) and Van Echtelt *et al.* (2008) in specific, because these authors take a broader view on inter-organizational management of ESI compared to other scholars. As a results of this literature review, we selected an existing, contingency based, analytical framework to analyze ESI practices in NPD projects of ASML. This framework focuses on contingency factors that may influence the NPD projects (inputs), the results of projects (outputs) and the critical processes underlying a NPD project (throughputs).

METHODOLOGY - The research design can be categorized as design-oriented and qualitative in nature. An in-depth field-based case study of ESI practices within ASML was conducted. We limited the relational set in our observation to the buyer-supplier interaction and to one particular occasion, i.e. the development of a new product. Five dyadic buyer-supplier relationships within four NPD projects of ASML (within three different functional disciplines; optical, mechanical and electrical) were studied retrospectively. Data was collected with the use of a questionnaire (based on the analytical framework), in-depth semi-structured interviews and internal documents. Descriptive statistics were use to analyze in depth the way in which ASML manages ESI in NPD projects. A root cause analysis was used to distil and analyze problems and issues encountered during ESI practices within the four NPD projects. This resulted in the final diagnosis. Recommendations for improvement were explored and summarized in a solution design. Furthermore, we developed three propositions based on the findings of this research.

FINDINGS - Our analytical and empirical work resulted in two main outcomes. The first outcome of this thesis is new in-depth knowledge and an integrated view on the critical conditions and processes for effectively managing ESI in NPD. The present study supported the proposition that ESI has a positive influence on short-term results such as 'product quality', 'part cost' and 'manufacturability'. However, we also found some negative influences of ESI on 'development costs' and 'time-to-market'. This concurs with previous findings that ESI does not speed up the overall product development time in turbulent changing industry segments and

that it increases development costs. Furthermore, a pattern of differences in the operational managerial process, project enablers and project drivers between successful and less successful projects was found. Intensive iterative communication webs and extensive evaluation sessions between the collaboration partners were likely to have a positive influence on the performance of ESI. As well as operational project enablers like 'supplier's capabilities' (project alignment and target cost) and 'geographical location', and intangible assets such as: 'experience in alliance' and 'matching cultures'. Concerning the driving factors, we found support that 'supplier dependency', 'manufacturing complexity' and 'technological uncertainty' have a negative influence on the success of ESI in NPD projects.

In addition, three determinants which have a specific role in ESI practices of high-tech environments were recognized. These are (1) *the level of modularity of design*, in which we have observed that projects with a low level of modularity of design were confronted with snowball effects by ECs of an external part that influenced the design of other parts, (2) *the level of uncertainty in technology,* which affected the time schedule and costs of the projects negatively and contributed to the inefficiency of ESI, and (3) *the level of supply risk*, which played an important role when analyzing the differences between highly and less innovative projects. We observed that the availability of capable suppliers in a high-tech environment is limited.

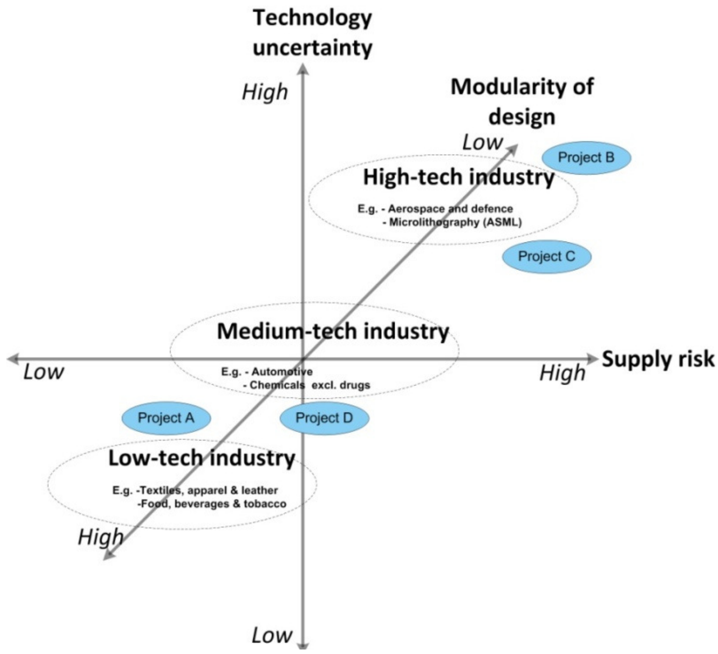


Figure I *Schematic overview of the coherence between modularity of design, supply risk and uncertainty within different industries*

In addition, the following three propositions were developed:

Proposition 1. A: In building blocks with a high level of modularity of design ESI has a positive impact on the efficiency and effectiveness of project performance.

B: In building blocks with a low level of modularity of design ESI has a negative impact on the efficiency and effectiveness of project performance.

Proposition 2. A: When the technology in a high-tech environment is new and its applications potential is still unknown, suppliers will be reserved in committing. As a result ESI will have a lower impact on NPD performance.
B: The high amount of technological uncertainty in high-tech industries leads to larger and inevitable information gaps between the buyer-supplier, which has a negative influence on the efficiency of ESI in NPD projects.

Proposition 3. Companies acting in a high-tech industry have to deal with less capable suppliers, which makes it difficult to integrate suppliers early in the development process.

DIAGNOSIS AND SOLUTION DESIGN - The second outcome of this thesis is the solution design to improve ASML's current organization regarding ESI management in NPD projects. Several problems occurred during the collaborations and led to ineffectiveness and inefficiency of ESI performances in these cases. The analysis of these issues showed that they can be reduced to four main areas of issues: *ASML's internal capabilities*, *supplier selection practices*, *supplier relationship management activities* and issues occurred by the specific *product characteristics* of a lithography system. These problems have impact on ESI practices in different stages of the projects. First, one of the key issues in regard of ASML's internal capabilities is related to the management on an ad hoc basis. The quality of project alignment capabilities of ASML is determined by individuals rather than on codified and formalized inter-organizational procedures, leading to a less systematic project approach. A lack of ownership of project targets within ASML resulted in conflicting objectives between internal functional areas of ASML, which delayed the projects also. Secondly, supplier selection issues were the result of the scarcity of capable suppliers in the supply chain of ASML. Thirdly, issues with regard to supplier relationship management result from cultural differences, communication noise between buyer-supplier project teams and the absence of a jointly evaluation process, which led to a mismatch of expectations about the desired behavior of stakeholders by both actors. Finally, the issues surrounding the specific product characteristics of a lithography system are a consequence of the architecture of a lithography system. The occurrence of excessive and often late engineering changes within one module creates a snowball effect of ECs from one component to another, resulting in additional iterations for proto types. Besides that, due to the large extent of technological uncertainty, a gap exists between the information already acquired by ASML, and the information needed to provide a supplier in order to perform its task. This lack of information makes it difficult for the supplier to complete its task, which resulted in project delays and exceeded budgets.

This diagnose enabled us to construct recommendations regarding the way in which ASML can improve its organization in order to manage ESI successfully in NPD projects, in the near future.

ASML should:

- *Implement a standardized operational management process for ESI activities.* This intervention makes ASML less dependent of individuals and strengthens the organization robustness in ESI performances.
- *Implement a risk assessment matrix for ESI practices in NPD project.* Developing a more explicit and systematic risk assessment, would help ASML to detect risks before they occur and would help to address them.
- *Create standardized communication interfaces between partners.* By introducing standardized communication interfaces ASML can facilitate communication and speed up design iterations.
- *Create strong ties with suppliers by establishing long term relationships.* Creating long-term and sound dyadic relationships will increase mutual trust and decrease cultural differences, which will reduce relational stress and create commitment.
- *Reduce the design margin for suppliers.* By recognizing and exploiting secondary properties of one building block, neighbor component elements can be eliminated from the design, which makes the individual building block of a project less vulnerable to 'external' ECs.
- *Implement joint evaluation sessions and feedback loops.* Implementing joint evaluation sessions and feedback loops creates learning opportunities, by which recurrence of problems can be avoided.

The recommendations above indicate that successful ESI practices should be well prepared by identification of, and anticipation on risks. Besides that, an organization needs to be tailored to support the NPD projects. These recommendations have been incorporated into a solution design. It fulfills the need for a pro-active and systematic approach of managing ESI, by proposing a stepwise ESI framework consisting of a planning, execution and evaluation phase.

Contents

List of figures, tables and abbreviations

Abbreviations

1st tier supplier	Supplier that delivers products directly to ASML
2nd tier supplier	Suppliers that delivers products to a 1st tier supplier
D&E	Development & Engineering department within ASML
ESI	Early Supplier Involvement
EC	Engineering Change
IE	Industrial Engineering, sub sector within ASML
IP	Intellectual proprietary
IPDS	Integrated Product Development and Sourcing framework
M&P	Manufacturing & Planning department within ASML
NGL	Next Generation Lithography
NPL	New Product Logistics
NPD	New Product Development
OMP	Operational Management Process
OEM	Original Equipment Manufacturer
PAM	Procurement Account Manager
PL	Project Leader
PFT	Product Family Team
PGP	Product Generation Process
QLTC	Performance Management evaluates the areas of the Supply Chain for: Quality, Logistics, Technology and Cost, covering the entire Product Lifecycle
RAMS	Reliability, Availability, Manufacturability, and Serviceability
RCA	Root Cause Analysis
R&D	Research and Development
SAT	Supplier Account Team
SCM	Supply Chain Management department within ASML
SEO	Supply Engineering & Outsourcing department within ASML
TPD	Technical Product Documentation, encompasses all information needed to create a product
TSM	Technical Supply Manager

Chapter 1
Introduction and problem statement

"It takes all the running you can do just to keep in the same place."
- Lewis Carroll, 1865

The quote at the start of this chapter refers to the Red Queen's race in Lewis Carroll's novel '*Through the Looking-Glass*'. The red queen was forced to run constantly across the chess board, in order to keep pace with the everlasting altering environment. In other words, you have to change in order to stay the same. Today's highly international competitive environment is comparable to the metaphor of Lewis Carroll. To maintain at the top, companies are binding to change continuously towards the market demands.

New product development (NPD) is considered to be an important factor for achieving sustainable competitive advantages (Brown & Eisenhardt, 1995; Eisenhardt & Trabrizi, 1995). In the last two decennia, two major forces increased the importance of product development for companies: (1) the increasing customer requirements; consumers become more sophisticated and demanding on tailored solutions of products that will completely fulfill their needs, and (2) the intensifying competition in which NPD is a tool by which companies can differentiate in their offering value from competitors (Wheelwright & Clark, 1992). The academic fields, as well as the practitioners, are continuously seeking for new methods and practices that will led to improvement of the organization and management of NPD processes. Since technological development becomes more multidisciplinary and dynamic, instead of relying on internal R&D, companies in technology-intensive industries are turning towards other companies to gain necessary technological know-how to compete. As more and more companies are outsourcing parts of their NPD activities to suppliers, it is not surprising to find out that research into how to manage supplier involvement in NPD and innovation has greatly expanded during the last thirty years (e.g. Clark, 1989; Hagedoorn, 2002; Johnsen, 2009). Earlier and more extensive involvement of suppliers in product development is brought forward to improve product development performances in terms of productivity, speed and product quality. It could also be a source of critical technologies and innovation (Henke & Zhang, 2010). Nevertheless, integrating suppliers early in de the product development process does not guarantee companies to improve their performances (Eisenhardt & Trabrizi, 1995; Koufteros *et al.*, 2007). Such a collaboration will denote a significant shift in the traditional buyer-supplier relationships and will also require more innovative business models (Van Weele, 2008). But, how should these business models look like? And, if there is already one business model that meets all demands, which determinants play a crucial role in that particular model? This master thesis investigates the way in which inter-company collaboration, and in particular vertical collaboration between an Original Equipment Manufacturer (OEM) and its suppliers, can be used to amplify the OEM's capability to develop new products. It aims to improve our understanding of how companies can manage collaborative innovation and product development processes with their suppliers in order to improve their business performance. In a wider perspective, this thesis intends to contribute to the theory on inter-organizational relations by focusing on the internal management and organization of buyer-supplier collaborations projects in a high-tech NPD environment.

In this chapter we will look at the main shortcomings of previous research. Based on the nature of the research objective, the research environment will also be described. After that, the problem and its context are addressed. Based upon this, the central research question and sub research questions are formulated. Finally, the research phases and methods used during this study will be discussed.

1.1 Previous research

Supplier involvement has been identified as a separate research topic in the late 1980s. The first academic reference about supplier involvement in a NPD environment was in a chapter in a book, entitled: 'the uneasy Alliance: Managing the Productivity-Technology Dilemma', (Imai *et al.*, 1985). It described the commitment of dedicated supplier networks to the so-called lead manufacturers. The authors explained the superior performance of the Japanese companies by their extensive supplier involvement in NPD projects. When searching in literature of innovation processes in industries, it becomes clear that companies do not innovate in isolation (Gilsing, 2003). Recent studies suggested that project innovations can be introduced faster, better and cheaper on the market, when the process of product development is done in cooperation with suppliers; also called inter-organizational collaboration. Much has been written about inter-organizational collaboration, Early Supplier Involvement (ESI) in NPD process of companies and similar constructs. As a result the topic has become more mature in terms of research methods as well as in an industrial and regional context (Johnsen, 2009). However, after years of analyzing supplier working relations in several technology-intensive industries and proposing theoretical concepts of how to transfer innovation from the suppliers towards the customers, it is still very complex to actually make the transferring happen in practice (Henke & Zhang, 2010). Hence, up till now, several questions remain.

First, despite the apparent benefits of ESI in NPD, previous research revealed incoherent results. Some empirical studies found not any relationship repeatedly, or even showed negative effects of ESI on key performance outcomes (e.g. Birou, 1994; Hartley, 1994; Eisenhardt & Trabrizi, 1995; Koufteros *et al.*, 2007). However, other empirical studies, found positive outcomes (e.g. Ragatz *et al.*, 1997; Primo & Amundson, 2002; Van Echtelt *et al.*, 2008; Henke & Zhang, 2010), see also Table 1. These mixed results could imply that ESI as a successful strategy depends on specific contextual factors. As outlined in the literature, technology uncertainty and complexity appear to have a major influence on project success (Eisenhardt & Trabrizi, 1995), particularly when suppliers have a major input in the design process. Secondly, Johnson (2009) mentioned that present research results are dominantly gathered in major studies which were carried out by the automotive and electronics industries. However, these industries are characterized by less variety of products and a high-volume, in contrast to the industries that operate in a high-tech environment, which are characterized with high variety of products and lower volumes (e.g. OEM's operating in the semiconductor industry like ASML).

Table 1. *Cases against and in favor of ESI*

Cases against ESI	Cases in favor of ESI
Survey of 79 companies in electro-mechanical industry (Hartley, 1994) ✓ no reduction in product cost; ✓ no better product; and ✓ no reduced cycle time	Survey 60 companies in electro-mechanical industry (Ragatz *et al.*, 1997) ✓ most significant improvements in product quality and cycle time
Survey 83 projects in automobile, electronics and medical industry (Birou, 1994) ✓ higher product and development cost; ✓ sometimes worse product quality and often longer time-to-market.	Survey of 38 projects in electronics industry (Primo & Amundson, 2002) ✓ improvement product quality.
Survey of 72 projects in computer industry (Eisenhardt & Trabrizi, 1995) ✓ supplier involvement does not improve product quality nor cycle time in turbulent changing industry segments.	8 projects in the printing industry (Van Echtelt *et al.* 2004, 2007, 2008) ✓ improvement in development cycle time; ✓ reduction in part development costs; and ✓ improvement part technical performance

Hence, the problems in relation to ESI may differ a lot between these two industries, being some problems described in literature of no relevance for the high-tech industry. Finally, most of the research in the area of ESI focuses on the (dis)advantages of and sometimes the barriers to ESI (e.g. Primo & Amundson, 2002; Johnsen, 2009). Only a smaller part is concerned with how the management of ESI takes place (e.g. Fliess & Becker, 2006; Jiao *et al.*, 2006). But most companies already know how they do it and why they do it, they just want to know how they should work in such a way to maximize the benefits of it. So, concluding that most shortcomings in literature are not technical but organizational in nature, conducting research from a managerial dimension would be most valuable in contributing to further understanding of this emerging phenomenon. In other words, how can companies successfully manage collaborative innovation and product development processes with their suppliers in order to improve their business performances?

A first attempt to help bridge these gaps is undertaken by conducting an in-depth case study within ASML, an OEM operating in the semiconductor industry. As a consequence of the increasing global competition, accelerating technology changes and growing customer expectations, companies in the semiconductor industry have to develop capabilities to deal with these factors, as a result of the time-based competitions. ASML is aware of these threats and argues that ESI is becoming more important to keep up with technological developments. In the next section a brief sketch of ASML and its challenges in meeting these industrial dynamics is given. Moreover, the design of the research within ASML will be introduced in order to define the problem statement and the research questions.

1.2 Research Environment: Background and Motives

Advanced Semi-conductors Manufacturing Lithography (ASML) is the world's leading provider of lithography systems, with a market share by revenue of 67% in 2009. Founded in the Netherlands in 1984, the company is publicly traded on Euro next Amsterdam and NASDAQ under the symbol ASML. Customers are located in more than 60 locations divided over 15 countries in Asia, Europe and the United States. ASML's main competitors are the Japanese companies Nikon and Canon. The current installed base is more than 3,000 systems; including steppers and scanners. In the year 2009 the company realized net sales of 1,596 million Euros. Table 2 shows some of the key performance indicators of ASML concerning the last three years. ASML designs, develops, integrates, markets and services advanced lithography systems. These systems facilitate their customers, being the major global semiconductor manufacturers, to create chips that power a wide array of electronic, communication and information technology products. ASML technology transfers circuit patterns onto silicon wafers in order to create integrated circuits (ICs), graphically this process is depicted in Appendix A.

Table 2. *ASML key performance indicators (Annual report, 2009a)*

Year ended December 31 (in millions, except market share and systems)	**2007** EUR	**2008** EUR	**2009** EUR
Net sales	3,768	2,954	1,596
Cost of sales	2,218	1,938	1,137
Net income (loss)	671	322	(151)
Market share (based on revenue)	65%	65%	67%
Sales of systems (in units)	260	151	70
Number of payroll employees in FTEs	6,582	6,930	6,548
Number of partnerships with universities, colleges and schools	9	16	21

Technology is central in making ICs smaller, faster and cheaper. ASML's technology is known as optical lithography. ASML systems are called Step & Scan systems (steppers and scanners, see also Appendix A). It uses a photographic process to image nanometric circuit patterns onto a silicon wafer, much like a traditional camera prints an image on film. ASML's mission is to *'provide leading edge imaging solutions to continuously improve our customers' global competitiveness'*. To succeed in its mission, ASML keeps up that all its activities must stem from its core values: Quality, Integrity, Trust, Continuity, Excellence and Professionalism.

1.2.1 Organization architecture

ASML's corporate headquarters is situated in Veldhoven, The Netherlands. Manufacturing sites and R&D facilities are located in Connecticut (USA), California (USA) and The Netherlands. Furthermore, the technology development centers and training facilities are found in Japan, Korea, The Netherlands, Taiwan and the United States. In total it employs approximately 7000 employees. On a high aggregate level ASML is divided into departments that belong to *product*, *operations* and *market* or *corporate support* related functions, as shown in Figure 1.

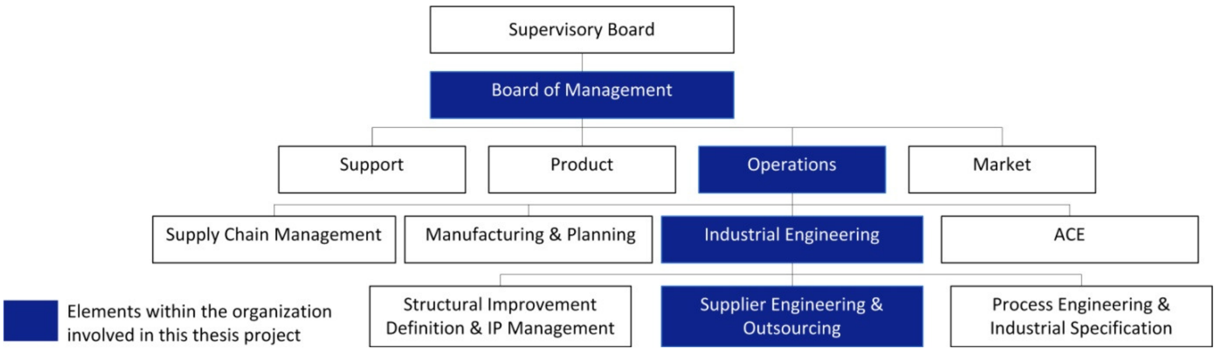


Figure 1. *Organizational chart ASML (ASML, 2010)*

This master thesis project is initiated by the department Supplier Engineering & Outsourcing (SEO). SEO was formed in 2005, in order to improve the control over suppliers. In this way high quality of the delivered parts should be ensured. The main activities of SEO are managing NPD projects with suppliers on the short term and supplier development on the long term. SEO is part of the sector Industrial Engineering (IE), which aims to increase product and process robustness within ASML by providing strong support in new product introduction (NPI) projects. IE is responsible for the technical management of suppliers and manages industrial competencies and structural issue resolution (ASML, 2009).

1.2.2 ASML Innovation challenge

New Product Development (NPD) is the key element of ASML in obtaining and maintaining a strong position in a growing competitive arena. The semiconductor market is highly competitive in terms of time-to-market (i.e. the time frame in which a new product is developed, manufactured and introduced to the market), compared with other industries. Gordon Moore, co-founder of INTEL, predicted that the chip density and hence the calculating capacity, will double every eighteen months, also known as 'Moore's law[1]'. The lithography technology is one of the main innovation drivers that accelerated this trend. ASML strongly focuses on innovation, investing around 18.23% of its annual turnover in research and development (R&D). The semiconductor industry is often described as a highly cyclic market with an enormous pressure on innovation. As a result, ASML is one of the most innovative organizations in the Netherlands. The International Property Owners association (IPO) listed the 300 organizations that were established with the most patents, by the U.S. Patent and Trademark Office in 2008. ASML granted 271 patents in 2008 and was listed as number 70 in the list of 300 organizations that granted the most patents in 2008 (IPO, 2008). Other Dutch organizations on this list were DSM, NXP, Philips and Unilever, as can be seen in Table 3. The data in this table indicates ASML to be a highly innovative organization.

Table 3. *Measures of innovation* in 2008 (IPO, 2008; Annual reports ASML, DSM, NXP, Philips and Unilever)*

Dutch organizations on IPO list	IPO ranking	Patents granted by US Patent and Trademark Office	R&D spending (million €)	R&D spending as percentage of turnover
ASML	70th	271	538	18.23
DSM	299th	55	394	4.24
NXP	103th	103	899	21.03
Philips	31st	584	1,622	6.15
Unilever	285th	60	927	2.29

*Measures of innovation include: the number of patents, R&D expenditures and the R&D expenses as a percentage of the turnover.

To this day, Moore's law has been accepted and chased by the entire semiconductor industry. Therefore, customers of ASML are assured that ASML is able to develop and offer the next generation of lithography (NGL) systems in time. Meeting Moore's law implies that the lithography systems as developed and produced by ASML, will become more and more complex every cycle. To be competitive in the global market, organizations must continuously develop innovative and high quality products and services, plus deliver them on time and at a lower cost as their competitors. As a result the production of semiconductors has developed into one of the pivotal industries for advanced capitalist economies (Sydow *et al.,* 2004, p. 1). The present systems of optical lithography face already their technological and commercial limits. Hence, there is a call for a next generation of production technologies. In order to meet Moore's law, this will lead to a break away from the current technological path sooner or later. Breaking with the current technological path is only possible if an alternative technology is developed into a whole new supply chain, feasible for large-scale production of more powerful chips (Sydow *et al.*, 2004).

1.3 Problem Statement

Time-to-Market is an iron law for ASML. As COO Frederic Schneider-Maunoury mentioned:

> "ASML has been incredibly successful, and this was due to one very visible and unique engine: the leadership in Time-to-Market."

Early market entry is critical since a company will maximize the time window during which profits can be reaped. If a company fails to speed up NPD, it may miss the boat and possibly end up bankrupt (time-based competition). Consequently, a short time between development and manufacturing is crucial. Involving suppliers in NPD is one way of gaining strategic flexibility by means of reduced development time. Besides that quality might improve and access to innovative technologies is stock on hand. Thus, involving supplier in new product development can help ASML to gain capture market share. ASML cooperates with about 500 suppliers that take around 90% of the costs of a lithography system, leaving ASML with the task of integrating

[1] Note that Moore's law is not a physical law but instead it is a paradigm within the semiconductor industry. As long as every stakeholder in the industry commit to this rule it will remain the standard.

these modules and parts into the final tool. NPD is the key element of ASML in obtaining and maintaining of a strong position in a growing competitive arena.

In the design of new products, ASML has to deal with lots of designers in and outside the company. As a consequence, overlapping in design stages, due to the concurrent engineering structure, is almost inevitable. This automatically leads to increasing risks, in terms of delayed market entrance, due to rework because of changes in the product design. The present ASML business model leverages technology leadership to deliver industry-leading innovation and quality to its global customers, with the goal of being the time-to-market leader in the market in which it participates. In order to stay at this position and even reinforce it, ASML needs a better empirical understanding of the critical processes and conditions for effective ESI. This allows ASML to achieve their short-term product development targets and strengthen their ability to improve the performances of future projects.

ASML desires more design work to be done by suppliers, in order to achieve:

- shorter project development lead times;
- improved perceived product quality (first time right);
- better manufacturability of new product design;
- improvement of the flexibility: a greater development and production flexibility to accommodate demand variations; and
- better leverage of supplier's technical capabilities and expertise.

ASML has the aspiration to increase early supplier involvement activities in the *feasibility*-, *requirements*-, and *design* phases of NPD. This will increase contribution of the suppliers in *(1)* design activities, *(2)* tooling activities, and *(3)* increasing the alignment of technology roadmaps.
Over the past years ASML experienced incoherent results of their NPD projects where ESI has taken place. Some projects found not any relationship repeatedly or even showed negative effects of ESI on NPD project performances. Because of these mixed results ASML has the desire to better understand why one project succeeds and the others not. For successfully involving suppliers in the design phase of new products, ASML needs to get more insight into the critical success factors for ESI, by which ASML can increase the controllability of the processes of development, logistics and production. These critical success factors which influence the ESI process need to be identified (conceptualization). After identifying the factors, there is a need to locate relationships between several factors, including previous experience, in order to validate these factors and the way in which they influence the ESI process of ASML (by means of a case study).

The aim of this study is to develop a framework that identifies the objectives, critical managerial activities and conditions for effectively leveraging supplier capabilities in product development, in such a way that the short and long-term objectives of ASML can be realized. Therefore, this master thesis project will answer the following research question:

How can ASML improve its organization in order to manage early supplier involvement in NPD projects successfully?

Graphically, this is depicted in Figure 2.

Figure 2. *Main research question*

1.4 Research Questions

In order to answer the central research question a set of more specific research questions need to be answered first (Verschuren, 1991). These questions have to be broad enough to enable freedom in the depth of investigation (Corbin & Strauss, 2008).

1. *By integrating the existing literature, the following questions will be answered:*
   a. What is early supplier involvement in NPD?
   b. What are the main factors that affect early supplier involvement performance?
   c. When is the organization of early supplier involvement in NPD projects successful?

2. *By collecting and analyzing empirical evidence, the following question will be answered:*
   a. How does ASML manage early supplier involvement in the current situation?

3. *By comparing and combining the findings from the literature and the empirical study, the following questions will be answered:*
   a. Which aspects are important in organizing early supplier involvement in NPD projects in a successful manner?
   b. Which aspects are unimportant in organizing early supplier involvement in NPD projects in a successful manner?
   c. In which way should these aspects be organized at ASML in order to setup a best practice of managing early supplier involvement in NPD projects?

1.5 Research design

A critical element in constructing a research is the choice of the research approach. Van Aken (2005) distinguished organizational science in an *empirical approach* and a *design approach*. The empirical approach refers to a quest for truth by developing knowledge aimed at the classical triplet of description, explanation and prediction (Denyer *et al.*, 2008). The empirical approach aims to answer the central question, '*how do organizations work in practice'.* Such an approach is based on following the steps of the empirical cycle. It is purely descriptive, explanatory, and mono-disciplinary. Van Aken (2005) argued that a purely empirical approach is not of practical relevance since these general theories are often not applicable to specific field problems. Therefore, he supported the development of a management theory, focusing on solution-oriented knowledge using a design approach. The paradigm of the design approach was initially founded by Simon (Simon, 1996). It compromises a search for improving the human conditions by developing knowledge to solve field problems, i.e. problematic situations in reality (Denyer *et al.*, 2008). The design approach aims to answer the normative design question, '*how should organizations work'.*

Considering the problem statement of the previous section (1.3), this approach can be largely characterized as design-oriented and qualitative in nature. Boland and Collopy (2004) already mentioned that manager's professional responsibility is not to discover the laws of the universe, but to act responsible in the world to transform existing situations into more preferred ones (p. 8). This is also driven by the novelty and the way in which interest in and knowledge on the topic of ESI initially emerged. Supplier involvement was first considered to be a practical phenomenon, which could contribute to the improvement of organizational performance. Yet, the mixed results of some empirical studies and the increase of anecdotal evidence indicate that our knowledge of this phenomenon is still limited. Moreover, companies (like ASML) are struggling with different complex managerial and organizational decisions in order to benefit from ESI (Van Echtelt, 2004, p. 19). So, the challenge of this study is to design and carry out a more substantial study, including both the empirical and design approach, to both theorize and design guidelines which are helpful for the design and management of organizational processes.

1.5.1 Research methodology

Figure 3 shows a schematic representation of the research design in terms of its cycles and chosen research strategies and methods. In this study the regulative cycle by Van Strien (1997) was chosen as a research strategy to conduct the case study. Since, Van Aken (2005; 2007) proposed the reflective cycle as an appropriate approach to develop scientific knowledge in combination with finding relevant solutions for a practical problem, this methodology was used to analyze the results and come to a conclusion. The product of the reflective cycle is the *technology,* respectively; the solution concept. It can be defined as "a chunk of general knowledge linking an intervention or artifact with an expected outcome or performance in a certain field of application" (Van Aken, 2005, p. 23). In this project a best practice of managing ESI in NPD projects. Its value lies in the fact that it makes general knowledge relevant to the extent that the rule[2] provides guidelines or prescribes how to translate knowledge to a specific context. The circular structure of the model indicates that the process is not a linear sequence of research activities. Reflection and the need for adaptations gradually emerge, based on various 'mini cycles' of data collection, literature reviewing and reflection. The first two steps of the cycle, as proposed by Van Strien, aimed to identify the business problem, which should be put in the context of several related problems. In the analysis and diagnosis phase the business process was investigated and the current business process, including the current supplier involvement performance, has been analyzed with use of a predefined framework (**Figure 7**). This framework is one of the results of the preceding literature review, which was conducted during the research. Gathered knowledge is also used to formulate propositions for the analysis. One of the propositions includes that if a product development project with ESI is executed following the framework, the project is likely to be successful and this success is influenced by several determinants. According to Yin (2003), such propositions guide the research and "direct the attention to something that should be examined within the scope of the study". In this analysis and diagnosis phase, both a qualitative empirical and theoretical analysis of the current supplier involvement process was conducted. According to Van Aken *et al.* (2007) qualitative analyses are appropriate when the research is aiming to discover the qualities of unknown determinants.

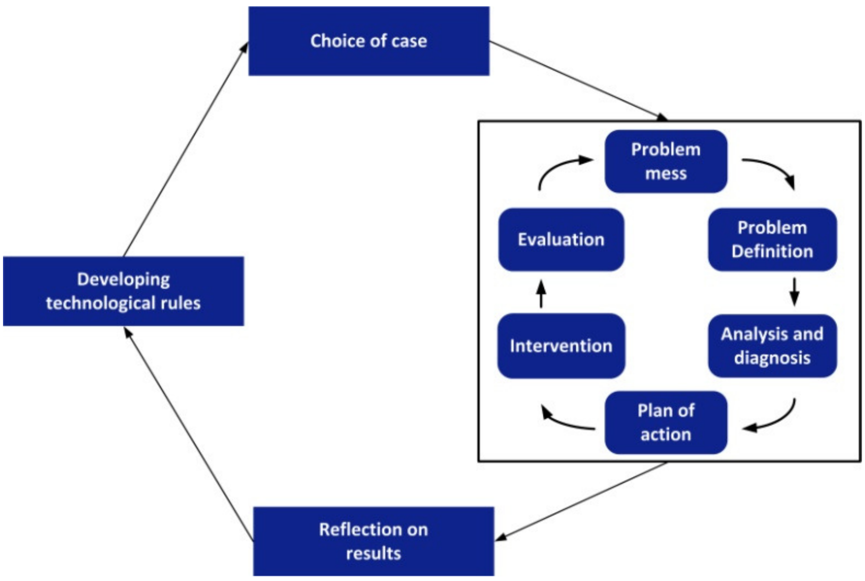


Figure 3. *The reflective cycle (Van Aken, 2004) in combination with the regulative cycle (Van Strien, 1997)*

As, in this research the occurrence and causes of situations and events. The analysis consists of an empirical exploration and validation of these qualities: the business problem and the causes that have led to the occurrence of the problem. Furthermore, the initial problem statement was validated in the analysis step, to make sure that the problem was real and not based on perceptions (van Aken *et al.*, 2007). The problems in the business process have been explored by conducting multiple case studies. Multiple case studies are especially suited to develop technological rules (Van Aken, 2004). The resulting diagnosis and structure of the

[2] Technological rules are not universal laws, but are grounded in academic research and can serve as design exemplars for practitioners in the field (Van Aken, 2004).

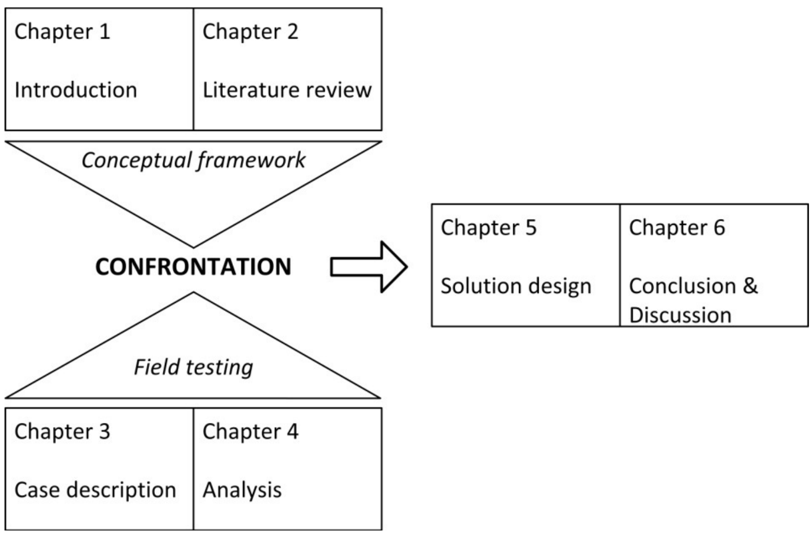
problem leaded to a plan of action to redesign the current ESI process in product development projects of ASML, in order to solve the problem. In the intervention[3] phase, a change plan was created to estimate the impact of the change in the current organization and determined the actions to be taken. In the final evaluation step, the impact of the change in the organization was evaluated. In summary, the master thesis project at ASML is divided into three phases:

1. *Orientation:* exploratory interviews, documentation consultation and case study selection;
2. *Analysis:* four case studies of ESI in NPD projects;
3. *Design:* definition of action research domain, redesign and reflection;

1.6 Outline of the thesis

The remainder of this thesis is structured as follows. Answers on research questions 1a-c are formulated in the next chapter. Knowledge on ESI in NPD, as gathered during the literature study, is used in order to come to these answers. It also presents a conceptual model that identifies the objectives, critical managerial activities and conditions for effectively leveraging supplier capabilities in NPD. Chapter 3 describes the in-depth case studies, starting with the adopted research methodology and continuing with the actual description of four embedded cases of buyer-supplier collaborations at ASML. The results of the case studies are described in chapter 4, and answers research question 2a. Chapter 5 presents the results of the action research project at ASML, and includes a comparison of the conceptual framework and the results of the analysis. The action research results in the development of a methodology and guidelines for successfully carrying out ESI in NPD projects, and answers research questions 3 a-c. The final chapter gives an answer on the main research question and presents the final conclusions, limitations and recommendations for further research, it furthermore describes the contribution to practitioners.

