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Ensuring Availability and Access to New and Existing Technologies in Cellular Terminal Business

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ABSTRACT

Major changes in the cellular terminal business market environment have resulted in a situation where supply chains need to realign their approach to demand and supply planning, supply dynamics and to technology cooperation practices to stay competitive. The purpose of this research was address the problematic of a dynamic and volatile business environment in regards to supply chains by creating a model of constructs to find solutions to the research questions through a case study approach outlined by Yin (1981, 1994).

Real time visibility to market demand both up and downstream in a supply chain can be obtained via various electronic tools and with market-driven collaborative planning efforts inside the supply chain. Limited editions manufacturing, consensus forecasting and effective demand marketing are approaches proposed for demand planning. An aspect to supplier collaboration and supplier management was identified: market environment affects the management practices especially upwards in the supply chain, so market demand clearly needs to one of the main criteria for supplier strategy creation. Also, implementing changes takes longer upstream in the supply chain.

Guiding principles have been proposed for managing the access to and development of new technologies. The "nucleus company" within a supply chain should take a leading role in bringing supply chain companies and third parties together to develop innovative solutions to end products within the context of the extended enterprise. The efforts could be coordinated through steering teams and technology roadmap sharing. Companies should also be encouraged to cooperate horizontally and outside the existing supply chain to optimize the number of and introduction speed of new innovations. Product development processes within the supply chain need to facilitate supplier and third party participation in product development. Resources and competencies could be shared within the supply chain to create new, innovative products to end customers. Open interfaces in product development and information sharing endeavor to lower total cost of development and to minimize the time-to-market of new products and applications. This research also proposes some metrics for availability logistics and technology cooperation so the actual value added through various forms of cooperation and collaboration could be measured and monitored.

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LIST OF ABBREVIATIONS

Sources: literature reference list and www.abbre.com.

ASIC	Application Specific Integrated Circuits
BTO	Build-To-Order
B2B	Business-To-Business
CAD/CAM	Computer Aided Design/Computer Aided Manufacturing
CFN	Customer Fulfillment Network
CM	Contract Manufacturer
DDR/DRAM	Double Data Rate/Random Access Memory
DOA	Dead On Arrival
DRAM	Dynamic Random Access Memory
EBN	Electronic Buyers' News
EDI	Electronic Data Interchange
EDO	Extended Data Output
E/EEPROM	Electrically Erasable/Programmable Read-Only Memory
EOQ	Economic Order Quantity
ESI	Early Supplier Involvement
FPM	Fast Page Mode
IC	Integrated Circuit
IPR	Intellectual Property Rights
JIT	Just-In-Time
MCU	Micro Control Unit
MRO	Maintenance and Repair Operations
MRP	Material Requirements Planning
OEM	Original Equipment Manufacturer
OTD	On-Time-Delivery
PC	Personal Computer
PLD	Programmable Logic Design
RF	Radio Frequency
RFQ	Request For Quotation
RISC	Reduced Instruction Set Computing
ROI	Return-On-Investment

SAW	Surface Acoustic Wave
SDRAM	Synchronous Dynamic Random Access Memory
SMI	Supplier Managed Inventory
SPC	Statistical Process Control
SRAM	Static Random Access Memory
TQM	Total Quality Management
UN	United Nations
WIP	Work In Process

1. DEFINING THE RESEARCH PROBLEM

1.1 Introduction

This research has been conducted to, first of all, increase understanding, review and verify practices in the area of demand-supply planning to ensure the availability of components, equipment and tooling in a highly fluctuating market environment of cellular terminal business, where new products are being introduced to the market at a constant pace. Availability in the context of this study means accessibility, being present or ready for immediate use (webster.com). Availability also depends on the product life cycle: it should either be maximized at the beginning of a new product life cycle or satisfied in product maturity and decline. Overall supplier management plays a key role in ensuring availability, capacity and accessibility to new technologies within the supply chain both in new product introductions and in mass manufacturing. Another target of this research has been to identify different forms of technology cooperation within the cellular terminal industry and to find the most beneficial ways to improve access to latest technologies within and outside the existing supply chain in a given business environment. New types of business models are emerging and innovations are being developed on regular intervals in the electronics industry. Optimal resourcing, common interfaces and shared guidelines steer the implementation of these new models within the concept of extended enterprise.

1.2 Background

Research for this Doctoral Thesis was started during the period when component, materials and equipment supply was extremely tight within the cellular terminal industry, and the race for the access to new technologies was accelerating. Then, during the writing of the Thesis, the growth rate of the industry in question started to decline, and began facing overcapacity. This thesis is analyzing the problems behind the constantly changing demand-supply environment and tries to find new ways of approaching the problems of optimal availability and timely technology access. The availability of existing, mass manufacturable components in sufficient quantities is essential in ensuring new product introductions and mass-volume manufacturing capability of consumer products, even in saturating markets. In today’s electronics business a backlog of consumer orders is not acceptable, and customers will turn to competitor's products in case of retail shortages. Timing is of the essence; new products need to be available to customers when promised, in sufficient quantities at a constant pace. The width of product portfolios and the increased number of new product launches also have a major impact on the supply chain: how to ensure availability in ramp up and ramp down situations for multiple new products at the same time? So, in addition to availability, the supply of materials and assets needs to be flexible both in terms of quantity and the specification. Availability of both new and existing end products to consumers is a major part of companies' competitive advantage and competitive strategy. At the same time, improving the efficiency of the supply chain drives cost reduction both in product cost and in operating expenses.

Technology access is becoming increasingly important for the industry. Products are getting more complex, having more features, variants and functionalities. Several new technologies are being introduced at the same time per product and consumers are becoming increasingly aware of quality and are demanding in getting new products at regular intervals. The differentiation from the competition is done with new technologies/features: which company is able to integrate them into a new product first. In addition, product life cycles are shortening and that forces product development cycles to become as compact as possible. Introducing new technologies in a timely manner and maintaining cost and quality on a reasonable level becomes even more of a challenge. This kind of availability problems both in new technologies and in the verified components was a new challenge for the industry in the late 1990's and now in the early 21st century the industry is facing another challenge. That is, how to adjust the operations to a smaller growth rate keeping in mind that the growth rate could be an ever-changing factor.

1.3 Previous research on the subject

Based on a literature research, there are plenty of material available concerning purchasing, supplier management and supply strategies. The main references used in this study are Poirier (1999), Goldfeld (1998), Pearson, Gritzmacher and Karen (1990), Ashkenas, Ulrich, Jick and Kerr (1995), Schorr (1998), Dyer (2000), Laseter (1998), Christopher (1998) and Hines (1994). In addition, several references have been made to electronics and purchasing related industry magazines. Materials availability related literature was more difficult to find due to the fact that the phenomenon in this extent, considering the large volumes, is a new one, so a lot of research has not been conducted around the topic yet. It has been verified through literature review and a survey conducted with some cellular terminal supply chain companies that demand planning is one of the most complicated and critical issues to be addressed in the whole industry, and volume forecasting cannot be the only tool for addressing the availability in the future, because forecasting as such, without concrete actions, does not improve availability. There is a lot of material, especially in the industry related magazines, available on recently introduced electronic demand planning and ordering tools, many of which, however, concentrate on intra-company development of demand planning processes.

Technology cooperation is typically addressed in the literature by actual case studies; theories around technology cooperation and partnership are also available. However, some of these approaches are quite theoretical and sometimes difficult to apply in practice due to the unique nature of each technology cooperation situation. Moving towards proactive technology scanning and multi-party partnering is a new approach in ensuring competitivity of a company in the long run. The best sources for the latest information are industry magazine case studies and industry related web pages. Most of the data available are qualitative of nature.

1.4 Scope of the research

The scope of this research is to study optimizing availability of both new and existing, multiple verified technologies within the cellular terminal business. The industry was selected due to the fast changing, multiple product variant, and high-volume business environment with a lot of focus on new technology development and speedy implementation of new ideas and innovations into new products. The phenomenon of availability problems has been the most visible recently in the cellular terminal business and the pace of new technology development within this industry is extremely high. Also, due to the reasons explained previously, this area has been studied to some extent, so research material in the form of theories and case studies has been sufficiently available.

This research does not try to cover the technologies themselves, but some cases and examples are presented to deepen understanding of the theory and processes. Various supplier management models, tools and strategies have been addressed in order to find alternative ways of technology access and a guaranteed, responsive supply from the existing and extended supply chains. The study does not address supplier management processes overall and does not give suggestions on the number of suppliers to use within a supply chain. This study will not address the improvement potential of internal order management and purchasing processes of individual companies. Some suggestions for further research and some ideas related to these suggestions have been presented at the end of this study.

1.5 Research problem

Based on the background information it can be stated that materials availability, supply chain flexibility and new technology access are critical factors for companies in terms of competitive advantage. The research problem was chosen to study ways to improve these areas as they were defined critical in cellular terminal business. Availability continues to be an important factor also in saturating markets due to the width of product portfolios and speed and frequency of new product introductions. The research problem is to address ways to both <u>optimize availability of materials and to gain access to new technologies to ensure long-term competitiveness in cellular terminal business.</u> The research problem has been addressed through two main research questions, each of which relates to different key areas of the research question. The different methods of this study, mainly qualitative, are literature review, survey and case studies. The findings of this study will be tested with some predefined metrics for validity. The research questions are:

<u>1. How to ensure availability of components and manufacturing tools?</u>

<u>2. What are the possible, practical guiding principles in developing new technologies within supply chains?</u>

The first question addressed the short and long-term availability of existing, verified technology components, products and materials both for new and existing end products. Traditionally availability has been managed through demand-supply planning processes and an alternative- sources approach to guarantee a responsive, scalable supply for verified, mass-manufacturable electronic raw materials, components, manufacturing equipment and tools. Instead of promoting traditional forecasting, this research tries to find more proactive and transparent ways for overall supply chain demand planning to gain flexibility and improved availability of the supply.

The second research question addresses technology access within supply chains to ensure availability of new technologies in the long-term. How can it be ensured that a company finds and guarantees the access to a particular new technology before competition? How can these new, applicable technologies be found and/or created, and what are the means of ensuring the availability of the particular technology in sufficient quantities? What are the optimal guiding principles for a new technology creation depending on the company and the technology in question in the future and are the existing supply chains and third parties being fully utilized in the process of gaining a competitive advantage? A successful business model represents a better way doing things than existing alternatives, or completely replaces the old way of doing things. Business models are variations on the generic value chain underlying all businesses (Magretta, 2002).

The links between the two research questions can be identified in four different areas: timescale, overall demand and supply process, product life cycle and scope within the supply base. The first research question addressed availability of existing components and equipment in short to medium term, with the existing products that are being either ramped up, mass manufactured or phased out of the manufacturing process. These components are typically in the maturity or decline phase of their product life cycle. The scope of the efforts is the existing supplier base. The second research question addressed the availability of new technologies that have not yet been fully developed, but will be integrated to end products and/or production lines and manufactured in the future. These technologies are either in the research or development phase of the whole demand and supply process, and the scope of the efforts within supplier base is both existing and new, potential suppliers. The product life cycle of these new technologies has not even started yet or is in the introduction phase.