Schematically:



[3] An intervention helps to test the framework based on the literature (Van Aken *et al. 2007)*.

Chapter 2
Exploring ESI in NPD: A literature review

2.1 Introduction

Esi got more and more attention as a topic of research during the last two decades. So, it will not be a surprise that the literature about ESI has been expanded greatly since the last twenty years. This chapter will highlight the key results and implications of the studies, as described in literature. It is mainly focused on the management of ESI in NPD. Before answering research questions 1a-b, the definitions as used in these questions will be formulated, in order to create an equal understanding of these definitions. Next, the drivers, risks and success factors of ESI will be enquired. This will result in an initial conceptual framework for analyzing ESI practices in the next chapter and will also lead to an answer of research question 1c.

2.2 Definitions

Several definitions of supplier involvement in NPD have been suggested in literature. Fundamentally it concerns *the integration of the capabilities that suppliers can contribute to NPD projects* (Dowlatshahi, 1998), *the tasks they are able to carry out on behalf of the customer, and the responsibilities they assume for the development of a part, process or service* (Van Echtelt *et al.*, 2008, p. 182). In the present study the definition of Van Echtelt *et al.* (2008, p. 182) will be used, since it emphasize on the management dimension of supplier involvement:

"*Supplier involvement refers to the resources (capabilities, investments, information, knowledge ideas) that suppliers provide, the tasks they carry out and the responsibilities they assume regarding the development of a part, process or service for the benefit of a buyer's current or future new product development projects.*"

Van Echtelt *et al.* (2008) referred to three elements in his definition. These three elements are: the *resources,* which can be provided by the suppliers, to the *tasks,* which can be carried out by the suppliers in order of the buying company and last, to the *responsibility* of the suppliers on behalf of the outsourced activity. By including the purpose of supplier involvement as a need of a company, and by recognition of the broadness of its activities, this definition will be the most suitable one. Hence, this definition will be used in the present study. Van Echtelt (2004) mentioned the importance of recognizing that supplier involvement concerns about the collaboration of two actors, namely (1) *the buyer* and (2) *the supplier*. In this study the buyer is defined as "any company, as long as it can be found at a stage in a specific supply chain where it depends on external companies for the delivery of products" (Van Echtelt, 2004, p. 28). The supplier is considered to be any company who provides goods or services (products) to a company or individual. Since this study is conducted in order of ASML, literature has been analyzed from the buyer's point of view. The domain of collaboration between the two actors is diminished to the NPD process only.

To describe NPD, the definition of Cooper is used in this study. As a prominent researcher in this field he described the *NPD process* as a "formal blueprint, roadmap, template, or thought process for driving a new product from the idea stage through to market launch and beyond" (Cooper, 1994, p3). The NPD process is usually presented as a process consisting of several sequential phases. For example, ASML NPD process consists of a: *Feasibility phase→ Requirement phase → Design phase → Proto phase → Pilot/Release for volume phase*, see also Figure 4. This study is in particular focused on the involvement of suppliers during these stages, and is therefore not focused on collaboration during the regular production nor in the basic and applied research, which are usually a pre stages of the NPD process. Since technological development has become more multidisciplinary and dynamic, instead of relying on internal R&D, companies in technology-intensive industries (like the semiconductor industry) are turning to other companies to gain necessary technological know-how to compete (Hagedoorn, 1993). So, collaboration with other companies is becoming an important source of getting access to knowledge, improving development speed and flexibility (Hagedoorn, 2002; Langerak & Hultink, 2008).

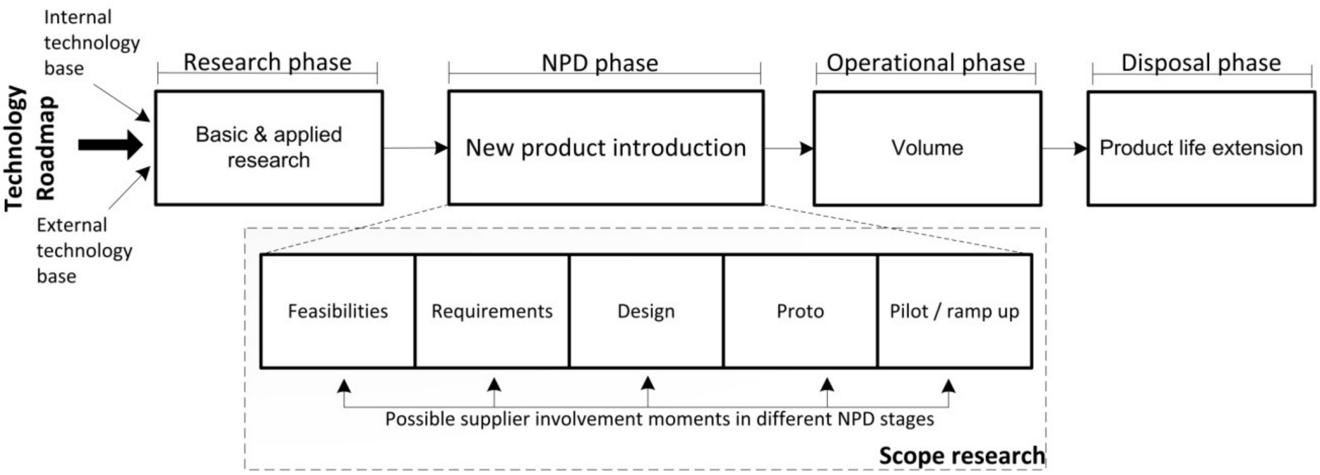
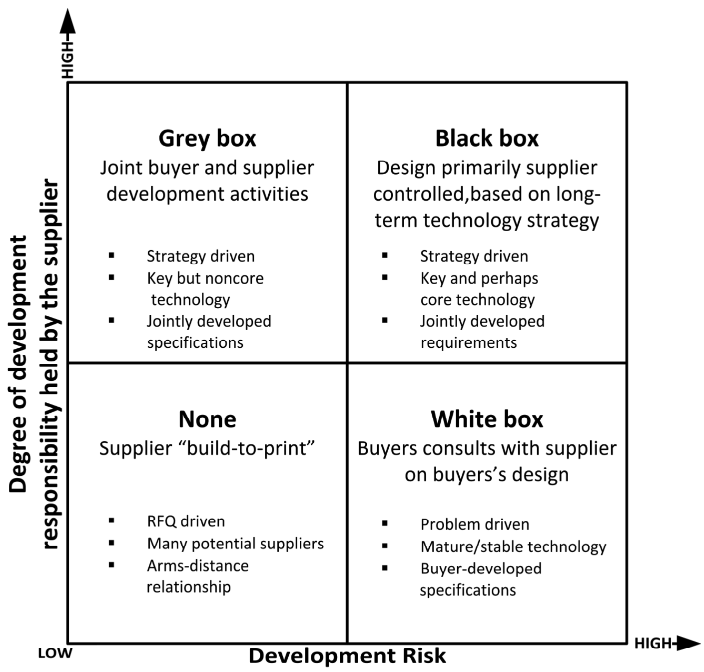


Figure 4. *Product evolution process of ASML*

There are two kinds of collaboration: (1) *horizontal collaboration* and (2) *vertical collaboration* forms. Horizontal collaboration refers to collaboration between two competitors or between companies in related or unrelated industries at the same stage of a supply chain (Dyer & Singh, 1998). There has been a substantial growth in various sectors regarding the use of relatively formal forms of horizontal inter-company collaboration. Such as strategic alliances in R&D (Hagedoorn, 2002). Basic thoughts are that companies which are flexible and able to move fast into new opportunities outperform less flexible firms due to the additional technological capabilities of the partnering company. Therefore, as a strategic response to this development, companies increasingly establish strategic alliances in the last century (De Man & Duysters, 2005). Horizontal strategic alliances in R&D have occurred particularly in those industries with high technology contents in their products, such as the semiconductor industry (e.g. the partnership of ASML with Zeiss).

Vertical collaboration on the other hand, refers to collaboration between two companies that act at different stages in a specific supply chain, in other words, collaboration between buyer and supplier (Van Echtelt, 2004). From a buyer's point of view, vertical collaboration means an increasing involvement of suppliers in its NPD process and in addition, to the manufacturing and logistics area. It also decreases a company's design cycle, as suppliers have more specialized capabilities based on more expertise and extensive technical knowledge in its specific area. Vice versa, suppliers are exposed to different customers, this generates ideas for improvements which can be used and transferred to several customers. Some studies (e.g. Bidault *et al.*, 1998) focused on the timing of supplier involvement, resulted in the concept of ESI. Integrating suppliers early in NPD, enables the supplier to provide design suggestions or even be given complete responsibility for the design, engineering and development of the new product. Involving suppliers early in the NPD process and using their skills and expertise in other, less formal, collaborative processes can reap great benefits for the buying company. These benefits include shortened NPD cycle times, lower cost and higher-quality end products (Henke & Zhang, 2010). Supplier influence in early design efforts is now regarded as a critical factor in the improved manufacturing designing (e.g. Swink, 1999). Several authors have addressed the role of the supplier in NPD; suppliers can be assigned for more or fewer activities in NPD. The level of a supplier's responsibility for the development of a component has also implications for the relationship between both parties. Several researchers proposed different levels of supplier integration, based on the degree of autonomy of the supplier and the development risk. Differentiation between several forms and phases of supplier involvement may help to set priorities in such a way that the involvement of suppliers becomes more manageable and economical. In literature, some more or less identical matrices are identified, to distinguish between four types of supplier involvement in NPD projects:

1. *None:* no supplier involvement during the design process "build to print";
2. *White box integration:* sources from suppliers based on technical specifications of buyer;
3. *Grey box integration:* involves co-development of engineers from the buyer and supplier; and
4. *Black box integration:* the highest level of integration design is primarily supplier driven, based on buyer's functional specifications.



The matrix distinguishes between four types of supplier involvement, based on two variables:

- *Degree of development responsibility*: the extent of involvement in NPD projects (e.g. the supplier only receives functional specifications versus almost complete blueprints)
- *Development risk:* the importance, newness and complexity of the development of a part/buildingblock.

Schematically represented in Figure 5.

Figure 5. *Spectrum of supplier integration (adapted from Handfield et al., 1999; Monczka et al., 2000; Petersen et al., 2005)*

2.3 Drivers, Risk and Success factors related to ESI

So far, a preliminary working definition of ESI and closely related items has been selected[4] first, in order to examine the current body of knowledge regarding the results of this phenomenon. ESI can be studied in terms of its drivers, risks and of its key success factors for NPD. These determinants in specific can encourage and enable organizations to take more advantage of the benefits associated with ESI in NPD. In the following sections these underlying explanatory aspects are reviewed.

2.3.1 Drivers of ESI

Driver factors are defined as those determinants in the environment, internal and external of a company working with suppliers, which encourage a company to involve suppliers early in their NPD process. Table 4 gives an overview of these potential driving factors, as described in previous research.

Table 4. *Drivers early supplier involvement mentioned in previous research*

Drivers	Source
Short-term drivers	
Shorter time-to-market	Imai *et al. (1985)*, Clark & Fujimoto (1991), Bonaccorsi & Lipparini (1994), Ragatz *et al.* (1997), Wynstra (1998), Monzcka *et al.* (2000), Mikkola & Skjoett-Larsen (2003), Van Echtelt *et al.* (2008), Langerak & Hultink (2008)
Improvement of product quality	Clark (1989), Ragatz *et al.* (1997), Wasti & Liker (1997b), Petersen *et al. (2005)*, Van Echtel *et al. (2008)*
Improvement of manufacturability	Dowlatshahi (1998), Swink (1999), Mikkola & Skjoett-Larsen (2003)
Reduced development and product cost	Burt (1989), Cusumano & Takeishi (1991), Wasti & Liker (1997a), Dowlatshahi (1998),Mikkola & Skjoett-Larsen (2003), Petersen *et al.* (2005)
Long-term drivers	
Alignment of technology roadmaps/strategies	Handfield *et al.* (1999), Monzcka *et al.* (2000), Van Echtelt *et al.* (2007, 2008)
Source of innovation	Imai *et al.* (1985), Takeuchi & Nonaka (1986), Von Hippel (1988), Dyer (2000), Monzcka *et al.* (2000), Koufteros *et al.* (2007), Johnson (2009), Henk & Zhang (2010)

The six drivers behind ESI, as defined in recent studies, are:

1. *Shorter time-to-market.* Studies by Langerak & Hultink and others amplified the thought that ESI can result in a reduction of development time. Development time is defined as the elapsed time from the start of an idea generation (when the company decided to develop a new product) till the market introduction (Langerak & Hultink, 2006, p. 204). When suppliers are included in the design process early, they can help to identify potential problems in time. For example, ESI can reduce the number of design changes of a NPD project by the early input about manufacturability and functional performance aspects. (Van Weele, 2008; Langerak & Hultink, 2008). In addition, ESI can be a source of 'extra' personnel to shorten the critical path for NPD projects (Clark, 1989).
2. *Improvement of product quality.* Product quality (or functionality) could increase when suppliers not only act as a co-maker but also as a co-developer. For example, suppliers may be able to suggest the use of alternative components which can increase the reliability of the product part.
3. *Improvement of manufacturability.* Improvement can be made as a result of a more in-depth knowledge of suppliers about manufacturability processes. In this situation their knowledge

[4] To ensure that only high quality studies was included in our analysis, the review focused specifically on papers published in major English-language North American and European journals. This means that the analysis considers mainly journal articles that are included as four stars on the latest Association of Business Schools (ABS) ranking (http://www.the-abs.org.uk/). These journals tend to have a high citation impact factor (Johnson, 2009).

of production can be used for better performing designs, resulting in a reduction of quality issues when the product parts transfers from the proto phase to the ramp up/volume phase.

4. *Reduced development and product cost.* A number of cost-related benefits are also identified. Suppliers can contribute in reducing the unit cost of a part by active participation in the alteration of a product design specifications with the process specifications. Suppliers have in-depth knowledge about the possibilities of their production and assembly equipment and this may result in a smaller number of redesigns, which consequently decreases the unit cost of the product part (Dowlatshahi, 1998).
5. *Alignment of technology roadmaps/strategies.* Another benefit which can be attained by companies is the possible access to suppliers (new) technologies. Wynstra (1998) argued that having a more permanent access to technological knowledge of suppliers might be of possible strategic importance. Especially when companies can align their technology roadmaps with key suppliers. These roadmaps are used to align technology with (future) market demands and can be used on a company level or on a multi-organizational (industry) level (Phaal *et al.*, 2004).
6. *Source of innovation.* Supplier's contribution could lead to differentiated products in the market and by that gaining of market share. Von Hippel (1988) already pointed out that suppliers are potential sources of innovation. Product innovation is described as the extent to which a new product is new in the target market, and in the developing company (Langerak & Hultink, 2008), which is fundamental for the continual prosperity of a company. This signifies the importance of new designs and innovations by suppliers in supporting a buyer to differentiate its product in the market place (Dyer, 2000). Therefore, suppliers may have an impact on revenues by increasing the innovativeness of the OEMs product proposition in the market (Koufteros *et al.*, 2007).

Short-term versus long-term drivers behind Early Supplier Involvement

When looking at the six drivers mentioned earlier, it becomes clear that these incentives can be organized according to their short-term and long-term characteristics, as well as according to their operational and strategic characteristics. Wynstra & Van Echtelt (2002) argued that in general, drivers associated with meeting project targets have a short-term operational character: drivers 1-4. These drivers add operational flexibility to the OEM. Other less tangible incentives have a long-term or a strategic character; drivers 5-6. They do not necessarily contribute to the current development performance, and may become just visible in the OEM of future development projects. Therefore, Wynstra & Van Echtelt (2002) proposed to distinct between short-term operational benefits, and long-term strategic benefits.

2.3.2 Risk factors Related to Early Supplier Involvement

In regard to the previous section, one might wonder why not all companies involve their suppliers in NPD. One organization might be not as successful in ESI as others, but any organization should be able to achieve some benefits. However, practice showed that this is not always the case. Several questions arise with ESI in NPD, many of them are associated with risk and it forces organizations of being reluctant towards ESI. For example; how to divide the development tasks, the associated risks and the revenues? As we will see in the next section, involving suppliers in NPD is not an easy task and it makes research in this area of great importance. Table 5 gives an overview of the potential risks as suggested by previous research.

Table 5. *Risk factors of early supplier involvement mentioned in previous research*

Risk factors	Source
Locked into supplier's technology	Christensen (1997), Handfield *et al.* (1999), Monzcka *et al.* (2000)
Clockspeed differences	Fine (1998), Wynstra & Van Echtelt (2002), Chou & Chou (2008)
Loss of knowledge (IP) or skills	Mikkola & Skjoett-Larsen (2003)
Relationship costs	Bensaou (1999), Bruce *et al.* (1995), Gadde & Jellbo(2002), Van Echtelt (2004)
Different interests and objectives of commitment	Dyer & Ouchi (1993) Bruce *et al.* (1995), Van Echtelt (2004)

Risks identified in previous research can be clustered into 5 categories:

1. *Locked into supplier's technology.* Companies in the fast changing high-tech environments might be at risk of getting locked in the supplier's technology (Christensen, 1997, Handfield *et al.,* 1999). In a situation of competing technology regimes, early involvement of suppliers can create an over-dependency of these suppliers (Van Echtelt, 2004). When, for example, the product architecture is partially controlled at the supplier's situation, an OEM could run the risk of losing control and flexibility to implement desired product design improvements, since its own technological knowledge is not sufficient anymore.
2. *Clockspeed differences.* The speed by which a supplier can develop new products might be significantly different from the time horizon of some of its customers. In addition, this speed may contribute to the way an industry is structured. So, it is possible that differences in clockspeed between supplier and customer, could pose a development risk in terms of obsoleteness of components and systems and validation problems. This could result in late market introduction and delivery problems ultimately (Fine, 1998; Chou & Chou, 2008).
3. *Loss of knowledge (IP) or skills.* ESI in NPD poses the potential risk for diffusion of proprietary knowledge (IP) and the loss of skills, which are crucial for future NPD (Wasti & Liker, 1997). A company which has outsourced a certain technology can become very dependent of a supplier, when the specific knowledge turns out to be very crucial later, and when internally rebuilding of this knowledge appears to be difficult.
4. *Relationship costs.* Costs related to supplier relationship management can increase tremendously when suppliers are intensively involved (Gadde & Jellbo, 2002). Coordinating the work between two collaborative parties and thereby ensuring accurate information exchange mechanisms, on both the operational and strategic levels, requires different management styles and budgeting processes within the same process. (Bruce *et al.*, 1995). Also incompatibility between the corporate cultures of both actors can cause a misfit between operating and management styles (Contractor & Lorange, 1988) what should be compensated with additional coordination activities. Therefore, the relationship becomes more concentrated and expensive to develop and maintain (Bensaou, 1999).
5. *Different interests and objectives of commitment.* This phenomenon concerns about disproportionate objectives between the buyer and supplier. Companies establish inter-organizational relationships as they expect them to be profitable. According to Van Echtelt (2004) the presence of mutual interest is an important incentive to remain committed to the collaboration. Though, the expectations about the way in which the collaboration will take place and the expected results may change over time, or they even may end up in conflict with each other. This may result in *opportunistic behavior* (Bruce *et al.*, 1995). For example, a supplier could behave in an opportunistic way when it gains additional skills and knowledge out of the cooperation with the buyer.

2.3.3 Success factors related to Early Supplier Involvement

Well defined success factors in ESI can be useful for organizations to take into account when managing their own supplier involvement. Table 6 gives an overview of the potential success factors, as suggested by previous research.

Thirteen success factors behind ESI have been recognized in recent studies:

1. *Top management commitment.* Several studies argued that the influence of senior management both on operational and strategic level is crucial for successful ESI. Successful ESI depends upon a high level of commitment and resource allocation, from both the buyer and supplier organizations. Senior management support in the provision of both financial and political resources is vital to accomplish successful ESI (Brown & Eisenhardt, 1995; McIvor *et al.*, 2006).
2. *Internal cross-functional coordination.* Hillebrand & Biemans (2004) noted the relevance of internal cooperation. Internal cooperation serves to coordinate external cooperation. For example, mutual problems across divisions inside and outside the company's border can resolve by the use of cross-functional teams.

3. *Supplier assessment.* The importance of careful supplier selection was stressed out by many researchers (e.g. De Boer *et al.*, 2001). Most models in the recent literature take the perspective of outsourcing supporting business activities; such as Information Technology, and cleaning services. Generally, these activities are less close to the core business than activities like manufacturing and design. The strategic importance and delicacy of manufacture and design activities for the production, may cause that companies become dependent of its suppliers. Thus, assessment of suppliers on various aspects (e.g. technology, quality etc.) to reduce risks and total costs is important to secure the supply of goods.

Table 6. *Key success factors early supplier involvement mentioned in previous research*

Success factors	Source
Internal Buyer Capabilities	
Top management commitment	Brown & Eisenhardt (1995), Spekman (1988), Ragatz *et al.* (1997), Monczka *et al.* (2000), Van Echtelt *et al.* (2007, 2008)
Internal cross-functional coordination	Ragatz *et al.* (1997), Hillebrand & Biemans (2004)
Supplier Selection	
Supplier assessment	Ragatz *et al.* (1997), Monczka *et al.* (2000), De Boer *et al.* (2001), Axelsson & Wynstra (2002)
Supplier capabilities alignment	Hartley *et al.* (1997), Handfield *et al.* (1999), (Heimeriks & Duysters, 2007)
Company size supplier	Kaufman *et al.* (2000), Wynstra & Echtelt (2002), Wagner (2003), Kouftos et al. (2007), Van Echtelt *et al.* (2007, 2008), Andersen & Drejer (2009)
Clear distinction of supplier roles & levels of involvement	Ragatz *et al.* (1997), Monczka *et al.* (2000), Johnson (2009)
Supplier Relationship Management	
Mutual trust	Bstieler & Hemmert (2008), Yeaung *et al.* (2009)
Agreed performance targets & measures	Ragatz *et al.* (1997), Whipple (2000), Petersen *et al.* (2005)
Communication/information exchange	Brown & Eisenhardt (1995), Dowlatshahi (1998), McIvor *et al.* (2006), Song & Di Benedetto (2008)
Shared training & joint problem solving	Dyer and Ouchi (1993), Ragatz *et al.*(1997), Monczka *et al.* (2000)
Risk & reward sharing	Smith & Reinertsen (1991), Camarinha-Matos & Afsarmanesh (2007)
Matching culture	Wynsta & Van Echtelt (2002), Ragatz *et al.* (2002), McIvor *et al.* (2006)
Long-term nature	Spekman (1988), Van Echtelt (2004), Koufteros *et al.* (2007)

4. *Supplier capabilities alignment.* The supplier's capabilities are a prerequisite in order to have an early and successful involvement in a project. According to Wasti & Liker (1999), the technical capabilities are a strong indicator for a fortunate ESI. Handfield *et al.* (1999) suggested that beside technical capabilities, a supplier also needs to have the 'right' organization and processes to meet customer's targets and alliance capabilities. With alliance capabilities we refer to the supplier's ability to capture, share, disseminate and apply vertical alliance management knowledge (Heimeriks & Duysters, 2007).
5. *Company size supplier.* It has been recognized that larger companies have more resources than smaller companies (Boyer *et al.*, 1996). Besides innovation competence, NPD requires extensive production management and large logistic abilities, which are found at most in large and more specialized suppliers (Andersen & Drejer, 2009). Large companies have more flexibility to devote resources to strategic supply chain activities, while smaller companies may not have the same level of flexibility. Small suppliers may also have difficulty in attracting first-class second-tier suppliers (Koufteros *et al.*, 2007).
6. *Clear distinction of supplier roles & levels of involvement* based on the degree of autonomy of the supplier and the development risk may help to set priorities in such a way that the involvement of suppliers becomes more manageable and economical. According to Monzcka *et al.* (2000) there are two major factors that should be considered when integrating a supplier into their NPD process: (1) the rate of change of the technology and (2) the level of supplier expertise in the given technology change. If the technology is undergoing a

significant rate of change, integration in the NPD process should take place later. However, if a supplier's design expertise is large and their technology experts can provide key insights which are helpful to crafting a new product, suppliers should be included in the NPD process early. Therefore, the buyer has to determine carefully what level of integration is required from the supplier up-front and find a supplier that fits these requirements. These possible moments of supplier integration can be framed within the context of the NPD process visualized in Figure 4.

7. *Mutual trust.* Trust in reference to the buyer-supplier relationship has been noted as a positive factor for a successful inter-organizational collaboration (e.g. Yeung *et al.,* 2009). Rousseau *et al.* (1998, p. 395) concluded that there seems to be a general consensus about trust, being "a psychological state comprising the intention to accept vulnerability, based upon positive expectations of the intentions or behavior of another." However, it takes a long time to develop mutual trust and by contrast, only a small conflict (e.g. by opportunistic behavior) is necessary, to destroy it.
8. *Agreed performance targets & measures*. Several studies argued that conflicts within the relationship can arise when clear defined and shared goals at the outset are lacking (e.g. Petersen *et al.*, 2005). These conflicts may arise as a consequence of misunderstanding between expected and actual outcomes of the relationship. So, it is important to find an agreement about technical metrics and targets at the start of a collaboration.
9. *Communication/information exchange.* Considering design and ESI as an information processing activity, inter-functional and inter-organizational communication is essential in regard to effective team-work and problem-solving activities (McIvor *et al.*, 2006). Almost all of the previous described success factors depend on the effectiveness of communication between the supplier(s) and the different departments in the buying company.
10. *Shared training and joint problem solving.* Ragatz *et al.* (1997) described the relevance of shared education and training in successful ESI. They suggested to use shared education and training strategically and selectively to drive success. Joint problem solving also seems to enhance trust between the supplier and buyer (Ragatz *et al.,* 1997). A mechanism that is frequently mentioned to establish joint problem solving, is the co-location of suppliers' representatives (e.g. engineers), who join a project team (Lamming, 1994). Co-location is considered to be effective for the companies' ability to address design problems rapidly as they arise in the design process.
11. *Risk & reward sharing.* The role of mutual interests and shared incentives for collaboration is often mentioned as a critical success factor (Camarinha-Matos & Afsarmanesh, 2007). It signifies that both risks and rewards resulting from the collaboration should be shared with all companies involved. However, 'win-win' does not necessarily mean an equal exchange of benefits or inputs, but depends on fair dealing. According to Smith & Van de Vent (1994) 'fair' dealing means that all actors receive benefits proportional to their investment.
12. *Matching culture.* Matching cultures between the buyer and supplier organization have to exist in order to facilitate and encourage shared values, operational style and problem solving style (Wynstra & Van Echtelt, 2002). If there is a mismatch in any of these three elements between a supplier and buyer, ESI can result in an ineffective relationship. Sirmon & Lane (2004) distinguished three types of cultural differences in an collaboration set-up: a) national , b) organizational (relates to shared beliefs in organization practices and processes) and c) professional (relates to individual people who share a set of norms, values and beliefs related to their work) differences.
13. *Long term nature.* Buyers look for suppliers which are experienced in NPD and can positively contribute in NPD projects. Bearing in mind that long-term relationships are established with only a few suppliers, it makes sense that those suppliers ought to be supportive and be in the forefront of NPD (Koufteros *et al.,* 2007).

Internal Buyer Capabilities, Supplier Selection and Supplier Relationship Management

When looking at the thirteen success factors mentioned above, it might be recognized that these success factors can be organized across three management areas, namely: (1) *internal buyer* *capabilities* (factors 1-2), (2) *supplier selection* processes (factors 3-6) and (3) *supplier relationship management* (factors 7-13).

2.3.4 Conceptual framework of factors affecting ESI success in NPD

Figure 6 gives a graphical overview of the relation between the benefits, risk and success factors of ESI based on previous sections. Early involvement of suppliers in NPD activities is not an easy task, as we will discover in the next chapters. This makes research in this area very important. The next section will give more insight into the operational processes for ESI in NPD.

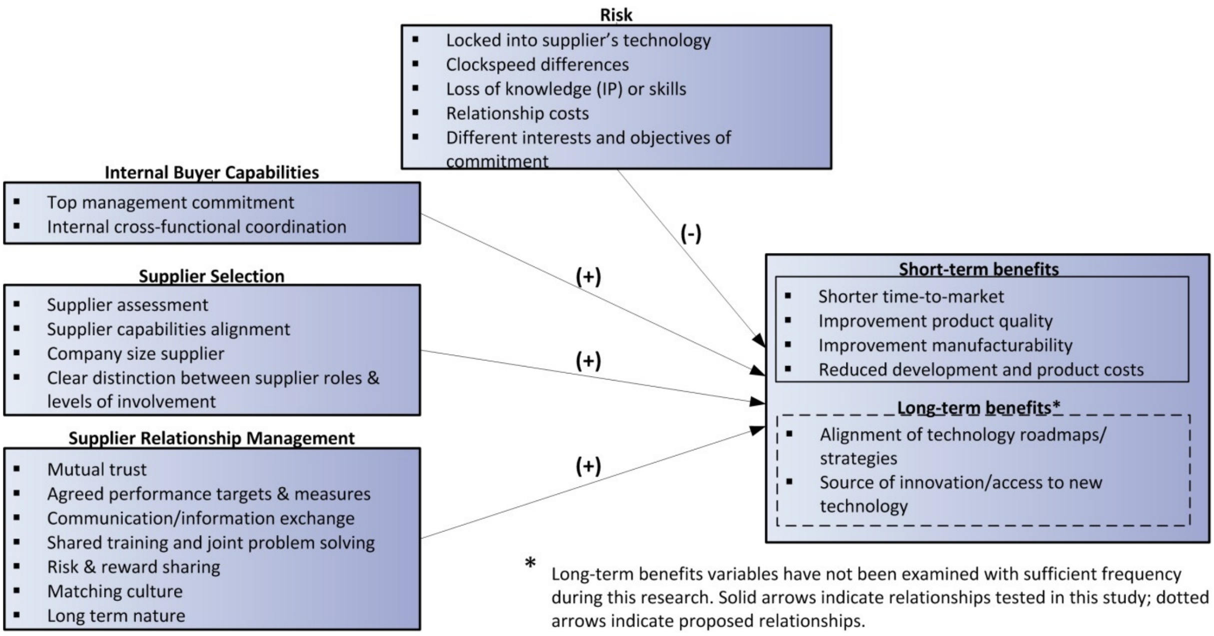


Figure 6. *Factors affecting ESI success in NPD*

2.4 The Integrated Product Development and Sourcing framework

Some authors argued that it is difficult to accomplish the apparently positive outcomes of supplier involvement in NPD (e.g. Wagner & Hoegl, 2006). For being successful in supplier involvement, they have pointed out the criticality within two domains: (1) *contingency* factors on the organizational level; and (2) *management factors* of supplier involvement on the project level. The contingency theory tries to understand and explain phenomena and organizational issues from a situational point of view. Basic thought behind this concept is the need for companies to adapt towards the most relevant aspects of the environment in which they are operating. Management of supplier involvement on the project level concerns about the relationship between the buyer and the supplier, as well as the interaction and inter-organizational exchange of project members from both organizations (Wagner & Hoegl, 2006). In other words, what managerial processes are most critical for companies when they want to involve suppliers in NPD?

The Integrated NPD and Sourcing framework (IPDS) merged these two domains into one model, for a graphical representation see Figure 7. The framework is a result of two models of supplier involvement in NPD by Wynstra *et al.* (1999, 2000) and Monczka *et al.* (2000). It is further developed and validated by Van Echtelt *et al.* (2004, 2007, 2008) and Van der Valk & Wynstra (2005). The framework is structured according to an input-throughput-output logic and analyses the topic of ESI in NPD from a buyer's perspective. The framework is focused on the consequences of situational factors which may influence NPD projects (input), products (output) as well as the critical processes underlying NPD projects (throughputs), see also Tables 7, 8 and 9.

- *Inputs.* Inputs are the starting conditions in terms of structure and capabilities of both the buyer and the supplier. The IPDS-framework distinguishes between *drivers* and *enablers*. These factors can be internal as well as external in perspective of the company, and can appear on three different units of analysis: strategic business unit level, operational project level and the buyer-supplier relationship level (Table 7). Drivers are interrelated with the characteristics of the company's operating environment.

Enablers are the conditions, which can assist a company to organize the required IPDS processes (Wynstra & Van Echtelt, 2002). These enablers can be present on an internal/external level as well as in a specific relationship between the buyer and supplier (Table 8).

Table 7. *Drivers on three units of analysis (Van Echtelt et al., 2008)*

Strategic corporate level	Operational Project level	Buyer-supplier relationship level
✓ Organization size	✓ Degree of project innovation	✓ Component development complexity
✓ Supplier reliance	✓ Project objectives priority setting	✓ Component technological uncertainty
✓ R&D reliance		✓ Component contribution to the overall system functionality
✓ Manufacturing type		✓ Degree of limitations on availability of suppliers
✓ Technological uncertainty		

Table 8. *Enablers (Van Echtelt et al., 2008)*

Internal enablers	External Enablers	Buyer-supplier relationship level
✓ Cross-functional integration	✓ Supplier technical capabilities	✓ Past experience of collaborations
✓ Human resources quality	✓ Supplier project alignment capabilities	✓ Compatibility of culture
✓ Top management commitment	✓ Supplier target cost capabilities	✓ Trust/social climate

- *Throughputs.* The core of the framework consists of the operational management processes (the throughputs). The purpose of these management processes are to set-up and manage supplier involvement in NPD from a buyer's perspective. These processes can be directly or indirectly related to ESI in NPD and can be either long-term strategic or short-term operational. Figure 7 represents the Operational Management Arena. The operational management arena consists of nine processes, which are aimed to plan, manage and evaluate the actual collaborations in terms of their development performance in a NPD project. As already suggested, the success of involving suppliers in NPD depends on the company's ability to capture both short- and long-term benefits. If companies spend most of their time on operational management in development projects, they will fail to leverage the effort of planning and preparing such an involvement, by strategic management activities (Van de Valk & Wynstra, 2005). According to Van Echtelt *et al.* (2008), the big challenge of ESI in NPD is to perform well on both processes, and therefore trying to balance these two types of objectives by:
    1. guaranteeing that the expected contribution of the supplier for a specific development project will be achieved, resulting in the desired project performance; and
    2. guaranteeing that the supply base is prepared for integration in future development projects, by supporting the competitive position of the firm on a longer term, while minimizing technology and supply risks.
- *Outputs.* The *outputs* are the (potential) results of involving suppliers early in NPD. All possible benefits as described in literature, were already summarized in section 2.3.1. Since a project can be carried out with help of several suppliers, the framework also distinguishes between various project efforts, see also Table 9.