In summary, the research problem of this Doctoral Thesis will address access to the latest, relevant technologies and using them in end products from the new product ramp-up onwards in optimal quantities to cellular terminal product, module or component design and production to ensure competitive advantage.

1.6 Selecting the research method

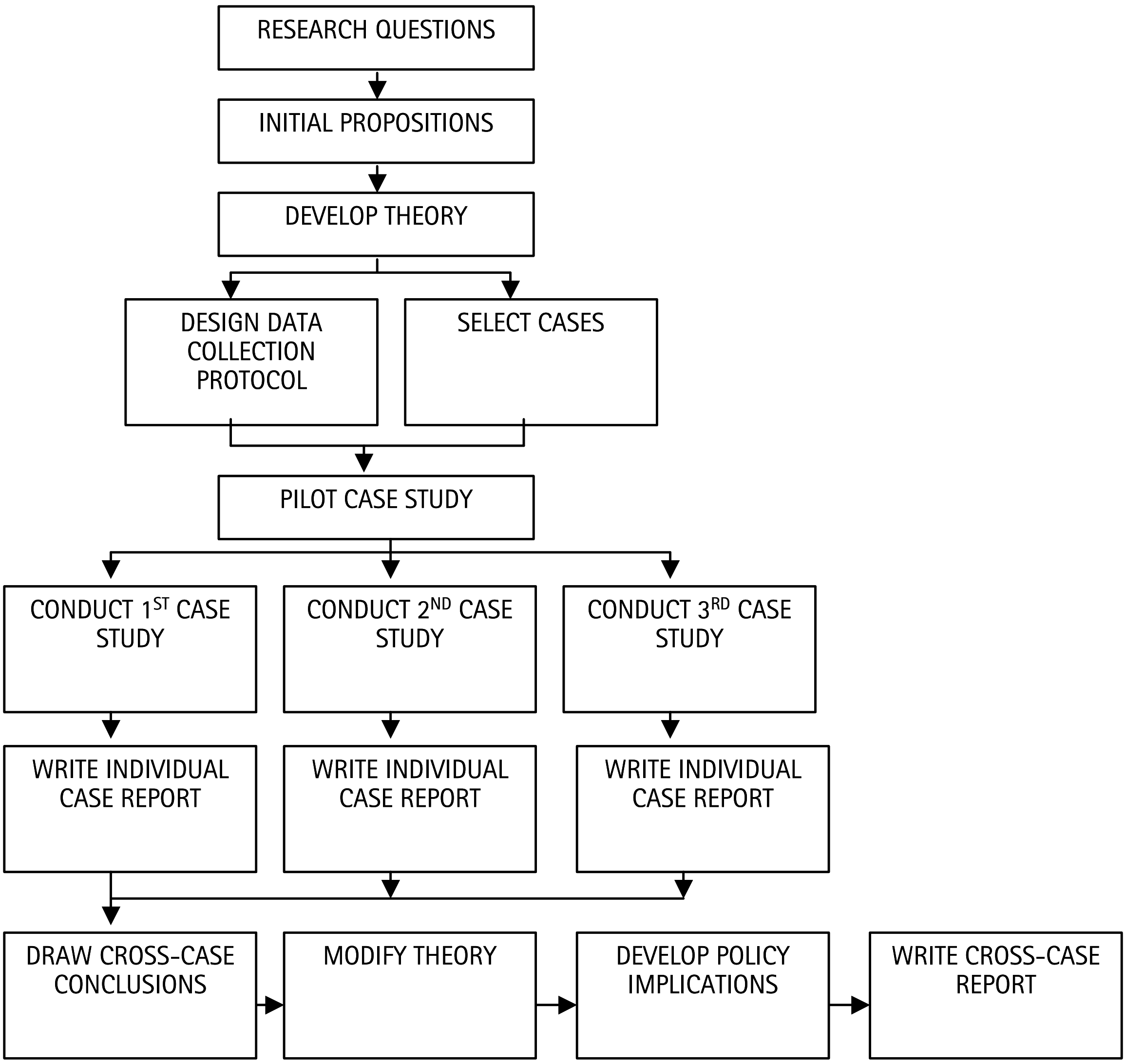
The studies conducted in the area of Industrial Engineering and Management are typically applied studies, and the contribution of these studies should be new, practical knowledge on the research subject both to the research community and to the related industry. The Thesis has been prepared at the department of Industrial Engineering and Management in Helsinki University of Technology, and typical characteristics of research being done in this department are relevance, contribution and evidence. Relevance means high priority in the domain of business problems and potential value for practitioners. Contribution means novelty of the research findings among the research community and positioning the findings in the existing body of knowledge. Evidence needs to be based on both empirical and rational reasoning. The criteria for the results of this study are applicability in practice, novelty of the ideas presented, ease of possible implementation and finding enough evidence to support the findings.

There were some alternatives in selecting the research method. The research problem is normative, supporting the decision making process. This research is also qualitative, as very little statistical data was available to support the research questions. Quantitativity was brought to the research through the metrics presented in the case studies. <u>The overall target of this research is to increase understanding in the areas of supply chain management and technology cooperation.</u> The results need to comply with the relevant theories to provide evidence to support the results. The different alternatives for qualitative research are case study research, constructive research, concept-analysis research and function-analysis research (Olkkonen, 1994). The nature of the research questions of this study was such that there was no single model to present to solve the problems presented in this study. The research questions of this study were typical case study questions, so the case study research methodology seemed to suit the overall objectives and the contemporary nature of this research the best.

The decision within case study methodology can be made between the methodologies proposed by Eisenhardt and Yin. Eisenhardt typically uses single or multiple cases to build new theories, whereas the Yin rather uses case studies to support and verify existing theory. Literature proposes case study to be used for theory building in cases when the purpose of the study is to provide freshness in perspective to an already researched topic (Eisenhardt, 1989). Case studies typically combine data collection methods such as archives, interviews, questionnaires and observations, either direct observations or participant-observations (Eisenhardt, 1989), (Yin, 1994). The applicability of a case study depends, according to Yin (1994), on the type of the research question, the extent of control over behavioral events and the degree of focus on contemporary as opposed to historical events. Case studies are the preferred method when “how” or “why” questions are asked, when the relevant behaviors cannot be manipulated, and when the focus is on a contemporary phenomenon with some real-life context.

Based on the methodology analysis, the approach by Yin was better suited for the research problem and the process of this study, as a large volume of existing theory is already available. Also, the overall purpose of this study was to develop existing theories, not to create new theories and, in addition, the number of cases and surveys in this study is too limited to act as evidence for a new theory. The case study research design consists of five elements (Yin, 1994): a study’s questions (research questions), its propositions (directing attention to scope of the study), its unit(s) of analysis (definition of case(s)), the logic linking the data to the propositions and the criteria for interpreting the findings.

Case study protocol should be followed in conducting the case studies to increase the reliability of the overall case study research. A pilot case can be selected to help in selecting the actual cases of the study, helping in designing the questions for the cases and assisting in conceptual clarification of the research design (Yin, 1994).



Picture 1: Case study method (Yin, Bateman and Moore, 1983)

The case study research findings and the quality of the research designs need to be evaluated for validity and reliability. Validity consists of construct validity, internal validity and external validity. Construct validity can be obtained by using multiple sources of evidence and by establishing a chain of evidence between research questions, evidence and conclusions, whereas internal validity is created through pattern matching and explanation-building. External validity methods are most used in multiple-case studies through replication logic. The reliability of the study can be verified through the carefully documented use of case study protocol and database (Yin, 1994 and Kidder and Judd, 1986). There are several different methods available for analyzing case study data. The general analysis strategy should either be based on theoretical propositions or a basic descriptive framework (Yin, 1994). The analysis in this study will be based on theoretical propositions. The dominant modes of analysis according to Yin (1994) are: pattern-matching, explanation building, time-series analysis and program logic models. This research will use mainly pattern matching and explanation building as analysis methods.

The possible risks of the case study method are the lack of rigor, no basis for scientific generalization, the length of the research and the amount of data (Yin, 1994). Following and documenting every step of the research and having enough relevant research data can minimize these risks.

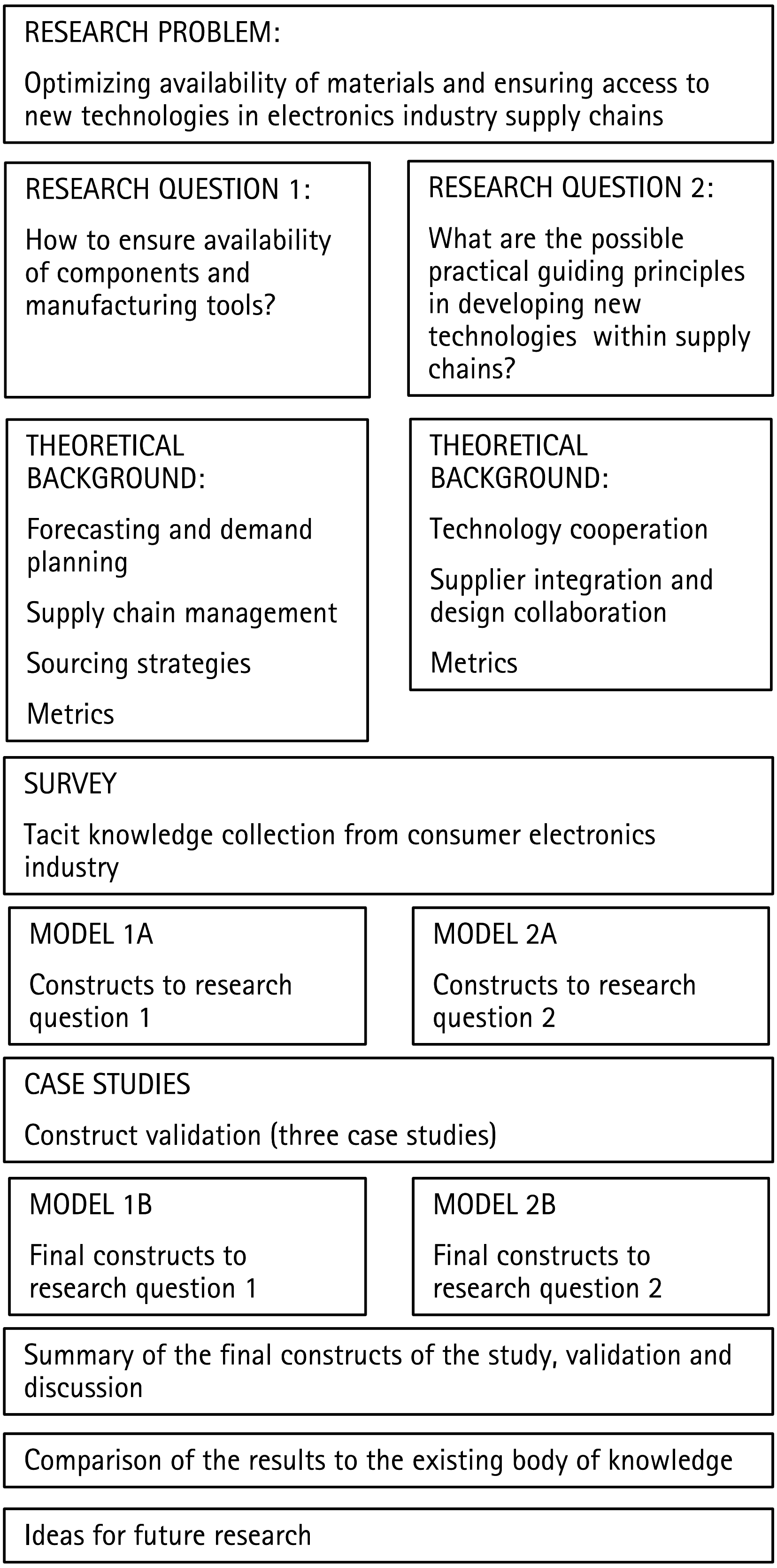
1.7 Structure of the research

This research first addresses the research background by reviewing the current state of the consumer electronics industry, more specifically cellular terminal business, material availability in general and the current state in the area of technology cooperation. Chapter 2 of this study covers these topics. Then the theoretical background is presented through literature review. The theories for the literature review have been selected based on some initial constructs defined by the researcher as the start-off ideas how to address the research questions based on the relevant literature and researcher's own experience. These initial constructs were: availability of supply, forecasting methods, supply chain management, technology cooperation, supplier integration and partnerships.