Table 9. *Outputs (adapted from Van Echtelt et al., 2008)*

Short-term project results	Short-term collaboration results
✓ Product quality	✓ Part technical performance
✓ Product/development cost	✓ Part/development cost
✓ Product time-to-market	✓ Part development lead time
✓ Manufacturability*	✓ Part manufacturability*

*This variable was added into the IPDS framework of Van Echtelt *et al.* during this research.

The basic thought behind the IPDS framework is that both operational and collaborative development processes need to serve effective and efficient supplier involvement.

Figure 7. *Operational project management arena (adapted from Van Echtelt et al., 2008)*

2.4.1 Reasons for using the IPDS Framework

The IPDS framework models the organization and management of ESI in perspective of the relationship between antecedent conditions (drivers and enablers), managerial activities and short- and long-term collaboration results. The IPDS framework is suitable for evaluating the process of ESI in NPD projects, because of its similarities with the 'Open System' model developed by Katz & Kahn (1978) and Harrison (1987), see also Figure 8. The Open System theory looks at organizations as being a system of elements, transforming inputs via behavior/processes and technology into outputs, while interacting with the environment in which it operates (Harrison, 1987), thus having an input-throughput-output logic. Both models distinguish between multiple variables that can possibly influence the study object, in this case, performance of ESI in NPD projects of ASML. However, the open system model also focuses on intangible variables (culture), whereas the IPDS-model focuses more on tangible aspects, i.e. the management processes, which can be seen as a disadvantage of the IPDS model. Since, most studies refer to the relevance of culture (values, norms and beliefs) in relationships; it should be measured even though. That is why we adapted the model and added the additional variables: matching culture and mutual trust. By using the IPDS-model, this project can investigate whether there are any differences in the occurrence of short-term supplier effects and short-

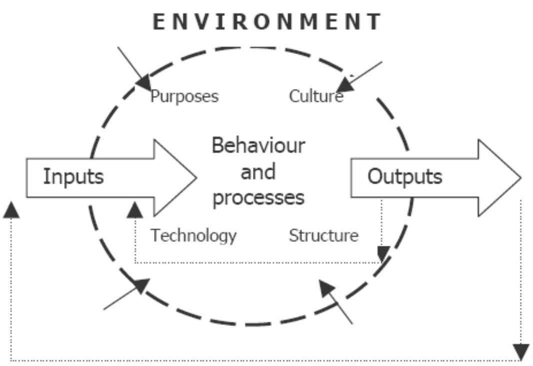


Figure 8. *The open system model (Harrison, 1987)*

term project execution effects. Furthermore, the extent to which long-term supplier effects can be expected in future projects, Furthermore, the extent to which long-term supplier effects can be expected in future projects, can be explained by using the IPDS model in evaluating the way in which current ESI in NPD are managed within ASML. For example by inspecting the way in which relevant management processes are carried out by ASML in advance of and during NPD projects. In addition, by using the framework in studying ESI in NPD, within the context of ASML, shortcomings of the framework itself may be identified. As a result, possible adaptations can be formulated. This would provide useful input for further development of the framework.

2.5 Conclusions

Previous research on ESI has been reviewed in this chapter and has led to some valuable insights on how companies can benefit from ESI. NPD is considered as an important factor for achieving sustainable competitive advantages. Two motives have increased the importance of NPD for companies: increasing customer requirements and intensifying competition. NPD is a tool by which companies can differentiate in its offering value from their competitors. Inter-organizational collaboration can be separated into horizontal and vertical collaboration. ESI is considered to be a vertical collaboration strategy. Van Echtelt *et al.* (2008) defined supplier involvement as being the resources (capabilities, investments, information, knowledge ideas) that suppliers provide, the tasks they carry out and the responsibilities they have regarding the development of a part, process or service.

An assessment of benefits, risks and success factors resulted in two general drivers of ESI short-and long-term benefits. In addition, five risk factors and thirteen success factors of ESI were recognized. Finally, the IPDS framework was introduced as a tool to analyze ESI in NPD projects. It focuses on contingency factors that may influence the NPD projects (input), on results of projects (output) and on critical processes underlying a NPD project (throughputs). The basic thought behind the IPDS framework is that strategic, operational as well as collaborative development processes need to be in service of effective ESI.

In the next chapter the research design and methodology for data collection and data analysis will be described. Furthermore, the context of the case studies in terms of the semiconductor industry characteristics and dynamics as well as by the characteristics of ASML, will be introduced.

Chapter 3
Managing ESI in NPD at ASML: Case description

"Over the years, we have been successful in managing a strong network of suppliers, thereby multiplying our research with partners bringing in unique expertise that we could not have developed as fast on our own."

- Eric Meurice, 2010, CEO ASML

3.1 Introduction

This chapter presents the case study in which the conceptual framework is used to analyze the effectiveness of the activities and conditions supporting the management of ESI in four different collaborations between ASML and supplier in NPD projects. First the background of the case studies in terms of the semiconductor industry characteristics, followed by the characteristics of ASML itself will be introduced. Next, the case study design and methodology used in this study will be introduced. Finally, four case studies concerning the collaboration with suppliers in NPD at ASML will be introduced.

3.2 The semiconductor industry

The production of semiconductors has emerged into one of the key industries for advanced capitalist economies (Sydow *et al.*, 2004). It is a market with its own specialized characteristics, in which OEMs need to meet specific demands and expectations. In case of ASML, their customers (e.g. Samsung and Intel) produce chips. The demand for chips is directly related to the requirement of electronic products by consumers, it is therefore, extremely sensitive to market fluctuations and often unpredictable. Popular products such as smartphones and laptops may induce a nearly explosive demand for the most advanced lithography equipment. Figure 9 visualize the impact on these highly business cycles on the sales of ASML's photolithography systems. From an evolutionary point of view, increased competition as a result of today's globalizing economy forces many companies to review the way in which they make use of their resources. In the past, internal R&D was considered to be a valuable strategic asset, even a barrier to entry by competitors in many markets. Only multinational corporations like Philips, IBM and Unilever could compete by doing the most R&D in their industries. These days, however, the leading industrial enterprises of the past have been encountering by remarkably strong competition from many startups (Chesbrough, 2003). When a globalized industry is also high-tech, participating companies face additional strategic complexity.

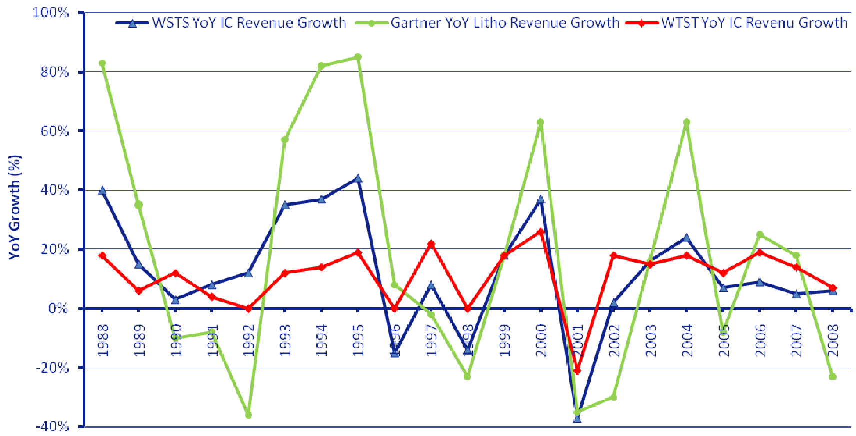


Figure 9. *Trend in IC sales and Litho revenue (ASML, 2010)*

This complexity is partially related to the technical content of the products. But is also fuelled by the variety and speed in which new technologies emerge.This increased variety of products to be developed and manufactured poses a co-ordination challenge for NPD processes, and requires flexible manufacturing and logistics processes. According to Chuma (2006), the semiconductor industry is a science-based industry[5] in which the necessity for reaching beyond borders is particularly high due to the extremely rapid speed of innovation, or the clockspeed. The concept of industry clockspeed has already been introduced in the previous chapter. In the fast clockspeed environment of ASML the sets of capabilities that have earned profits and growth for ASML at one point of time need to be reassessed, renewed, or sometimes even turn over to a new set of competencies in a short time frame. Otherwise, ASML cannot maintain their competitive position in the semiconductor industry or even guarantee their survival. This eventuates in that companies acting in the semiconductor industry need to find a way in which they can move from one temporary advantage to the next one, in order to survive in this continuous changing landscape.

3.3 ASML strategic responses on a changing landscape in NPD

As Van Echtelt (2004) argued that the phenomenon of ESI has emerged from, and co-evolved with at least three strategic responses to deal with these challenges:

a. *outsourcing innovation*;
b. *concurrent engineering;* and
c. *inter-organizational collaboration*.

Strategic response I: outsourcing innovation

The first action to address the NPD demands is the move towards outsourcing activities that are not critical in achieving a competitive advantage in certain markets. Outsourcing business activities have been a trend in industry since the 1990's (Berggren & Bentsson, 2004). It was applied in many companies to free up resources, gain access to resources, increase flexibility and to leverage the core competences (Van Weele, 2008). It is at the interface between outsourced activities and NPD that the collaboration areas with suppliers have gradually been shifted from focusing on a production and logistics-oriented improvement towards optimization of component design (Van Echtelt, 2004). This has resulted in lower manufacturing costs and faster manufacturing cycle times. Since the beginning, ASML has been using this strategy, resulting that the number of outsourced units of their microlithography system is 7 to 8, more than those outsourced by Nikon and Canon (ASML's most important competitors). Which means that ASML's machines are decomposed to a bigger chunks compared to Nikon and Canon (Chuma & Aoshima, 2003), see also Table 10.

[5] An industry is called science-based if the time lags between scientific discoveries and their industrial implementation are very short. Pharmaceutical, biotechnology, semiconductor, and fine chemical industries fall into this category (Chuma, 2006).

Table 10. *Extent of outsourcing at ASML (adapted from Chuma, 2006)*

Major components	ASML	Nikon	Canon
Projection lens			
Development & design	Zeiss	In-house	In-house
Glass making	Zeiss	In-house, Ohara	In-house
Polishing	In-house	In-house	In-house
Assembling	Zeiss	In-house	In-house
Illumination system	Zeiss & Lambda Physics	In-house	In-house
Stage			
Development, design & assembling	Philips group	In-house	In-house
Light sources			
Marcuray lamp	Mainly Ushio	Mainly Ushio	Mainly Ushio
DUV	Cymer, Lambda Physics	Cymer & Giga photon	Cymer & Giga photon
Body (development & fabrication)	Philips and Philips group	In-house	In-house
Alignment system			
Development & design	Zeiss & Philips	In-house	In-house
Interferrometer, bar mirror etc.	Agilent, Zygo, etc. & Zeiss	Zygo etc.	Zygo etc.
Software			
System design	In-house	In-house	In-house
OS	Outside	Outside	Outside
Tool software	In-house & Zeiss	In-house	In-house

Strategic response II: concurrent engineering and cross-functional collaboration

A second action to the NPD challenges of ASML was the introduction of concurrent development and engineering approaches which increased internal cross functional collaboration. This approach became known as parallel development or concurrent engineering (Clark & Fujimoto, 1991). Thus, companies were able to reduce the time-to-market by executing some of the product and process design/engineering activities in parallel, rather than in series. This meant that the trade-off between product design aspects and manufacturing and logistics aspects took place earlier in the design process than before (Smith & Reinertsen, 1991). This approach demands more on process adaptations and requires a more cross-functional communication between team members (Clark & Fujimoto, 1991), which addresses the link with outsourcing. Because suppliers often already possessed information on manufacturing technologies, they had to be involved earlier in the project. This earlier involvement came in conjunction with increasing responsibilities for more complex assemblies of components. Parallel development might be successful if suppliers will be involved earlier in project phases in order to modify the product and process design of components. According to the concurrent development strategy, ASML is working in a concurrent stage gate NPD model, see also Appendix B.

Strategic response III: inter-organizational collaboration

The final strategic action Van Echtelt (2004) mentioned, was the increasing engagement in collaborative arrangements between companies in the area of technology and NPD. By comparing it with the outsourcing action, this response gives us insight into different, though corresponding, motives behind companies adopting ESI as a strategy. Based on the interviews during this study, reasons for the increased importance of inter-organizational collaboration are two-fold. First, the reduction of in-house NPD resources increases the need for ESI (mainly as "capacity projects"). Second, an appreciation for knowledge located with key suppliers drives their involvement through access to knowledge ("know-how") projects. These arguments are confirmed by recent research (e.g. Hagedoorn, 1993; Wagner & Hoegl, 2006). Inter-organizational collaboration was crucial for the current success of ASML (Chuma, 2006). ASML began to collaborate widely, with chip, tool and material manufacturers in the mid 1990s, accelerating the pace of their collaboration in 1998. ASML draws upon a unique technology network of close partner companies, private research companies, universities and research institutes for innovation. According to Chuma, ASML was the first one in the microlithography industry that recognizes this opportunity. Although, creating such a self-assembling organization is not a simple task, the key word to establish this is collaboration. ASML introduced the Value sourcing strategy to fulfill these requirements. This strategy has a Multi-Level Perspective (MLP). This strategy shows how ASML intends to collaborate with its suppliers in NPD projects. The value sourcing strategy has three cross functional teams (PFT, SAT and NPD projects), which can be seen in Figure 10.

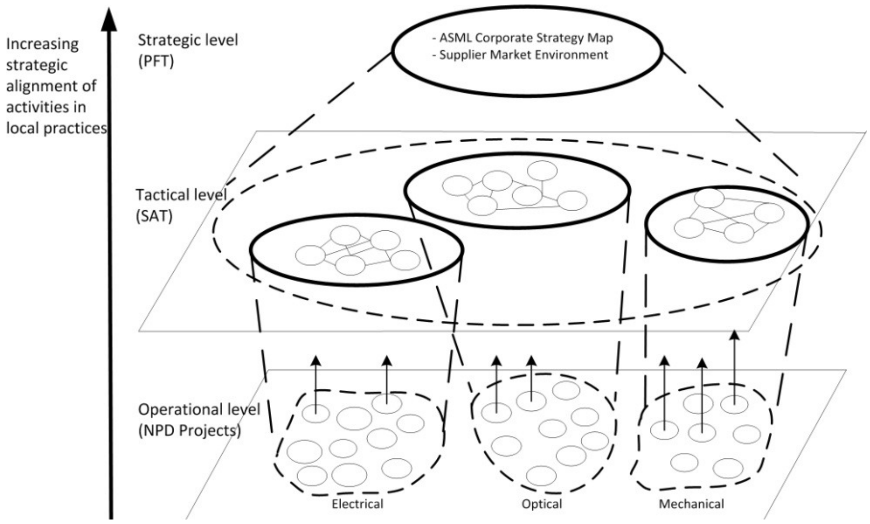


Figure 10. *Three layers of the value sourcing model*

The *Product Family Teams* (PFT) are responsible for maintaining a globally competitive supply base (strategic level). These teams are composed of members of different departments of the ASML organization. If there is no supply base available, the decision to outsource is turned around and the activities are done in-house. By setting performance targets, the product family teams determine the expected performance of the relationships between ASML and the suppliers. These performance targets are set on the areas of Quality, Logistics, Technology and total Cost (QLTC). The product family teams make a selection of suppliers that are expected to be capable of meeting these targets. A risk assessment tool helps the product family team, in consultation with the supplier account team, to make the final supplier selection for a particular NPD project.

The *Supplier account teams* (SAT) monitor the relationship between ASML and these suppliers on a tactical level. To ensure the success of the relationships for the future, goals are aligned in what is called the supplier strategic alignment process. If agreement is reached upon the future of the relationship, long term agreements are signed. In these long term agreements, the supplier and ASML have agreed to reach and maintain the performance targets. The supplier account teams continuously measure the performance and detect any differences between the targets and actual performance. The SAT teams are composed of employees of both the supplier and ASML and come from different functional departments. (Dijkhuis, 2006) At the final (operational) level NPD project teams are executing the projects, note that this level is the unit of analysis within this study. Currently, the value sourcing strategy is evolving, where it is creating and managing network–level knowledge-sharing processes through diffusing its knowledge from a bilateral approach to a multilateral approach. Some practical experiences support this line of thought (box 1).

Box 1. ASML supports Small and Medium Enterprises

ASML has made "Value Sourcing" methodology available to the high-tech industry in the Netherlands. A platform called "Point One" has been created by the Netherlands Ministry of Economic Affairs which enables an exchange of knowledge between large OEMs and the supply industry. ASML has a leading role in this platform, whose main goal is to create a standard for supplier requirements of large OEMs for small and medium enterprises (SMEs). ASML shared its sustainability knowledge and method of supplier management with this platform, which is now part of the standard determined requirements. In this way, SME suppliers can work more efficiently and focus on the appropriate aspects. This was recognized in the field as well, for example at the Dutch consultancy Berenschot: "It was difficult for SMEs to meet international standards. The highly divergent supplier management methodologies used by OEMs hindered this possibility. The methodologies are now better aligned with each other." (ASML sustainability report, 2009b)

The Concept of Modularity and its implications for ASML NPD projects

One key predecessor for executing these strategies (outsourcing, concurrent engineering and inter-organizational collaboration) in practice is the degree of modularity of a product. Another explanation of the success of ASML in becoming the market leader, according to Chuma (2006), is its understanding of the modularity of its system. The benefits of interim modularity is more effectively utilized by ASML in contrast with Nikon and Canon (2006, p. 396). But what is exactly meant by product modularity? And how does it influence NPD processes? Ulrich (1995, p.420) defines product architecture as follows: “the arrangement of functional elements, the mapping from functional elements to physical components and the specification of the interfaces between interacting physical components”. Where, *modular architecture* implies “a one-to-one mapping from functional elements in the function structure to the physical components of the product, and specific de-coupled interfaces between components” (Ulrich, 1995, p.420). Furthermore, Baldwin & Clark (1997) argued that in a modular system, each module communicates and interacts with each other via standardized interfaces, which allows module decoupling of each self-contained key component. Such modular architecture could provide: (a) expansion in the range of complexity addressable, (b) extension of the scope of addressable business risks, by parallel development and (c) shortening of various lead times by parallel development and production or outsourcing (Baldwin & Clark, 2000). So product modularity enables the possibility to outsource sub modules of a system to suppliers. Hence, modularity admits the opportunity to design and manage horizontal and vertical inter-organizational relationships (Hoetker *et al.*, 2007), as well as it creates flexible and scalable production systems based on sub-assembly and pre-testing (Campagnolo & Camuffo, 2009). So, it might be clear that modularity positively influences NPD processes of ASML a lot.

In this study we assume that modularity and outsourcing are tightly connected and that the characteristic of the product modularity determine the outsourcing of modules. Researchers demonstrated different paths towards product modularity and module outsourcing (e.g. Sako & Murray, 1999b). Sako (2003) considered one set of tasks (that is design only, production only or package of design and production), in a case of a vertically integrated company, with a modular product design. He recognized three main pathways (Figure 11), in which the direction is based on the choices along the process: (*acd*) the company defines modular product architecture before outsourcing one or more modules, (*abd*) the company starts to outsource some product components before moving towards a modular design and (*ad*) the company simultaneously implements product modularity and outsourcing outlines the three pathways. ASML is currently working via pathway acd. It operates in a growing industry and ASML’s incentive is to develop its own architecture and to impose it on the market. So, the role of ASML is to act like an architect in the supply chain of the microlithography industry in which suppliers act like designers. Paths abd and ad seems for now not realistic for ASML. The study of Ernst (2005) showed that module outsourcing is not a ‘natural’ consequence of product design modularity in the semiconductor industry. Due to the quick changes and unpredictability of this technology (high clockspeed), codification fails to reduce the level of complexity, and organizations are forced to remain integrated. Table 11 summarizes the modularity and outsourcing pathways of ASML at the current situation as well as its future possibilities.

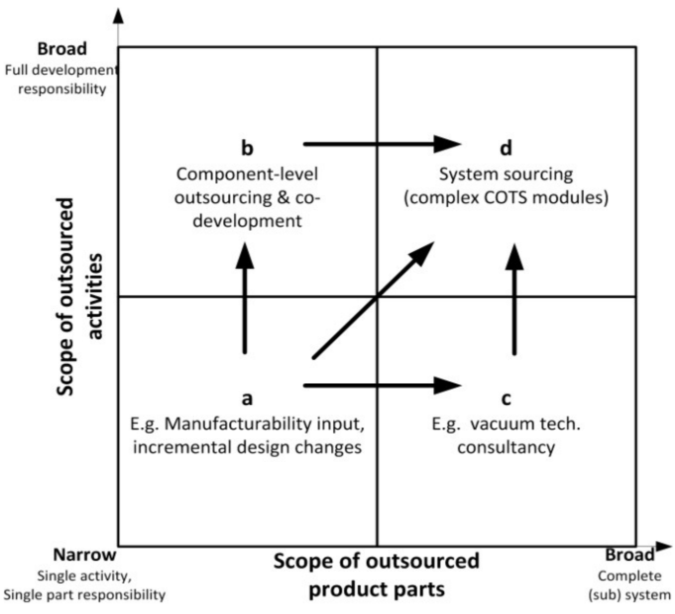


Figure 11. *Paths towards modules outsourcing (Sako, 2003)*

Table 11. *Modularity and outsourcing paths: example ASML Twinscan (adapted from Sako, 2003)*

Modularity/ Outsourcing path	Company strategy	Module supplier	Company pre-outsourcing knowledge	Company post-Outsourcing knowledge	Context	Example
Abd	Architect	Architect/designer	Incomplete knowledge about product, components, functionalities	?	Mature industries	Automotive industry
Acd	Architect	Designer	Exhaustive knowledge about product components functionalities	System Integration Knowledge	Growing industries	Twinscan (ASML)
Ad	-	Architect/designer	Some 'useless' knowledge about product, components, functionalities	-	A company needs to realign its strategy to an ongoing industry evolution towards product modularity.	

3. 4 Case study design and methodology

The empirical part of this research is based on half-year research collaboration with ASML. During this period the stakeholders of this study held meetings when a milestone was delivered, with the key researcher and his supervisors, in order to discuss the set-up of the research and to report on the research process and results. In the period's in-between, individual members were contacted when necessary for more specific questions and discussions. Their involvement proved to be critical in creating access and commitment within ASML, in contact with suppliers and when reflecting on the results. As already mentioned in Chapter 1, this study can be largely characterized as design-oriented and qualitative in nature. It was decided to conduct multiple case studies to analyze ESI in NPD projects. This seems suitable for the following reasons:

1. As stated in section 1.3, the current study aims to obtain a deep understanding of ESI in a high-tech NPD environment. In case studies a deep understanding of one or more objects or processes can be obtained (Yin, 2008);
2. The problem definition of the current study is of the 'how' type, as can be seen in section 1.3 and according to Yin (2003) case studies are appropriate when: "a *how* or *why* question is being asked about a contemporary set of events, in which the investigator has little or no control."; and
3. Yin (2003) stated that the context and phenomenon are not distinguishable as in the situation of ASML in which the business context and business problem are impossible to tell apart.

3.4.1 Exploratory research phase

The first phase was exploratory in nature, and the aim was to generate a general understanding of the internal organization, the technical aspects of lithography systems, and the process by which ASML develops them. An initial series of 14 exploratory semi-structured interviews have been carried out with managers and employees from different departments. These interviews are listed in Appendix I. Furthermore, several meetings involving members from the SEO have been attended. These meetings include departmental meetings involving introductory course for NPD projects and internal process optima.

3.4.2 Case study selection, sample and unit of analysis

A series of case studies regarding four ESI collaborations between ASML and suppliers in the context of a specific NPD project, was conducted. The strategy of multiple case studies was chosen because this increased the understanding of the phenomena of interest (Yin, 2008). Also, conducting four case studies was feasible within the available time and in-depth investigation was still sufficient. Furthermore, it was expected to lead towards the needed generalizability of results. Cases were selected in consultation with the SEO department of ASML. The selection criteria were:

1. Number of organizations involved (≥2), because ESI requires at least two organizations;
2. The spectrum of supplier involvement should be at least at a grey box integration level, since outsourcing of the design phase of NPD projects (ESI) only take place in grey- and black box integration of suppliers;
3. To spread the workload among the organization and to prevent bias, the projects are selected from the three functional disciplines (optical, mechanical and electrical) of ASML; and
4. Relevance of analysis of the project, because ASML wanted to have a critical view on these projects.

The four cases that were selected, projects A-D, are displayed in Table 12 and in Appendix E2 you can see an overview of the supplier sample.

Table 12. *Selection criteria case studies*

Project Selection criteria	Project A LLB	Project B TIS NXE	Project C MDB	Project D PAAC 500/65
# organizations involved	3	2	2	2
Spectrum of supplier involvement	Black box integration	Grey box integration	Black box integration	Grey box integration
Functional discipline	Electrical	Optical	Mechanical	Electrical
Expected relevance	The design of and manufacturing was outsourced by two suppliers. Would the time-to-market have been shorter if only one supplier did both (design and manufacturing)?	The design of the product is highly interrelated with other modules in the lithography system, which makes it very vulnerable to redesigns of 'external' parts.	This project began very well; nevertheless many problems occurred in the course of time. How could the project have slide off from project- to problem driven management?	This project is an exemplary project. What are probable causes of this success?

The chosen sampling method is referred to as 'polar types' (Eisenhardt & Graebner, 2007), which refers to selection of cases with either high or low characteristics on success. This method of non-random sampling is proposed by Eisenhardt and Graebner (2007) in order to achieve maximum results in theory building research. Cases B and C are perceived as unsuccessful and project A and D as successful. It should be noted that some extreme forms are not possible, because unsuccessful NPD projects are stopped early in the NPD process for example. Besides that, the exact score on both success and sustainability cannot be fully evaluated up front.

3.4.3 Data collection

In this study a *questionnaire, in-depth semi-structured interviews* and *internal documents* were used in order to answer the research questions, based on empirical evidence, see also Appendix C. The case studies started with conducting a questionnaire survey with representatives from multiple functions involved in a specific ESI development project within ASML (e.g. the project leader, developer etc., see also Appendix C). These questionnaires were used to obtain some rough insights on the projects under study by means of quantitative measurements of how the project members within ASML involved *perceived* the project. The questionnaire was adapted and customized from a survey questionnaire developed by Van Echtelt *et al.* (2008), as shown in Appendix D2. The results of the questionnaire were used as input for in-depth semi-structured interviews, to obtain qualitative data about the projects under study. All persons who cooperate with the questionnaires have been interviewed afterwards. The main questions were based on elements of the adapted analytical framework developed in the previous chapter. In terms of the results, activities and conditions identified beforehand. These questions had an open character and were complemented by clarifying questions. This enabled us, to reveal the 'why', 'how', 'who' and the 'when' of the management actions during the projects, and allow key themes and patterns to emerge from the process rather than being specified at the outset (Eisenhardt, 1989;

Yin, 2008). In addition, supplier representatives have been consulted to obtain partial verification of case data and to better understand the problems encountered in the collaboration. Hereby the detection of events, issues and perspectives that could help to further understand the possible explanations for the outcome of the collaboration was important. The initial set of interviewees has been identified with the help of the stakeholders within ASML. The semi-structured interview questions can be found in Appendix D3. All interviews were recorded and fully transcribed in order to facilitate further analysis. To triangulate interview data, all participants were asked to provide relevant documentation about the project (e.g. project plan, technical reports etc.). These internal documents have been consulted to verify outcomes of the interviews and provided insight on how the collaborations evolved over time.

The events were further verified and discussed in a seminar, where all the project team members interviewed during the case studies were invited. This provided extra background information, which the involved persons may not have recalled individually.

3.4.4 Validity and Reliability

Because this study is based on retrospective data, several potential biases should be dealt with. Four potential sources of bias that could influence reliability (i.e. the consistency of the measurement instrument), are identified (van Aken *et al.*, 2007). These are (1) *bias by the researcher*, (2) *the instruments*, (3) *the respondents* and (4) *situational factors*. Several methods, instruments, and procedures have been used, during this research, to prevent bias. These methods and instruments have been discussed in the previous sections; Table 13 provides an overview and includes the referring section numbers. Validity means that the conclusion of a study can be stated with some confidence (Mentzer & Flint, 1997). Three types of validity are identified by Van Aken *et al.* (2007); (1) *construct validity*, (2) *internal validity* and (3) *external validity*. Construct validity addresses establishment of the proper operational measures for the concept being studied (Ellram, 1996). Internal validity concerns the completeness and justifiability of the relationships between phenomena (Van Aken *et al.*, 2007). External validity concerns the generalizability of the results and conclusions of a study to other locations or situations (Van Aken *et al.*, 2007). The methods and instruments that have been used to enhance construct, internal, and external validity of the empirical study can be seen in Table 13. The results of a study are reliable when they are independent of the particular characteristics within a study and can be replicated in other studies (van Aken *et al.*, 2007). In this study transparency on research methods and interim results ensure a high level of controllability (Yin, 2008). With controllability we mean the influences of the research on the changeableness of the environment, e.g. in a turbulent environment the chance of changeableness is high which can influence the degree to which the measurement instrument yields each time the same result (i.e. reliability). Controllability is a prerequisite for determining the levels of reliability and validity (Yin, 2008).

Table 13. *Methods and instruments that improved the validity and reliability of this research*

	Reliability				Validity		
Method/ instrument	Bias by researcher	Bias by instruments	Bias by respondents	Bias by situational factors	Construct validity	Internal validity	External validity
Multiple case studies (3.4.2)			√	√		√	√
Selecting extreme cases from different functional disciplines (3.4.2)				√			√
Multiple data sources (data triangulation) (3.4.3)		√	√	√		√	
Semi-structured interviews (3.4.3)	√		√			√	
Supplier representatives consultation (3.4.3)					√	√	
Codes have been used from conceptual model which is based on literature review (3.4.3, 3.4.4)	√	√			√	√	
Case descriptions and quotations (3.5)		√					

3.4.5 Data analysis

After data collection was established, data analyses were conducted in order to answer the research questions. This section describes the analyses of all data collected. After conducting the questionnaires and it follow-up interviews a narrative strategy was used for the construction of a detailed story from raw data (Langley, 1999). Hence, the four embedded cases, are described by using a historical description of the collaboration in terms of the start of the development activities, followed by the preparation of the collaboration with the selected supplier. The execution of the collaboration is then described and finally the release of the part/building block towards the end of the development project is analyzed. In Chapter 4 the results of the questionnaires were matched with the qualitative data obtained from the interviews, to try to connect them to project and collaboration results. Based up on this, a diagnosis is set about the NPD projects under study; these methods were adapted from the study of Van Echtelt *et al.* (2008). Collecting qualitative data in addition to a quantitative assessment strengthens the ability to interpret the observed scores. Questionnaire and interview findings were converted into tables, graphs and in some cases quotes were used to support the findings in the analysis. In summary the approach used:

1. collecting questionnaire results;
2. obtain data on the different framework elements from the interviews and formulated qualitative descriptions; and
3. value the qualitative descriptions by scoring them on an ordinal scale;
    a) input: three-point scale;
    b) throughput: five-point scale; and
    c) output: three-point scale.

Next, the main issues and problems observed during the collaboration were deduced from and summarized in a cause and effect diagram. The aggregate of these findings was verified once more among all interviewees and matched with literature findings resulting in key area(s) of interest in how the patterns in the managerial activities and conditions can deepen our understanding of the performance of ESI collaborations in a high-tech environment (i.e. short-term collaboration results). Using this approach vital process drivers, patterns and dynamics have been derived inductively, which results in moderate generality, since there was space for interpretation (Langley, 1999).

3.5 Four cases of early supplier involvement in NPD

This section describes four product development projects where ESI has taken place. Each case is described in a chronological sequence, including the preparation of the collaboration, the acual start, the development, the pilot/ramp-up production and finally the isues and problems that occurred during the projects. Appendix E beholds the sourcing model variants which ASML used during these projects and a summary of the supplier sample.

3.5.1 Case 1: Leveling Laser Control Board – Project A

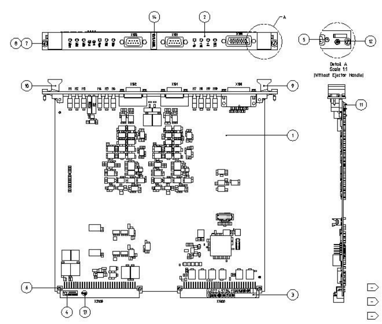


Figure 12. *The Leveling Laser Control Board*

The Leveling Laser Control Board (LLB) is an electronic component able to control the level sensor. The level sensor is an optical measurement system that provides height information. Because ASML has a single sourcing strategy, focusing on building long-term relationships, it did not send a request for proposal to the electronic market for capable suppliers. ASML just approached supplier A_2, a preferred supplier whose main competence is to built up components as a co-maker, rather than to design components. Previous projects have showed that supplier A_2 is not capable of designing modules by its own and therefore ASML selected a second first-tier supplier (supplier A_1), that was responsible for the design of the board. Supplier A_1 was in the lead of the proto and volume phase, and therefore also responsible for the cooperation between supplier A_2 and ASML. A large motivator of outsourcing this project was the lack of internal engineering capacity (capacity projects) and the strategic relationship that have been built up through the last decades with both suppliers (≥ 10 years supplier A_1; ≥ 15 years collaboration partner supplier A_2). Since all parties involved were familiar with the technology and production characteristics, the project was regarded as low innovative. The LLB project was a typical black-box sourcing model where suppliers $A_{1,2}$ developed and produced the unit, based on the product requirements supplied by ASML. In other words, the suppliers developed the technology and ASML received the products and know-how. The collaboration with suppliers $A_{1,2}$ started without a development contract and used a rough planning without detailed intermediate milestones and required activities. Nevertheless, no major problems were experienced during the project. The specifications were relatively stable and the product performed well, it has been produced with a three month delay. The delay was due to personal circumstances of the project leader as well as to a late re-design activity, initiated by ASML. The suppliers were both located in The Netherlands, and were within easy driving distance of each other. According to the project leader this turned out to be a valuable asset. Whenever a problem appeared, ASML project members could step into the car and were immediately on spot to solve the issues. An evaluation process has not taken place, which was justified according to the project leader since the collaboration during the project went smooth.

3.5.2 Case 2: Transmission Image Sensor – Project B

This case concerns about the development of the Transmission Image Sensor (TIS). The TIS is an optical component that can optically measure the aberration of the aerial image of certain structures. It has been used in multiple occasions; but it plays most importantly a key role during the alignment of the reticle to the wafer stage. Since the TIS project was subject of a strong internal time-to-market pressure, the project team chose to involve supplier B already in the feasibility phase, right before the supplier selection procedure has been started up. This is not unusual within the optical development environment of ASML (ref: development engineer). There was no development contract and supp lier B was paid out by a design fee construction. The account buyer sent a request for proposal to supplier B, settled in Germany, and to the ASML internal optical department, located in the US. According to the account buyer, the choice for supplier B was based on technical considerations and the strategic relationship that has been built up within the last decade (≥ 10 years collaboration partner). During the pre-design phase, supplier B had shown to be capable of developing the TIS unit. Since the technology was new for ASML and the technical specifications were towards the physical boundaries of nature, the project was regarded as high innovative. The project was defined as a grey-box sourcing model, by which supplier B developed and produced the TIS unit, and by which the design of the TIS was in cooperation with ASML. The sensor marks consist of a series of gratings, under which a photo diode was placed to measure the light intensity. This photo diode is a critical part of the TIS, in the past supplier B has demonstrated being not capable of designing this part by itself. Therefore ASML commended a second-tier supplier, responsible for the design and production the diode. Assessment of this second-tier supplier was based on the technical competence of the supplier and was outsourced to a Dutch research institute, which had demonstrated to own the expertise needed to develop this diode. After feasibility of the concept had been proven for the specific optical function, further development and design refinements were carried out. One year after the kick-off, the second-tier supplier showed up with problems concerning the delivery of the diode. Specific changes regarding the mechanical stability of the sensor diode array were necessary in four prototype cycles. It was the most critical development aspect which could not be solved within one prototype cycle. The second-tier supplier has proved that the technology works, but until now they have not been able to transfer the diode from the prototype to the pilot phase. Since

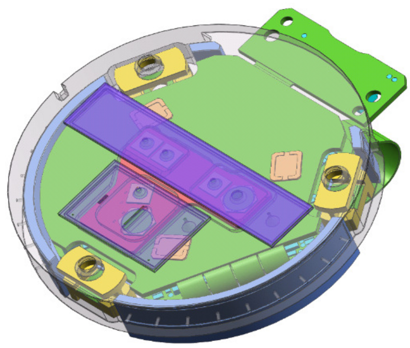


Figure 13. *The Transmission Image Sensor*

supplier B was forced to cooperate with a specific second-tier supplier, they refused to come up with a solution for ASML (ref: development engineer ASML). Therefore the project was stored in the fridge until a new selection procedure was completed. This time the selection of the second-tier supplier was not only focused on the technological aspects, but also on quality and logistics. Although, the new second-tier supplier was a research institute again (settled in Belgium), up till now no direct/urgent problems occurred. As a result the development team devoted much more attention to the development, than originally planned. Since time-to-market had become top priority, further delays were not acceptable. As a consequence, the development engineers carried out only the most critical redesign activities, leaving other aspects for after the release. According to the project leader this kind of decisions are quite common in the engineering environment of ASML. A final problem concerned the communication between the engineers of the two companies. Communication was difficult due to the language barriers in combination with the physical and cultural distance between both parties. Therefore face-to-face communication was restricted (ref: development engineer). At this moment the TIS project is in its volume phase. But the selection of a new second-tier supplier, the high amount of testing activities and rejection rates, resulted in high costs for ASML. An evaluation never took place. When asking why, project members could not come up with a solid answer. It just did not happen.

3.5.3 Case 3: Mini-environment Distribution Box – Project C

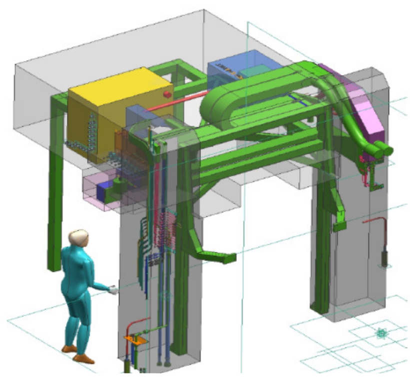


Figure 14. *Mini-environment Distribution Box*

The third case concerns about the development of the Mini-environment Distribution Box (MDB). The MDB is a mechanical component that controls the gas conditions, in terms of flow, pressure and cleanliness. The gasses are supplied to the mini environment and the vacuum chamber, where they clean the optics and sensors. Since ASML did not have enough knowledge regarding the conditioning of gasses in a vacuum environment yet, the development engineer looked for a supplier that would be able and well-willing to develop and produce the MDB unit at a specific tolerance, suitable for ASML's unique lithography proce ss. In cooperation with the procurement department, two suppliers were approach with preliminary functional specifications. One Dutch supplier and one US supplier. ASML had experience with both suppliers, from previous projects (both: relationship ≥ 5 years). Because of ASML single sourcing strategy, focused on building long-term relationships, ASML did not send a request for proposal to the mechanical market for new suppliers. After an informal selection procedure, the US supplier (supplier C) was selected for this project. According to the purchaser involved, the choice for supplier C was based on its ability to provide customized parts for the functional specifications. Since the technology was new for ASML but not for the supplier, the project was regarded as medium-high innovative. The MDB project was a typical black-box sourcing model, where supplier C developed and produced the module, based on the product definition of ASML. The supplier developed the technology and ASML received the products and know-how. Although, it was a black-box development model, ASML commanded a second-tier supplier for a critical part, the mass flow controller, in the MDB unit. This device is used to measure and control the flow of gasses. Though, supplier C came up with a recommended a supplier, ASML neglected this second-tier supplier suggestion and forced supplier C to cooperate with its personal preferred second-tier supplier. This second-tier supplier promised ASML a special technical spec (calibration function) which could not be provided by supplier C itself. Supplier C did not have good experiences with this second-tier supplier from the past and it therefore recommended ASML not to cooperate with this second-tier supplier. Six months after the kick-off, the second-tier supplier had problems with delivering the part. After several tests the collaboration with this second-tier supplier was stopped. After a half a year delay the project was restarted without the second-tier supplier. This time supplier C developed the mass flow controller by its own. During the sequel of the engineering phase, continuity of the relationship had been at stake. After restart of the collaboration, ASML got doubts/discussion regarding the supplier's assembly, test and production capabilities. Project delay occurred due to the fact that supplier C had divided the MDB module across five plants all around the US. All units had to be shipped back to one plant, where they did not have all the knowledge to perform integration tests for every single part. The supplier admitted that it underestimated the amount of development work (ref: project leader supplier C). Moreover, this was the first time that they collaborate with ASML not only as a co-maker but also as a co-developer. Besides that, the original idea at the start (2,5 years ago) was different from the image of today. The original thoughts compromised of frozen specifications, low complexity, no research needed and documentation is just a small part of the work (ref: project leader supplier). Other issues were related to cultural differences. "*We thought the customer is always right. ASML is big/impressive and seemed to know all the answers. We know now that specifications can change, research is to be expected, high level of complexity is present (both as single unit as well as system level dependencies) and documentation is a considerable part of the work. Besides that, ASML is not always right (ref: development engineer supplier).* The supplier learned that ASML is open for new views and options, as long as they are stated firmly. A last issue, of organizational origin, was the changing of team composition on both sides, which had its effect on the technical collaboration. Though, this should be regarded in perspective of the worldwide economical crisis, since both organizations were forced to fire people. Furthermore, in the end of 2009 supplier C disconnected from its mother holding, starting for its own. Further problems appeared due to noise in the communication and because of the physical distance between the supplier and ASML (ref: development engineer). The frequency of face-to-face meetings was rather low: ~ 3 times in 2,5 years. *Personal meetings should take place on a more frequent basis and during escalations only. Contact via e-mail and conference calls was good, but that is not always sufficient* (ref: project leader ASML). ASML also believed that supplier C did not always informed them in time when problems occurred. Thus, ASML could not anticipate and take action against possible overruns in time (ref: supply chain engineer ASML). After one year of delay, the project is now in its volume phase. The industrialization of the unit is successful according to the latest project planning of ASML. In the end all the technical specifications have been met, but the final costs passed excessive the development budget limit. Overall, ASML as well as the supplier stated that they have learned a lot about understanding each other's business drive and processes. An evaluation session is planned for the near future.

3.5.4 Case 4: PAAC 500/65 – Project D

The last case study involves the development of the Power Amplifier Alternating Current 500-65 (PAAC). The PAAC is an electronics component developed as a part of the NXT project for the Twinscan scanner reticle and wafer stage. It is physically positioned in the remote power cabinets and has to provide power on demand of a specific function; the wafer stage. In general, the development of power supplies is influenced by the supply market itself and by the directives and norms (or changes of it) as set by international regulatory bodies. According to the development engineer, ASML's policy is to use power supplies generally developed by current strategic partners. Lack of internal engineering capacity as well as the strategic relationship with the supplier, built up in the last decades, were strong motivators for outsourcing this project. As in the LLB project, ASML did not have a formal supplier selection process. It just approach supplier D, a preferred supplier (≥ 15 years collaboration partner) with good qualities as a co-developer and manufacturer of power supplies. All parties involved were familiar with the technology and production characteristics, but as the power supply technology was towards its physical limits level, because of the extreme power demand of the new NXT system, the project was regarded as medium innovative. The project was a grey-box sourcing model where the supplier developed and produced the PAAC,

Figure 15 *The PAAC 500/65*

except for the design of the PAAC which was in cooperation with ASML. During the project a debate has been going on, at both the project and management level, regarding the ownership of knowledge about the power supply technology developed by supplier D. In the past supplier D performed only build-to-print development projects where ASML designed its own power supplies. This was the first time of being a black-box supplier. According to the development engineer it was the first time that supplier D hesitated of sharing their proprietary information. "*We do not want to share our architectural design documents with ASML because our competitors are also suppliers of ASML. In addition, at the moment ASML cannot guarantee that this IP sensitive information remains internal (ref: project leader supplier D)*. The supply chain of ASML is characterized by suppliers having competitive interests, due to the dynamic roles and positions of actors in several division of work. So, it can occur that suppliers are forced to collaborate with their potential rivals. A second problem, concerning the collaboration between ASML and supplier D, arose when a redesign was needed. This redesign was initiated by unstable functional requirements on ASML's responsibility. It was detected during a proto evaluation and solved with the know-how of the supplier (ref: supply chain engineer ASML). Obviously, resulting in higher development costs. Besides these two issues, the supplier's electronics and mechanical design capabilities did meet ASML's expectation once again, and no major problems occurred during the project. However, there were some changes in the members of the project team. Six months after the kick-off, the project leader of supplier D was removed from its position on recommendation of ASML, since he did not fulfill the expectations (ref: development engineer ASML). At the end of the project an extensive evaluation session had taken place, initiated by the project leader of ASML. A competitor of supplier D joined the session, decided by the project leader of ASML. It is believed that the quality of future collaboration projects will increase by sharing knowledge/experience among the supply chain. The atmosphere and communication during the session was perceived as open and all parties were aware of the points of interest for new projects (project leader supplier D). Both parties intended to address these points for improvement in future projects.

3.6 Conclusion

This chapter described the background of the semiconductor industry and introduced ASML's strategic responses to the changing landscape in which it is operating. This refers to the demand for microlithography and the changing supply chain strategies of companies in order to adapt to these demands. ASML, being the market leader, is forced to evaluate critically how to combine internal and external resources to improve its competitive position. ASML's supplier involvement policy emerged from, and co-evolved with, at least three strategic responses in order to deal with these challenges: outsourcing, concurrent engineering and inter-company collaboration. Product modularity is a predecessor for executing these three strategies in practice.

In addition, a case study design and methodology which allowed us to study the phenomenon of ESI and the managerial activities, was presented. Four development projects where ESI was used, were selected and investigated retrospectively. This chapter also served to construct the case history. It presented a first refinement of issues and problems faced by ASML, during the collaborations. It seems that in some projects ESI required much more resources and time than expected, creating reservations about the added value of involving suppliers early in the development process.

In the next chapter, the main outcomes of the projects will be analyzed in more detail. It provides an in-depth analysis of the way in which ASML manages ESI in NPD projects, by linking the issues and problems to the different parts of the framework. Finally, the circumstances which delayed and facilitated the efficient and effective involvement of suppliers will be analyzed.

Chapter 4
Analysis

"For us it is a black box how a company with so much chaos as ASML succeeds to have a complex system up and running in such a short time over and over again."

- Supplier of ASML

4.1 Introduction

Chapter four gives an analysis of the main results of the four case studies, as introduced in the previous chapter. The foremost step in the analysis of data is the validation of the problem statement, which allows to test if the initial problem statement is not just a problem of perception but a genuine problem, according to Van Aken *et al.* (2007). They proposed to use empirical evidence for this validation. The initial problem in this thesis was the incoherent results of ESI in NPD projects, within ASML. Some projects did not find any relationship of ESI on NPD project performances and others even showed up with negative effects. To validate the reality of the problem, insight into the efficiency and effectiveness of the individual projects was gathered first. Next a cross-case analysis was conducted, in order to enhance the external validity (Yin, 2008). Differences and similarities for each of the determinants mentioned in the initial conceptual framework are discussed. By comparing the similarities across the different cases, insight in the factors for successfully managing ESI in NPD projects in a high-tech environment has been created. That enables answering the research questions 2 and 3a-b.

4.2 Validation of the problem statement

The individual cases have been assessed in terms of the *efficiency* and *effectiveness* of the project performances. Effectiveness refers to the degree in which technical performance, manufacturability and part cost targets have been met. Efficiency makes reference to the use of resources in terms of project lead time and co-ordination costs. Table 14 provides an assessment, which is distracted to the short-term results of the projects (see also section 4.3.1).

Table 14. *Development efficiency and effectiveness*

Outcome	Project A LLB	Project B TIS	Project C MDB	Project D PAAC 500/65
Development collaboration efficiency	High	Low	Low	Medium
Development collaboration effectiveness	High	Medium	Medium	High

ASML appears to invest additional time and resources in setting up and coordinating the collaborations, resulting in a reduced amount of efficiency. However, a more positive picture emerges regarding the effectiveness since almost all targets were met within every project. So, it can be concluded, that the overall effectiveness was evaluated as sufficient. However, it is likely that the additional costs due to extra activities and delay, have negatively influenced the effectiveness. The efficiency, as characterized by the interviewees, was low in two out of four projects. In contrast, the other two projects were regarded as highly efficient. These cases demonstrated the mixed results of ESI in the context of a NPD project, and therefore validate the initial problem statement. The proposed problem (incoherent results ESI in NPD projects) is therefore a real problem.

4.3 Analysis results case studies

This section will analyze the operational management processes of the four cases as well as the operational project conditions and enablers. Next, the main findings will be validated with the information of the suppliers who were involved in the collaborations with AMSL. Hereafter, we reflect on the main findings and examine the differences between the successful and less successful projects in order to explore if there is a pattern by which these mixed outcomes can be explained.

4.3.1 Short-term collaboration results

The first step in analyzing the cases was to measure the short-term collaboration results. Results were expressed in terms of the accomplishment degree, concerning five different development targets. The selection of these targets was based on the results of the literature review. The targets assessment was based on the results of the questionnaire (Appendix F) and the written data regarding targets and actual performances. If these sources were absent; opinions from key informants were used. Table 15 gives an overview of the short-term collaboration results.

Table 15. *Short-term collaboration results*

	Effectiveness related targets									Efficiency related targets					
	Part Technical Performance			Manufacturability			Part Cost			Part Development Costs			Time-to-Market		
Cases	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Project A LLB		■				■		■			■		■		
Project B TIS		■			■		■			■			■		
Project C MDB		■			■			■		■			■		
Project D PAAC		■				■		■		■			■		

1: below target; 2: on target; 3: above target

When analyzing the short-term collaboration results, ASML succeeded in meeting its own '*technical performance*' targets in all collaborations, as studied in this research. However, none of the technical performance targets surpassed the predefined specifications. This can be explained by the fact that ASML's system demands approximate the current physical laws (ref: D&E manager). With respect to '*manufacturability*'; respondents judged the results to be on target. ASML succeeds in meeting its manufacturability targets in all of the cases and two projects performed even better than expected. This corresponds with the general perception of ESI. Involving suppliers earlier in the development process will result in a better manufacturability in the volume and ramp off phase of a product (Swink, 1999). When focusing on '*part cost*', three out four projects succeeded in meeting its part cost targets. These results confirm the findings of previous research (e.g. Dowlatshahi, 1998; Petersen *et al.*, 2005). However, notable is the pattern related to 'part development costs'; three out of four projects went beyond their budget. Even more striking is the result that not a single project met the 'time-to-market' target for their building-blocks. This concurs with previous findings, which described that ESI does not speed up the overall product development time in turbulent changing industry segments (Eisenhardt & Trabrizi, 1995). Nevertheless, these results need to be interpreted with caution, taking into account specific contextual circumstances contributing to these deviations.

Until now managerial requirements for involving suppliers early in the NPD process have not been studied. This triggers a more in-depth assessment of the managerial processes meant to prepare and carry out such collaborations in NPD projects.

4.3.2 Operational Management Process results

So, the second step in analyzing the cases, was to measure the operational management process results as defined in Chapter 2. After gathering information by questionnaires and interviews, the managerial processes were classified by using a five-point ordinal scale, which characterized the degree of active and systematic execution of the processes, graphically depicted in Figure 16. This approach was adapted from the work of Van Echtelt *et al.* (2008).

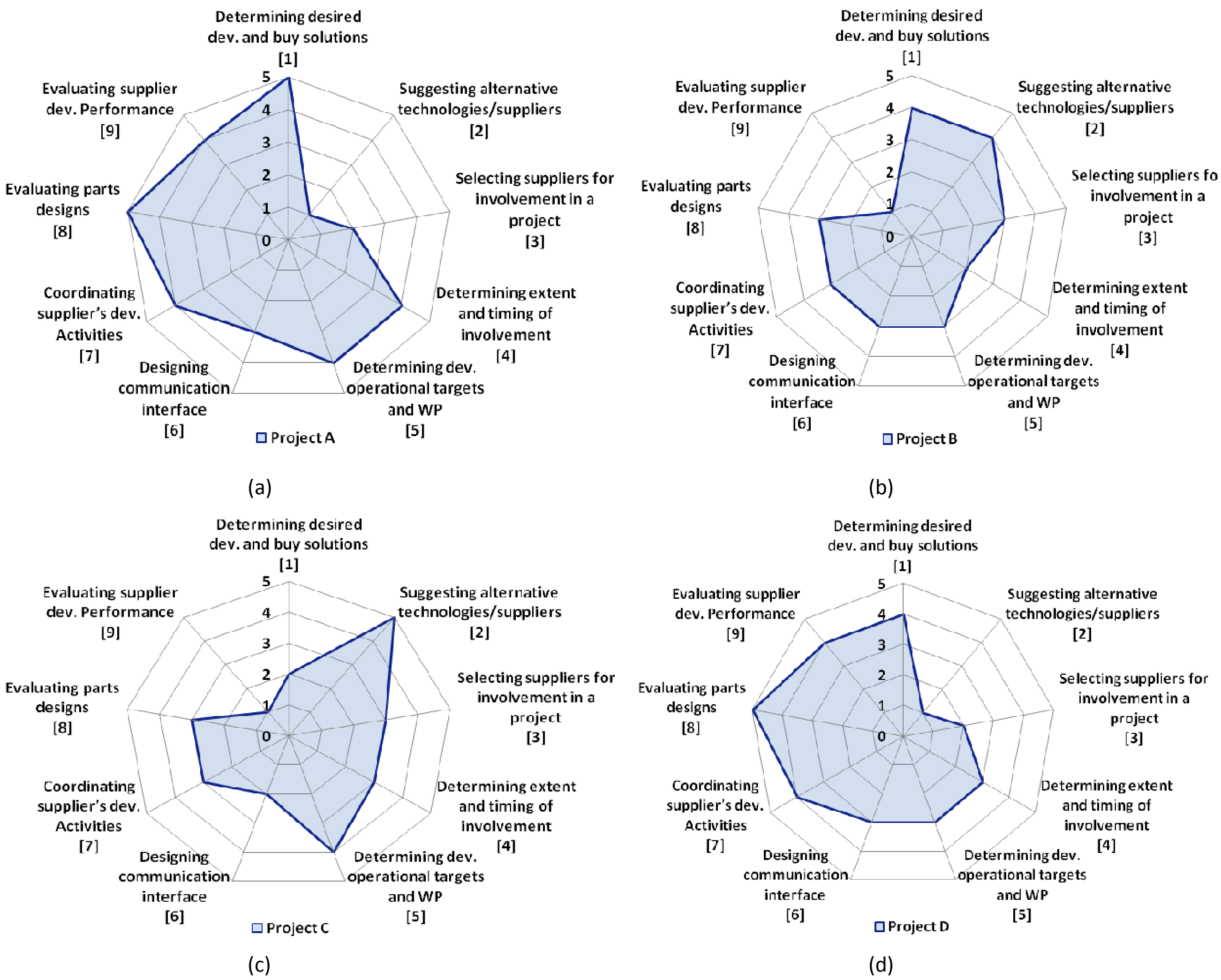


Figure 16. *Operational management process results per individual case* (n= 14)*

* Scale: 1-Absent: the process is not carried out; 2-Reactive: the process is carried out in an ad hoc way, as a result of occurring events; 3-Pro-active: the process is carried out following an implicit structure or set of activities; 4-Systematic: as in ‘ pro-active’ , but supported by systems, procedures and guidelines; 5-Intelligent: as in ‘ systematic’, but able to critically review the processes in the light of the situation and to adapt (incidentally or more permanently) when necessary.

Operational management process of project A (Leveling Laser Control-Board)

When analyzing the way ASML dealt with the operational management process of the collaboration with suppliers A_1 and A_2, it became clear that ASML had a clear vision of how to develop and produce the LLB part with the help of external suppliers (OMP1). Because ASML is using a single sourcing strategy[6], focusing on long-term relationships, the project team did not suggest alternative suppliers nor technologies (OMP2). Therefore, selection of suppliers scores so poorly (OMP 3). Since all parties were familiar with the way of working by similar projects in the past, the extent of involvement of both suppliers was clear for all entities (OMP 4). Although only a rough planning without detailed intermediate milestones and required activities was used, no major problems were experienced during the project, and the milestones appeared to be very accurate (OMP 5). As already mentioned in the case description, both suppliers were located in The Netherlands and they were within easy driving distance of each other. According to the project leader this turned out to be a valuable asset for joint problem solving (OMP 6, 7). At the end of the project an intensive evaluation had taken place on the part design of supplier A1 and ASML, which was triggered by a late re-design activity initiated by ASML (OMP 8).

[6] Prospective partners of ASML are usually chosen from a pool of previous collaborations in order to avoid opportunistic behavior and ensure the right fit that will guarantee success during the alliances.

Although the jointly evaluation session did not include an evaluation of the collaboration itself, which is rather an exception than the rule, according to the project leader (OMP 9).

Operational management process of project B (Transmission Image Sensor)
By analyzing project B, managerial processes 1 and 2 attracted our attention because of their relatively high scores compared to the other managerial processes. The sensor market is a niche market that requires mono disciplinary knowledge, and therefore only a few suppliers are available to deliver satisfying solutions for ASML. Most of them with a background as research institute (with a core competence of doing research instead of product development). ASML aims a single sourcing strategy, but as they have not found a compatible supplier in the sensor market that meets all requirements QLTC yet, they are continuously looking for alternative technologies or suppliers. This explains the high scores on OMP 1-2. For the low scores on the other managerial processes are a number of responsible events, which can explain why the project slipped slowly away from project to the problem driven management. First, the TIS project was subject of a strong internal time-to-market pressure. Therefore the project team chose to involve supplier B already in the feasibility phase, before a formal supplier selection procedure was started. Furthermore, the design of the product was highly interrelated with other modules in the lithography system, which made it vulnerable to redesigns of 'external' parts. This is reflected by high uncertainty of the TIS project and the difficulty to predict which work packages were necessary for realizing the functional specifications. This led to struggles for the project team in determining clear prices, and development targets, as well as in appointing the extent and timing of involvement of supplier B. This could explain the low scores on OMP 3-5. Furthermore, no clear communication interfaces were set up at the beginning of the project, which turned out to be a delaying factor because of the language barriers in combination with the physical and cultural distances between both actors. At the same time the assigned second-tier supplier could not supply, and therefore the project coordination did not go smoothly (OMP 6, 7). At the end, no jointly evaluation session had taken place, suggesting a poor link with (exploiting) learning experiences.

Operational management process of project C (Mini-environment Distribution Box)
Project C was not set up in a pro-active and systematic approach, resulting in low scores for OMP 1-9, with the exception of OMP 2. Since ASML has not enough knowledge regarding the conditioning of gasses in a vacuum environment yet, it was aware of this risk factor in the supply chain and was therefore continuously looking for alternative technologies or suppliers. Because of the high uncertainty involved in the MDB project, it was not clear which functional specifications could be realized and which work packages would be necessary for realizing these functional specifications. Secondly, the novelty of the supplier's technology for ASML resulted in an overestimation of the capabilities of supplier C, by ASML (ref: project leader ASML). The novelty of ASML as a customer for supplier C on the other hand, led to an underestimation of the amount of development work by the supplier (ref: project leader supplier C). The supplier was located in the US, which did not help in regulating the expectations and perceptions of the collaboration deliveries. However, most issues were resolved during the project. Overall, ASML as well as the supplier stated that they have learned a lot about understanding each other's business drive and processes, but an evaluation about the development performance together with the supplier did not take place. Such an evaluation session could be helpful in tackling issues for the future and decrease relationship stress (ref: project leader supplier).

Operational management process of project D (PAAC 500/65)
ASML was capable to determine the desired development and buy solutions, based on the experience of previous projects (OMP1). As in the LLB project, ASML did not have a formal supplier selection process. The extent of involvement was not systematically determined due to the presence of a supplier with experience of developing and producing power supplies for ASML. This explains the rather low scores on OMP 2-3. At the kick-off of the project, ASML and the supplier agreed on the target cost prices and time schedules, but no statement of work

(development contract) were used. The collaboration was characterized by a number of technical problems. Several re-designs of the proto had to made, which were caused by unstable functional requirements on ASML's responsibility (ref: supply chain engineer) (OMP 4-6). However, the coordination of the development activities went extremely well, according to the development engineer (OMP 7). According to the project leader this score can be explained by the strong ties between both development departments. A strong agreement between both professional cultures has been developed in the last several years. This has led to informal communication channels between both actors, where they only need a few words to understand each other (ref: project leader supplier D). After the project an extensive evaluation session had taken place, initiated by the project leader of ASML. The atmosphere and communication during the session was perceived as open, and all parties were aware of the points of interest for new projects, which explains the high scores on the OMP 8-9.

When conducting a cross-case analysis of the operational management processes two different patterns were observed; namely two projects (B,C) scored high on the front of the managerial processes and two projects (A,D) scored high on the back of the managerial processes based on the OMP scores in Figure 16. When zooming in further on specific managerial processes it becomes clear that the formal selection process (OMP 3) received a relative low score across all cases, this could be explained by ASML's value sourcing strategy, focusing on long-term relationships.

Nevertheless, when confronting these findings with the short-term results (section 4.3.1) of each project, the lack of pro-active and systematic routines do not automatically lead to the conclusion that less systematic processes result in off-target performances, since all the projects met most of their targets. Projects A and D even scored high on the project efficiency targets. This suggests that additional explanations are needed for answering the question about which aspects are important in organizing ESI in NPD in a successful manner. Therefore, the next sections examine the levels and roles of project enablers and driving factors.

4.3.3 Operational project enablers

The next step in analyzing the cases was to investigate the operational enabling factors for effective and efficient management of ESI in the four case studies. This section investigated three main categories of conditions that facilitate the management of ESI, as identified during the literature review. Three internal enablers of the buying company (top management commitment, human research quality of the organization and internal cross-functional coordination), three external enablers (the supplier's technical, project alignment and target cost[7] capabilities) and finally three supplier relationship enablers (past experience, mutual trust and matching culture). These enablers were measured in terms of their degree of presence, using a three-point scale. The main results of the operational enablers are represented in Table 16.

Internal enablers, all projects scored high concerning the top management commitment and internal cross-functional coordination, and they are crucial for successful ESI (e.g. Brown & Eisenhardt, 1995; Hillebrand & Biemand, 2004). In addition to the relation between cross-functional organization and successful ESI, the quality of human resources can be an important moderator that positively influences this relationship (Wynstra & Van Echtelt, 2002). The extent to which the collaboration in the case studies was facilitated by the actual presence of capable human resources is quite stable between all cases. This is also supported when regarding the education level of all ASML employees. In 2009 almost 70% of the ASML employees deployed in Veldhoven had a bachelor or master degree (ASML, 2010). Notable is that all purchasers involved, possessed a significant amount of technical experience which had been gained internally, some of them had even been working for years in the D&E department.

[7] With supplier's target costs capabilities we mean how well suppliers can determine the cost price for a new part, so the part can be purchased on competitive terms for ASML.

Table 16. *Overall results operational enablers*

Criteria	Project A	Project B	Project C	Project D
Internal enablers^				
Top management commitment	medium	medium	high	high
Human resource quality organization	medium	high	medium	high
Internal cross-functional organization	medium	medium	high	high
External enablers^				
Supplier project management capabilities	high+	low	medium	medium
Supplier technical capabilities	high+	medium	medium	medium
Supplier target cost capabilities	high+	low	low	medium
Supplier relationship enablers^				
Past collaboration experience	medium+	medium	low	medium
Mutual trust	medium+	medium	medium	high
Matching culture	medium+	low	low	High

^ Informants: internal project team (n=14).
+ This project included more than one supplier and the scores refer to averages for these suppliers.

This was also supported during the interviews:

"On my first day at ASML it was like I was ended up at a technical university."
– Purchaser ASML

External enablers, the supplier's capabilities (i.e. technical, project alignment and target cost capabilities) are a prerequisite in order to have an early and successful involvement of suppliers in a NPD project. When asking the project members involved in the supplier selection phase of the cases, they stated that the degree of technical capabilities has been the most important factor for selecting the right supplier for the collaboration. This was supported by the fact that all suppliers scored well on their technical capabilities. In addition, mixed results were observed in the project alignment and target cost capabilities. Handfield *et al.* (1999) already suggested that beside technical capabilities, a supplier also needs to have the right organization and processes to meet customer targets. This is supported by research of Wasti & Liker (1999), they described that these capabilities are a strong indicator for fortunate ESI in NPD. When analyzing the scores for project management and target cost capabilities, we observed that cases B and C scored below standard. A good example for this conclusion was the choices for the second tier suppliers, which were just based on technical promises of these suppliers. As described in Chapter 3, both second-tier suppliers were not capable to perform, because of their failing project management competences.

With regard to the **Relationship enablers**, the scores were mixed and often lacking. For the most cases it was the first time that suppliers were involved early in the design phase of NPD projects with ASML, with case A as an exception. These low scores resulted in issues surrounding the expectation and perception of development targets between ASML and the suppliers. The MDB project is a good example that expectation and perception were different as a consequence of lack of experience between both actors (as mentioned in section 3.5.3). This distilled the problem of misunderstanding between both actors.

When considering the levels of mutual trust in the collaborations, scores were rather high. All people interviewed during the case studies gave high praise of the collaborations, based on the degree and frequency of information exchange. Chapter 2 concluded already that it takes a long time to develop mutual trust, this proposition can be supported in this study since all suppliers involved in the cases have a long history as collaboration partner (average length relationship ≥ 10 years). In a number of cases cultural differences between ASML and its suppliers delayed the communication and coordination of development activities. Several types of cultural differences in a collaboration set-up were introduced in Chapter 2. These differences were also recognized during the case study findings. For example we observed *national differences* in the MDB project, where supplier C is an American supplier and the way of working is based on the 'customer is king' philosophy. At the supplier selection phase of the project, the supplier promised that they could fulfill all the requirements of ASML. Afterwards they admit to have underestimated the technical complexity of the building block:

> "Now we know that specifications can change, high level of complexity is present and documentation is a considerable part of the work. Besides that, ASML is not always right."
>
> – Project leader supplier C

Furthermore, we observed cultural differences on *organizational*- and *professional* levels. Quite remarkable was the difference on cultural scores between the suppliers of project A and D, since all suppliers involved were Dutch and stationed in the same area with a similar customer base (see also Appendix I). During the interviews the project members were asked to explain the difference in performance between suppliers A_2 (described as *do'ers*) and D (described as *thinkers*). Possible explanation is the history of both suppliers, supplier A2 started as a Jobber and Supplier D as an electronic design company. Moreover, as a result of cultural differences it took a long time to resolve the misunderstandings resulting from differences in interpretation and expectation of the product requirements provided by ASML. In recap, the issues, problems and unsatisfactory results can be ascribed to the absence or limited presence of the supplier's:

- project management and target cost capabilities;
- collaboration experience; and
- cultural differences on a national and professional level.

This resulted in communication noise and additional coordination of development activities (OMP 5 and 7) and a more intensive discussion session on part designs (OMP 8), as described in the previous section. The previous observations correspond with the general perception of ESI, that intangible variables as experience and culture have its influence on collaborations within NPD projects. However, as these conditions are considered as being dynamic, they can also be improved. Although, a pro-active and systematic project approach of ESI is a necessary, it is insufficient to bring in expertise and build up a matching culture in inter-organizational collaborations, as we will discover in the coming sections.

4.3.4 Corporate and project driving factors

After the analysis of the short-term results of ESI, one issue still remains. Namely, are these determinants (managerial processes and project enablers) not simply influenced by situational factors as different levels of dependency, complexity and degree of project novelty? The basic thoughts behind this proposition is that a large amount of driving factors require more pro-active systematic and adaptive processes to mitigate the risks of ESI (Van Echtelt, 2004). Table 17 gives a graphical overview of the results of corporate and project driven factors of the case studies. The overall scores on driving factors showed a difference of one construct, namely the difference between high and less innovative projects. Innovation is one of the key drivers at the project level. In order to distinguish high and low levels of innovation, we ranked the projects based on corporate and project driving factors scores (level of dependency, complexity and technological novelty), as shown in Table 17.

Table 17. *Overall scores driving factors*

Criteria	Project A	Project B	Project C	Project D
Strategic corporate drivers^^				
BU size supplier	small+	medium	small	small
Supplier dependence	low+	high	high	medium
R&D dependence	low+	high	high	low
Manufacturing complexity	low	high	high	low
Technological uncertainty	low	high	medium	medium
Operational project drivers^				
Degree of project innovation	low	high	medium	Low

^ Informants: internal project team (n=14), ^^ Informants: internal documents.
+ This project included more than one supplier and the scores refer to averages for these suppliers.

The scores were awarded for the different levels of innovation dimensions, based on the extent to which the projects met specific requirements as derived from theory. Using the total scores in Table 17, the cases are divided in projects scoring low on innovation level (low) and projects scoring high on innovation level (medium/high):

- projects having a low innovation level: A & D;
- projects having a high innovation level: B & C.

Table 18 represents an overview of the overall results between the low and high level of innovation projects.

Table 18. *Overall results of the highly and less innovative projects, respectively*

Criteria	Project A (LLI)*	Project B (HLI)*	Project C (HLI)	Project D (LLI)
Average Short-term effectiveness results^^	Above target	On target	On target	On target
Average Short-term efficiency results ^^	On target	Below target	Below target	On target
Average operational planning processes activities^ (OMP 1-7)	Pro-active	Pro-active	Pro-active	Pro-active
Average operational learning processes activities^ (OMP 8-9)	Intelligent	Reactive	Reactive	Intelligent
Average operational project enablers^	Medium	Medium	Medium	High

* LLI= low level of innovation; HLI= high level of innovation.
^ Informants: internal project team (n=14), ^^ Informants: internal documents.

The overall results showed no big differences between low and high level innovative projects when it comes to effectiveness. However, a slightly better score for project A was reported, as it surpasses its initial targets (on manufacturability). For the efficiency (i.e. project lead time & development costs) a clear pattern was observed. The highly innovative projects did not met the initial targets, in contrast to the less innovative projects, which performed on target. In other words; the higher the level of complexity and uncertainty within a NPD project, the lower the efficiency of the collaboration. Earlier in this section the assumption was made that high level of uncertainty and complexity would require a more pro-active systematic and adaptive process to mitigate the risks of ESI. Nevertheless, we did not observe a more systematic and pro-active approach in the highly innovative projects (average operational planning processes (OMP 1-7). In addition, less innovative projects scored much better, compared to highly innovative projects on learning activities (OMP 8-9), suggesting a strong link between efficiency and learning in inter-organizational relationships for NPD projects. This is also encountered in previous research (Sobrero & Roberts, 2001). Finally, in Chapter 2 we made the assumption that the company size of the supplier has a positive influence on the performance of ESI in NPD projects because of their increased access to resources (Andersen & Drejer, 2009). This study did not found evidence for this proposition, since all suppliers involved in the cases were small or medium sized.