The literature reviewed consists mainly of books, industry magazines, web pages and different cellular terminal industry companies' processes and guidelines together with previous research, i.e. theses on related topics such as supplier management and technology cooperation. The literature review is addressed in chapter 3. Each chapter defines which research question it is relating to and a summary of the presented theories is compiled at the end of the chapter. The topics covered by the literature review are refined as the theoretical background research progressed. Following, a survey is conducted within a few cellular terminal industry companies to gain deeper understanding on industry practices in the area of demand-supply planning and technology cooperation. The survey is used for collecting tacit knowledge from the electronics industry. This information assists in refining the theory-based constructs. The survey also acts as a pilot case study according to the case study design proposed by Yin (1994) to verify the relevance of the research questions and the literature review. There are practices and ideas, tacit knowledge, across the cellular terminal industry in the area of supply chain management and technology cooperation, that are much more advanced and practical than the existing literature. Interviews are seen as the best method for capturing the data.

After building an understanding of the theoretical background for the research problem and collecting the tacit knowledge from the cellular terminal business, a two-fold model is proposed with constructs to answer both of the research questions.

The following phase are the case studies based on the methodologies proposed by Yin. The study is a multiple case design, so the study falls under one of the four categories described by Yin (Yin, 1994). The criteria for selecting the cases presented in this study are reviewed in chapter 8. The cases should be selected based on the following principles: typical to the industry, different approaches to research questions and some special, atypical approaches. The number of cases used depends on the research problem and the availability of data (Olkkonen, 1991) and a case study can consist of either one or multiple cases (Yin, 1994). Case study reports are presented in a linear-analytic structure. The constructs will be validated with the information and findings presented through the case studies. The evidence, possible changes to the propositions and the relevance to existing literature is presented in each case separately for all constructs. Later, the quality of the case study is reviewed based on the guidelines presented by Yin (1994) through a cross-case analysis. The last phase of the research reviews the results, analyzes the practical value of the model of constructs to the cellular terminal business, and compares the findings to the existing body of knowledge. Last, areas for further studies are identified.



Picture 2: Framework of the research.

1.8 Definitions

The terminology used in this study has been presented in order to clarify the terms and their content within the scope of this research.

ABCD-analysis

The division of suppliers into different categories of non-critical-, leverage-, bottleneck-and strategic suppliers. The criteria typically are the influence on company's results and procurement risk (Goldfeld, 1998). ABCD analysis can also be described as Pareto segmentation based on purchasing volumes and prices. This classification can then later be used as a basis for supplier strategies (Laseter, 1998).

Agreement

A long-term relationship between firms, concerning one or more areas of activity – product lines, market areas or business functions – which allows the parties to regulate their future conduct by means of more or less formally specified contractual mechanisms (Cainarca, Colombo, Mariotti, 1992).

Availability

Accessibility to products and services being present or ready for immediate use (webster.com). Companies can strive to either maximize or satisfy the availability based on market demand.

Core competence

Collective learning in the organization, communication, involvement and a deep commitment to working across organizational boundaries through organization of work and delivery of value (Prahalad, Hamel, 1990).

Equity investment

In a broad sense, equity alliances can include minority investments, joint ventures and consortia, the criteria being common ownership (Lewis, 1990). A form of cooperation between companies, which, in the long run, could affect the technological performance of at least one “partner” (Hagedoorn, Schakenraad, 1994). A firm can issue equity, i.e. the firm can sell shares of its company to investors in return for the money it needs (Afuah, 1998).

Extended enterprise

A formalized network through cross-investments, common resourcing and partnership arrangements. To outside companies this coalition could look like being only one company, but based on ownership it is not. The term extended enterprise is used in a similar way as virtual integration. An extended enterprise is referred to be a set of firms within a value chain or production network that collaborate to produce a finished product (Goldfeld, 1998).

Forecasting accuracy

In this research forecasting accuracy is defined as the difference between a forecasted demand and the actual demand during a certain time period. Due to this, accuracy can only be measured historically. A percentage can be used as a unit of measure. The theory shows 40% as a typical forecasting accuracy (Poirier, 1999). The survey conducted stated that forecasting accuracy should be beyond 50% to be usable.

Horizontal and vertical integration

Horizontal integration means that companies doing business in a certain commodity area merge with their competitors in order to prevent unnecessary competition and to become stronger against other competitors. Horizontal collaboration occurs between competitors operating at the same level of the production process, who extend their expertise by sharing knowledge, skills and personnel (UN, 1996). The end product manufacturer invests substantially in or owns component manufacturing as well. As a result, several levels of supply chain activities actually happen in-house. Vertical collaboration occurs throughout the chain of production from the provision of raw materials to distribution and after-sales servicing (Dyer, 2000, Fine, 2000).

Joint venture

A cooperative business agreement between two or more firms that want to achieve similar objectives. This agreement usually involves the creation of a new corporate entity to satisfy the mutual needs of all parties involved (Schillaci, 1987). A joint venture occurs when two or more companies pool a portion of their resources within a common legal organization (Kogut, 1988). Those companies that have shared R&D as a specific company objective in addition to production, marketing, sales etc. are considered joint ventures (Hagedoorn, 1990).

Licensing

Obtaining a right to use and/or manufacture a certain technology without having ownership, i.e. intellectual property rights (IPR's) to the technology in question. Licensing cost can be either a flat annual payment or manufacturing quantity related payment to the owner of the IPR is question. Multiple kinds of licensing arrangements exist, for instance cross-licensing, have-made rights, royalty free licensing and joint licenses (Hagerdoorn, 1993).

New technology

Technology is any tool or technique, any product or process, any physical equipment or method of doing or making, by which human capacity is extended (Schon, 1967). Practical examples: a new innovation, combination of existing technologies, new application for known technology, previously unused technology, modification of known technology, previously used, but new to the company, technology new to a supplier, technology created in cooperation with supplier or new process, method, material or product (New Technology Introduction Process, Group Work of OEM technology training, 2001). Another definition by Mayer and Lehnerd (1997) states: technology is an implementation of knowledge with the potential to be incorporated into a product or service.

Partnership

A commitment by customers/suppliers, regardless of size, to a long-term relationship based on clear mutually agreed objectives to strive for world-class capability and performance (Erridge, 1995). Partnering is a business culture that fosters open communication and a mutually beneficial relationship in a supportive environment built on trust. A relationship between two co-operating organizations, which have aligned strategies for long-term goals and which operate jointly to achieve those common goals (OEM Collaboration guidelines, 2001).

Procurement

Procurement, also described as purchasing and/or order management, is the actual buying transaction of a product or service (Harris, 2001, iSource Business).

Scalability

Ability to adjust up or down from a baseline (webster.com).

Strategic alliance

A close, long-term, mutually beneficial agreement between two or more partners in which resources, knowledge, and capabilities are shared with the objective of enhancing the competitive position of each partner. Strategic alliances can be defined to be a wide array of organizational forms ranging from long-term purchasing agreements to co-marketing and licensing agreements, to R&D collaboration teams to joint ventures (Spekman, Forbes, Isabella, MacAvoy, 1998). Lewis (1990) states that a strategic alliance is a relationship between firms in which they cooperate to produce more value than a market transaction. Also, any partnering arrangement that can change an industry's profitability potential can be determined as strategic (Harrigan, 1995). Strategic technology alliances can be defined as those inter-firm cooperative agreements, which are aimed at improving the long-term perspective of the product market combinations of the companies involved. Joint ventures, research co-operations and strategic alliances are combinations of the economic interests of at least two separate companies in a distinct firm; profits and losses are usually shared according to equity investment, depending on the agreement made when starting the initiative. (Hagedoorn, 1993).

Strategic sourcing

A cross-functional and cross-enterprise process aimed at optimizing supply chain lifecycle performance. Strategic Sourcing is an organizational issue, a methodology that a company chooses to adopt internally. It is considered to entail the following components: spend analysis, developing a sourcing strategy, negotiating and monitoring and managing the relationships (Harris, 2001, iSource Business). Sourcing in general is the decision process that is gone through to determine from who company one is going to be buying from (Harris, 2001, iSource Business).

Supply chain

In this research the term supply chain is preferred over supply network and/or supply web to illustrate the material flow from suppliers to end customers. This includes material, information and monetary flows that can move up and downwards in the chain.

Supply chain management

The management of upstream and downstream relationships with suppliers and customers to deliver superior customer value at less cost to the supply chain as a whole (Christopher, 1998).

Supply partnership

Partnering endeavors to ensure timely, high quality and lowest total cost of supply of components, raw materials and equipment (Vilkamo, 2000).

Tacit knowledge

Knowledge that is embedded in the experience and skills of people, but not yet fully in designs and specifications (Ploanyi, 1958).

Technology partnership

Strategic technology partnering is the establishment of cooperative agreements aimed at joint innovative efforts or technology transfer that can have a lasting effect on the product-market positioning of participating companies (Hagedoorn, Schakenraad, 1994). Inter-firm partnerships that have a technology element in them, although they are often directed to a variety of objectives, e.g. market access, commercialization and finance, can be described as technology partnerships (UN, 1996). Two-way relationship based on joint knowledge production and sharing, where the knowledge component extends to include technology adaptations and minor improvements can also be described as a technology partnership. The goal is to gain a (temporary) monopoly edge and achieve a breakthrough innovation in a particular product or production process through the pooling of resources that could not be supplied by one firm alone (UN, 1996).