4.3.5 Results interviews suppliers

This section represents the results of the consultation session with the suppliers involved in the case studies. Consultation session were conducted to obtain partial verification of case data and to better understand the problems encountered in the collaboration. Hereby the detection of events, issues and problems which could help to further formulate possible explanations for the performance of the cases was important. Figure 17 represents the key issues of ESI regarding the implementation of ESI on the project level, as appointed by the suppliers. From Figure 17 you can derive two main topics of issues surrounding all the issues appointed during the interviews:

- the level of modularity of design; and
- the project alignment capabilities.

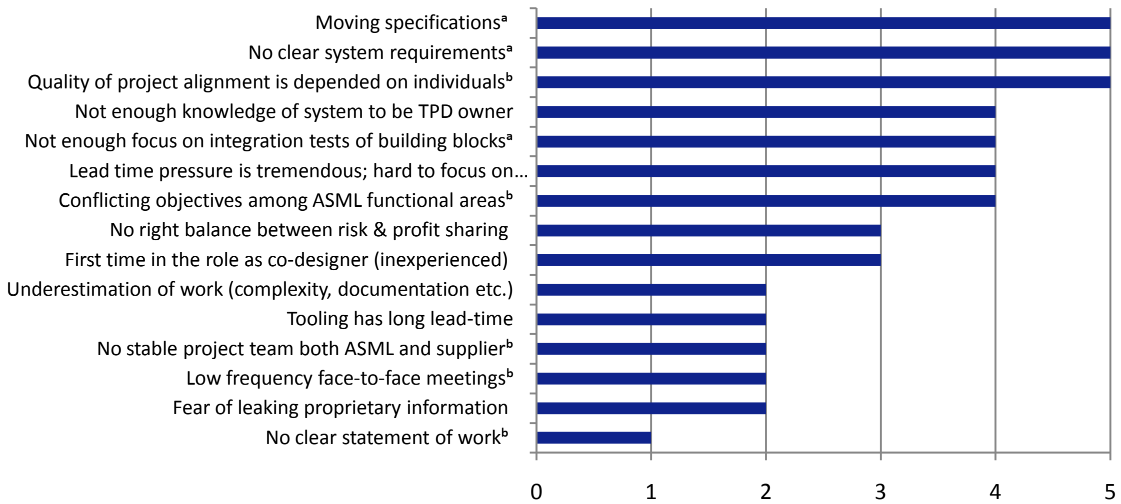


Figure 17. *Key issues and problems mentioned by suppliers (n=5)*
[a] items related to the level of modularity of design.
[b] items related to lacking project alignment capabilities of ASML.

The level of modularity of design was one of the topics emphasized repeatedly during each interview. Although the suppliers were co-owners of the designs of the specific building blocks in all cases, they were confronted with moving specifications, vague system requirements and of often late integrations test of building blocks during the projects, resulting in project delays and exceeded budgets. In an ideal situation of a modular system, each module communicates and interacts with each other via standardized interfaces, which allows decoupling of each self-contained key component (Baldwin & Clark, 1997). But according to the suppliers, the components of ASML do not have the same stable architecture and mature technological content as components from other customers they collaborate with (e.g. OEMs in the automotive or healthcare industry). As problems often arose in the final testing phase as executed by ASML, and not during earlier testing protocols by the supplier, this required last minute solutions:

"We don't have the architectural knowledge about the ASML's systems, so for us the system is like a black hole that requires delayed and unexpected specification changes, which cost a lot of efforts."

- Project leader supplier D

As Zirger and Hartley (1996) already pointed out, involving suppliers too early may result in integrations issues and decreased inefficiency.

Lacking project alignment capabilities of ASML was another main topic emphasized time and again. According to the interviewees the quality of project alignment depended on individuals, rather than on codified and formalized inter-organizational procedures, leading to a less systematic project approach from ASML side. Also, remarkable is that some suppliers noticed that they have missed ownership of project targets within ASML, resulting in conflicting objectives between internal functional areas of ASML and delayed projects:

"ASML is like a corrupt army: after the deal is done suddenly all professionals within ASML come to defend their QLTC puzzle within the project."

- Project leader supplier D

Other impediments that emerged by our informants (e.g. fear of leaking IP knowledge, low frequency face-to-face meetings etc.) have already been appointed earlier in this thesis.

Once considering all the issues and problems that suppliers must overcome during collaboration with ASML, you could wonder if it is even profitable to start a long-term relationship with ASML? Confronting suppliers with this question resulted in one uniform comment:

> "ASML is a stress customer in our customer base. It forces us to cross existing knowledge boundaries and we can use this as a spin-off for other markets we serve (e.g. automotive and healthcare industry)" - Project leader Supplier A_2

So it seems that the collaboration driver from the suppliers' point of view is based on a source of innovation/access to new technology. This implies that ASML's contribute in improving performance in other sectors (spillover), by sharing its knowledge through their network. A paradox in this finding is the fact that suppliers are reserved to invest in technology roadmaps with ASML, when the technology is still in its infancy. Expressed by one supplier as:

> "ASML's products are 'tailorized'; we cannot sell these products to other markets/industries. This makes it difficult to optimize our internal processes for ASML products."
> - Project leader Supplier

This lack of willingness to invest in new technology is powered by the attitude of ASML as it is not able to commit to the supplier by promising it late back up orders.

4.4 Reflection of main findings

4.4.1 Successful versus less successful projects

It is interesting to look at the differences between successful and less successful NPD projects regarding their scores on the operational managerial process, project enablers and corporate and project driving factors. In order to award a project as successful, the metric "short-term effectiveness results" and the "short-time efficiency results" have been used. Projects which scored high on both outcome measures were considered as successful in regard to their ESI practices, on the other hand projects that had a low score were considered as being less successful.

Table 19 summarizes the main findings on differences on product, supply chain characteristics and inter-organizational coordination between successful versus less successful projects. It shows a typical pattern of differences in the *operational managerial process*, *operational project enablers* and *inter-organizational coordination* categories between the successful and less successful projects respectively. The successful projects operated in the electrical functionality of the lithography system, where the less successful projects operated in the optical and mechanical disciplines. In contradiction to the optical and mechanical industry, actors in the electrical industry are forced to work according to international standardized directives and norms. Besides that, the electrical industry production processes are well developed in terms of the automation and testing procedures in order to be able to produce high volume parts. This in contrast to the mechanical and optical industry, were processes still largely depending on manual production. Automation reduces labor costs, decreases production cycle times and increases product quality and consistency which lead to learning opportunities (Groover, 2007). The level of modular design is also different between the less and successful projects. The modules of the successful projects were less interrelated with other modules in the lithography system. This takes away some vulnerability for redesigns of 'external' parts. The less successful project had actually to deal with late Engineering Changes (ECs), these ECs "snowball" from one component to another resulting in additional iterations for proto types within NPD projects of a new type of lithography system. Capable technical suppliers in the optical and mechanical industry are much scarcer compared to the electronic field, which forces ASML to cooperate with less capable suppliers (e.g. in project D, ASML was forced to cooperate with a research institution whose core competence is doing research instead of production). Due to the small availability of capable suppliers in the supply chain, ASML was forced to collaborate with suppliers from abroad in the less successful projects. This was not in favor of the inter-organizational coordination of these collaborations. In the successful projects all suppliers involved were located in The Netherlands. According to both the interviews with suppliers as to ASML this turned out to be a valuable asset (e.g. whenever a problem appeared, ASML project members could step into the car and were immediately on spot to solve the issues).

Table 19. *Main differences successful versus less successful ESI NPD projects*

	Successful (projects A and D)	Less successful (projects B and C)
Operational Management Process		
Presence of formal selection procedure	No	Yes
Prescribing 2nd tier suppliers by ASML	Did not happen	Happened
Communication	Iterative, face-2 face when necessary	Low/Medium
Evaluation taken place	Yes, both cases even multilateral	No
Operational project enablers		
Supplier project management capabilities	Medium/high	Low/medium
Supplier target cost capabilities	High	Low
Past collaboration experience	Medium	Low
Matching culture	High/medium	Low
Geographical location	Both in The Netherlands	Germany, USA
Corporate and project driving factors		
Supplier dependence	Low/medium	High
# suppliers in the supply chain	Many suppliers in the field with the same technical capabilities	Less suppliers in the field with the same technical capabilities
Manufacturing complexity	Low	High
Functional discipline	Both electrical	Optical and mechanical
Presence of international regulatory standardized directives and norms	Yes	No
Technological uncertainty	Low/medium	High/medium
Degree of project innovation	Low	High/medium

A final striking difference was the use of an extensive evaluation sessions in the successful projects, which have not taken place in the less successful project, leading to a poor link of (exploiting) learning opportunities of the ESI organization.

4.4.2 Barriers to ESI in a high-tech environment

This section will reflect on the question if low and medium tech environments (e.g. food and automotive industries) are comparable to high-tech environments (e.g. aerospace and microlithography industries), when it comes to organizing ESI in NPD projects. Publications exploring ESI in NPD projects in contexts of high-tech industries are scarce, leaving the issue largely unexplored. Having analyzed the results between successful and less successful projects, we have learnt that NPD projects within ASML were faced with different sources of performance factors (e.g. technology uncertainty, modularity of design, availability of capable suppliers, communication, learning opportunities, matching culture etc.), that influences the effectiveness and efficiency of ESI in NPD project. The mixed results in regard to success could imply that ESI as a successful strategy depends on the specific market mechanisms. Reflecting these findings to the current literature of ESI, we recognize three determinants that specifically affect ESI in a high-tech context compared to ESI in low and medium-tech context. These three determinants are:

1. level of modularity of design;
2. technological uncertainty; and
3. supply risk.

The level of modularity design was one of the topics repeatedly emphasized during the case studies. Products of a high-tech environment, such as a lithography system, are complex systems because they comprise of a large number of components, with many interactions in non simple ways (Simon, 1969). Although different authors proposed different definitions of modularity, they tend to agree on the core concept, namely the notion of interdependency within modules and independency between modules (Zirger & Hartley, 1996). By decoupling of interfaces of highly modular systems (Ulrich, 1995), it is also possible to decouple the development of one module from the other. Furthermore, if interfaces can be standardized, it allows development of components in separation from the company that integrates the system (Langlois & Richard, 1992). However, in reality it is often difficult to effectively partition a complex system (Gadde &

Jellbo, 2002). This holds certainly for a lithography system produced in a high-tech supply chain of the semiconductor industry, where genuine conditions of modularity are often not feasible. High-tech companies as ASML do strive for at least some degree of modularity (e.g. Chuma, 2006), but they do not succeed in separating the modules perfectly yet. Some case studies clearly presented the "snowball" consequence of limited modularity. Changes of one module led to integration problems with the other module and therefore the necessity for changes, which led to integration problems with the next module and so on, resulting in project delays and exceeded budgets We observed that the degree of EC management in the final phase of the design of a lithography system influences the efficiency of ESI in NPD projects. So, if an OEM (in this case ASML) is not able to suspect and address possible integration problems in front, it is difficult to set up clear defined design boundaries for its suppliers, as they are responsible for the design of the modules (what is the case with ESI). Hence, the level of modularity of design (ceteris paribus) influences the effectiveness and efficiency of ESI in NPD projects.

Technological uncertainty is inherent to the development of new technology. However, in high-tech industries, the degree of complexity and novelty of the developed products is especially high compared to low and medium-tech industries (i.e. more certain industries). It can be argued that complexity and novelty are both closely related to the concept of uncertainty (Wasti & Liker, 1997b). A type of uncertainty in regard to technology sourcing decisions in ESI projects, is industry uncertainty, or exogenous uncertainty (Van de Vrande *et al.*, 2006). This study has shown that suppliers of ASML are reserved to invest in technology roadmaps when the technology is still in its infancy, since the extent of success is unknown at that moment. Especially in a high-tech environment with high-mix low volume characteristics, the ROI time is low. ASML is not willing to commit to the supplier by promising late back up orders. Hence, suppliers are less committed to align their roadmap to that of ASML. Continuing this way of thinking, uncertainty in technology also affects schedule time and the cost of the project (Van Oorschot, 2001). This eventually increases the inefficiency of ESI in NPD projects. In conclusion, the degree of technological uncertainty (ceteris paribus) influences the effectiveness and efficiency of ESI in NPD projects.

Finally the **supply risk** plays an important role in ESI success of NPD projects within a high-tech environment, as demonstrated in this research. In this thesis, supply refers to technical competencies and capabilities of (potential) suppliers contributing to OEM's NPD activities (Smals, 2008). Since this study aimed to gain insight into inter-organizational collaboration of development tasks from the viewpoint of the buyer, the availability of external competencies (by means of suppliers) is the primary aspect of concern. This comprises the availability of parties in the supplier network that have the technological competencies needed (Petersen *et al*., 2003), the supplier selection (e.g. Van Echtelt *et al.*, 2008) and also the organizational match between these suppliers and the OEM (e.g. intangible assets such as matching cultures). For example, the difference in availability of capable suppliers in a high-tech environment compared to low- en mid-tech environments, was revealed during this research. In addition, it was observed that the availability of capable suppliers is an important factor of successful ESI in NPD projects. According to interviewees, depending on a few suppliers, is the result of the low availability of competent suppliers in the optical and mechanical supply chain of ASML (projects B, C), this in opposite to the electrical market where suppliers of project A and D are operating in. Hence, the level of supply risk (ceteris paribus) influences the effectiveness and efficiency of ESI in NPD projects.

These three determinants are mapped and graphically depicted in Figure 18[8]. This figure consists of three axes which represent the relationships of the three determinants; technological uncertainty, supply risk and modularity of design.

[8] The examples of low-, medium- and high-tech industries are taken from the study of Hatzichronoglou (1997)

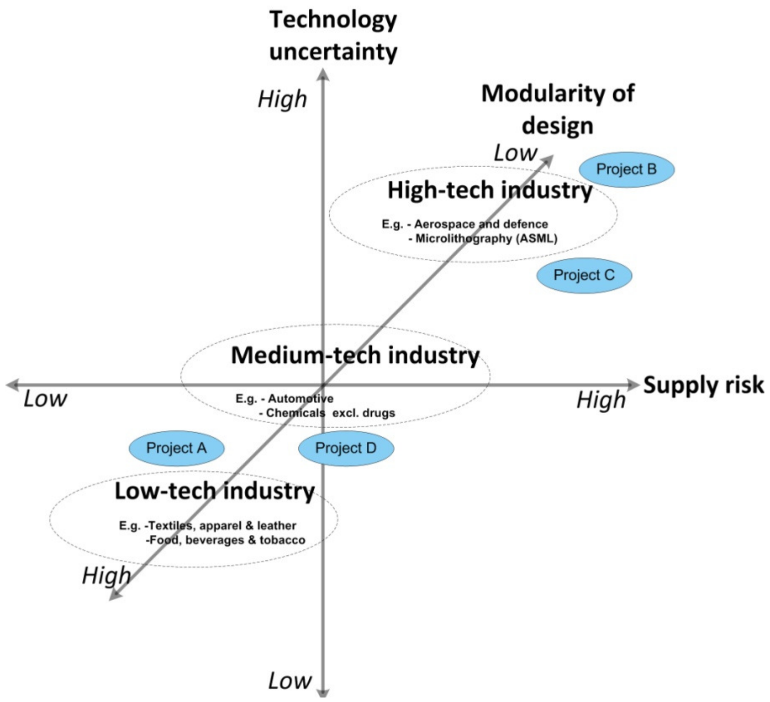


Figure 18 *Schematic overview of the coherence between modularity of design, supply risk and technology uncertainty within different industries*

4.5 Conclusion

In the previous chapter, we ended our case description with a summation of the various issues and problems occurred during these cases. In order to explain the observed project results and issues, this chapter has analyzed the specific characteristics of ASML's management approach in ESI. Furthermore, three insights regarding the management of ESI were developed.

First, this study supports the proposition that ESI has a positive influence on short-term factors like 'product quality', 'part cost' and 'manufacturability'. This corresponds with the general perception of ESI based on previous research (e.g. Swink, 1999; Petersen *et al.*, 2005). However, we also found some negative influences of ESI on 'development costs' and 'time-to-market'. This concurs with previous findings that ESI does not speed up the overall product development time in turbulent changing industry segments (Eisenhardt & Trabrizi, 1995) and that it increases development costs (Birou, 1994). Secondly, a pattern of differences in the *operational managerial process*, *project enablers* and *project drivers* between successful and less successful projects was found. An intensive iterative communication web and extensive evaluation sessions between the collaboration partners have a positive influence on the performance of ESI. Operational project enablers like 'suppliers capabilities' (project alignment and target cost)' and 'geographical location' have also a positive influence on ESI performance in NPD. As well as the intangible assets: 'experience in alliance' and 'matching cultures'. Concerning the driving factors, we found support that 'supplier dependency', 'manufacturing complexity' and 'technological uncertainty' have a negative influence on the success of ESI in NPD projects. And finally, three determinants have been recognized, which have a specific role in ESI practices of high-tech environments. These are (1) *the level of modularity of design*, in which we have seen that those projects with a low level of modularity of design were confronted with snowball effects by ECs of external part that influenced the design other parts, (2) *the level of uncertainty in technology,* which negatively affected the time schedule and costs of the projects contributing to the inefficiency of ESI, and (3) *the level of supply risk*, which played an important role when analyzing the differences between highly and less innovative projects. We observed that the availability of capable suppliers in a high-tech environment is scarce.

The next chapter goes one step further, by providing an answer on the central research question how ASML can improve its organization in order to manage ESI in NPD projects successfully..

Chapter 5
Diagnosis and solution design

"Everyone you meet admits that the mindset of ASML is not efficient; working from crisis to crisis and from issue to issue, always mobilizing, energizing and solving. But at the same time everybody considers it is an asset"

- *Senior supply chain manager ASML*

5.1 Introduction

So far, this thesis has developed a framework for analyzing the management activities of ESI in NPD. We limited the relational set in our observation to one type of interaction (i.e. buyer-supplier) and one particular occasion (i.e. the development of a new product). Four case studies of ESI collaborations between ASML and suppliers in a NPD context were conducted. This provided an in-depth analysis of the way in which ASML manages ESI in NPD projects. Chapter 5 goes one step further by providing an answer on the central research question. First the information from the case studies is organized by means of a root cause analysis[9] (RCA), resulting in a final diagnosis of the main root-causes of ineffectiveness and inefficiency of ESI performances. This diagnosis serves as input for a solution design that can help to improve the effectiveness and efficiency of ESI performances in NPD projects. In this chapter we provide the specifications and outline of the solution design. The final change plan describes the way in which ASML needs to move from the current situation to the desired one (IST-SOLL).

5.2 Diagnosis

This section presents the diagnosis of the problem statement and combines the insights from the analysis into a coherent explanation. In doing so, the information from the questionnaire, interviews and documents is organized by means of a RCA. In Chapters 3 and 4 we presented a number of issues and problems that occurred throughout the four projects. Both in- and after-project quality issues and problems were observed, see also Table 20. Distilling the issues and problems and assessing how common they are throughout the projects, provides us a good starting point for a diagnosis story that will serve as input for the solution design. Please take in mind that we did not ignore the less frequent, but potential important issues.

[9] A RCA is a structured in-depth investigation into the causes of an identified problem. In a RCA one tries to uncover what caused something to go wrong so that its recurrence can be avoided.

Table 20. *Overview of problems and issues during the collaborations*

Problems and Issues	A (LLB)	B (TIS)	C (MDB)	D (PAAC)	Number of Cases
Excessive and often late engineering and specification changes	√	√	√	√	4
Focus on intra- and not inter-project learning	√	√	√	√	4
Absence of evaluation process afterwards	√	√	√		3
Cultural differences	√	√	√		3
Conflicting objectives between ASML's internal functional areas		√	√	√	3
Ad-hoc product driven project management by ASML		√	√	√	3
Supplier operating for first time as co-designer		√	√		2
Doubts/discussion regarding supplier's assembly, test and production capabilities after collaboration started		√	√		2
High interdependence among building blocks		√	√		2
ASML prescribing second-tier suppliers		√	√		2
Noise in the communication (supplier-buyer) due physical distance		√	√		2
Supplier don't share internal problems during project		√	√		2
Supplier not able to keep the same people in the project team			√	√	2
Fear of leaking proprietary information				√	
Supplier already involved in the design phase, before the formal supplier selection procedure was started		√			1
Supplier disconnected from holding			√		1
Physical distance between supplier's business units			√		1
Total number of problems	**4**	**13**	**15**	**6**	**38**

5.2.1 Ishikawa diagram

Although the analysis in Chapter 4 and the table above provides more insight in the problems, an additional method was used to found the root causes of these problems. The causes of the ineffectiveness and inefficiency of ESI performances in NPD projects were synthesized in an Ishikawa diagram (Ishikawa, 1990). This analysis resulted in the diagram as shown in Appendix G. Four main problem areas of ineffectiveness and inefficiency have been identified: *ASML's internal capabilities, supplier selection, supplier relationship management,* and *product characteristics*.

ASML's internal capabilities

As already addressed in the previous chapter, one of the top ranking issues in Table 20 is the occurrence of projects that were managed on an ad hoc basis. In more than half of the cases, there was discussion about the project alignment capabilities of ASML and the suppliers. The quote at the start of this chapter refers to general perception of ASML's way of working. It seems that ASML has the mindset of a firefighter. To support this view several opinion of ASML employees about the relationship between 'the ASML culture' and 'project efficiency', are enclosed in Appendix I. According to the suppliers, the quality of project alignment depends on individuals rather than on codified and formalized inter-organizational procedures, leading to a less systematic project approach from ASML side. Besides that, the organization root-cause showed a lack of ownership of project targets within ASML, resulting in conflicting objectives between internal functional areas of ASML, which led to delayed projects.

Supplier selection

The supplier capabilities branch showed problems related to the selection of capable suppliers, as a consequence of scarcity. Due to the high-demanding requirements of ASML (i.e. mono disciplinary technological knowledge) in combination with the low order volumes of new developed products only a few suppliers are available to deliver satisfying solution. As a consequence ASML was forced to cooperate with suppliers having lower capabilities (e.g. a collaboration with a research institution whose core competence is doing research instead of product development), or with suppliers from abroad, which resulted in cultural differences between the organizations and noise in the communication. This was not in favor of the inter-organizational coordination of these collaborations. In one of the projects there was no clear timing and moment of supplier involvement in the NPD process, instead the supplier was already involved before a formal supplier selection procedure was started. In two cases ASML rejected the second-tier supplier as chosen by the first-tier supplier, resulting in relational stress because both second-tier suppliers as advised by ASML, were not capable to perform. All these issues resulted in more iterations of the proto types than planned, to reach the required performance, which had a negative influence on the efficiency of the projects.

Supplier relationship management
The issues regarding supplier relationship management were deduced to the absence of an evaluation process, cultural differences and/or noise in the communication. In a number of cases, cultural differences between ASML and its suppliers delayed the communication and coordination of development activities. These cultural differences led to a mismatch of the expectations about the desired behavior of the suppliers (organizational and professional) between both parties. The communication related relationship management problems cover language barriers in combination with the physical and cultural distance between both actors, and influence predominately the interpretation of conversations. This resulted in issues surrounding the expectation and perception of development targets between ASML and the suppliers. Also the absence of joint alliance evaluation session at the end of each project and the absence of a feedback loop to the SAT teams, suggests a poor link of short-term efficiency and longer-term learning opportunities within the relationships.

Product characteristics
The final category refers to the specific product characteristics of a lithography system. The occurrence of excessive and often late engineering changes within one module, creates a snowball effect of ECs from one component to another, resulting in additional iterations for proto types. Besides that, the semiconductor industry is a science based industry, where the ambition level of the required technological specification of a building block is balancing on physical laws this causes to a very large extent of technological uncertainty. As a consequence of this uncertainty, a gap exists between the information already acquired by ASML, and the information needed to provide a supplier in order to perform its task. The lack of information makes it difficult for the supplier to complete its task. This resulted in project delays and exceeded budgets, which influence the efficiency of ESI in NPD projects.

5.2.2 Cause and effect diagram
Based on the issues and problems identified in the empirical analysis, a cause and effect diagram has been constructed. The diagram in Figure 19 (larger version available in Appendix H) shows which problems have led to project delay, additional development costs and increased part cost within the four projects. The colors of the main problem areas shown in the diagram, correspond to those of the Ishikawa diagram (Appendix F). This cause and effect diagram supports the findings that ineffectiveness and especially inefficiency of ESI performances in NPD projects are real problems. Inefficiency is caused by the need for additional iterations in the proto phase to attain the specified product requirements. Ineffectiveness is caused by additional costs resulting from these iterations, and by relational issues that requires additional time for solving. The three causes responsible for extra iterations and non-complying samples are: (1) *construction errors:* due to suppliers with lower capabilities as a result of high demanding ASML requirements, corporate time-to-market pressure and a lack of experience; (2) *excessive and often late engineering changes*: because of low modularity of design, high technology uncertainty, conflicting objectives between internal functional areas and ad hoc project management; and (3) *miscommunication*: due to the physical distance between ASML and the suppliers resulting in low frequency of face-to-face meetings, late internal problem sharing by the suppliers and the absence of jointly evaluation sessions. Two additional observations are related to relational issues that requires time to be solved: *fear of leaking proprietary information:* due to the absence of a clear non-discloser business model and a lack of trust; and *cultural differences* (national and professional). All these issues together are responsible for project delay, additional development costs and increased part cost.

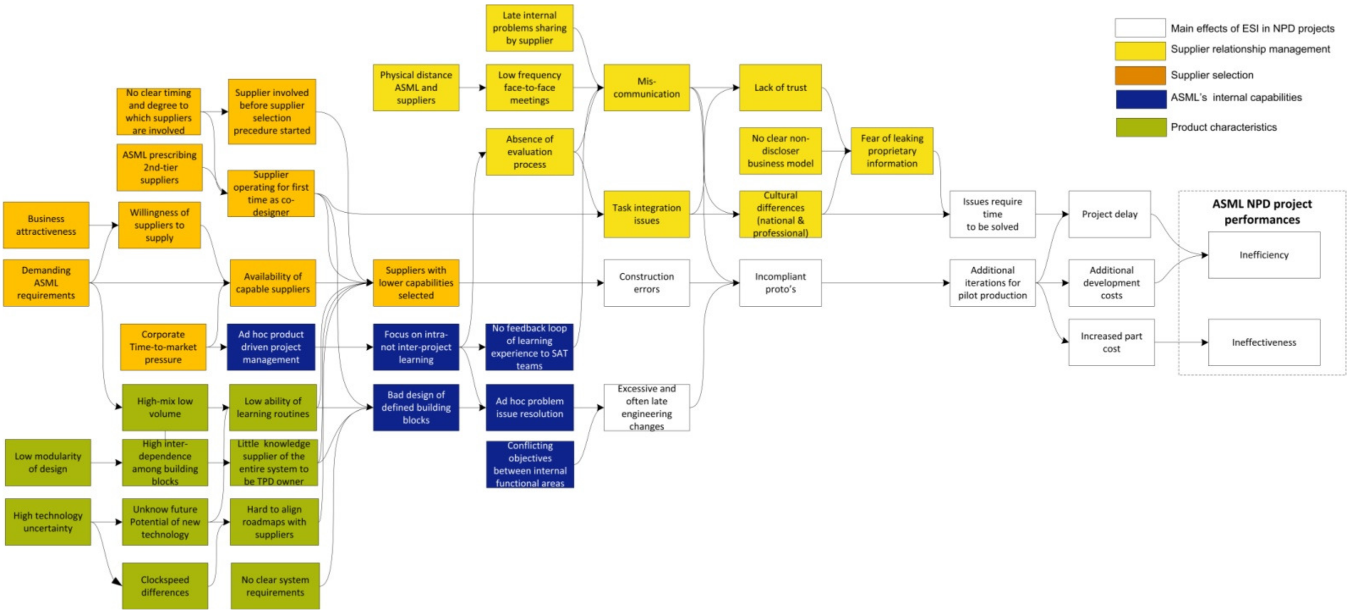


Figure 19. *Cause and effect diagram of managing ESI in high-tech NPD projects at ASML*

5.3 Solution design

The following sections describe the solution to overcome the problem as described in the previous section. The plan of action is the next step in the regulative cycle (Figure 3). Van Aken *et al.* (2007) proposed a general model of key activities (Figure 20) for a design process, which starts with a problem analysis. First, specifications of the design will be formulated. Next, the outline for the design will be described, and a final change plan is given afterwards. This change plan describes the way in which ASML needs to move from the current situation to the desired one (IST-SOLL).

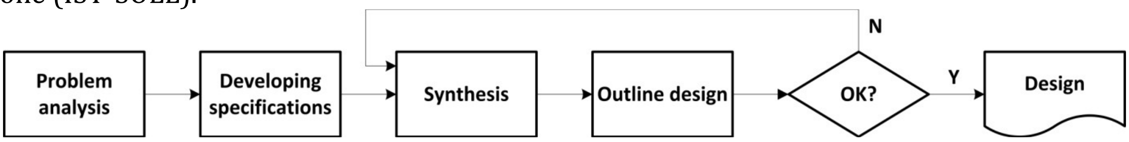


Figure 20. *Key activities of a design process (adapted from Van Aken et al., 2007)*

5.3.1 Specification

In the design phase, the logic order is from specification to solution. With respect to the requirements of a solution design, which describe a preferred solution, one can distinguish: *functional requirements*; describing the desired performance of the design, *user requirements*; boundary conditions which should be unconditionally met, and *design restrictions* (Van Aken *et al.*, 2007).

Table 21. *Specifications for the solution design*

Requirements
Functional Requirements
The solution should reduce inefficiency and ineffectiveness
The solution should solve as many root-causes as possible
The solution should fit within the general NPD processes of ASML
User requirements
The solution must fit within the existing way of working
The solution should fit within the current organizational structure
The use of the solution should be attractive to the stakeholders
Boundary conditions
The solution must fit within the current organizational boundaries
Design restrictions
The solution should impact the organization as little as possible

Based on these categories several specifications have been formulated for the present design (Table 21). The specifications will guide the design, by creating boundaries and directions for the solution. The diagram in Figure 19 can be separated in two parts (i.e. graphically depicted as 'front' and 'back' parts of the cause and effect diagram), problems and issues inherent to the semiconductor industry (e.g. clock speed, high-mix low volume; front part) and difficulties related to the ESI management in NPD projects (back part issues). In the solution design we focused on the management issues directly related to inefficiency and ineffectiveness of ESI management in NPD projects, since solving these issues have a big pay-off and are easy to implement. Besides that, these possible solutions fit within the current NPD policy of ASML. If ASML succeeds to overcome the problems inherent to the industry, it would have a major impact, but this will take time and is difficult - if not impossible - to change for an individual company like ASML. Therefore it is beyond the scope of this solution design. The rough design which followed from the specifications and causes of the problem, is described in the outline design.

5.3.2 Outline design

The diagnosis of the four projects show that the main causes for project delay and exceeded development budgets are related to ASML's internal capabilities, the supplier selection process, supplier relationship management and the specific product characteristics of a lithography system. In Figure 21, these problem areas are reproduced in a linear model, i.e. without feedback loops. However, in reality feedback loops might exist. For example, the quality of ASML's internal cross-functional coordination within NPD projects (1) may influence the quality of the supplier selection process (2) and the supplier relationship management (3), since internal cooperation serves to coordinate external cooperation (Hillebrand & Biemans, 2004). This effect must be included in further research within ASML, but it is beyond the scope of this project. In order to improve the current ESI practices within ASML's NPD process performance, the solution should impact these four areas. Several scholars have devoted their work in providing guidelines for ESI practices in NPD and have been addressed during the literature review. These guidelines served as guidance for conceptual design choices, but are mainly based on the observations during the case studies.

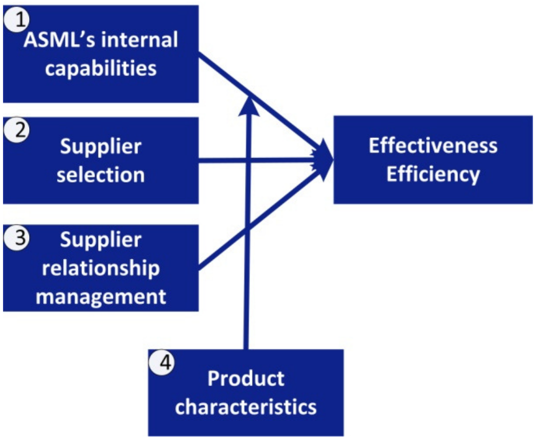


Figure 21. *Main causes of ineffectiveness and inefficiency*

The observations of ESI issues in NPD are listed below, and followed by a description of the design choices to be applied to the current organization of ASML.

Observations[10]

1.1 Ad-hoc product driven project management impede sound decision making

The quality of project alignment capabilities of ASML depends on individuals rather than on codified and formalized inter-organizational procedures, leading to a less systematic project approach from ASML's side.

1.2 A lack of ownership of project targets delay project decisions

The organization root-cause shows a lack of ownership of project targets within ASML, resulting in conflicting objectives between internal functional areas, which delayed the projects.

[10] The numbering of these headings corresponds with the problem areas in Figure 21.

2.1 Capable suppliers are scarce in a high-tech supply chain
OEMs are in some cases forced to start a collaboration with suppliers having less capabilities to deliver the expected performance. This obligatory concession leads to an increased supply risk for ASML as acting in a high-tech context.

2.2 Prescribing second-tier suppliers creates relational stress
ASML forced first-tier suppliers in cases B and D to cooperate with its personally preferred second-tier suppliers, which violated the internal trust in the relationship.

3.1 Lack of trust and cultural differences reduce the efficiency of ESI performances
Cultural differences and trust issues (i.e. not shearing entire information) between ASML and its suppliers resulted in issues surrounding the expectation and behavior of the suppliers, which delayed the communication and coordination of development activities.

3.2 Noise in the communication interfaces impedes supplier coordination process
Language barriers in combination with the physical and cultural distance between the team members of ASML and supplier make the communication related relationship management impossible.

3.3 Location can make a difference in successful ESI practices
While communication patterns in NPD depend on the nature of the project and the organizational structure, we observed that distance between buyer and supplier also plays an important role for successful ESI practices.

3.4 Absence of jointly evaluation sessions and feedback loops
The absence of joint alliance evaluation sessions at the end of each project and the absence of a feedback loop to the SAT teams suggests a poor link of short-term efficiency and long-term learning opportunities within the relationships.

4 Low modularity of design and technological uncertainty lead to late engineering changes
High interdependency between building blocks creates snowball effects from one component to another when ECs of an 'external component' are needed. Technological uncertainty results in additional iterations for proto types.

These observations lead to the following intervention choices.

Interventions

I ***Implementation of a standardized operational management process for ESI activities***
This gives ASML the opportunity to manage their collaborations pro-active and in a systematic structure, which makes ASML less dependent on individuals and strengthen the organization robustness of ESI performances. (Based on observations 1.1 and 1.2)

II ***Implementation of a risk assessment matrix for ESI practices in NPD projects***
Conducting a risk assessment in the initiation phase provides insight in the risks of ESI and its potential pitfalls during a project, which will improve project planning. (Based on observations 2.1 – 4)

III ***Create standardized communication interfaces between partners***
By introducing standardized communication interfaces, ASML can facilitate communication processes and speed up design iterations. (Based on observation 3.2)

IV ***Create strong ties with suppliers by establishing long-term relationships***
Creating long-term and sound dyadic relationships will increase the mutual trust and decrease cultural differences, which will reduce relational stress and creates commitment. (Based on observations 2.1, 2.2 and 3.1)

V ***Implementation of joint evaluation sessions and feedback loops***
Implementing joint evaluation sessions and feedback loops create learning opportunities. (Based on observation 3.4)

VI ***Reduction of the design margin for suppliers***
By recognizing and exploiting secondary properties of one building block, neighbor components can be eliminated from the design, which makes the individual building blocks of a project less vulnerable to 'external' ECs. (Based on observation 4)

The intervention choices above indicate that successful ESI practices should be well prepared through identification of and anticipation on risks by an organization which is tailored to support the NPD projects. The first is fostered by knowledge of sourcing risks, originating from the geographical/cultural dispersed character, the products, and organizational factors such as preparation of clear goals and objectives. In the next section a modified ESI framework will be proposed which combines these elements into a project preparation and success assessment tool. As the outline showed, the emphasis of the solution is on the management of the project and by thorough preparation, based on ESI knowledge. In the coming section these directions will be further elaborated.

5.3.4 A modified ESI framework for ASML's NPD projects

The objective of the final design is to impact the main causes of ineffectiveness and inefficiency as shown in Figure 21. In order to help ASML to manage their ESI practices in NPD projects by identifying risks in the process and addressing success factors of ESI practices, a "modified ESI framework for implementing ESI practices[11]" was developed. This solution entails three phases: *project- planning*, *execution* and *evaluation* (Figure **22**). The planning phase of this framework refers to the need to satisfy the ESI fundamentals before other steps in the framework can be implemented effectively. Therefore, this phase is most important to secure effectiveness and efficiency throughout the project. The stepwise planning, coordination and evaluation process is illustrated below.

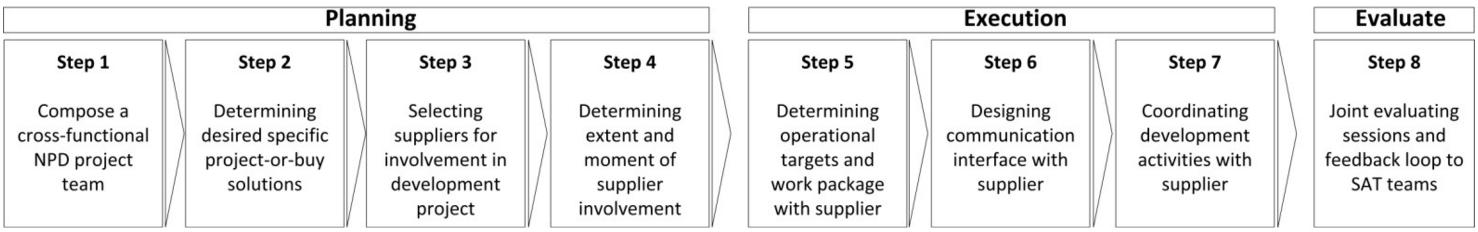


Figure 22. *ESI framework for ASML's NPD projects*

Step 1: Compose a cross-functional NPD project team

The first step in ESI practices in NPD projects is the composition of a cross-functional team that is capable of executing a NPD project. This cross-functional team should consist of team members from all relevant disciplines involved. Table 22 shows the composition of the project team for ASML, and their responsibilities. This step results in a team which is empowered to make important decisions in accordance with the level of responsibility. These decisions include managing the day-to-day activities of the project, working out technical issues, and selecting suppliers, for example. This will create a clear ownership of project deliverables. In addition, commitment from the senior management is needed for the provision of the required resources (both financial and political).

[11] Most of the activities in this framework are not new for ASML in NPD, but - until now - they were not executed in a fix order within the projects and were not focused on ESI.

Table 22. *Composition of the cross-functional project team members within ASML*

Responsibility	Team member ASML
Project planning and control	Project leader
Contract and commercial aspects	PAM
Quality and technical (RAMS) aspects	TSM*
Design aspects	Lead engineer(s)*
Logistic aspects	NPL planner
RAMS aspects, manufacturing process quality factory and field support aspects	IE supply chain engineer

*added to the team in future NPD projects

Step 2: Determining project specific-or-buy solutions

The second project planning activity regards project specific develop-or-buy solutions. The outsourcing decision is a key step for supplier integration in ASML's NPD process. It contains technologies and capabilities which ASML will seek from outside sources and will develop internally. Although ASML has a general long-term sourcing policy (see subsection 3.3), and this activity can be addressed as a long-term activity, this did not always automatically imply which decisions need to be taken at the project level. For example, we observed that by the reduction of in-house NPD resources for electronic components (long-term decision), not all development work, usually undertaken, could be undertaken. This increases the need for ESI (mainly as "capacity projects"). This activity should be guided on the basis of a risk assessment by three questions, each of which is answered by the cross functional team (composed in the previous step) as it involves many different business aspects: (1) *Does the potential outsourcing of the product or service contribute to the ASML's competitive strength?* (2) *Is there a competitive, worldwide supply base from which the specific service or product can be purchased*? And (3) *once ASML has purchased a specific product from a certain supplier, does ASML become dependent of that supplier*?

Step 3: Selecting suppliers for ESI in NPD projects

The third activity is focused on the selection of a capable supplier who is willing to collaborate. The importance of careful supplier selection was stressed out by many researchers (e.g. Axelsson & Wynstra, 2002). The choice has to be based on the *supplier's capabilities* (Handfield *et al.*, 1999), the *willingness to collaborate* (Van Echtelt, 2004) and the *existence of long-term collaborative relationship* (Lakemond *et al.*, 2006). The last point will create long-term and sound dyadic relationships which lead to strong ties. As Coleman (2007) already argued, strong ties are necessary to create trust. Obligations, expectations and trust, by ASML and suppliers are created due to these strong ties, which Coleman calls social capital. Social capital enforces the diffusion of information and knowledge (Burt, 2000; Coleman, 2007), which is necessary during ESI (Sobrero & Roberts, 2001). This will develop a common understanding and mutual expectations to facilitate ESI in future projects. Thirdly, ASML should not force the first-tier supplier to cooperate with a prescribed second-tier supplier, this will only violate the internal trust of the relationship between both actors. Based on the experience of the studied cases, the following elements are likely to be important in considering new or existing suppliers for ESI:

- Targets: is the supplier capable of meeting affordable targets regarding QLTC?
- Technical and project alignment expertise: does the supplier have the required engineering expertise and physical facilities to adequately develop, design, manufacture, and solve problems?
- Timing: will the supplier be able to meet the NPD schedule?
- Location: is the physical distance between ASML and supplier on driving range?
- Long-term relationship: is the supplier a preferred supplier?
- Ramp-up: will the supplier be able to increase capacity and production fast enough to meet volume production requirements?

Step 4: Determining the extent and moment of supplier involvement

This fourth step of the tool is closely related to activities two and three in the project planning phase. ASML should not simply embark on ESI without being clear about which areas it wants the supplier to contribute to and precisely what that contribution will be. ASML cannot expect from a supplier to supply 'turnkey solutions' in the first attempt. In the case studies we saw that the same high level of involvement in comparable building blocks, was not always needed in different projects; each individual situation should be analyzed separately, to judge the appropriate level of supplier involvement. In reaching a consensus on steps 3 and 4, we developed a systematic process for determining the extent and moment of supplier involvement in NPD projects (Appendix J).

Step 5: Determining (jointly) operational targets and work packages

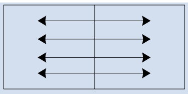
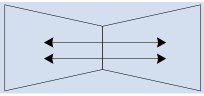
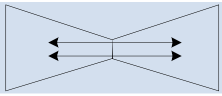
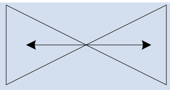
Before establishing clear goals and objectives, a risk assessment matrix should be assessed by the NPD team, see Appendix K. That will enable ASML to detect risks before they actually occur, and will help to address them (for example, when the design of the building block is highly interrelated with neighbor components the design margin where the supplier is responsible for should be decreased, see also Appendix L). This creates a more explicit and systematic risk assessment activity which makes ASML aware of potential pitfalls. When being aware of the potential pitfalls in a specific project, a work breakdown structure should be constructed in a project management software tool, consisting of all the activities, as detailed as possible. Several important aspects per activity should be listed: *estimate ambition levels of functional specifications, work pack's & work package structure, planned start and finish dates of work pack's (and the planned flow time), allocation of the work pack's to engineers, amount of human resources required,* and *go/no-go milestones based on the PGP process*.

Based on this information resources can be discussed with the management of both parties, to obtain a commitment. Furthermore, the costs and duration of the project can be accurately estimated now. Critical activities can be identified and should be monitored closely during execution, to prevent delays. Finally, a Statement of Work (SOW) needs to be documented, where the project teams of both ASML and supplier can make agreements about how to mitigate risks (e.g. how to ensure systematic availability of competent engineers, planning and defining the project milestones etc.). This is an important requirement to align expectations, and to ensure clear goals and objectives, in order that all stakeholders are aware of what is expected of them, at which moment in the project.

Step 6: Designing communication interfaces with suppliers

As already addressed, by introducing standardized communication interfaces ASML can facilitate communication and speed up design iterations. We believe that the degree of supplier integration defines the way how should be communicated. For instance, in a black-box sourcing model the supplier is already involved in the initiation stage of ASML's NPD process. Therefore most information is inaccurate and vague. The supplier perceives a high level of uncertainty because it does not know precisely what ASML wants (e.g. in project C). Consequently, the collaboration needs to be close and interactive. As there are various kinds of information to be exchanged (e.g. technical and commercial) to close the information gaps and because information exchange must not delay the project, rich media tools are needed (e.g. face-to-face meetings, conference calls, etc.). So communication lines should be short so that, for example, development engineer from both sides can communicate directly with each other (Wynstra & Pierick, 2000). Table 23 presents the guidelines for the communication interfaces in the different NPD relationships between ASML and supplier.

Table 23. *Guidelines for the interfaces in the different collaboration relationships*

	Black-box	Grey-box	White-box	Build-to-print
Kind of collaboration	An ASML dedicated product, designed and manufactured by the supplier, documented in supplier owned TPD	An ASML dedicated product, designed and manufactured by the supplier, documented in ASML owned TPD	An ASML dedicated product, designed by ASML/supplier and manufactured by the supplier, documented in ASML owned TPD	Manufacturing of a proto using ASML owned TPD
Amount of communication	High	Medium	Medium	Low
Functional disciplines	Cross sectional IE, D&E, SCM, M&P	Cross sectional IE, D&E, SCM, M&P	Cross sectional SCM, D&E	Cross sectional SCM, D&E
Communication medium	Rich media* ✓ Face-tot-face ✓ Group meetings ✓ conference calls ✓ telephone ✓ e-mail	Rich media ✓ Face-tot-face ✓ Group meetings ✓ conference calls ✓ telephone ✓ e-mail ✓ mail	Lean media ✓ conference calls ✓ telephone ✓ e-mail ✓ mail	Lean media ✓ telephone ✓ e-mail ✓ mail
Content of communication	Technical and commercial information	Technical and status information	Status information	Status information
Communication structure				

* The intensity of communication is also called the richness of communication (Daft & Lengel, 1986). For example face-to-face communication gives immediate feedback and contains multiple cues via gestures, tone of voice and the message content is expressed in natural language. This makes face-to-face the richest communication medium (Sosa *et al.*, 2002).

Step 7: Coordinating development activities with suppliers

This step concerns the coordination of the development activities of suppliers with those of internal departments (e.g. SEO, NPL etc.) of ASML. At this point in the project it is clear that by collaborating with the supplier the goals can be obtained. Despite the attempt to plan the project in detail, the case studies made clear that unexpected issues and problems may emerge during the project. Therefore, it is important to constantly monitor and update the plan during the execution, especially when new information comes available. Furthermore, the feasibility of the goals may change when new information is incorporated, during a milestone meeting. The project leader should be aware of this and use the predefined milestones of the project to examine this, and if the project cannot attain the objectives within the set margins; decide to terminate it. Most important when issues and problems arise, conduct joint problem solving activities with the supplier, as it will decrease relational stress and increase trust (Ragatz *et al.*, 1997). A mechanism to establish and facilitate joint problem solving is the co-location of suppliers.

Step 8: Planning of joint evaluation sessions and implementation of feedback loops to SAT teams

To benefit from collaboration learning experiences and to transfer (innovative) solutions to other projects and future collaborations (spin-off best practices within ASML), it is critical to first set up cross-functional and inter-organizational evaluation processes to identify them (Van Echtelt, 2004). Therefore, ASML should finish every project (or a major milestone within a project) with a detailed joint evaluation session. In the past, this step was likely to be forgotten by ASML, since it has no direct need and it is time consuming. However, to establish a knowledge base of ESI it is important to include the learning's in the product evaluation. To make sure that this joint evaluation session takes place, ASML should implement a payment milestone point within their SOW[12]. Possible questions that should be asked during evaluation are:

[12] Suppliers are paid proportionally, when individual milestones within the project are reached. Completion of these milestones is mutually agreed by supplier and ASML via a Statement of Work.

"Hard factors"

- Have the predefined targets been met (specifications, time and budget)?
- If not, what are the root causes? What could be done better?
- What have we learned?

"Soft factors"

- Were people motivated during the project?
- What could be done to improve the experience
- How should we change the collaboration for coming projects

The final product of this evaluation session is an owner for each problem area (addressed during the session), who is responsible to develop an action plan as reported to the SAT team. Hereby, ASML creates a feedback loop in order to close the learning loop from past problems, so that it recurrence can be avoided in future projects.

5.3.5 Change plan

The change plan is the implementation design, which provides a model of the processes through which the solution design can be realized within ASML. It defines how the proposed changes of the previous section can be translated into practice. First a delta analysis is presented, which identifies the main objectives of the redesign and the expected resistances against the solution design. Next, the intervention strategy describes the possible countermeasures to overcome this resistance.

Delta analysis

By comparing the current situation (IST) with the proposed redesign (SOLL), main objectives to be accomplished were determined. These objectives are the goals to be achieved in order to reach the desired situation.

Main objectives:

1. standardized operational management process for ESI practices;
2. risk assessment matrix for ESI practices;
3. reducing the design margin for suppliers;
4. standardized communication interfaces;
5. joint evaluation sessions and feedback loop to SAT teams; and
6. redesign of the Statement Of Work manual.

The proposed solution design means a change in the current organization, which will entail internal resistance since people do not want to change, on average. Table 24 plots the objectives against the five sources of organizational resistance, identified by Van Aken *et al.* (2007). If resistance can be expected from one or more stakeholders, the cell is marked. The stakeholders in this redesign are ASML's NPD team and the involved supplier. In general, little resistance is expected since the solution fits within ASML´s current organizational boundaries, i.e. the departments and the functions of the stakeholders will not be affected, and for those reasons the implementation is considered as a small transformation.

Table 24. *Resistance analysis (adapted from Van Aken et al., 2007).*

	Objectives					
Organizational Resistance	**1**	**2**	**3**	**4**	**5**	**6**
Lack of understanding						
Different opinions	X		X	x	X	x
Lack of trust						
Low willingness to change	X				x	
Conflict of interest	x		X		x	

X= resistance expected, x= some resistance expected, empty= no resistance expected

Of the five sources of organizational resistance, *different opinions*, *low willingness to change* and a *conflict of interest* are likely the be the most prevalent, in regard to the specific objectives of the proposed redesign. Different opinions and a low willingness to change are possible source of resistance for almost all objectives. Since the proposed objectives introduce a more pro-active and systematic structure of managing NPD projects with suppliers within ASML, it will drastically reduce the freedom of space of individuals within the project. The culture of ASML is based on freedom of movement with a mindset of a firefighter, which is consider as an asset and privilege by the employees of ASML, however, the redesign threatens this freedom of space and involves a change in responsibility and associated 'political' power, and it may be delicate for some employees. So, this should be taken into consideration during implementation of the methodology. A conflict of interest can emerge by the suppliers involved, since objective 4 (reducing the design margins) may be interpreted as a lack of confidence in the design skills of the supplier. Besides that, it will take away some responsibilities from the supplier. Therefore, it is important to emphasize to the supplier that it remains co-owner of the designs, but in the new situation the project would be less vulnerable to moving specifications, which in the end is a mutual benefit for both ASML and supplier. Moving specifications were reported as the number one issue by the suppliers, causing project delays and exceeded budgets. Also the introduction of joint evaluation sessions can create a conflict of interests within the project team. Since these sessions have no direct impact on short-term project performances and are time consuming. Especially if the stakeholders do not see many problems in the current situation, the lack of a feeling of urgency may result in low willingness to implement these evaluation sessions. However, since the solution requires little extra effort from the stakeholders and promises a more useful tool for ESI practices in NPD, this kind of resistance is expected to be marginal.

Intervention strategy

An intervention strategy is designed to keep these sources of resistance minimized during the implementation of the solution (Van Aken et al., 2007). Of the three general intervention types: technical (concerns technical and economic issues), cultural (concerns how the different stakeholders participate in the redesign), and political (concerns the formal and informal power a person or group may use to protect their interests), we believe that the cultural and political interventions should be used to neutralize the organizational resistance. If the rationale behind the redesign and its value for the stakeholders are made clear, resistance due to a difference in opinion, low willingness to change and a conflict of interest should decrease. So, before the redesign can bear fruit, it requires commitment from the different departments involved in the project team, and of senior management. The group leaders of those departments (e.g. D&E and SCM) have to be convinced of the necessity to participate. Showing them the requirement of their knowledge and the effect of the solution is likely to help to take away the resistance. In fact, their expertise was already required during this study and has now been given a formal and structured form.

Secondly, a crucial action to be undertaken is to educate the project leader to manage his team. A process structure for this management has already been defined in the solution; however, it requires also skills like knowledge sharing and committing to the NPD project to successfully execute the project. The project leader (PL) should thus be educated in motivating the team to follow the proposed preparation steps, and to communicate about their insights of ESI risks. Furthermore, the solution implies that monitoring, updating and managerial work is under larger responsibility of the PL. It is therefore important that the PL has the possibility to delegate. A group leader should ensure that sufficient time is available for him to perform these tasks. In addition, ASML should focus on one pilot project that serve as a best practice in showing the added value of this redesign which will convince all stakeholders. The elements of the change plan, as described above should, guarantee a successful implementation of the proposed solution design. It allows ASML to determine which contributions from suppliers are expected by different departments, and what preparation is needed to allow these design contributions to be realized. As such it facilitates discussions and helps to improve the way ASML involves their suppliers in NPD.

5.4 Conclusion

This chapter provided a solution design that can help ASML to improve the effectiveness and efficiency of ESI performances in their NPD projects. We used the diagnostic results from the four case studies at ASML and the literature review as input for a solution design. These were combined in a three-phase ESI framework, consisting of a planning, execution and an evaluation phase. This framework concerns primarily the management of involving suppliers in specific NPD projects, and helps to identifying risks in the process. In general, the implementation of this redesign is to be considered a minor organizational change since the solution fit within ASML´s current organizational boundaries, and therefore little resistance from the stakeholders is expected. However, it requires the commitment from the different departments involved in the project team and of senior management, since they perceive the ESI process from a different point of view.

In the next chapter we merge the main findings from this chapter with the insights developed in previous chapters and put it into perspective. It presented the final conclusions, limitations, recommendations for further research and the contribution to practitioners.

Chapter 6
Discussion and conclusion

6.1 Introduction

In this thesis we examined managerial practices of ESI in high-tech NPD. First, literature on ESI and NPD projects was studied to derive factors which influence the performance of ESI activities in NPD. Second, empirical studies were performed on five dyadic buyer-supplier relationships within four NPD projects of ASML (in three different functional disciplines: optical, mechanical and electrical), to verify the determinants found in literature. Third, based on the results of both literature and the case studies, design solutions to improve the effectiveness and efficiency of ESI performances in NPD projects have been proposed. In this final chapter, the findings of previous chapters are linked and put in perspective of each other. In the next subsection the main findings of this research project are summarized and the theoretical issues posed by the results are discussed. Hereafter, we discuss the contribution to existing literature and present the managerial implications. We close with the limitations of this study and give suggestions for further research.

6.2 Findings and discussion

The four case studies showed inefficiency in term of exceeded budgets and project delays and to a lesser degree ineffectiveness of ESI performances. The optimized framework of Van Echtelt *et al.* (2008) was used to study profoundly how the ESI process is influenced by factors resulting from inter-organizational collaborations. The main findings of this in-depth study are summarized below.

ESI practices improve product quality, manufacturability and reduce part costs

The results of the case studies supported the proposition that ESI has a positive influence on product quality, part cost and manufacturability. Product quality increased mainly due to suggestions of suppliers to use alternative components, and decreasing part costs are the result of the supplier's contribution in the cost estimation process; which entails more reliable information as input for estimating the unit cost of a part. The results correspond with literature, as various scholars report on the positive effects of involving suppliers early in the NPD process (e.g. Von Hippel, 1988; Henke & Zhang, 2010). Involving suppliers earlier in the NPD process, results in a better reproduction of prototypes during the volume phase. This is explainable since suppliers were already responsible for the production of the proto types, within ASML's NPD processes. By means of ESI, suppliers receive a vote in the initiation phase, by which ASML can leverage from the more in-depth knowledge of the manufacturability processes of the supplier.

ESI practices have a negative influence on development costs and time-to-market
We found negative effects of ESI on time-to-market and development costs. This negative influence on development costs could possible originates from the relationship management efforts (Gadde & Jellbo, 2002). Coordinating the work between two collaborative parties (i.e. ensuring accurate information exchange mechanisms) requires different management styles and budgeting processes within the same process (Bruce *et al.*, 1995). In respect of early involvement, the relationship becomes even more concentrated and expensive to develop and maintain (Bensaou, 1999). In contrast to literature, which described a positive effect of ESI on time-to-market, we found a negative effect. The negative influence on project time could be explained by the high amount of technological novelty and uncertainty as faced in the high-tech industry. Eisenhardt and Tabrizi (1995) argued that the effect of ESI in time-to-market depends on the different levels of technological and market uncertainty. Since the semiconductor industry is a science-based industry, in which the necessity for reaching beyond borders is particularly high, NPD projects within ASML are more confronted with technological and market uncertainty.

Mechanisms influencing the operational management process of ESI practices
The importance of *intensive communication interfaces* in NPD projects was one of the main issues discovered during the case studies. An extensive communication web is crucial for successful ESI performance. We observed that especially in highly innovative projects, intensive knowledge-oriented information exchange, concerning technical issues for example, is necessary. In a co-located environment, information exchange gains most profit by face-to-face communication. Therefore, we argue that *location* can make a difference since it determines the possibility of intensive and iterative face-to-face meetings.

Secondly, the cases taught us the importance of *evaluation sessions*. We found that the successful projects included extensive evaluation sessions, in contrast to the less successful projects which did not included such sessions, leading to a poor link of (exploiting) learning opportunities of the ESI organization. We argue that extensive evaluation sessions with collaboration partners have a positive influence on the performance of ESI since it allows long-term interests to be balanced with short-term pressure, and it channels learning experiences for the benefits of collaboration with a supplier in the future.

The effect of operational project enablers on ESI practices
We demonstrated that *conflicting objectives* between ASML's functional areas can create considerable stress for suppliers. Some suppliers missed ownership of project targets within ASML. Conflicting objectives between internal functional areas of ASML resulted in delayed projects. This concurs with findings from previous research (e.g. Jiao *et al.*, 2006).

Also the s*carcity of capable suppliers* in the supply chain had a negative impact on ESI performances. This scarcity forced ASML to start collaborations with suppliers having insufficient project alignment and target cost capabilities, or with suppliers from abroad, which resulted in cultural differences between the organizations and noise in the communication. This was not in favor of the inter-organizational coordination of these collaborations. These results are also supported by previous research (e.g. Wasti & Liker, 1999). Project alignment and alliance capabilities are described to be prerequisites in order to have successful early involvement of suppliers in a project. Technical competence itself is not enough. Furthermore, the findings of the case studies correspond with the general perception of ESI, that intangible assets have a huge impact on vertical collaborations within NPD projects (e.g. McIvor *et al.*, 2006). For example c*ultural differences* between ASML and its suppliers delayed the communication and coordination of development activities. We observed increased internal complexity in projects where global suppliers were involved, due to *national differences.*

In addition, ESI *experience* of suppliers was considered to explain persistent performance differences between the projects studied. The less successful projects, had low experience scores and was experience often lacking. These low scores can explain the issues in regard to the expectation and perception of development targets between ASML and the supplier. This is quite obvious because companies experienced with ESI, will have more knowledge about factors which are important to use during the collaboration.

Last, we found that l*ong-term relationships* have a positive influence on *mutual trust*. All persons interviewed gave high praise of the collaborations, based on the degree and frequency of information exchange. Furthermore, all suppliers involved in the cases have a long history as development partner of ASML (average length relationship ≥ 10 years).

The effect of corporate and project driving factors on ESI practices
Concerning the driving factors, we found a negative influence of *technological novelty and manufacturing complexity* on ESI practices. The technological novelty of the components was predominately associated with the manner in which technical problems were solved during the project (i.e. technical coordination). The manufacturing complexity was mainly related to the structure of the new product (Henderson & Clark, 1990), and is a composite measure of the number of components and the degree of dependency between the interfaces (i.e. modularity of design). We observed that these corporate and project driving factors influence the operational management process and operational project enablers for a large amount, which is in accordance with literature (Lakemond *et al.*, 2006). For example technological novelty and complexity are negatively related to factors like the number of design cycles, the time until the final design is frozen, the need for prototype building, the extent of testing, the intensity of communication, and the frequency and complexity of trade-off decisions. In the semiconductor manufacturing industry, module outsourcing is not only the 'natural' consequence of product design modularity; but it is also due to rapid changes towards more complex technologies. These changes are rather unpredictable due to altering customer requirements and evolving industry standards (Ernst, 2005), which makes it hard to design standardized component interfaces to provide a form of embedded co-ordination (Campagnolo & Camuffo, 2009). Hence, overt exercise of managerial authority to achieve co-ordination of development processes is of great importance. In other words, technological novelty and complexity of the building blocks of a lithography system need a higher degree of inter-organizational coordination. This finding concurs with the main thoughts of the study by Ernst (2005, pp. 331), he stated that: if codification does not reduce complexity (which is the case when technologies keep changing fast and are unpredictable, such as in the world of ASML), then the division of innovative labor will remain constrained, and requires more coordination by system integrators.

Besides the information of ESI practices in NPD projects, gathered by the multiple case studies, we identified also the root causes which were responsible for a large number of issues and problems that emerged during these cases. This brings us to the next sub research question. Several problems have led to ineffectiveness and inefficiency of ESI performances in NPD projects. As the cause-and-effect diagram (Figure 19) shows, the number of additional iterations to achieve the required supplier performance, delayed the project substantially and causes therefore ineffectiveness. The analysis of these issues by use of an Ishikawa diagram (Appendix G) shows that these inefficiency problems can be reduced to four main areas of issues: *ASML's internal capabilities*, *supplier selection practices*, *supplier relationship management activities* and issues emerging from the specific *product characteristics* of a lithography system. These problems have impact on ESI practices in different stages of the projects. First, one of the key position issues in regard of ASML's internal capabilities is related to the management on ad hoc basis. The quality of project alignment capabilities of ASML is determined by individuals rather than on codified and formalized inter-organizational procedures, leading to a less systematic project approach. The organization root-cause showed also a lack of ownership of project targets within ASML, resulting in conflicting objectives between internal functional areas of ASML, which delayed the projects.

Secondly, the selection of a supplier issues were the result of the scarcity of capable suppliers in the supply chain of ASML. Thirdly, issues with regard to supplier relationship management result from cultural differences, communication noise and the absence of an evaluation process. Cultural differences and communication problems comprehend language barriers in combination with physical and cultural distances between both actors. It mainly influences the interpretation of conversations. This resulted in issues in reference of the expectation and perception of development targets between ASML and the suppliers. The absence of joint alliance evaluation session at the end of each project, and the absence of a feedback loop to the SAT teams suggests also a poor link of short-term efficiency and longer-term learning opportunities within the relationships.

The final category refers to the specific product characteristics of a lithography system. As already addressed a lithography system comprises a large number of components with many interactions between them. The occurrence of excessive and often late engineering changes within one module, creates a snowball effect of ECs from one component to another, resulting in additional iterations for proto types. Besides that, due to the large extent of technological uncertainty, a gap exists between the information already acquired by ASML, and the information needed to provide a supplier in order to perform its task. This lack of information makes it difficult for the supplier to complete its task, which resulted in project delays and exceeded budgets.

The issues from these four problem areas express that ASML - striving to increase supplier involvement - can be confronted with numerous obstacles and disappointing experiences. Although, ASML started to realize the importance of ESI over the past decade, they have not discovered how to implement it successful. With the knowledge retrieved in the previous chapters, it is now possible to answer the main research question as isolated from the problem statement described in Chapter 1:

How can ASML improve its organization in order to manage early supplier involvement in NPD projects successfully?

ASML should:

- *Implement a standardized operational management process for ESI activities.* This intervention makes ASML less dependent of individuals and strengthens the organization robustness in ESI performances.
- *Implement a risk assessment matrix for ESI practices in NPD project.* One of the most challenging tasks for ASML, concerning ESI, is to manage different kinds of risk, especially those risks that have an impact on the collaboration with suppliers. ASML's representatives strongly question to which extent particular risks can be anticipated and to which extent these risks lead to problems in collaborations with suppliers. We do not content that all risks can be foreseen or avoided, however, developing a more explicit and systematic risk assessment , would help ASML to detect risks before they occur and help to address them.
- *Create standardized communication interfaces between partners.* By introducing standardized communication interfaces ASML can facilitate communication and speed up design iterations
- *Create strong ties with suppliers by establishing long term relationships.* Creating long-term and sound dyadic relationships will increase the mutual trust and decrease cultural differences, which will reduce relational stress and creates commitment.
- *Reduce the design margin for suppliers.* By recognizing and exploiting secondary properties of one building block, neighbor component elements can be eliminated from the design, which makes the individual building blocks of a project less vulnerable to 'external' ECs.
- *Implement joint evaluation sessions and feedback loops.* Implementing joint evaluation sessions and feedback loops create learning opportunities, so that recurrence can be avoided.

The recommendations above indicate that successful ESI practices should be well prepared by identification of, and anticipation on risks. Besides that, an organization needs to be tailored to support the NPD projects. These recommendations have been incorporated into a solution design, which is addressed by the third sub research question. It fulfills the need for a pro-active and systematic process of managing ESI, by proposing a stepwise ESI framework consisting of a planning, execution and evaluation phase.

6.3 Theoretical contribution to the knowledge of Early Supplier Involvement

The results of this research gave some relevant insight in the question if low- and medium-tech environments (e.g. paper printing and automotive industries) can be compared with high-tech environments (e.g. aerospace and pharmaceuticals industries), when it comes to organizing ESI in NPD projects. So far, publications exploring ESI in NPD projects in contexts of high-tech industries are scarce, leaving the issue largely unexplored. In the next section, the findings of this study will be critically evaluated and compared to earlier studies on the topic. The three most important areas where ESI management differs between the high-tech and low- and medium-tech context were identified and described. This enables us to construct hypotheses regarding the influence of a high-tech environment on ESI management.

6.3.1 The effect of modularity of design for ESI in a high-tech environment

Products of a high-tech environment, such as a lithography system, are complex systems because they comprise of a large number of components, with many interactions in non simple ways (Simon, 1969). In the design of these complex systems, individual components are designed separately, but influence one and another (Mihm *et al.*, 2003). In reality it is often difficult to effectively partition a complex system (Gadde & Jellbo, 2002). Ongoing problem choices in other components make the requirements for a particular component inherently unstable. This holds certainly for a lithography system produced in a high-tech supply chain of the semiconductor industry, where genuine conditions of modularity are often not feasible. High-tech companies as ASML do strive for at least some degree of modularity (e.g. Chuma, 2006), but they do not succeed in separating the modules perfectly yet, which results in project delays and exceeded development budgets. We also observed that the degree of EC management in the final phase of the design of a lithography system influences the efficiency of ESI in NPD projects. So, we argue that the degree of modularity of a system influence the performance of ESI in NPD projects. This leads to the following proposition:

Proposition 1a. *In building blocks with a high level of modularity of design integration of suppliers early in the development process has a positive impact on the efficiency and effectiveness of project performance.*

Proposition 1b. *In building blocks with a low level of modularity of design integration of suppliers early in the development process has a negative impact on the efficiency and effectiveness of project performance.*

6.3.2 The effect of technological uncertainty for ESI in a high-tech environment

Technological uncertainty is inherent to the development of new technology. However, in high-tech industries, the degree of complexity and novelty of the developed products is especially high compared to low and medium-tech industries (i.e. more certain industries). It can be argued that complexity and novelty are both closely related to the concept of uncertainty (Wasti & Liker, 1997b). A type of uncertainty in regard to technology sourcing decisions in ESI projects, is industry uncertainty, or exogenous uncertainty (Van de Vrande *et al.*, 2006). This study has shown that suppliers of ASML are reserved to invest in technology roadmaps when the technology is still in its infancy, since the extent of success is unknown at that moment. Especially in a high-tech environment with high-mix low volume characteristics, the ROI time is low. ASML is not willing to commit to the supplier by promising late back up orders. Hence, suppliers are less committed to align their roadmap to that of ASML. Therefore we propose:

Proposition 2a. *When the technology in a high-tech environment is new and its applications potential is still unknown, suppliers will be reserved in committing. As a result ESI will have a lower impact on new product development performance.*

As a consequence of the technological uncertainty, a gap exists between the information already acquired by the organization, and the information needed to provide a supplier in order to perform its task. We believe that this discrepancy plays a crucial role in project performance

(Huchzermeier & Loch, 2001), especially when suppliers have a major input in the design process (Eisenhardt & Trabrizi, 1995). The lack of information makes it difficult for the supplier to complete its task, and therefore ESI is more likely to be unsuccessful. This has already been seen during the case studies, as it affects schedule time and cost of the project negatively. Moreover, the higher the uncertainty, the larger the gap between the information needed for the supplier to process and the amount already acquired. Companies acting in a high-tech environment are more often confronted with information gaps, as they have deal with radical innovations, and as they perform towards the physical boarders. The larger extent of novelty of the technology, as a consequence of technological uncertainty, will also results in larger and inevitable gaps. This eventually will decrease the efficiency of ESI in NPD projects. Therefore high-tech companies will have less profit from ESI compared to low- and medium-tech industries as they are less often confronted with technological uncertainty and therefore by information gaps. Hence, we propose:

Proposition 2b. *The high amount of technological uncertainty in high-tech industries leads to larger and inevitable information gaps between the buyer-supplier, which has a negative influence on the efficiency of ESI in NPD projects.*

6.3.3 The effect of Supply risk for ESI in a high-tech environment

We demonstrated in this research that the supply risk plays an important role in ESI success of NPD projects within a high-tech environment. Prior research confirms that supplier's capabilities are a prerequisite in order to have an early and successful involvement in a project and is a strong indicator for a fortunate ESI (Wasti & Liker, 1999). Since this study aimed to gain insight into inter-organizational collaboration of development tasks from the viewpoint of the buyer, the availability of external competencies (by means of suppliers) was the primary aspect of concern. This study revealed that the availability of capable suppliers is scarce in a high-tech supply chain, and therefore OEMs are in some cases forced to start a collaboration with suppliers having less capabilities (e.g. within two cases ASML started a collaboration with research institutions which main competence is doing research not product development). This obligatory concession leads to an increased supply risk for companies acting in a high-tech context, therefore it is stated that:

Proposition 3. *Companies acting in a high-tech industry have to deal with less capable suppliers, which makes it difficult to integrate suppliers early in the development process.*

6.4 Limitations and directions for further research

While this thesis contributes to our understanding about how companies can manage ESI in high-tech NPD, a number of limitations should not remain unmarked. Contributions and limitations are both the result of the adopted methodology and the theoretical and conceptual choices. Hence, they are closely related with each other. What follows now is an overview of these limitations.