2. RESEARCH BACKGROUND

2.1 Current state analysis and future predictions of the electronics industry

In consumer electronics business, the whole supply chain needs to be increasingly responsive and scalable due to the volatile market requirements to compete efficiently in the marketplace. The future of digital convergence, merging different technologies and products, especially in the area of communications technologies, sets requirements for both supply chain management and technology cooperation between companies (Covell, 2000). Increased global competition in that particular environment has forced companies, which historically have developed different capabilities and skills internally, into a process of rapid convergence (Doz, Hamel, 1995). Due to this, firms are increasingly building cooperative ventures to sustain and enhance their competitiveness. Particularly in the high-technology industries where a single company rarely has the full range of knowledge or expertise needed for timely and cost-effective product innovation, forging cooperative links with external partners has become a necessary part of firms' strategies for cost and risk reduction, and more importantly for access to knowledge and capabilities unavailable internally (Lam, 1997). The requirements concerning cost and quality are not the main focus of this study, but it is critical that these requirements exist simultaneously with responsive supply and technology requirements.

The technology domain of electronic components, especially the semiconductor industry, is increasingly moving towards supplier operated consignment stocks or even manufacturing line-replenishment strategies to cut back the lead-times and warehousing costs as much as possible. New electronic tools are being used more widely to provide visibility on the component demand without delay, real-time. Flexibility requirements up- and downwards volume-wise will become broader due to a wide variety of products, variants and shorter product life cycles. Product customization and different variants to the core product are being introduced as late in the manufacturing process as possible. Demand uncertainty will also increase when product ranges become broader, i.e. there is a possibility that the forecast errors start cumulating resulting in an increasing gap between forecast and reality; actual sales. These requirements are set for the whole supply chain, not just to individual companies or the OEM. Availability of end products with the latest technologies at competitive prices is a competitive strategy that most consumer electronics' companies follow. Developing a flexible supply chain and a network of cooperating technology providers enables the fulfillment of that strategy. These requirements also set targets for departments dealing with suppliers. The requirements for the sourcing function in today's environment are: optimized supplier base, continuous improvement through, for instance, supplier development, long-term, strategic relationships, shortest possible lead times, electronic, on-line transfer of information and cost reduction in all areas of operation (Erridge, 1995), (Christopher, 1998). Data from the Wall Street Journal (Kneeland, 1996) shows that strategic partnering efforts typically reduce the number of suppliers dramatically.

Table 1: Strategic partnering: effect on number of suppliers (Kneeland, 1996)

	Number of Suppliers		
	Previous	Current	Percent change
Xerox	5000	500	-90%
Motorola	10000	3000	-70%
Digital Equipment	9000	3000	-67%
GM	10000	5500	-45%
Ford	1800	1000	-44%
Texas Instruments	22000	14000	-36%
Allied Signal	7500	6000	-20%

This data is slightly questionable as it has not been mentioned what type of suppliers have been cut from the existing supply base, and also, the source is from 1996. The time line for the reduction and the market situation during the time of the reduction are not disclosed. Yet the data does illustrate the overall tendency for supplier consolidation in the electronics industry.

2.1.1 Materials availability

Based on the electronics manufacturing business related literature during 2000 and 2001 it can be stated that one of the driving businesses in that domain today is cellular terminal manufacturing due to recent exponential volume growth. There are considerable availability optimization challenges in that business, that being the reason for cellular terminal manufacturing being referenced for this theoretical study (EBN articles 2000-2001). According to one source, worldwide mobile terminal production was 172M units in 1998, 224 M units in 1999 and 340M on 2000. Then, worldwide PC production was 90M pcs in 1998, 110M pcs in 1999 and 120 m pcs in 2000 (Roos, Serious Case of the Shorts, EBN, 2000), (Mayer, EBN, 2000).

Table 2: Cellular handset unit sales predictions 2000-2004 in millions of units (Gain, Dunn, EBN, 2000).

Source	00	01	02	03	04
MicroLogic Research	286	336	391	437	509
In-Stat Group	399	555	760	1007	1289
Strategics Group Inc.	398	535	668	840	994
Semico Research Corp.	420	603	734	880	1000

Nokia's prediction for year 2001 mobile phone market size is between 450 and 500 million units sold (Nokia Press Release 1Q, 2001). These estimates were slightly readjusted in a second quarter result press release stating that the market size in 2001 would be approximately on the same level as 2000, i.e. around 405 M units (Nokia Press Release 2Q, 2001). During the third quarter of 2001, the sales in the Americas had picked up, but the overall prediction for 2001 cellular sales was reduced to 390 M units (Nokia Press release 3Q, 2001). A Nokia press release for fourth quarter results shows the stabilization of cellular markets, so 20% growth in 2002 was optimistic (Nokia Press Release 4Q, 2001). During Q1 in 2002 Nokia announced 2001 volumes to have been 380 M units and the estimate for 2002 market size was 400 to 420 M units (Nokia Press Release 1Q, 2002). As another reference within consumer electronics, automotive component market has been predicted to be growing, according to the table presented on the next page, during 1999/2005.

Table 3: Automotive component market growth and component type division prediction 1999-2005 in Billions of US Dollars (Shah-Baljko, EBN, 2000).

%	1999	2002	2005
IC's	76.3	74.6	69.5
Hybrid circuits	1.5	0	0
Sensors	13	17	23
Discrete components	4.9	4.6	4.3
Displays	4.3	3.8	3.2
Total spending	**$10.31 B**	**$13.24B**	**17.09B**

With these projections, electronics component suppliers have been adding manufacturing plants under pressure from cellular and other consumer electronics OEMs and distributors (Ojo, EBN, 2000). Sullivan (EBN, 2000) explains the magnitude of the electronic component availability problem that the business was facing during 2000. Another example of the future of the electronics business is the estimated annual growth in discrete-semiconductor market sales in the coming years (Ojo, EBN, 2000): 22% in 2000, 15% in 2001, 8% in 2002 and 3% in 2003.

As a reference, in year 2000, 290 billion discrete components and 82 billion IC components were produced for the electronics manufacturing purposes. A large part of the shortages in the electronic component industry occurring in the late 1990's and early 2000 were due to the growth of cell phone manufacturing. The demand requirements move upwards the supply chain to the first, second and third tier suppliers slowly, and thus most component suppliers do not get an early warning for the need of increased capacity. The visibility in almost every segment of the electronics industry has been no more than 60 to 90 days, so suppliers were reporting lengthening lead-times and increased component the prices (Cell phone demand squeezing components supply, EBN, 2000). When demand greatly exceeds supply, costs tend to increase (Wallace, 1999). At the same time, some suppliers were reluctant to add capacity due to past experiences with the volatile electronics business growth (Roos, Serious Case of the Shorts, EBN, 2000). Additionally, supplier revenue margins were under pressure because of the inventories and capital investments (Liotta, Squeeze on supply, EBN, 2000). It was anticipated that in 2002 the electronics component market would reach overcapacity, however, the overcapacity situation was encountered during the first half of the year 2001. Electronics component makers' capital investment spending increased dramatically, 30% from 1999 to 2000, but in 2002 the manufacturing capacity utilization rate, especially in

USA ands Japan, was very low. Electronics industry is expected to renew the growth experienced in 1999 again in 2003 (Haughey, 2002), (Day, Having their day in the sun, EBN, 2000), (Ojo, A Tough Juggling Act in A Tight Component Market, EBN, 2000).

The top 10 capital expenditure spenders in the electronics business worldwide in 2000 have been: Intel, TSMC (Taiwan Semiconductor Manufacturing Company), Samsung, UMC, TI, ST, NEC, Micron, Motorola and Hyundai/LG. This capital investment expenditure-spending list shows that the biggest investments in the electronics industry today are not made by Original Equipment Manufacturers (OEM's) or Contract Manufacturers (CM's), but by the electronic component suppliers. Based on this it can be stated that the amount of investments increase upwards in the supply chain. At the same time, the time to build up the capacity also increase with first, second and third tier suppliers due to specificity of the manufacturing equipment and tooling and capital investment intensity of the business.

2.1.2 Technology cooperation

The March 2001 Forrester Report studied supplier collaboration in the area of new products. In the study, 72% of the firms interviewed believed that collaboration would be critical to their success in 2003 (Beard, iSource Business, 2001).

How important is design collaboration with suppliers?

	Today	2003
Mildly important	12%	6%
Very important	54%	22%
Critical	34%	72%

What are the obstacles for building collaborative product development relationships with your suppliers?

Protecting proprietary information	26%
Cost	22%
Supplier technology issues	22%
Internal culture	18%

Different software platforms	18%
Developing trust with suppliers	14%
Internal technology learning curve	8%
Poor infrastructure	6%

What are your top goals for (online) technology collaboration?

Faster time-to-market	74%
Reduced product cost	48%
Increased quality levels	32%

What are the key attributes of a trading partner relationship?

Trust	40%
Timely communication	35%
General competence	25%
Responsiveness to change	25%
Aligned objectives	23%
Aligned technologies	15%
Risk and reward sharing	15%

This data from Forrester Research will be later compared with the survey results and the model of constructs. Forrester Research study is well aligned with the findings of Poirier concerning the importance of trust when improving the supply chain (Poirier, 1999).

2.2 Main challenges in the electronics industry today and in the future

The research material includes a survey that was conducted during spring 2001 among nine international companies in cellular manufacturing and design industry. The participants, survey techniques, questions and results have been described in detail in chapter 5. Two of the survey questions addressed the current and future challenges of the cellular terminal business. All nine participating companies described quite similar challenges, and a summary of these challenges is presented in this chapter.

First, all acknowledged that contract manufacturers (CMs) would play a bigger role in the future as manufacturers and possible co-designers of cellular terminal products. OEMs will still play a major role, but the utilization of CMs is increasing, especially in the area of standardized products. The role of CM's will increase within supply chains: in many cases they will be managing the whole supply chain and the OEMs role in operations will be to invoice its' customers and guide the supply chain while focusing mainly on customer interface of the chain. Some companies were concerned with this increasing role of CM's especially in the area of demand planning.

A second area was standardization of products in product creation and the modularity of manufacturing capacity. Both product development and product delivery lead times are shortening, and standardization of products typically cuts back development times of new products and makes variants more manageable. Standardization also makes it easier to integrate supplier-developed and manufactured parts and modules into end products. The typical results of the modular approach in building capacity are shortened ramp up times of new production capacity and added capacity flexibility for different product variants.