First, one of the key methodological questions in any research is that of external validity, in other words: to which extent can the results be generalized in other contexts (Yin, 2008). As in this study: to other companies operating in a high-tech environment. We realize that the collected data is company-specific, and that the conclusions as based on this data may be due to the characteristics of this specific company and therefore the results might be not applicable to other companies or industries. Furthermore, the developed theories cannot be grounded by statistical analyses due to the small number of cases. But as we have used four cases (six companies) distributed over three different functional disciplines, generalization was persuaded to the maximum. Nevertheless, case study replication and hypothesis testing study (i.e. a case-control study) is recommended in order to acquire evidence to support the (emergent) theories. So, for further research we would suggest to validate the results of this study in similar high-tech environments (e.g. the aerospace and defense industry).

Secondly, we limited the relational set in our observation to one type of interaction (i.e. buyer-supplier). Yet, dyadic relationships do not occur in a vacuum. Actors interact simultaneously with more than one partner, and more than one partner is involved jointly in the solution of a specific problem often (Sobrero & Roberts, 2001). This study paid limited attention to the management of multiple network relationships. According to Van de Ven & Ferry (1980) there are three levels of analysis for studying inter-organizational relationships: (1) dyadic relationships (1:1), (2) inter-organizational sets (1:N) and (3) inter-organization networks (N:M). This study focused only on the first level of analysis, and has indirectly examined the role of second-tier suppliers and the related managerial and organizational architecture. But, as we addressed mainly to the buyer-supplier relationship, second en third level are not of primary interest for this study. Nevertheless, we recommend to include these two levels of analysis for further research, to gain more insight in the complete overview of ESI in NPD projects within ASML.

Thirdly, this study observed that the probability of learning is one of the potential benefits of involving suppliers early in NPD projects. It makes future collaborations less resource consuming and more effective. Though, many companies do not take this learning advantage and make the same mistakes over and over again (e.g. Eisenhardt & Brown, 1995). We argue that structured evaluation processes are needed at different organizational levels, to allow learning experiences to pass down. Up till now no research has investigated the effect of evaluation processes on ESI practices. Hence, it is not possible to ground our findings with results from other research. We came up with the first suggestion of the positive influence of an evaluation session in regard of ESI, and it would be very interesting to study the effect of implementing this alliance tool on ESI practices.

Another limitation of this research is the lack of long-term aspects of ESI practices, in our analyses. From a more holistic point of view, ESI can be regarded as an extensive involvement of a supplier in a specific NPD project, which may be initiated by a company-wide supplier development program (e.g. within ASML value sourcing), where suppliers are assisted in building up their product development competences, and not just by project exigencies (Lakemond *et al.*, 2006). So, besides the degree of project task dependency between the buyer and the supplier, long-term and strategic aspects may also play an important role (Van Echtelt *et al.*, 2007, 2008), and the effects of increased ESI need to be evaluated beyond a particular project. We did not include this long-term perspective since we have focused on the operational short term dimensions. To evaluate the long term dimensions, we suggest to evaluating ESI practices (within ASML) beyond the particular project, by conducting a longitudinal study.

A final shortcoming of this study is the present uncertainty about the outcomes of the solution design. Due to time constraints, the plan has only been designed, and not implemented and evaluated within ASML yet. Although a review by experts of ASML did not result in many comments, it has not been proven that the design principle interventions may function correctly and that the mechanisms are correctly apprehend. It makes this solution design highly exploratory in nature.

In conclusion, we believe that this study about the role of ESI in NPD project performance is valuable, as it provides important suggestions about the way in which ESI can contribute to better performances of an OEM acting in a high-tech environment. Besides that, it showed how ESI can differ in several project environments. For practitioners in high-tech industries, this research will deliver managerial implications that may be beneficial in the management of collaboration projects with suppliers. In any case, we believe that in the coming years and even decades the interest of ESI in a high-tech NPD context will be growing and that many researchers in academia and managers in the industry will devote great attention to this popular theme.

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Appendices

Appendix A

Figure A1. *ASML Twinscan lithography system with the key buildingblocks*

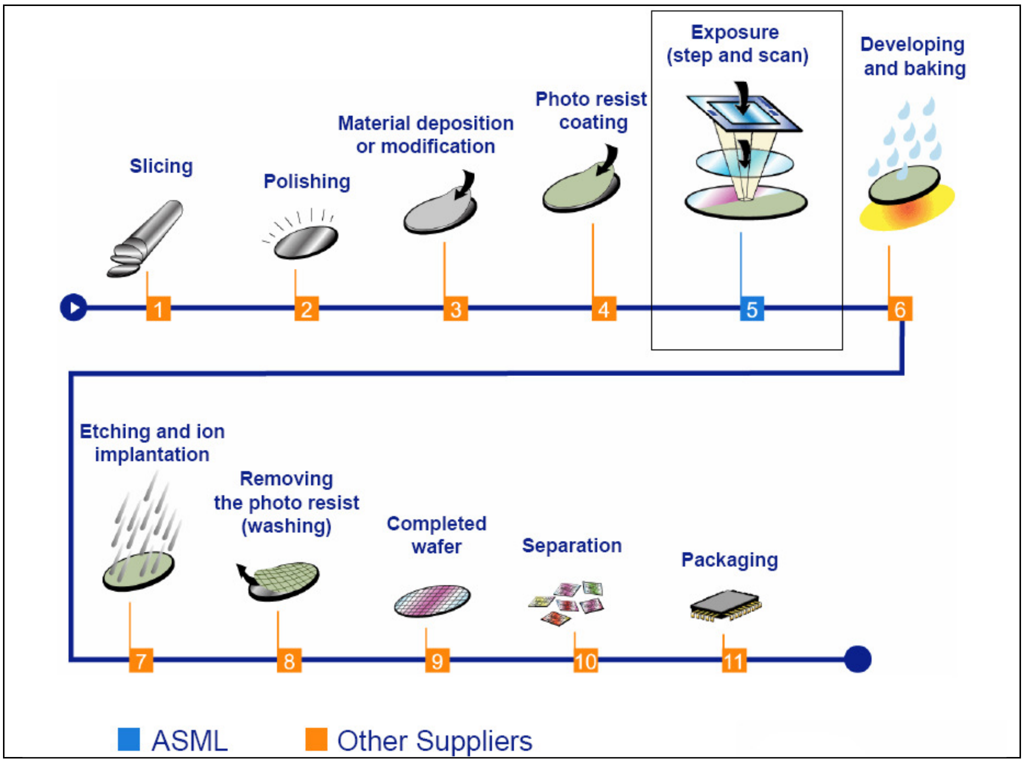

Figure A2. *The IC manufacturing process*

Appendix B Project Generation Process

Figure B below shows the general phase review concept of ASML product development process.

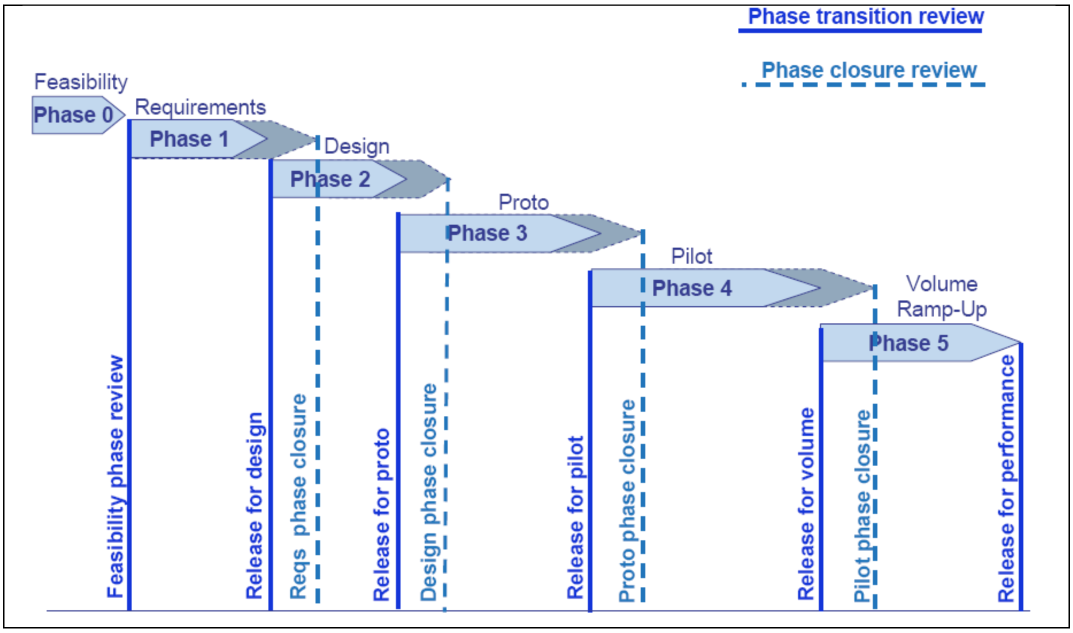

Figure B.. *Schematic overview of ASML's product development process (until 2010)*

Explication of the New Product Development phases
Six NPD phases are included in ASML's PGP process:

- *Phase 0: Feasibility.* Defining the project, evaluate feasibility in terms of business and technology. Analyzing what the risks are and what resources are required.
- *Phase 1: Requirements:* Product plan and technical requirements of the NPI project are described in more detail. If a positive conclusion is reached a NPI project is started up.
- *Phase 2: Design.* Detailed design of all components, make / buy decision an initial ordering take place.
- *Phase 3: Proto.* Build and test a system prototype.
- *Phase 4: Pilot.* Conduct beta tests and the verification of manufacturability take place.
- *Phase 5: Volume Ramp-up.* Transition from development to maintenance team. Feedback collected and assessed.

Phase review concept
The transition from PGP phase 0 to 1 is fixed. The product development can only start on phase 1 deliverables when all phase 0 deliverables are met. All other phase reviews can contain two parts: a phase transition and a phase closure. If the current phase cannot be closed, because there are some open issues left, it will be closed at a PGP phase review meeting after all open issues are resolved.

Appendix C Overview of interviews

Table C. *Overview of interviews ASML*

Department, function	General	Project A	Project B	Project C	Project D
SEO, mechanical technical supply manager	4				
SEO, electrical technical supply manager	2				
SEO, optical technical supply manager	1				
SEO, senior manager	1				
Global Sourcing, senior manager	1				
External, consultant	1				
D&E, project leader	2	1	1	1	1
Procurement. senior manager	1				
Procurement, PhD student	1				
M&P, project leader	1				
Corporate Quality, program manager	1				
SEO, supply chain engineer			1	1	1
Procurement, purchaser		2	1	1	1
D&E, development engineer		2	1	1	1
Supplier, account manager		1		1	1
Supplier, project leader		1			1
External sourcing specialist, consultant	1				
Total (39)	**17**	**7**	**4**	**5**	**6**

Appendix C2 Overview resources data collection

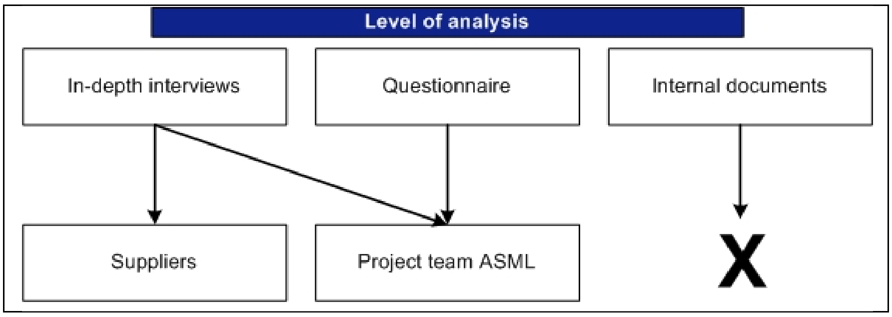

Figure C2. *Overview resources data collection*

Appendix D Questionnaire

Appendix D1Basic Framework Elements Questionnaire

Results

Element	Variable	Items (questions)
Short-term Project results	Final product quality	Compared to target (Q4, 9)
	Final product cost	Compared to target (Q5, 10)
	Final development costs	Compared to target (Q6, 11)
	Time-to-market	Compared to target (Q7, 12)
	Final manufacturability	Compared to target (Q8, 13) *(new)

Element	Variable	Items (questions)	Items (questions)
Short-term Collaboration results	Part technical performance	Supplier X compared to target (Q29)	Share of the total number of suppliers involved have performed worse/similar/better on Part Technical performance compared to targets set at the beginning (Q34)
	Part cost	Supplier X compared to target (Q30)	Share of the total number of suppliers involved have performed worse/similar/better on Part costs compared to targets set at the beginning (Q35)
	Part development costs	Supplier X compared to target (Q31)	Share of the total number of suppliers involved have performed worse/similar/better on Development costs compared to targets set at the beginning (Q36)
	Part development time	Supplier X compared to target (Q32)	Share of the total number of suppliers involved have performed worse/similar/better on Development time compared to targets set at the beginning (Q37)
	Part manufacturability	Supplier X compared to target *(new) (Q33)	Share of the total number of suppliers involved have performed worse/similar/better on Development time compared to targets set at the beginning *(new) (Q38)

Operational Management Process

Element	Variable	Items (questions)	Items (questions)	Items (questions)
Operational Management Process	**OMP1**	Project team actively involved in identifying upfront the different building blocks of the final product for which development activities were planned to be outsourced to external suppliers. (Q47)	Project team actively involved in defining the preferred supplier development responsibility regarding the various building blocks of the final product (before the supplier is chosen). (Q48)	
	OMP2	Project team actively involved in collecting suggestions from suppliers on alternative technologies or components during the product development process (Q49)	Project team actively involved in comparing alternative suppliers and their technologies or components for further evaluation during the project. (Q50)	
	OMP3	Project team actively involved in defining the criteria for selecting key suppliers for the development of different elements (Q51)	Project team actively involved in choosing the actual supplier(s) to be involved (Q52)	
	OMP4	Freezing the final degree of supplier development responsibility in the project when the supplier has been chosen (Q53)	Project team actively involved in planning in which project phase the suppliers' development activities must start (Q54)	
	OMP5	Project team actively involved in defining upfront the actual supplier development activities (e.g.proto-typing, tooling, testing) with the supplier in a project agreement (Q55)	Project team actively involved in determining upfront the specific operational performance targets with the supplier (Q56)	Project team actively involved in specifying contractual conditions regarding the collaboration in a formal contract. (Q57)
	OMP6	Project team actively involved in determining upfront the communication structure between project team and individual first tier suppliers (Q59)	Project team actively involved in determining upfront the communication structure between the first tier suppliers and their subsuppliers (Q60)	
	OMP7	Project team actively involved in coordinating supplier development activities between the project team and individual first tier suppliers (Q61)	Project team actively involved in coordinating supplier development activities between the first tier suppliers and their sub suppliers (Q62)	Project team actively involved in joint problem solving during the project (Q 58)
	OMP8	Project team actively involved in evaluating supplier designs regarding commercial aspects (e.g., component availability, lead-time costs). (Q63)	Project team actively involved in evaluating supplier designs regarding technical aspects (e.g., quality, manufacturability, serviceability). (Q64)	Project team actively involved in investigating possibilities for simplification (standardization) of building block designs. (Q65)
	OMP9	Project team actively involved in reviewing how suppliers performed in this development project. (Q66)	Project team actively involved in feeding forward suppliers' development performance to be included in the preferred supplier list for future supplier selection. (Q67)	

Enabling conditions

Element	Variable	Items (questions)	Items (questions)	Items (questions)	Items (questions)
Project team enablers	**Cross functional orientation D&E/Procurement SEO project team (CFT)**	representatives from the Procurement and SEO department were involved from the beginning. (Q 68)	representatives from the Procurement and SEO department were involved extensively. (Q 69)		
	Development Team Stability (DTS)	the same buyers stayed on the project team as long as their involvement was necessary. (Q 70)	the same supply chain engineers stayed on the project team as long as their involvement was necessary. (Q 71)	the same D&E members stayed on the project team as long as their involvement was necessary. (Q 72)	
	Educational level team	The majority of the project team members from the Procurement and SEO department had at least a higher educational degree. (Q 76)	The majority of the project team members from the D&E /Engineering department had at least a higher educational degree. (Q 80)		
	Experience team	The majority of the project team members from the Procurement and SEO departments have been working before in other company departments. (Q 75)	The majority of the project team members from the D&E/Engineering department have been working before in other company departments. (Q 79)	The majority of the project team members from the procurement and SEO department had a sufficient technical understanding of the elements of the final product. (e.g., components, modules) (Q 77)	The majority of the project team members from the D&E department had sufficient commercial skills when designing the elements of the final product. (value analysis etc.) (Q 81)
	Credibility team	The majority of the project team members from the Procurement and SEO departments accepted suggestions from engineers on technical aspects of the elements of the final product. (e.g., components, modules) (Q 78)	The majority of the project team members from the D&E/Engineering department accepted suggestions from purchasers on commercial aspects of the elements of the final product. (e.g., components,modules) (Q 82)		
	Top management commitment *new	From senior management their was support in the provision of financial resources. *new (Q 73)	From senior management their was support in the provision of political resources. *new (Q74)		
Collaboration enablers	**Supplier Technical Capabilities**	Satisfaction with the technical capabilities the suppliers brought into the project? (Q 39)	Extent to which suppliers thoroughly understood our product requirements. (Q 83)		
	Supplier Project Management Capabilities	Satisfaction with the project management skills the suppliers used in the project? (e.g., planning the project and coordinating activities between departments) (Q 40)	The supplier in this project, had the necessary skills to plan, to monitor and to coordinate development activities (Q84).		
	Supplier Target Cost capabilities	Extent to which Suppliers thoroughly understood our commercial project requirements (Q 85)			

	Relevant past experience	Share of new Suppliers (Q41)	Share of suppliers Involved in one previous project (Q42)	Share of suppliers involved in multiple projects (Q43)	Share of suppliers that have assumed a greater development responsibility (Q44, 45 & 46)
	Compatibility in culture and operating style	The supplier in this project had the organization and way of working well- fitted with our organization (*new) (Q 87)			
	Mutual trust	The supplier provided all the information we needed (*new) (Q 86)	The project team provided the supplier with all the information they needed (*new) (Q28)		

Driving conditions

Element	Variable	Items (questions)	Items (questions)	Items (questions)	Items (questions)
Business Unit	**Busines Unit Size (BUS)**	Total Revenues for Business Unit in 2009[13]	Nr of employees for Business Unit in 2009*		
	Supplier Dependence (SDE)	Purchased value in 2009*	Total Revenues for Business Unit in 2009*		
	Manufacturing Type	E.g. Unit/small series Production/ Project based production etc.*			
	D&E dependence (RDE)	D&E expenditure as a percentage of total revenues in 2009 for ASML.*			
Project drivers	**Project Complexity/ Size (PSI)**	Available D&E budget at the start of the project: (Q 1)	Average number of people on the project team: (Q 2)	Actual development lead time of this project. (Q 3)	
	Degree of project innovation	How new were the elements of the final product at the start of the project as perceived by the project team? (Q 17)	How new was the Final product configuration at the start of the project as perceived by the project team? (Q18)	How new were the product technologies of the final product at the start of the project as perceived by the project team? (Q19)	How new were the manufacturing technologies of the final product at the start of the project as perceived by the project team? (Q20)
Collabora Tion drivers	**Part Development Complexity**		*		
	Part Development Novelty		*		
	Part Technological uncertainty		*		
	Part's Contribution to overall product functionality		*		

Sourcing model (*new)

Element	Variable	Items (questions)	Items (questions)	Items (questions)	Items (questions)
Sourcing model	**Spectrum of supplier integration**	For each category of parts, please indicate the proportion of the total purchasing value it represents. (Q21, 22, 23)	Please indicate the *relative influence* of the project team versus the suppliers on, product design decision for setting original specifications (Q24, 25)	Please indicate the extent to which the project team, defined detailed specifications (Q26)	Please indicate the extent to which the project team specified manufacturing tolerances (Q27)

[13] *: Source for measuring these determinants are open-ended questions and/or internal documents.

Appendix D2 Questionnaire

A Survey on Early Supplier Involvement in New Product Development

Principal Researcher:

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General Instructions:
Thank you in advance for participating in this research project. This survey is supported by ASML and Eindhoven University of Technology. By answering this questionnaire, you contribute to a series of case studies on the successful management practices and conditions for using suppliers as a source of competitive advantage in new product development.

This survey contains statements, which may or may not apply to you. For each statement circle the answer, that best represents your opinion. Please make sure that your answer is in the correct box or number. If you cannot answer any specific questions for some reasons, please tick the do not known option and proceed to the next question.

Confidentiality:
All responses will be held in the strictest confidence. Data will only be analyzed at the aggregate level. No individual responses will be released or disclosed. No one except the principal academic researcher will have access to the raw data.

Structure questionnaire:
Part A contains questions regarding some characteristics and performance of the selected project.
Part B contains questions regarding the specific activities the project team carried out to work together with suppliers in new product development.
Part C contains questions regarding the organization/capabilities and experience of both customer and suppliers.
Part D contains questions regarding your professional background.

Important notes:
- Filling out the questionnaire will take approximately twenty-five minutes.
- If some of the terms used in the questionnaire are unclear, we suggest you to read the definitions below.
- Room for additional remarks is left at the end of the questionnaire.

Definitions:

1.	**Building blocks:**	those elements of the final product configuration that may appear as subsystems, modules, subassemblies, major components, etcetera in the final product.
2.	**Building block technical performance:**	the functional performance, conformance to specifications, the reliability and durability of the Building block developed together with your suppliers.
3.	**Building block costs:**	the cost or contract price of the building block developed, assembled and/or manufactured by your supplier(s)
4.	**Building block development costs:**	include costs related to internal development and engineering activities regarding those building blocks mainly developed by suppliers. This also includes any development expenses by suppliers as fast as your company pays for them.
5.	**Building block development time:**	the time between the first moment of supplier involvement to the moment of building block release.
6.	**Product configuration:**	the way the building blocks are linked together is the product configuration also called product architecture or systems design.
7.	**Market introduction:**	the moment of first customer shipment.
8.	**Project start:**	the moment on which the formal project go-ahead has been given by approving the project definition.
9.	**Purchase values**	The purchase value is the total amount paid to all suppliers delivering building blocks/services for the selected product.
10.	**Supplier development responsibility:**	refers to the level of specifications at which the supplier's contribution in the project starts (e.g. CoTS, build-to-print, grey box or black box specification). The categories are ordered from a low level to higher levels of responsibility.
11.	**Supplier development activities:**	those activities that typically need to be carried out for the design, engineering and preparation for production regarding the building block (E.g. CAD drawing, prototyping, testing, tooling development, etc.

THANK YOU VERY MUCH IN ADVANCE FOR YOUR COOPERATION

Part A. Project Characteristics

In the next set of questions, we focus on some specific characteristics of the project you selected beforehand.

1. Please indicate the available budget at the start of the project:____________________________€.
2. Please indicate the number of persons working on the project team:______project team members.
3. Please indicate actual development time used in his project (time between project start and first customer shipment):

☐	☐	☐	☐	☐	☐	☐
< 0.5 year	0.5-1 year	1-2 years	2-3 years	3-4 years	4-5 years	>5 years

Please indicate the relative importance of the project performance objectives at the beginning of the project	Not at all 0	1	2	3	4	5	6	7	8	9	Very 10	Do not know
4. Final product technical performance	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
5. Final Product cost	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
6. Development cost	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
7. Time-to-market	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
8. Manufacturability	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Compared to the target set at the beginning, how did the selected project (i.e. the final product) perform in terms of (please tick the appropriate box)	A lot worse than target 1	2	3	Exactly on target 4	5	6	Much better than target 7	Do not know
9. Final product technical performance	☐	☐	☐	☐	☐	☐	☐	☐
10. Final product cost	☐	☐	☐	☐	☐	☐	☐	☐
11. Development cost	☐	☐	☐	☐	☐	☐	☐	☐
12. Time-to-market	☐	☐	☐	☐	☐	☐	☐	☐

13. Please describe what events have impacted on the reported project performance

____

____

Compared to the target set at the beginning, how did the selected project (the total final product) perform in terms of:	A lot worse than target 1	2	3	Exactly on target 4	5	6	Much better than target 7	Do not know
14. Sales volume	☐	☐	☐	☐	☐	☐	☐	☐
15. Market share	☐	☐	☐	☐	☐	☐	☐	☐
16. profitability	☐	☐	☐	☐	☐	☐	☐	☐

The following questions deal with the newness of various aspects of the final product as perceived by the project ream, at the start of the project. (Please tick the appropriate box).

Concerning the final product for ASML, how new were the following elements:	Not new at all 1	2	3	Some what new 4	5	6	Completely new 7	Do not know
17. the <u>building blocks</u>	☐	☐	☐	☐	☐	☐	☐	☐
18. the <u>product configuration</u>	☐	☐	☐	☐	☐	☐	☐	☐
19. the <u>product technologies</u>	☐	☐	☐	☐	☐	☐	☐	☐
20. the <u>manufacturing technologies</u>	☐	☐	☐	☐	☐	☐	☐	☐

21. Please indicate the relative share of the purchase value of all building blocks in the product cost price at market introduction. (Please tick the appropriate box).

☐	☐	☐	☐	☐
0-20%	20-40%	40-60%	60-80%	80-100%

22. Please indicate the relative share of the supplier's engineering hours in the total engineering hours invested in the selected project. (Please tick the appropriate box).

☐	☐	☐	☐	☐
0-20%	20-40%	40-60%	60-80%	80-100%

In the next section, we ask you for the total value of purchased parts of the final product. We would like to understand how this value is distributed across different categories of parts. Each category refers to a specific distribution of tasks and responsibilities between the supplier and the development team regarding the development part.

23. For each category of parts, please indicate the proportion of the total purchasing value it represents.

Part categories	**% of total purchasing value**
Commercial of the shelf (CoTS) Commercial available product from an OEM supplier program, products are available to other customers besides ASML.	%
Build-to-print Manufacturing of a product using ASML owned TPD	%
White box An ASML dedicated product, designed and manufactured by the supplier, documented in ASML owned TPD.	%
Grey box parts An ASML dedicated product, designed and manufactured by the supplier, documented in ASML owned TPD.	%
Black box parts An ASML dedicated product, designed and manufactured by the supplier, documented in supplier owned TPD.	%

Total purchase value = 100%

Please indicate the *relative influence* of the project team versus the suppliers on,	Almost all project team 1	2	3	Equally project team and supplier 4	5	6	Almost all suppl-ier 7	Do not know
24. product design decision for setting original specifications	☐	☐	☐	☐	☐	☐	☐	☐
25. product design decision for the first prototype	☐	☐	☐	☐	☐	☐	☐	☐

Please indicate the extent to which the project team,	To a very low extent 1	2	3	To some extent 4	5	6	To a very high extent 7	Do not know
26. defined detailed specifications	☐	☐	☐	☐	☐	☐	☐	☐
27. specified manufacturing tolerances	☐	☐	☐	☐	☐	☐	☐	☐
28. provided the supplier with all the information they needed	☐	☐	☐	☐	☐	☐	☐	☐

In this section, we would like to ask you about the development performance of the collaboration with all suppliers involved in the selected project. Performance indicators are Building block technical performance, Building block cost, Building block development costs and Building block development time.

Please indicate for each of the performance indicators the respective percentages of the total number of suppliers involved that have performed worse, better than, or on target.

Building Block Performance targets	**% of suppliers performing worse than target**	**% of suppliers performing on target**	**% of suppliers performing better than target**	**Total should be**
29. Technical performance				100%
30. Cost				100%
31. Development costs				100%
32. Development time				100%
33. Manufacturability				100%

Please indicate the respective percentages of the total number of suppliers involved that have performed *worse*, *the same*, *better than* compared to the performance of *similar building blocks in previous projects*.

Building Block Performance targets	**Worse than the performance of the Building blocks in previous projects (%)**	**The same compared to the performance of Building blocks in previous projects (%)**	**Better than the performance of Building blocks in previous projects (%)**	**Total should be**
34. Technical performance				100%
35. Cost				100%

36. Development costs				100%
37. Development time				100%
38. Manufacturability				100%

	Completely dissatisfied 1	2	Neither dissatisfied nor satisfied 3	4	5	6	Completely satisfied 7	Do not know
39. To what extent were you satisfied with the technical capabilities the supplier brought into the project?	☐	☐	☐	☐	☐	☐	☐	☐
40. To what extent were you satisfied with the project management skills the suppliers used in the project (e.g. planning the project and coordinating activities between departments)?	☐	☐	☐	☐	☐	☐	☐	☐

Please indicate the extent to which suppliers in the selected project have collaborated in *previous* projects.

	% of total suppliers involved in the selected project
41. New supplier(s)	____________%
42. Supplier(s) involved in one previous project	____________%
43. Supplier(s) involved in multiple projects	____________%
	Total 100%

Please indicate the extent to which the level of supplier development responsibility differed in the collaboration compared to the *previous* project. (supplier proprietary parts/CoTS, grey box parts and black box part). The aforementioned categories are ordered from a low level to a higher levels of responsibility.

	% of total suppliers involved in the selected project
44. Suppliers that have been involved on a lower level in the previous project	____________%
45. Suppliers that have been involved on the same level in the previous project	____________%
46. Suppliers that have been involved on a higher level in the previous project	____________%
	Total 100%

Part B. Management of Early Supplier Involvement in the selected project

In the next series of questions, we ask you to make observations regarding specific activities and processes to work with suppliers in the selected project. These activities and processes could be carried out by the project team members.

Please indicate to what extent you agree with the following statements. (Please tick the appropriate box).

In the selected project, the *project team* has been actively involved in:	Strongly disagree 1	2	Neither disagree nor agree 3	4	5	6	Strongly agree 7	Do not know
47. identifying upfront the different building blocks of the final product for which development activities were planned to be outsourced to external suppliers.	☐	☐	☐	☐	☐	☐	☐	☐
48. defining the preferred supplier development responsibility regarding the various building blocks of the final product (before the supplier is chosen).	☐	☐	☐	☐	☐	☐	☐	☐
49. collecting suggestions from suppliers on alternative technologies or components during the product development process.	☐	☐	☐	☐	☐	☐	☐	☐
50. comparing alternative suppliers and their technologies or components for further evaluation during the project.	☐	☐	☐	☐	☐	☐	☐	☐
51. defining the criteria for selecting key suppliers for the development of different building blocks.	☐	☐	☐	☐	☐	☐	☐	☐
52. choosing the actual supplier(s) to be involved.	☐	☐	☐	☐	☐	☐	☐	☐
53. freezing the final degree of supplier development responsibility when the supplier has been chosen.	☐	☐	☐	☐	☐	☐	☐	☐

54. planning in which project phase the development activities of different suppliers must start.	☐	☐	☐	☐	☐	☐	☐	☐
55. defining upfront the *actual* supplier development activities (e.g. prototyping, tooling, testing) with the supplier in a project agreement.	☐	☐	☐	☐	☐	☐	☐	☐
56. determining upfront the specific operational performance targets with the supplier (e.g. building block quality target, cost target, etc.)	☐	☐	☐	☐	☐	☐	☐	☐
57. specifying contractual conditions regarding the collaboration in a formal contract (e.g. ownership of knowledge jointly developed, etc.).	☐	☐	☐	☐	☐	☐	☐	☐
58. joint problem solving during the project.	☐	☐	☐	☐	☐	☐	☐	☐
Determining upfront the communication structure between								
59. the project team and individual first tier suppliers.	☐	☐	☐	☐	☐	☐	☐	☐
60. the first ties suppliers and their sub suppliers.	☐	☐	☐	☐	☐	☐	☐	☐
Coordinating the actual development activities between								
61. the project team and individual first tier suppliers.	☐	☐	☐	☐	☐	☐	☐	☐
62. the first tier suppliers and their sub suppliers.	☐	☐	☐	☐	☐	☐	☐	☐

In the selected project, the project team has been actively involved in:	Strongly disagree 1	2	3	Neither disagree nor agree 4	5	6	Strongly agree 7	Do not know
63. evaluating supplier's building block designs regarding commercial aspects (e.g. component availability, lead time and cost).	☐	☐	☐	☐	☐	☐	☐	☐
64. evaluating supplier's building block designs regarding technical aspects (e.g. quality, makeability and serviceability).	☐	☐	☐	☐	☐	☐	☐	☐
65. investigating possibilities for simplification (standardization) of building block designs.	☐	☐	☐	☐	☐	☐	☐	☐
66. reviewing how suppliers performed in this development project.	☐	☐	☐	☐	☐	☐	☐	☐
67. feeding forward supplier's development performance to be included in the preferred supplier list for future supplier selection.	☐	☐	☐	☐	☐	☐	☐	☐

Part C. Organization/Capabilities and Experience

In this section, the questions address the organization, the capabilities and available experience of Procurement SEO (before the Supply Chain Engeering department), D&E/engineering department and of the suppliers involved in the selected project. (Please tick the appropriate box).

Please indicate the extent to which you agree with the following statements:

In the project team:	Strongly disagree 1	2	3	Neither disagree nor agree 4	5	6	Strongly agree 7	Do not know
68. representatives from the Procurement and SEO departments have been involved *from the very beginning.*	☐	☐	☐	☐	☐	☐	☐	☐
69. representatives from the Procurement and SEO departments have been involved *extensively* in the selected project.	☐	☐	☐	☐	☐	☐	☐	☐

70. the same buyers have stayed on the project team as long as their involvement was necessary.	☐	☐	☐	☐	☐	☐	☐	☐
71. the same supply chain engineers stayed on the project team as long as their involvement was necessary.	☐	☐	☐	☐	☐	☐	☐	☐
72. the same D&E members have stayed on the project team as long as their involvement was necess`ary.	☐	☐	☐	☐	☐	☐	☐	☐
From Senior management:								
73. their was support in the provision of financial resources.	☐	☐	☐	☐	☐	☐	☐	☐
74. their was support in the provision of political resources.	☐	☐	☐	☐	☐	☐	☐	☐

The majority of the project team members from the Procurement & SEO department,	Strongly disagree 1	2	3	Neither disagree nor agree 4	5	6	Strongly agree 7	Do not know
75. have been working before in other company departments.	☐	☐	☐	☐	☐	☐	☐	☐
76. have at least a higher educational degree.	☐	☐	☐	☐	☐	☐	☐	☐
77. have a sufficient technical understanding of the building blocks of the final product.	☐	☐	☐	☐	☐	☐	☐	☐
78. accepted suggestions from engineers on commercial aspects of the building blocks involved.	☐	☐	☐	☐	☐	☐	☐	☐

The majority of the project team members from the D&E department,	Strongly disagree 1	2	3	Neither disagree nor agree 4	5	6	Strongly agree 7	Do not know
79. have been working before in other company departments.	☐	☐	☐	☐	☐	☐	☐	☐
80. have at least a higher educational degree.	☐	☐	☐	☐	☐	☐	☐	☐
81. have sufficient commercial skills (e.g. use value analysis) when designing the building blocks used in the final product.	☐	☐	☐	☐	☐	☐	☐	☐
82. accepted suggestions from purchasers and supply chain engineers on technical aspects of the building blocks involved.	☐	☐	☐	☐	☐	☐	☐	☐

The suppliers in this project,	Strongly disagree 1	2	3	Neither disagree nor agree 4	5	6	Strongly agree 7	Do not know
83. thoroughly understood our product requirements.	☐	☐	☐	☐	☐	☐	☐	☐
84. had the necessary skills to plan, to monitor and to coordinate development activities.	☐	☐	☐	☐	☐	☐	☐	☐
85. thoroughly understood our commercial (e.g. cost price) project requirements.	☐	☐	☐	☐	☐	☐	☐	☐
86. provided all the information we needed	☐	☐	☐	☐	☐	☐	☐	☐
87. had the organization and way of working well- fitted with our organization	☐	☐	☐	☐	☐	☐	☐	☐

Part D. Respondent Profile

Please provide the following professional background information.

- Name: ___________________________
- Position: ___________________________
- Number of years working in D&E/Supply chain area: ___________________________
- Number of years working for ASML: ___________________________

If you have comments and / or additions on this questionnaire, please record them here.

____
____
____

On behalf of the research team at ASML and Eindhoven University of Technology, we thank you very much for your valuable time and contribution to this study.

Appendix D3 Semi-structured interview

A Survey on Early Supplier Involvement in New Product Development
Interview questionnaires

Part A. General Questions

1. In what way were you involved in this project/ what was your role in this project?
2. What were your responsibilities during this project?
3. Which activities did you perform in the light of this project?
4. What were the reasons for ASML to involve this supplier in the project?
5. Are you content with the result of the project (in terms of the final product)? Why/why not?
6. Has the involvement of the supplier influenced the project result? If yes, in what way(s)?
7. Are you content with the building block the supplier provided (in terms of the module the supplier supplied)? Why/why not?
8. Are you content with the collaboration with this supplier in this project? Why/why not?
9. Can you think of any factors that might have influenced the course of the project, but that were beyond your control? If yes, can you name some factors? To what extent and in what ways have these factors influenced the project result?
10. Do you think that your understanding of your supplier's knowledge and skills have been improved during this project? If yes, why do you think so?
11. Has ASML had any learning experiences with this supplier in this project? If yes, can you give an example?

Part B. Operational Management Processes

12. How does ASML determine which elements of a product are outsourced and which elements of a product are developed in-house?
13. How does ASML determine the extent of supplier responsibility?
14. Do you, in advance of or during the project collect suggestions on alternative technologies or building blocks that might fit well into the product being developed?
15. Which people are involved in that mostly?
16. What do you do with these suggestions?
17. In advance of the choice for one specific supplier, do you compare multiple suppliers and their technology or building block offerings? On what criteria do you compare them?
18. How is determined which supplier is best suited to the project?
19. Which criteria are used for choosing a supplier?
20. Are these criteria fixed for all projects?
21. How does ASML determine when a specific supplier will be involved in the product development process?
22. Are the definite extent of supplier responsibility and the timing communicated to the supplier? If so, how is this done?

23. Are the actual activities that the supplier must carry out determined before the start of the project? How is this done (e.g. by ASML, by the supplier or by both)?
24. Does ASML in advance of the project specify operational targets with regard to product performance? How is this done (e.g. by ASML, by the supplier or by both)?
25. Does ASML in advance of the project specify operational targets with regard to planning and project management? How is this done (e.g. by ASML, by the supplier or by both?)
26. Is the product development project documented/described in a development contract? How are the contents agreed upon?
27. Does the supplier in this project have suppliers of his own?
28. Who is concerned with the communication between ASML, the supplier and his subsupplier(s)?
29. Are there more suppliers alongside the supplier that's involved in this product development project? Is it necessary to co-ordinate between these different first-tier suppliers? Who is concerned with that?
30. Has ASML in advance of the project determined a communication structure for:
    a. the project team and the first-tier suppliers?
    b. the first-tier suppliers and the second-tier suppliers?
    c. the different first-tier suppliers?
31. Approximately, how often were these groups communicate (e.g. very frequently, seldom)?
32. What was communicated about?
33. Were there any specific problems in the communication?
34. Are supplier designs evaluated in advance of the project (e.g. supply, throughput time)? Who is mostly concerned with that?
35. Are suppliers evaluated after the project has terminated? On what criteria are they evaluated (e.g. building block performance, collaboration skills)? How is this evaluation carried out?
36. Does the supplier receive feedback about the evaluation? How is this done?
37. Are the results of the evaluation feed back to the list of preferred suppliers? How is this done?

Part C. Conditions

38. Is purchasing and supply chain engineering formally involved in the product development process?
39. What's purchasing's contribution to the new product development process?
40. What's supply chain engineering contribution to the new product development process?
41. Do manufacturer and supplier exchange design information? If so, how?
42. Does ASML have some sort of database with information on alternative suppliers?
43. Does ASML have some sort of database with information on components and markets?
44. Are technical capabilities a condition for a supplier to be involved in new product development at ASML?
45. Are project management skills a condition for a supplier to be involved in new product development at ASML?
46. Are innovative capabilities a condition for a supplier to be involved in new product development at ASML?
47. Are resources in the supplier's network a condition for a supplier to be involved in new product development at ASML?

Appendix E

Appendix E1 Sourcing models ASML

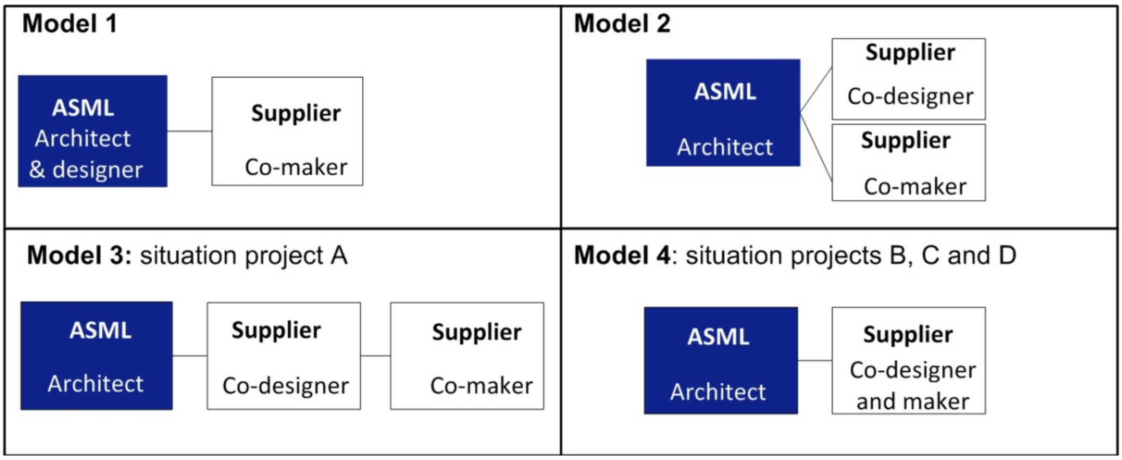


Figure E1. *Sourcing models ASML*

Appendix E2 Summary of supplier sample

Table E2. *Summary of supplier sample*

Criteria	Supplier A_1	Supplier A_2	Supplier B	Supplier C	Supplier D
General description	Electronics design company.	Electronics manufacturing company	Specialized in photonics and optics	Design and production of gas and chemical modules	Electronics design and production company.
Size (Approximate Number of Employees)	Small (N=40)	Medium (N=1,676)	Medium (N= 8,540)	Small (N= 250)	Small (N= 200)
Geographic Locations	Enschede, Eindhoven	Eindhoven and several international locations	Jena, Berlin, Altenstadt, Eisenachm Herrenberg	Oregon, Austin, Texas, and several international locations	Eindhoven, The Netherlands
Primary Products or Services	Co-developer of electronic boards	Co-maker of electronic boards	Optics & Polymer optics, diode lasers etc.	Gas and liquid delivery systems	Power Electronics, Embedded processing etc.
Founded	1990	1969	1846	Result of corporate break-up of corporate holding by the end of 2009	1993
Examples of key types of external partners	Healthcare, Semiconductor industry, etc.	Healthcare, Semiconductor industry, etc.	Defense, Aerospace, Semiconducto r industry, etc.	Solar/Photovol taics, Semiconductor industry etc.	Healthcare, Semiconductor industry, etc.

Appendix F Overall results questionnaire

Table F1. *Overall results of ASML's product development projects on drivers*, enablers* and results** (n= 14)*

Projects	Criteria					
	Operational project drivers^	Strategic corporate drivers^^	Operational project enablers	Operational management processes^	Short-term Collaboration results	Short-term Project results
Project A LLB+	1	1	2,4	3.6	3	2
Project B TIS NXE	3	2,8	2,4	2.9	1.4	1.4
Project C MDB	2	2,2	1,9	2.9	1.4	1.6
Project D PAAC 500-65	2	1,8	2,5	3.2	2.2	1.8

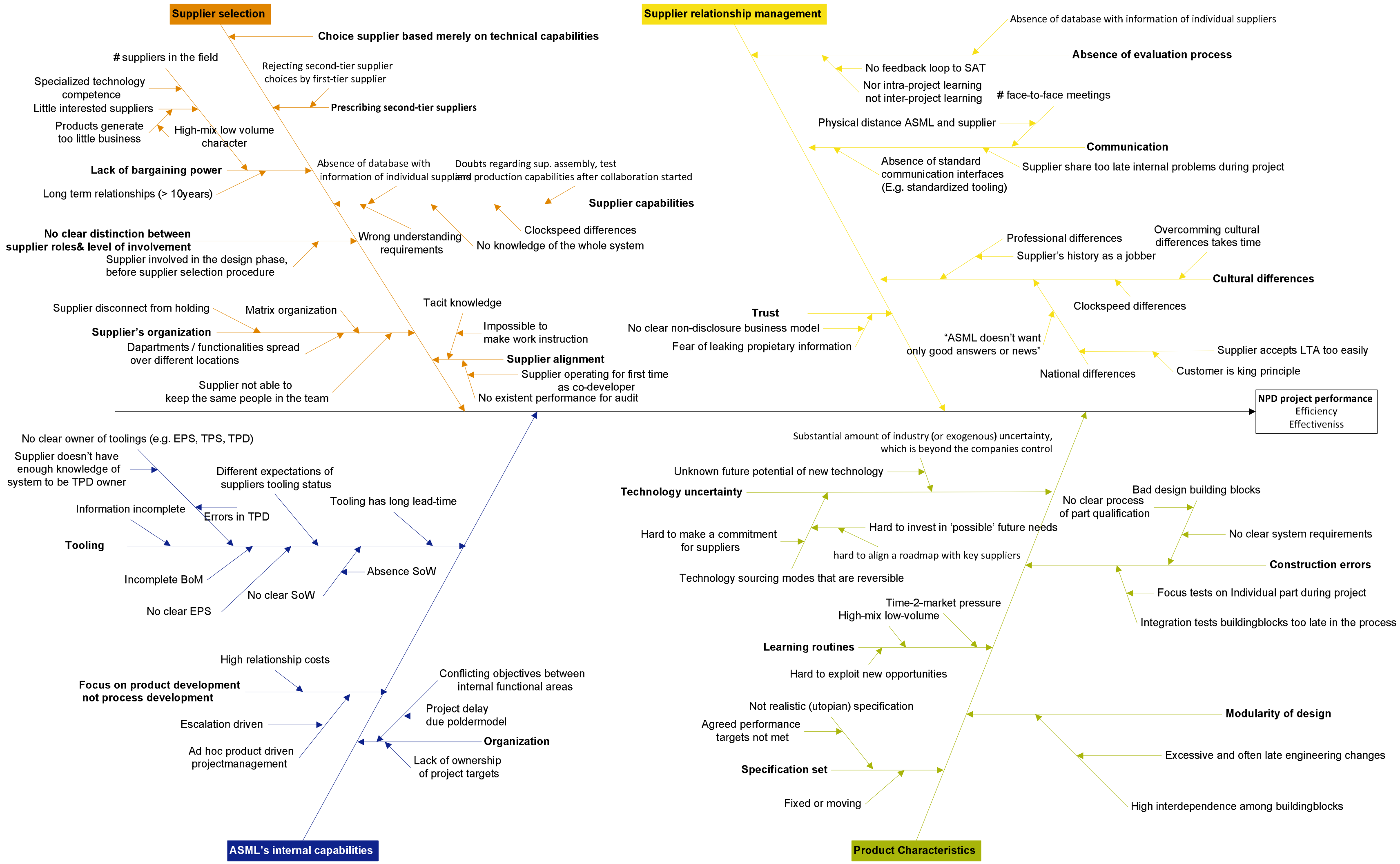
*****: Scale: 1-low; 2-medium; 3-high.
*********: Scale: 1-Absent: the process is not carried out; 2-Reactive: the process is carried out in an ad hoc way, as a result of occurring events; 3-Pro-active: the process is carried out following an implicit structure or set of activities; 4-Systematic: as in ' pro-active' , but supported by systems, procedures and guidelines; 5-Intelligent: as in ' systematic', but able to critically review the processes in the light of the situation and to adapt (incidentally or more permanently) when necessary.*
*******: Scale 1-below target; 2-on target; 3-above target.
^: Informants: internal project team, ^^: Informants: internal documents
+: This project included more than one supplier and the scores refer to averages for these suppliers.

Table F2. *Detailed results of ASML's product development projects on drivers*, enablers* and results** (n=14)*

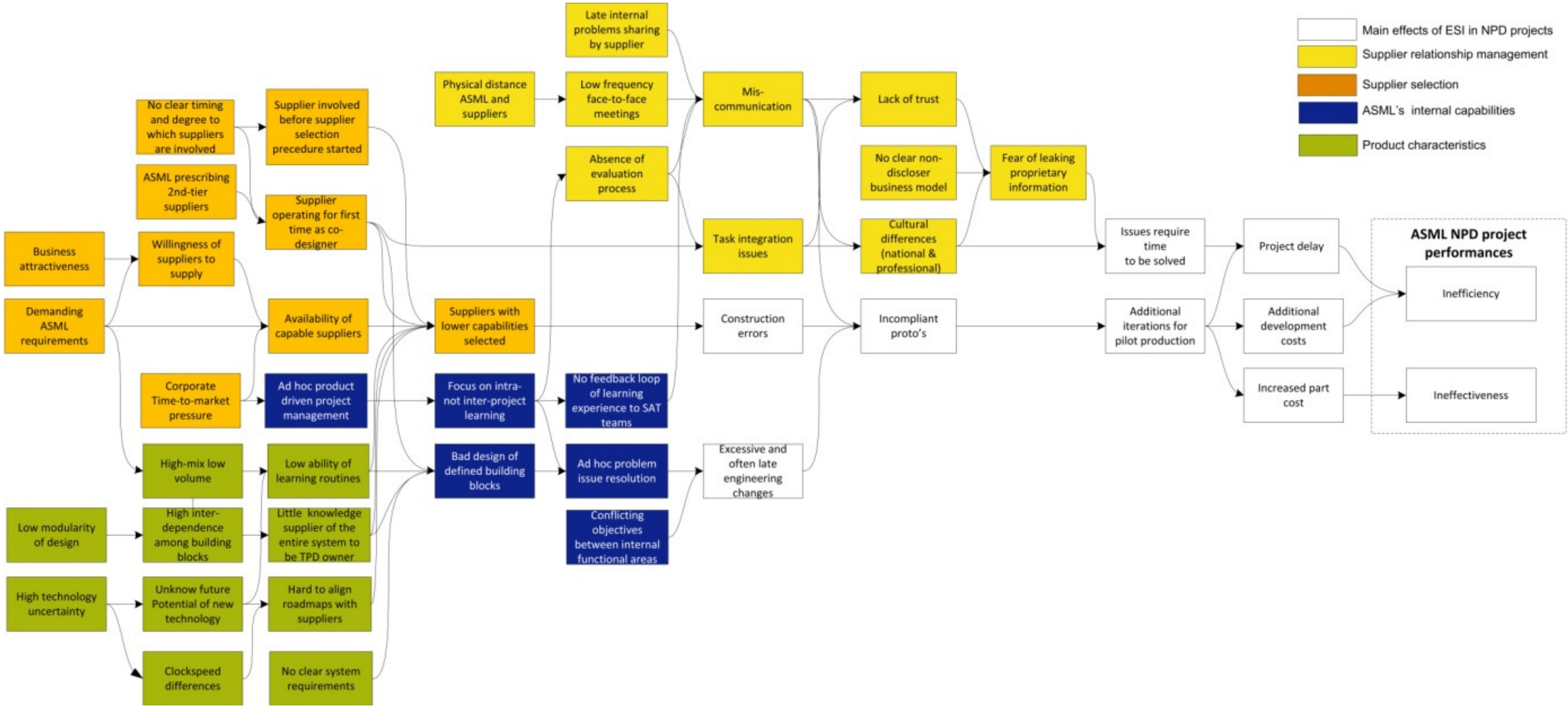
Criteria		Project A	Project B	Project C	Project D
Short-term project results^	Product quality	2	2	2	2
	Product cost	2	1	2	2
	Development cost	2	1	1	1
	Time-to-market	1	1	1	1
	Manufacturability	3	2	2	3
Short-term collaboration results^	Product quality	3+	2	2	3
	Product cost	3+	1	1	2
	Development cost	3+	1	1	2
	Time-to-market	2+	1	1	2
	Manufacturability	3+	2	2	2
Operational management process^	Determining desired develop and buy solutions	5	4	2	4
	Suggesting alternative technologies/components/suppliers	1	4	5	1
	Selecting suppliers for involvement in a project	2	3	3	2
	Determining extent and timing of involvement	4	2	3	3
	Determining development operational targets and work packages	4	3	4	3
	Designing communication interface	3	3	2	3
	Coordinating supplier's development activities	4	3	3	4
	Evaluating parts designs	5	3	3	5
	Evaluating supplier development performance	4	1	1	4
Operational project Enablers^	Cross-functional organization	2	2	3	3
	Top management commitment	2	3	2	2
	Human resource quality organization	3	3	3	3
	Supplier project management capabilities	3	2	2	2
	Supplier technical capabilities	3	2	1	2
	Supplier target cost capabilities	3	2	1	2
	Mutual trust	2	3	2	3
	Matching culture	1	2	1	3
Strategic corporate drivers^^	BU size supplier	1	2	1	1
	Supplier dependence	1	3	3	2
	R&D dependence	1	3	2	3
	Manufacturing complexity	1	3	3	1
	Technological uncertainty	1	3	2	2
Operational project drivers	Degree of project innovation	1	3	2	2

*: Scale: 1-low; 2-medium; 3-high. ***: Scale: 1-Absent: the process is not carried out; 2-Reactive: the process is carried out in an ad hoc way, as a result of occurring events; 3-Pro-active: the process is carried out following an implicit structure or set of activities; 4-Systematic: as in ' pro-active' , but supported by systems, procedures and guidelines; 5-Intelligent: as in ' systematic', but able to critically review the processes in the light of the situation and to adapt (incidentally or more permanently) when necessary.* ***: Scale 1-below target; 2-on target; 3-above target.
^: Informants: internal project team, ^^: Informants: internal documents
+: This project included more than one supplier and the scores refer to averages for these suppliers.

Appendix G Ishikawa diagram



Appendix H Cause and effect diagram

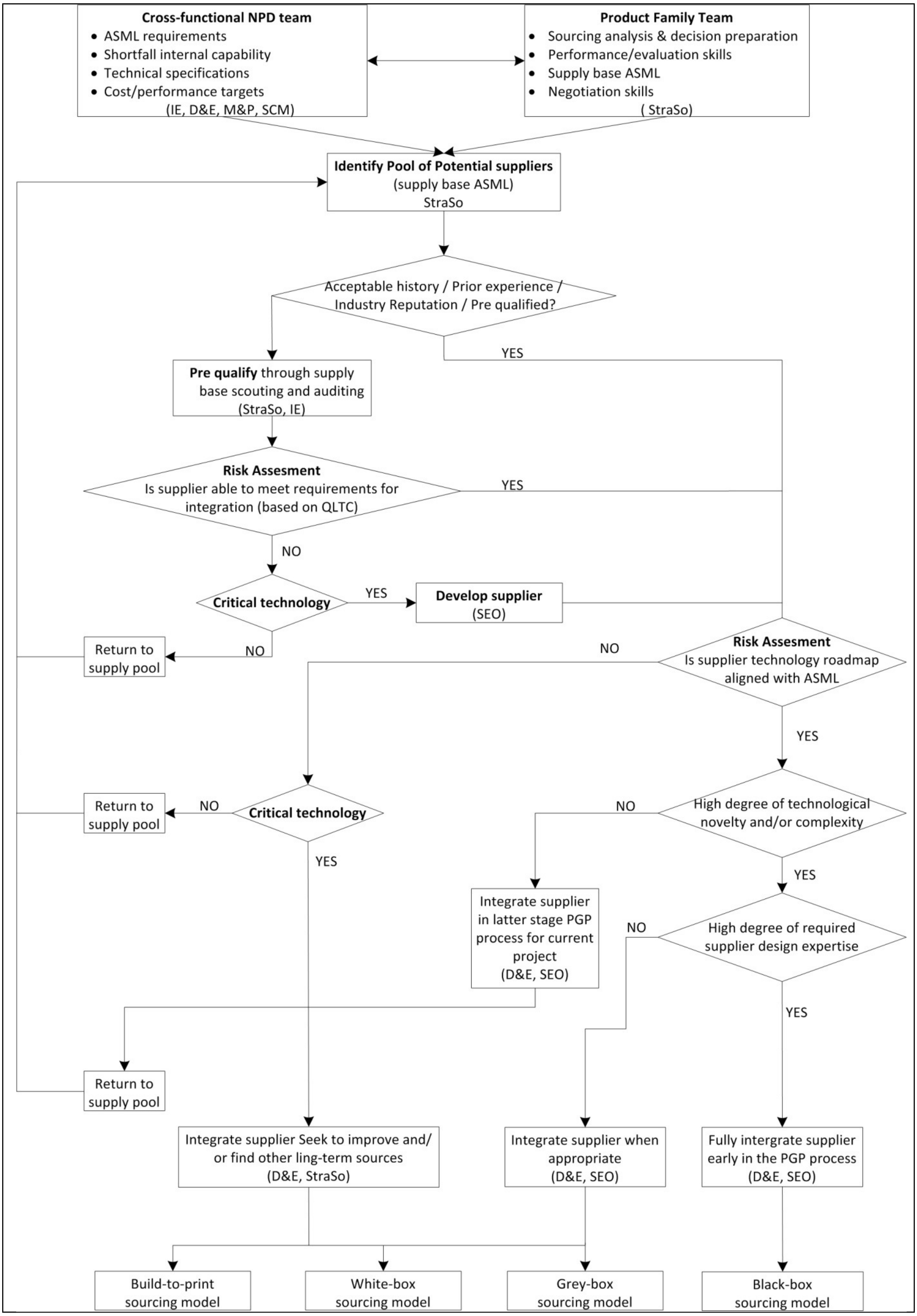


Appendix I Quotations describing the culture of ASML

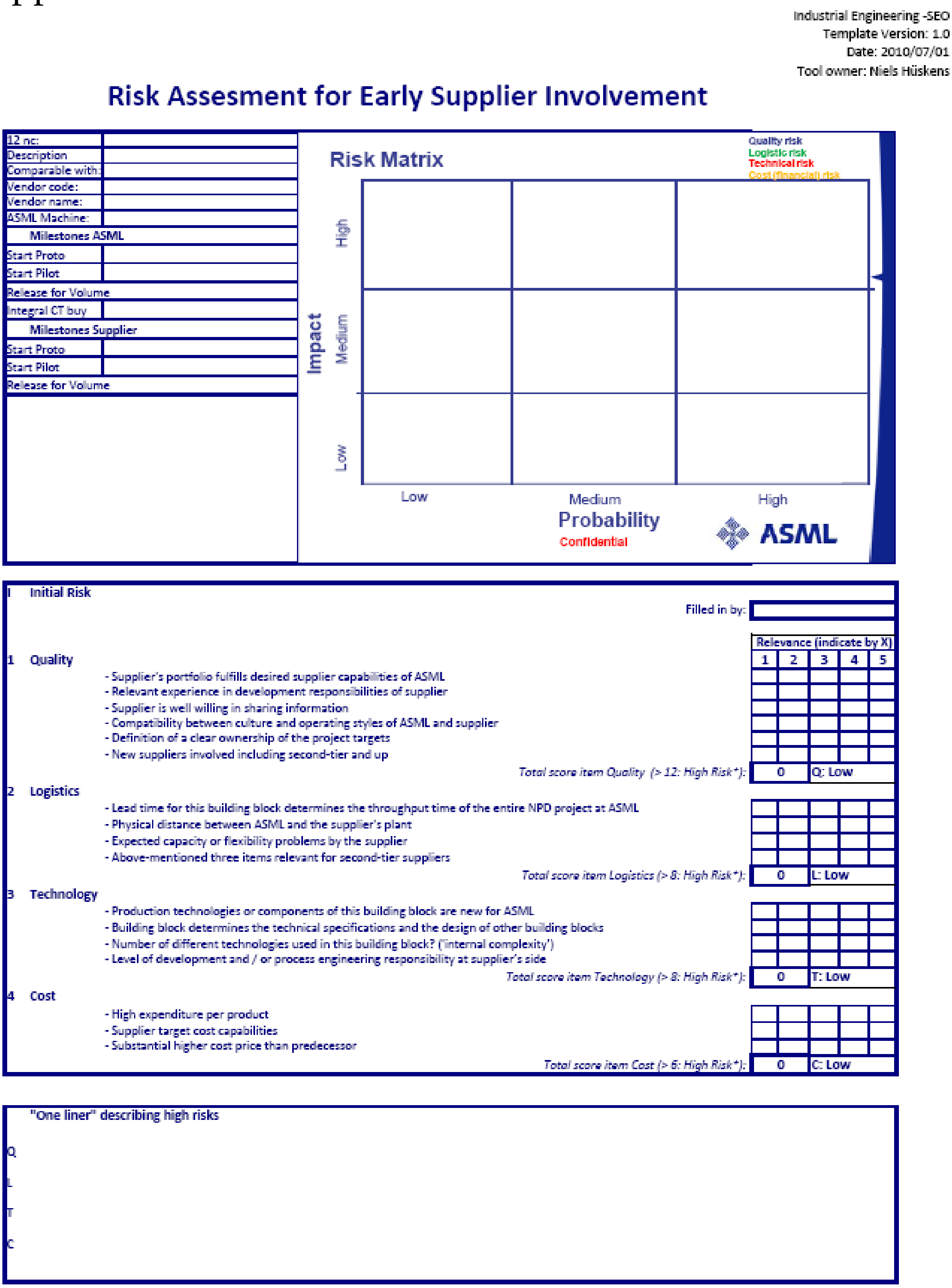
Table I. *Quotations describing the culture of ASML*

"It is unbelievable to be able to make an innovative product of which competition believes it is not possible to make them."
"ASML has the mindset of a fire fighter. If a fire breaks out, we're there to put it out. But the same fires keep popping up in different places! And that's far from efficient."
"ASML is changing. We started off as a niche player, grew to a technical leader and then even further to market leader. In this role. People working here are raised in a world which is still very close to the pioneer phase of a business."
"On my first day at ASML it was like I was ended up at a technical university."
"We are not an organization which is characterized by cost awareness; all developments we do are very innovative and lie at the top-end of the market; costs…well, after all we do make a beautiful product…"
"What we have here is an organization which is eager to develop new things. We do not like it at all to spend our times on putting effort into making existing products cheaper. Our natural tendency is to innovate. It is against our nature to work more efficiently."
"Everyone you meet recognized that the mindset of ASML is not efficient; working from crisis to crisis and from issue to issue, always mobilizing, energizing, solving. But at the same time everybody recognizes it is an asset."
"Our organization is very innovative. The amount of people working at development is very large. Moreover, if you look at their doors, they are either doctor or engineer, so they are also heavy-weighted developers. I think this is characteristic for this type of product."
"I can imagine if an outsider comes here he or she will not mention the word efficient when describing our business and processes. But it is special if you make a product, which is very complex, needs many people to work on, but of which the amounts produced are relatively small. This forces you to work less efficiently."
"Getting a kick out of beautiful things, technically challenging and costs…well who cares! This is really a cultural issue."
"People are very enthusiastic about product and technology."
"One is inclined to say: ASML is so difficult and complex, we do not have to look outside."
"My experience is that in particular engineers are much more stimulated by appealing to their sense of honor as an expert rather than encouraging them financially."

Appendix J Supplier integration process



Appendix K Risk assessment matrix



Industrial Engineering -SEO
Template Version: 1.0
Date: 2010/07/01
Tool owner: Niels Hüskens

Risk Assesment for Early Supplier Involvement

12 nc:	
Description	
Comparable with:	
Vendor code:	
Vendor name:	
ASML Machine:	
Milestones ASML	
Start Proto	
Start Pilot	
Release for Volume	
Integral CT buy	
Milestones Supplier	
Start Proto	
Start Pilot	
Release for Volume	

I Initial Risk

Filled in by:

Relevance (indicate by X)

	1	2	3	4	5

1 Quality

- Supplier's portfolio fulfills desired supplier capabilities of ASML
- Relevant experience in development responsibilities of supplier
- Supplier is well willing in sharing information
- Compatibility between culture and operating styles of ASML and supplier
- Definition of a clear ownership of the project targets
- New suppliers involved including second-tier and up

Total score item Quality (> 12: High Risk):* 0 Q: Low

2 Logistics

- Lead time for this building block determines the throughput time of the entire NPD project at ASML
- Physical distance between ASML and the supplier's plant
- Expected capacity or flexibility problems by the supplier
- Above-mentioned three items relevant for second-tier suppliers

Total score item Logistics (> 8: High Risk):* 0 L: Low

3 Technology

- Production technologies or components of this building block are new for ASML
- Building block determines the technical specifications and the design of other building blocks
- Number of different technologies used in this building block? ('internal complexity')
- Level of development and / or process engineering responsibility at supplier's side

Total score item Technology (> 8: High Risk):* 0 T: Low

4 Cost

- High expenditure per product
- Supplier target cost capabilities
- Substantial higher cost price than predecessor

Total score item Cost (> 6: High Risk):* 0 C: Low

"One liner" describing high risks

Q

L

T

C

Appendix K2 Example of a completed risk assessment matrix for project B

Risk Assesment for Early Supplier Involvement

12 nc:	*4022.622.00751*
Description	*Transmission Image Sensor NXE*
Comparable with:	*TIS XIAS*
Vendor code:	*123*
Vendor name:	*Supplier B*
ASML Machine:	*NXE*
Milestones ASML	
Start Proto	*2009 week 25*
Start Pilot	*2009 week 45*
Release for Volume	*2010 week 1*
Integral CT buy	
Milestones Supplier	
Start Proto	*2009 week 11*
Start Pilot	*2009 week 45*
Release for Volume	*2010 week 1*

TIS Project Risk Matrix

Quality risk
Logistic risk
Technical risk
Cost (financial) risk

Impact \ Probability	Low	Medium	High
High	No clear ownership project targets	Operating style 2^{nd} tier supplier Lifetime diode	Design highly interrelated with other modules Development budget
Medium		Lead time diode New 2^{nd} tier supplier Expected capacity problems 2^{nd} tier supplier	P3 price diode Physical distance Manufacturability diode
Low		Cultural differences	Language barrier Departments spread over different locations Pre-scribing 2^{nd} tier supplier

Probability

Confidential

ASML

I Initial Risk

Filled in by: Niels Hüskens

		Relevance (indicate by X)				
		1	2	3	4	5
1 Quality						
	- Supplier's portfolio fulfills desired supplier capabilities of ASML	x				
	- Relevant experience in development responsibilities of supplier		x			
	- Supplier is well willing in sharing information	x				
	- Compatibility between culture and operating styles of ASML and supplier				x	
	- Definition of a clear ownership of the project targets			x		
	- New suppliers involved including second tier and up					x
	Total score item Quality (> 12: High Risk):*	16	Q: High			
2 Logistics						
	- Lead time for this building block determines the throughput time of the entire NPD project at ASML			x		
	- Physical distance between ASML and the supplier's plant			x		
	- Expected capacity or flexibility problems by the supplier	x				
	- Above-mentioned three items relevant for second-tier suppliers				x	
	Total score item Logistics (> 8: High Risk):*	11	L: High			
3 Technology						
	- Production technologies or components of this building block are new for ASML	x				
	- Building block determines the technical specifications and the design of other building block				x	
	- Number of different technologies used in this building block? ('internal complexity')				x	
	- Level of development and / or process engineering responsibility at supplier's side			x		
	Total score item Technology (> 8: High Risk):*	12	T: High			
4 Cost						
	- High expenditure per product			x		
	- Supplier target cost capabilities			x		
	- Substantial higher cost price than predecessor		x			
	Total score item Cost (> 6: High Risk):*	8	C: High			

"One liner" describing high risks

Q The pre-scribed second tier supplier is new for ASML (research institution DIMES TU Delft) and JenOptik disagreed with the choice.

L The diode stack has a long lead time and JenOptik has its functional departments spread over different locations.

T The design of the TIS is highly interrelated with other modules in the lithography system, which makes it very vulnerable to redesigns of 'external' parts.

C The development budget is very tight, certainly with the knowledge that supplier D has a lack in target cost capabilities as shown in previous projects.

* High risk: project subject to release for volume critical part

Appendix L Design margin

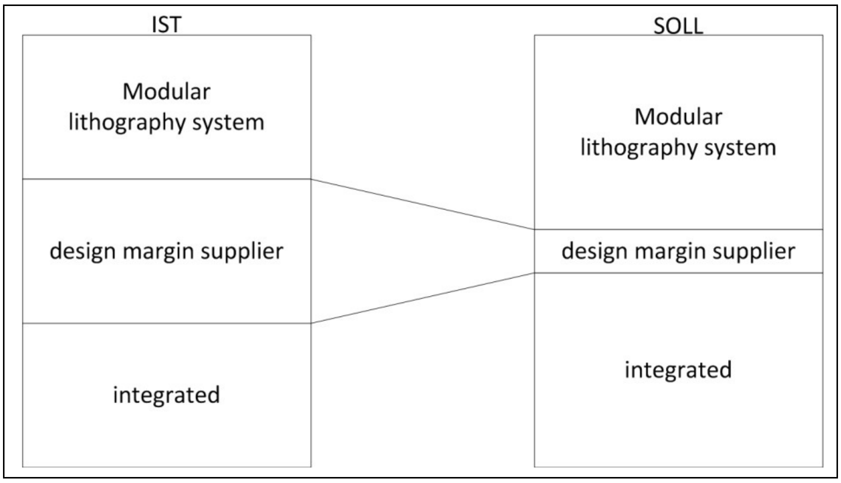


Figure L. *Design margin*

Logic behind it

By recognizing and exploiting secondary properties of one building block, neighbor components elements can be eliminated from the design, which makes the individual building blocks of a project less vulnerable to 'external' ECs.