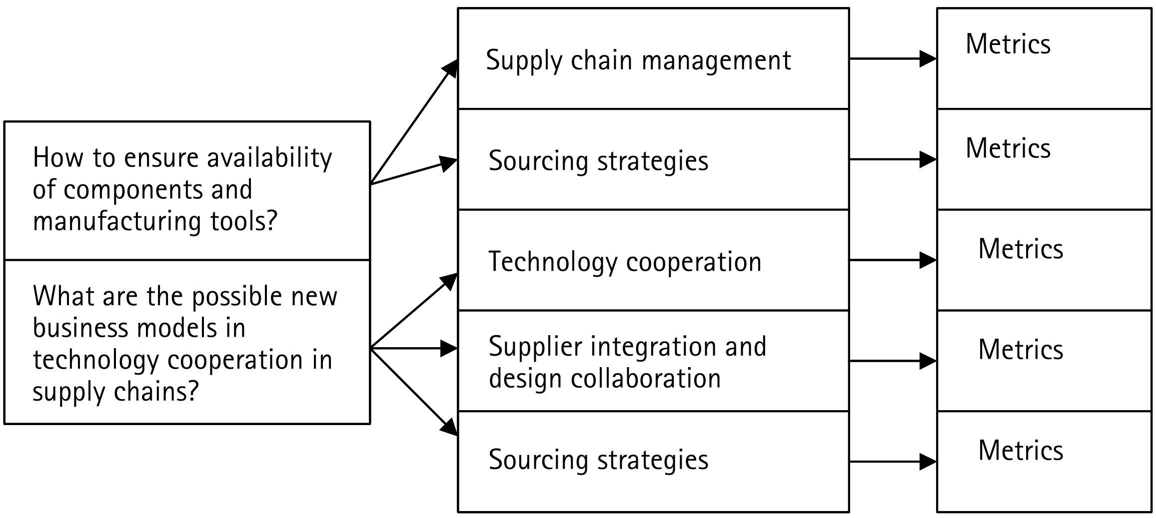
The third area mentioned, especially as a challenge for today, was increasing efficiency. The existing capacity should be used in an efficient manner, so the capacity utilization rate should be as high as possible to avoid inefficiently used capacity. Most interviewees thought that efficient supply chain management with visibility to the end product demand is going to be essential to the success of all cellular terminal manufacturing companies in the future mainly due to the reasons explained in the chapter 2.1 including planning investments and optimizing the overall capacity balance of the supply chain. Some first and second tier suppliers were concerned with cost pressures bringing sub optimization in the supply chain, inventories getting pushed upstream in the supply chain instead of optimizing overall supply chains' inventories.

3. THERORETICAL BACKGROUND

The theoretical background of this research attempts to find possible solutions to the research questions from the existing theories. The theory review consist of four main topics, based on the initial propositions of the research:

- Supply chain management
- Supply strategies
- Technology cooperation models
- Supplier integration and design collaboration

The purpose of the first two topics is to address the availability of existing technologies, materials and products. The third and fourth topics will endeavor to give insight into technology cooperation models and the methods of ensuring access to new technologies. The topic of partnerships will be addressed from both the supply and the technology cooperation aspect. The literature review will also include a review of possible metrics related to the main topics of the study. Some of the metrics presented will be quantitative, some qualitative. The purpose of the metrics review is to bring a quantitative aspect to the research.



Picture 3: Theories relating to each of the research questions.

3.1 Supply chain management

The purpose of supply chain management is to integrate planning and to balance the supply and demand across the entire supply chain to make the full chain competitive (Schorr, 1998). It ties suppliers, customers and their different functions together in one concurrent business process focused on the ultimate end customer. A firm selling to an end market is essentially the customer interface of the extended enterprise or value chain. When this entire chain is lean, the product it produces is most likely to succeed in the marketplace (Dyer, 2000, Hanna, Newman, 2001 and Poirier, Reiter, 1996). In today's electronics business, there are some new challenges in network building: a company can function simultaneously as a supplier, customer, competitor or even a joint venture collaborator.

Jussi Heikkila states in his Doctoral Thesis (2000) that the term demand chain management would better describe the activities in satisfying needs in the marketplace instead of using the traditional term supply chain management, which directly relates to suppliers, i.e. to the sourcing and purchasing function of a company and to the push-approach of fulfilling demand (Murphree, iSource, 2003). Reliability of supply pertains to the ability of one or more suppliers to provide a good-quality supply of products and services at a good price over short-and long-term periods. The number of suppliers is a key component of the general approach to a reliable supply of goods together with the development potential of suppliers and a reserve of new, possible suppliers to ensure short and long term availability of products and services (Cavinato, 1983).

3.1.1 Improving visibility

According to Dyer (2000), a supply chain is a customer fulfillment network (CFN), which should be customer responsive, internetworked, real-time, event driven and adapted to high clock speed world. Improvements in demand planning and visibility can be divided into two categories: short- and long-term improvement. Demand marketing deals with the problematic ensuring that suppliers believe customers forecasts and are committed to the increased/decreased volumes in long-term. This commitment can be gained by sharing information on industry trends with suppliers openly, being willing to share a part of the investment or development risk if needed and by trying to improve the forecasting accuracy and actions based on the forecast jointly with suppliers. This kind of approach is especially important when ramping up a new product, as there is no historical data on the consumption. As distributing the forecast does not improve availability as such, taking action based on the forecast does. The problems with different forecasting models traditionally have been strong fluctuations and inaccuracy together with long response times in distributing the information, and these factors have resulted in a situation that suppliers no longer believe the forecasts and thus do not act according to them. Market demand fluctuates greatly on both volume and product mix and these fluctuations are many times stronger and have a significant effect upward in the supply chain (Forrester-effect or bullwhip-effect) (Simchi-Levi, Kaminsky, Simchi-Levi, 2000). This effect is possibly strengthened by the supply chain specialization, as it makes the chain more complex (Laseter, 1998), (Baily, Farmer, Jessop, Jones, 1994). The same has been stated by Handfield and Nichols (1998) and Butman (2002) in their bullwhip-theory and statement that demand related information does not pass effectively from manufacturers to first and second tier suppliers. In literature demand marketing has been addresses as a tool for identifying the right suppliers and managing them, but same approach can be used for ensuring availability as well (Baily, Farmer, Jessop and Jones, 1994). Another way to diminish the effect is centralizing demand information and enabling the overall supply chain to have visibility to actual customer demand. Reducing product variability and lead times help diminishing the bullwhip effect (Simchi-Levi, Kaminsky, Simchi-Levi, 2000). Another concept presented by Murphree (2003) is consensus forecasting.

Limited editions approach means that only a certain, pre decided quantity of a given product would be manufactured. A typical example of a company using the limited edition approach is the Swiss watchmaker Swatch or some car manufacturers. They manufacture a pre-determined number of certain model and then move on to manufacture the next model or version. This approach also helps the products to become collector’s items. Forecasting accuracy in this research has been defined as forecast for a given time period divided by the actual demand. A study conducted by Poirier (Poirier, 1999) shows that typical long-term forecasting accuracy level in the consumer product industry is around 40%. Poirier (1999) presents improvement ideas of forecasting being based on actual consumption, real time data exchange, reduction of safety stocks and shorter planning horizons. Murphree (2003) complements these ideas by emphasizing the need to improve the collection of the point-of-sale information and transforming supply networks into consumption driven rather than forecast or distribution center-demand driven.

Implementing different information management and e-tools are ways of improving visibility in the supply chain in the long-term. E-enabled systems are more proactive; suppliers are responsible for getting the information from the given Web portal, or straight from customers' MRP-systems. A significant issue here is data integrity. If the data are not of high quality and the process for data capture is not in place, no tools can improve the situation. All this data could eventually be visible to the end customers as well. This relates closely to the concept of "glass pipeline", the transparency within supply chain, where the results of the chain are visible to customers as virtual inventory (Poirier, 1999). Similar logistics pipeline has also been described by Christopher (1998). Christopher's (1998) approach to visibility improvement within supply chain is the concept of "demand penetration point".

Theory by Hines (1994) proposes that a supply chain model to be chosen for customer-supplier relationship network depends on the company's business environment and sourcing strategy according to the predefined guidelines regarding competition, information exchange, capacity management, role of R&D, quality and delivery practices. Based on these guidelines it could be stated that the optimal supply chain design for the consumer electronics business would be a CFN together with levels 3 or 4 supply chain model from the Theory presented by Poirier (1999) added with clear supply strategies to segment different suppliers and to develop the chain and the integration level according to the criticality of the supplier. The reason for this is that data to the supply chain is typically fed through one "central" organization. This enables the right prioritization of activities, and sales function involvement helps suppliers gain more visibility to short-and long-term end product demand and business environment. Other supply chain management principles proposed by Hanna and Newman (2001) includes: product differentiations closer to customers, supply chain wide information technology strategy and commonly adopted performance measurements. In addition to these principles, Poirier's model proposes product development time-to-market reduction, forecasting accuracy, pricing, order fulfillment and logistics. Another approach is defined by Baker and Laseter (2002): the continuous sourcing cycle of capturing margin, reducing cost, managing demand and crating value.

Over time, supply chains need to adjust to new types of business models such as sell-source-ship, s^3 -approach (Reese, iSource Business, 2001). Dell Computers is the classic example of an s^3-enabled company because Dell generally draws components from suppliers and assembles its computer products in response to orders received from customers, all the while maintaining minimal inventory levels. Possible drawback of the system could be that the major player, “the channel master” imposes the model on suppliers and pushes the inventory back up the supply chain and into the supply partners’ warehouses (Reese, iSource, 2001).

3.1.2 Forecasting models

The most traditional way of ensuring long-and short-term availability of standard components, materials and equipment is planning inventory. There are five basic types of inventories: pipeline, lot-size, buffer (demand and supply fluctuation), anticipational and speculative (Buffa, 1979), (Virolainen, 1992). There are alternative models in place for calculating order quantities and for controlling stock internally. Classic inventory control method is reorder point (ROP) system. Another model is Economic Order Quantity (EOQ) that is calculated from the variables of price, rate of usage or demand and internal costs. An alternative system for production planning, stock control and purchasing is Just-In-Time (JIT). Quick Response logistics (QR) has been developed based on JIT (Baily, Farmer, Jessop and Jones, 1994), (Christopher, 1998). On the other hand, suppliers can manage inventory replenishment and the demand within the concept of Vendor Managed Inventory (VMI) (Christopher, 1998). Having inventory has both positive and negative implications on the supply chain concerning availability, cost and potential process problems (Hanna, Newman, 2001). When keeping costs, change management and shortening product life cycles related issues in mind, inventory does not seem the most viable solution in demand fluctuations management in any part of the supply chain.

Another traditional way to ensure the availability of materials and products is forecasting. Common forecasts allow each node in the supply chain to plan resources in a consistent manner. However, there are three basic problems with forecasting processes: long-term forecasts being more inaccurate than short-term ones, aggregate forecasts being more accurate than line-item ones and the fact being that all forecasts are wrong (Laseter, 1998), (Simchi-Levi, Kaminsky, Simchi-Levi, 2000). Forecasts would need to address two different aspects of demand: volume and mix (Wallace, 1999). The most typical forecasting methods have been widely described in literature (Cavinato, 1984), (Lancaster, Lomas, 1985), (Makridakis, Wheelwright, 1990), (Wallace, 1999).
Typical shortcomings of quantitative forecasting methods, especially time-series forecasts, are the short forecasting period, insufficient accuracy, time consuming data collection,

need for historical data, quantity of the data required, lack of explanations behind the forecasted data and analysis and traceability of the forecasting data to source (reliability and buy-in). The major shortcomings of the subjective forecasting methods are costs of compiling the forecasts, potential inaccuracy of the estimates, subjectivity of the forecasts and the actual commitment to the forecasts (Lancaster, Lomas, 1985), (Makridakis, Wheelwright, 1990).

Cavinato (1984) states that the forecasts prepared for sales projections would have to have a different scope and content than the ones prepared for materials management. This statement will later be challenged in the model of constructs. The majority of the before mentioned forecasting models rely on the patterns in historical data: horizontal or stationary, trend and seasonal (Lancaster, Lomas, 1985). There are some prerequisites for selecting a forecasting model (Lancaster, Lomas, 1985): availability of hard and soft data, dependent and independent variables, planning horizon, the nature of the historical data, time, cost and the structure of the market. Alternative forecasting models could and should be used parallel for accuracy and data cross checking (Makridakis, Wheelwright, 1990). Poirier (1999) recommends that operational forecasting systems should be based rather on actual consumption than historical information. Makridakis and Wheelwright (1990) also identify a fundamental problem with forecasting: the lack of commitment. Organizations tend to commit to plans, not forecasts. Wallace (1999) points out that forecasts need to be developed with a cross-functional team with members from product development, operations, finance and product marketing. He also emphasizes that product grouping into categories and families facilitates forecasting. It can be stated that modularity and standardization of products enables this categorization.

As an example later in this chapter will illustrate, forecasting based on any historical data will be inaccurate in an unstable business environment like consumer electronics. New products can account for one-fourth to one-third of a firm’s annual revenues, so the accuracy of new product forecasts can be critical. Forecasts provide quantitative information for new product introduction go/no-go situations and for building capacity in the supply chain (Thomas, 1993). Due to the lack of historical data, the forecasting methods for new products are typically subjective/judgmental, like pre- and test marketing and early sales models, and diffusion model (Lancaster, Lomas, 1985). The typical forecasting types for new products are market opportunity, sales and financial forecast (Thomas, 1993). Forecasting accuracy example from the cellular terminal manufacturing business illustrates the forecast fluctuations on a mass-manufactured consumer electronics product. Forecasting accuracy is defined as forecasted demand divided by actual demand.

Table 4: Forecasting accuracy within the cellular mobile manufacturing (Historical data from one OEM company).

Factory	Baseline P0	P+1	P+2	P+3	P+4	P+5	P+6	P+7	P+8	P+9
A	Q	+67,3%	+2,5%	+13,2%	+17,6%	+6,9%	-1,3%	-18,2%	-26,4%	+37,1%
B	N	+6,1%	+4,2%	0	0	-1,9%	-34,3%	-37,6%	-55,9%	-54,5%
C	M	+7,6%	-31%	+14,7%	+23,4%	+23,4%	+27,2%	+26,1%	+21,7%	+26,1%
D	I	+1,7%	0	+47,4%	+30,6%	+21,4%	+15%	+24,3%	+24,1%	+19,7%

This data is based on a ten-month period during 2000 and 2001 when demand was estimated for a rolling, continuous 12-month period. The letters from A to D refer to four (4) different manufacturing sites. Then, letters Q, N, M and I refer to a baseline forecast quantity distributed during the first month (P0). P1, P2 etc. refers to months from the first month up to ninth month (P+9). This quantitative data shows in practice the level of fluctuations in the forecasting accuracy from the baseline of P0. The median fluctuation is approximately 20%. If the forecasted quantities are significant, for example millions of pieces per month, the demand fluctuations quantity-wise can be substantial. On the other hand, the data also show a lot of consistency with the forecasted volumes considering the volatility of the market environment in this type of business, meaning that the forecast information really is a valuable tool for demand-supply management. However, the same supplier did not necessarily supply all sites or even if the supplier was the same, the suppliers' distribution and manufacturing sites might vary, and these facts add to the effects of fluctuation. This data helps in understanding that conventional methods of demand planning, like forecasting based on historical data, are not sufficient for addressing the overall issue of demand and supply management in a turbulent market environment.

3.1.3 Collaborative planning

As described in the previous chapter, forecasts will probably never be fully reliable and keeping inventory is a costly way to ensure availability. So supply chains need to go through a paradigm shift from inventory to information: demand based replenishment with quick responses (Christopher, 1998), (Murphree, 2003). The most common areas for collaboration between companies are on both the strategic and operational business planning. The main areas are (Ashkenas, Ulrich, Jick, Kerr, 1995): product development, production planning, billing, customer service, purchasing shipping and inventory management. The focus of this chapter is collaborative planning in the area of demand/supply planning. Collaboration in the area of product development will be addressed later in this study, in chapter 3.4. Collaborative planning refers to joint activities, where supply chain companies cooperate in structuring and executing the processes to bring a product from raw material sourcing to finished goods consumption as efficiently as possible both in short-and long-term (Poirier, 1999). A study conducted by Forrester Research indicates that by 2003 72% of organizations expect supplier collaboration to be critical to their success compared to 34% (Whyte, iSource Business, October 2001). As an example, with the push towards the built-to-order (BTO) mode of manufacturing, Ford is relying on e-business tools to rationalize and streamline the supply chain process, reduce overall chain inventories and provide improved productivity throughout the chain. The biggest challenge for Ford in supply chain compression seems to be not challenging quality, but rather suppliers fearing for their innovations, i.e. the fact that their intellectual property will be exposed to competitors (Banham, iSource Business, July 2001).

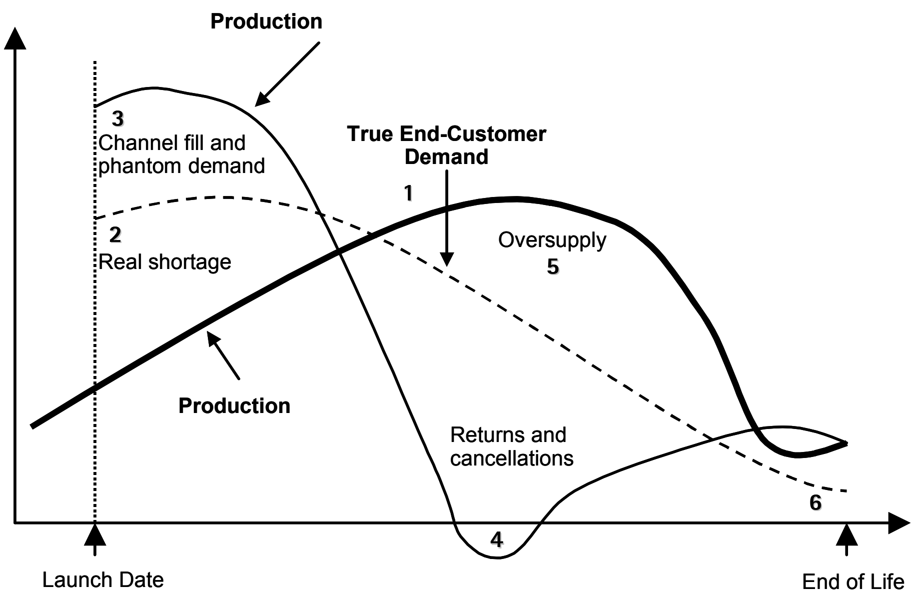
There are some prerequisites for a successful collaboration. All members of the supply chain collaboration team need to be committed to the new tools, costs encountered and business processes together with both short-and long-term goals (Rodin, iSource Business, November 2001). Companies need to be willing to share sensitive information and to develop common processes and information synchronization methods to speed up the transfer of demand related data and to make it as safe as possible (Orr, iSource Business, 2001). The tools and solutions selected need to address and focus on demand uncertainty of the end product market and the uncertainty of supply in terms of capacity planning and delivery reliability (Lee, iSource Business, 2002). Poirier (1999) and Greenbaum (2001) mention several major improvements that could be attained through successful collaborative planning between suppliers, distributors and key customers such as faster reaction times, reduced cycle times, real-time view on customer requirements and the maximum use of assets.

A positive example of implementing Phase 3 in Poirier’s collaboration model is a business process simplification project that was executed by Sun Microsystems. Key achievements were (Poirier, 1999): reduction of turnaround time of materials, 80% reduction in total inventory and reduction of total lead- time. Other best practices from other actual cases include 5-20% increase in revenues, 20-40% improvement in depreciation, 20-80% reduction in scrap, 20-70% improvement in time-to-market and 20-110% improvement in return on assets. These examples naturally represent implementation cases with the most positive results.

Schorr (1998) describes ten (10) basic steps for developing a supply chain management process in a company. These steps are clearly meant for intra-company development activities, but the steps can also be used when designing a system for collaborative planning inside a supply chain. To avoid individual companies developing and optimizing the supply chain to meet their individual needs, companies should engage in joint strategic planning and operational execution towards minimizing cost and maximizing value across the entire supply chain resulting in cost reduction, value enhancement and the execution of advanced collaborative planning activities (Verghese, iSource, 2001). Forrester Research study presents additional benefits: reduced product costs and an increased quality level (Whyte, iSource Business, October 2001). The goal is to evolve the supply chain to the point where people throughout the organization have the data they need to make timely, intelligent choices for sourcing and to truly optimize the value chain so they can find the lowest cost service or product (Field, iSource Business, November 2001).

An area of future challenge in supply chain collaboration will be: how to distribute and share both profit and risk within the chain. Laseter's (1998) view on this problematic is that all companies need to remain at least partly responsible for their own results and success. Then, some risk sharing is required, depending on the joint targets and investments. The same problematic has been addressed by Kogut (1988). Risk level for chain members can be defined with a simple equation presented by Jarillo (1988). If a supplier, i.e. chain member carries all risk related to the relationship, then $\alpha = 0$. If, alternatively the "nucleus company", i.e. the OEM carries all risk, $\alpha = 1$. In this situation there is no real network relationship. The factor α represents the share of risk variance taken up by the network "principal". The principal is the ordering entity, in this case the OEM. Efficient chains should show a fact $1>\alpha>0$. A study conducted by Kawasaki and McMillan (1986) shows averages in the range of α=0.69 with many of the companies being in the situation above α=0.75. This suggests that the "nucleus company" is bearing the majority of the risk keeping in mind the fact that the data is from 1986. Together with risk sharing, also profit sharing should be addressed. Should uncertainty of the demand generate risk premiums for supply chain companies through demand based pricing, joint capital investments, OEM or supplier financing or inventory liability sharing?

Collaborative planning can take place within a supply chain or even between competitors. A number of automotive companies have concentrated their efforts concerning supply chain to the Web, for instance to US Car Consortium (Miller, iSource Business, August 2001). Chrysler also has initiatives of its' own in the area of collaborative planning with suppliers (Baker, Laseter 2002). The initial production start of a new model or a product, as future sales of a new product are the most difficult to predict even in the short-term. (Shah-Baljko, EBN, 2000), (Poirier, 1999). The picture 4 below illustrates the problems with initial and across the lifecycle market demand. However, the timeline in the illustration is not very clear keeping in mind that the overall lifecycle of a new product can be as short as one year.



Picture 4: Supply and demand misalignment (Poirier, 1999).

Explanations of the numbering in the picture 4: (1) True end-customer demand is unknown, must be anticipated. (2) Production cannot meet initial projected demand resulting in real shortages. (3) Channel partners over order in attempt to meet demand and stock their shelves. (4) As supply catches up with demand, orders are cancelled or returned. (5) Financial and production planning are not aligned with real demand; therefore production continues. (6) As demand declines, all parties attempt to drain inventory to prevent write-down.

3.1.4 Supplier coordination

Supplier coordination activities could be regarded as being part of supply chain development activities, but in this study the coordination efforts have been described separately for clarity. The reasons being that the coordination activities typically address a pre-selected group of suppliers, not necessarily the majority of suppliers within the chain. The criteria can vary depending on the case, sometimes these activities are targeted to companies positioned as bottlenecks and at other times to the high volume, strategic suppliers within the supply chain.

According to Hines (1994), supplier coordination refers to the activities made by a customer to mould their suppliers into a common way of working so that competitive advantage can be gained particularly by removing inter-company waste. One of the ways to coordinate supplier activities is forming a supplier association (Hines, 1994). In Japan supplier associations play a significant role in translating customer requirements to the subcontractors' and suppliers' requirements. Early supplier involvement is encouraged and emphasized through these associations with management guidance. Hines' approach assumes that the buying company, i.e. typically the nucleus company, has more advanced processes and ways of working, which is not necessarily always the case. Another approach could be supplier partnership workshops implemented by Lucent Technologies. The purpose of these workshops is to generate cost savings ideas for existing and future products. Typically 20% of the ideas generated by the workshops are implemented (Carbone, 2002).

In Japanese supplier associations the idea is that the profit-level is predetermined together and should be approximately the same throughout the chain, around 2% of the turnover of each company. This is quite different from the expected profit levels of the supply chain in Europe and United States, where these types of percentages are used as typical annual cost cutting targets. Inter-company knowledge and technology transfers are being done within the chain to obtain the targets, and different methods for this communication could be: business group integration, strengthening of management, employee release from customer to supplier and vice versa, training and education, resident engineers and watching brief by banks (Hines 1994), (Hagedoorn, Schakenraad, 1994). An important reason behind knowledge transfers between OEM's and suppliers or "nucleus companies" and other members is the fact that it is not possible for one company to develop all the necessary new technology competencies fast enough for the marketplace, so different competencies need to be collected across the chain. At the same time, the most knowledgeable company needs to transfer intellectual capital and information systems across the chain to bring all necessary companies to a sufficient competency level (Laseter, 1998). Dyer (2000) has described the way Toyota facilitates learning in its supplier chain.

Table 5, Toyota supplier association facilitation process (Dyer, 2000)

Process	Nature of the transfer process	Type of knowledge	Toyota functions involved
Supplier association	Multilateral	Explicit knowledge	Purchasing
On site consulting	Bilateral	Tacit knowledge	Operations management, supplier support center
Supplier learning teams	Multilateral	Tacit knowledge	Operations management, logistics administration
Problem solving teams	Bilateral	Tacit knowledge	Quality assurance, manufacturing operations
Employee transfers	Bilateral	Tacit knowledge	Purchasing, personnel
Performance feedback process monitoring	Bilateral	Explicit knowledge	Purchasing

Another example describes Chrysler's extended enterprise process (Dyer, 2000), which begins by building trust by co-located cross-functional teams, pre-sourcing, target costing and long-term commitments. Pre-sourcing means selecting suppliers early in the vehicles concept-development stage and giving them significant, if not total responsibility for designing a given component or system. The rationale for pre-sourcing is that it permits many engineering tasks to be carried out simultaneously rather than sequentially, thereby speeding up the development process. Target costing involves determining what price the market, or end customer will pay for the vehicle and then working backward to calculate the allowable cost for systems, subsystems and components. One formal program that was established by Chrysler was the supplier cost reduction effort (SCORE) to help suppliers and Chrysler reduce system-wide costs without hurting suppliers' profits. (Dyer, 2000). Other classic cooperation cases, rather between competitors than suppliers are General Motors and Toyota cooperation NUMMI and General Electric and SNECMA alliance (Doz, Hamel, 1995), (Lewis, 1990).

Honda of America is also frequently mentioned in the literature in cases concerning supplier development and value engineering with suppliers. Honda prefers working with a small number of suppliers long-term. They keep a reserve of potential suppliers as a backup, but typically they operate on a single-source basis. This small network of companies then receives intensive training and coaching together with very aggressive, measurable goals to achieve (Laseter, 1998). Honda of America's supplier association has programs called "Design In" and "Best Practice", which invite suppliers' employees to relocate in Honda's facilities within Research and Development and to participate as a member of development teams in all stages of new product development and to share best practices in other development areas (Laseter, 1998), (Baker, Laseter, 2002).

Second-and third tier suppliers are not mentioned in Hines' and Dyer's material concerning supplier associations. This is somewhat contradictory to the fact presented earlier in this study stating that investment intensity and lead-times grow with second and third tier suppliers. Other ways to improve supplier coordination are various tools, including e-business tools, shared websites etc. that are available to integrate companies more closely with each other within the supply chain. An integrated system enables event-management. By adding common processes and common goals, the chain will start executing "if-then" business rules: if this happens-then do this. This approach helps to gain speed and lower costs by acting in a speedy manner (Gulisano, iSource Business, August 2001).

As a summary, supplier coordination can be used as a tool to coach bottleneck suppliers to increase their reliability and, on the other hand, to introduce and implement common tools and processes across the supply chain.

3.1.5 Scalability of operations

Scalability in essence means adjustability both up and downwards from a baseline to the actual need (webster.com). The need for scalability of operations comes from the end product market uncertainty and the width of the overall product portfolios. Consumer product business in general, including cellular terminal business, is an economy and trend-driven market, where fluctuations in demand can be substantial even on a weekly basis. The globality of operations can either add to the regional demand fluctuation pattern or even it out globally. This is why the whole supply chain needs to be able to adjust to changes in order not to create buffers anywhere in the chain to accumulate costs.

Manufacturing flexibility can be attained on several levels – firm, plant, system or machine (Nishiguchi, 1994). When reviewing scalability, the general assumption always is to ensure upward scalability. The challenge in the future will be how to prepare for a possible downward turn in customer demand and downward scalability. In operations the critical area is cost: together with flexibility, companies are required to be cost-conscious through a maximum utilization of capacity. This leads to the concept of risk and profit sharing within the network. The flexibility types described by Nishiguchi can be applied in the cases of both up and downward flexibility. In practice, flexibility guidelines are difficult to determine for the supply chain. Upward flexibility typically suggests extra manufacturing capacity and extra component or raw material inventory. Downward flexibility typically results in a similar situation: idle capital investments and extra component and raw material inventory, unless capacity is partly outsourced. There are a lot of practical examples of the difficulty of downward scalability the cellular terminal business supply network has experienced with the saturation of cell phone market demand (tacit knowledge).

Another possibility for capacity increase, in addition to investing, is either capacity outsourcing or acquiring other companies' production lines rather than investing themselves and instead of buying whole companies. This arrangement eliminates significantly costs associated with a full acquisition (Liotta, Now you see them, now you don't, EBN, 2000). In addition, there are different financial arrangements, leasing (operational or financial) or renting, depending on the market situation that can be used instead of purchasing the capacity. Component level flexibility could be obtained through hub and consignment stock arrangements.

As a summary, the chapter describes the current problematic and accuracy requirements of the consumer electronics industry forecasting and presents alternative tools for improving visibility, cooperation and availability within the supply chain. These tools and methods include: information sharing tools and databases, demand marketing efforts, collaborative planning, limited editions-approach and keeping inventory. Also, alternative supplier management and development methods were presented: single and/or multiple sourcing, chain profit distribution, supplier cooperation and supply chain capacity scalability both up and downward.

3.2 Sourcing strategies

In general, companies' supply strategies are aimed at ensuring availability of existing technologies, whereas innovation strategies try to ensure the availability of new technologies and innovations (Afuah, 1998). Effective demand-supply planning is the core process for ensuring short-and long-term availability. When the volume requirements are known, it needs to be decided where to source these quantities. A sourcing strategy addresses the before mentioned issues emphasizing quality and cost of the commodities sourced and how sourcing and purchasing functions should be positioned within the manufacturing company, and where the decision concerning the suppliers should be made. The strategy is then used to define the number of suppliers per commodity area and the supplier management practices depending on the criticality of the supplier. There are several different types of approaches to creating a sourcing strategy. In this literature review, four different models are described. They can all be used either separately or as any combination thereof. These sourcing strategies are reviewed to gain more understanding on how the supplier selection process affects the availability of materials and to identify which approach or combination of approaches suits the cellular terminal business the best. Alternative approaches will be compared to the guideline presented by Baily, Farmer, Jessop and Jones (1994): the position of the business in its supply chain, the number of effective sources, the pace of technological development and the volatility, the degree of government involvement and the ability of the buying company to manage a strategy. Other influencing factors could be the overall supply chain strategy, if any, and the availability of resources to implement the strategy on all levels of the supply chain and/or each company.

3.2.1 Supply management strategy by Goldfeld

According to Goldfeld, a strategic sourcing plan should include identifying the key factors that influence the success in the marketplace and determine what effect the materials that are acquired have on that success. The procurement risk inherent in the acquisition of the material needs to be assessed and there are a number of steps to be taken in developing a supply management strategy (Goldfeld, 1998): (1) Select a cross-functional team for the positioning process, (2) Select the material or commodity to be positioned, (3) Determine the influence and relative weight on company results and (4) Calculate procurement risk, determine the relative strength of the competitive forces.

In this model, cross-functionality is the most important aspect. Internal commitment for supplier selection decisions within the company is best obtained by joint participation. The functions involved should include a representation from OEM's customer interface to gain end-user market understanding within the supply chain and the team does not have to be internal to one company. Different types of commodity group strategies are not addressed, i.e. how to create the strategy and how to manage different kinds of commodity groups. All factors influencing the strategy outlined by Baily, Farmer, Jessop and Jones (1994) have not been taken into account in this model to full extent. Two items especially important in this study are partly missing: pace of the technological development and volatility of the end market.

3.2.2 Purchasing function sophistication model by Pearson, Gritzmacher and Karen

There are seven key characteristics which can determine the sophistication level of a purchasing function: (1) Organization structure, (2) Organizational perceptions, (3) Information access, (4) Information technology, (5) Decision issues, (6) Supplier network and (7) Strategic management.

Material price and availability issues, together with supplier performance are given higher priority when purchasing is recognized as a function managing a worldwide supplier chain. The table on the next page will explain the stages to strategic purchasing according to this theory.

Table 6: Stages to strategic purchasing (Pearson, Gritzmacher and Karen, 1990).

Characteristics	Operational Approach	Strategic Approach
Organization Structure	Low visibility, lenghty reporting chain to top management.	High visibility, direct reporting to top management.
Organization perception	Isolated ineffective paper pushers.	Active, effective strategic material supply managers.
Information access	Limited exposure to critical reports and meetings.	Access to library of internally and externally generated information.
Information technology	Inundated by non-computerized data.	Paperless computer integrated information system.
Decision issues	Clerical function that makes decisions based on price.	Provides expert analysis of forecasting, sourcing, delivery and supplier information.
Supplier network and relationships	Works with many suppliers, adversial relationships.	Works with fewer suppliers. Co-operative family relationships.
Strategic Management	Non-existing input to the strategic decision making process.	Chief strategist of material price, availability and supplier issues. Provides critical information to strategic management.

The model is quite clear from the organizational point of view, but does not give many guidelines on how to achieve the different sophistication levels. Different types of strategic commodity groups have not been addressed in this model either and the internal processes of the buying company, i.e. how to create the commonly agreed supply strategies, supplier selection processes and supplier management practices have not been reviewed. The market environment and technologies have not been taken into account either. The model is designed for more intra-company purchasing function development than a sourcing strategy tool. It can be stated based on this model that a purchasing function of any given company within the supply chain needs to be in a sufficiently advanced stage in order to ensure availability of components, raw materials and equipment across the supply chain.

3.2.3 Sourcing function maturity level model by Hines

Another way of describing the maturity of Purchasing or Sourcing function is through a strategic competitive positioning model developed by Hines (1994). The strategic competitive positioning model is divided into four stages. Hines' model is based on the concept that the supplying company starts from a position where it uses low single-technology techniques and offers no added value services and evolves through price and quality competition towards coordination and development of suppliers. The highest maturity level of this model is strategic partnerships. Different commodity groups can be in the different stages of this positioning model at all times. Some commodities do not require strategic partnerships to be managed cost efficiently. From the total cost point of view, it is not economical to address all the commodity groups in a similar way. This model can be linked to supplier coordination efforts presented in the previous chapter by Dyer (2000), Laseter (1998) and Hines (1994). As with the previous model, this model addresses the customer supplier interface only, on a first tier level, not the internal processes for developing the appropriate strategy for the supply chain management. Market environment is not part of the criteria in this model either, and the possibility for inter-company cooperation remains unexplored. The merits of this model are that it does map the stages for proceeding towards strategic partnerships/cooperation with key suppliers. Some similarities can be found with Poirier's (1999) supply chain optimization model with the four different stages.

3.2.4 Strategic positioning matrix by Goldfeld

The strategic positioning matrix created by Goldfeld (1998) helps to set priorities in supplier and risk management by positioning of different commodity groups. Balancing the two elements of procurement risk and influence on company results in a matrix helps to establish priorities in a form of segmentation. There are four quadrants on the grid, representing the four classifications for components/material categories.

<u>Non-critical components</u> – rankings that fall in the lower left hand quadrant typically are not critical components. They have little or no influence on company results and little or no procurement risk.

<u>Leverage components</u> – components falling into the upper left hand quadrant definitely have an influence on company results, but they too pose little or no procurement risk.

Bottleneck components - they have little or no influence on a company success but they do have a greater than normal degree of procurement risk. Components are difficult to get, may cause scheduling problems, because they consume an inordinate share of valuable resources, as well as creating problems and delays, without any real payback.
Strategic components – the components that fall into the upper-right hand quadrant have both characteristics. Commodities here play a significant role in company's success in the marketplace and also pose problems in their acquisition. These are the mission critical parts, items that make up the subset of parts that are the primary basis for competitiveness.

Leverage components	Strategic components
Non-critical components	Bottleneck components

Influence on company results

Procurement risk

Picture 5: Strategic positioning matrix (Goldfeld, 1998)

After the strategic positioning matrix has been completed different strategies to be used for different categories should be created. Typical strategies that have been found to be effective for different categories are described by Goldfeld (1998).

	Strategic	Leverage	Bottleneck	Non-critical
Partner/alliance	x			
Cultivating suppliers	x	x	x	
Long-term agreements	x	x	x	x
Standardize	x	x	x	x
Quality improvement	x	x		
Overhead cost reduction	x	x		x
Consolidate with other divisions		x		x
Competitive bidding		x		x
Supplier reduction		x		x
Cross commodity leverage		x	x	x
Internal price benchmark		x	x	x
Re-source to new suppliers			x	
Substitute			x	
Price rollback		x		x

Picture 6: Sourcing strategy matrix (Goldfeld, 1998).

This model is the most comprehensive and easiest of the four models presented in this study to apply due to clarity. Yet these different models can be combined to reach the most comprehensive supplier strategy creation process. Mostly the same elements were missing from this model as from the previously presented models. These points were described in conjunction with the former models already.

The key difference between different sourcing strategies proposed by Goldfeld (1999), Hines (1994) and Pearsons, Gritzmacher and Karen (1990) and the Customer Fulfillment Network theory proposed by Dyer (2000) is that Sales or another end-customer interface function is involved in the supply chain management strategy process and decision making process. The sales function is not typically involved with sourcing processes unless cross-functional sourcing strategy team includes a participant from the sales or the marketing function. The main input from this sales interface would be end product demand visibility information, explanations behind the periodical changes in demand and input on the market situation and future business opportunities at a more detailed level.

3.2.5 Alternative supplier positioning tools

Matrices can be used in various ways for analyzing suppliers' or component/product types. Ore's Matrix analysis takes place along two axes, cost on the vertical axis and risk on the horizontal axis. Different supplier management and purchasing strategies can then be created and applied based on this categorization. Tayur's Matrix suggests defining the matrix so that vertical axis is the degree of importance of components and the horizontal axis is the degree of fragmentation. The vertical axis separates components/products into standard and customized or key and non-key components/products. The horizontal axis then defines the level of fragmentation in the supplier base, i.e. number and size of suppliers (Dunn, iSource Business, August 2001). Another type of matrix is presented by Laseter (1998). This matrix describes different purchasing approaches depending on one hand on commitment to competitive pricing and on the other hand commitment to cooperative relationship.

Overall, none of these models have described metrics to measure the effectiveness of the supply chain management or measures for successfulness of the chosen strategy. Financial reliability and stability could be measured to ensure that the supplier will be around in the future. This evaluation can be done by a number of companies. (Kotabe, 1992 and Murphy, iSource Business, July 2001). The models do not take into account the new challenges that the sourcing functions of electronics manufacturing companies face, including optimizing availability, access to new technologies, second to third tier supplier management and product and component standardization efforts. Company internal communication model was missing, i.e. how the supplier related decisions and strategies are created internally and coordinated with the supply chain. Technology and market environment related issues were not mentioned in the positioning matrices very clearly. As supplier performance could be measured in many ways, good performance should also be rewarded. As an example, Dell Computers presents four awards to the best performing suppliers annually (McKeefry, EBN, May 2000). Metrics will be addressed later in this study.

3.2.6 Risk management: single or multiple sourcing

An integral part of ensuring availability is risk management both internally and externally. Managing risk related to the supply chain is one of the essential elements of ensuring availability and guaranteeing long-term supply of components, raw materials and capital equipment. More than one supplier per commodity area is needed as a risk management tool (Goldfeld, 1998). There are also benefits in reducing the supplier base, having single sourcing as a strategy, as the theory presented by Hines (1994) describes. Some observations to the Goldfeld theory: economies of scale are not necessarily lost if volumes are split between two or more suppliers. This depends on the total volume per commodity and the break-even point where these savings can be obtained. If there are sufficient resources to manage a larger number of suppliers, personal relationships can be built with more than one supplier per commodity area. Investments in tools and manufacturing capacity can be made with several suppliers simultaneously or with no suppliers at all, if the investments are justified with increased scalability and improved risk management. The strategic importance of the commodity in question was not mentioned in Goldfeld theory, but the decision-making whether to have one or several suppliers per commodity clearly depends on the strategic importance of the commodity in question. If basic processes like supply and demand planning are not in place and working efficiently, there are no guarantees of the successfulness of either single or multiple sourcing strategies. It is important to note that risk management exercises should be extended to second and third tier suppliers as well, either by the OEM or by the first tier suppliers.

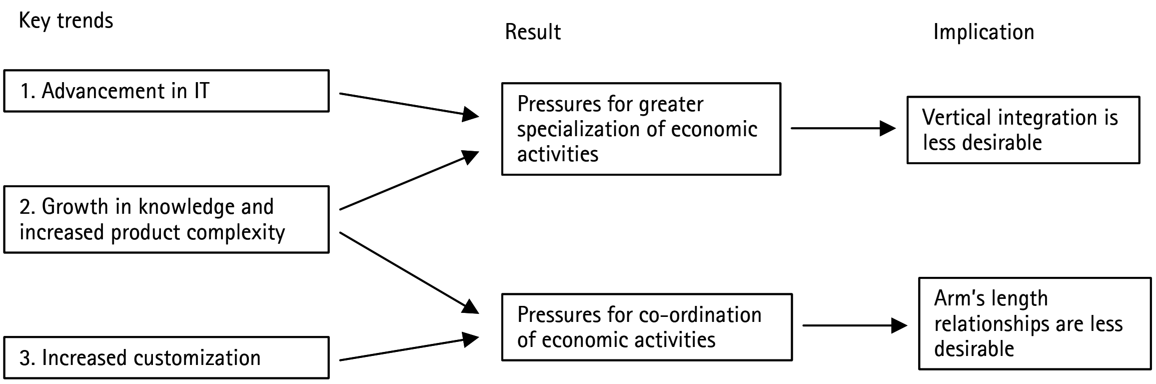
3.2.7 Creating partnerships

Hines lists the most important reasons cited for maintaining these long-term relationships (Hines 1994): 88% stable supply; 73% good quality; 50% competitive price and 48% trusting relationships as a result of long-term trading. Creating partnerships was mentioned in the literature as one of the possible supplier strategies that can be used by advanced purchasing organizations with strategic and critical suppliers. Supplier related partnerships could be divided into supply-and technology partnerships. Supply partnership refers to partnering efforts in the area of ensuring timely, high quality and lowest total cost of supply of components, raw materials and equipment. Technology partnership refers to more technologically focused long-term joint technology efforts between companies (Vilkamo, 2000), (OEM Collaboration Guidelines, 2001). This theory on supply partnership is presented in order to study the concept of partnership into more detail and to determine whether creating partnerships adds value that can be measured in terms of ensuring the availability of continuous, timely and high quality supply.

Another way of classifying different types of partnering efforts is: customer management, supplier management and relationship management (Avery, 1998). Supply and technology partnerships fall into the category of supplier management partnering. Avery (1998) and Kneeland (1996) summarize the prerequisites for partnering: attitude and behavior change, recognition of long-term mutual dependencies, senior management commitment, strategic nature of the initiative, reasonable expectations, early partner involvement, especially in design phase, time and resources available and follow up, measurement and monitoring of the goals. The key benefits of partnership have been presented quite widely in literature (Goldfeld, 1998, Erridge, 1995, Doz and Williamson 2001, Dyer 2000, Avery 1998 and Kneeland 1996).

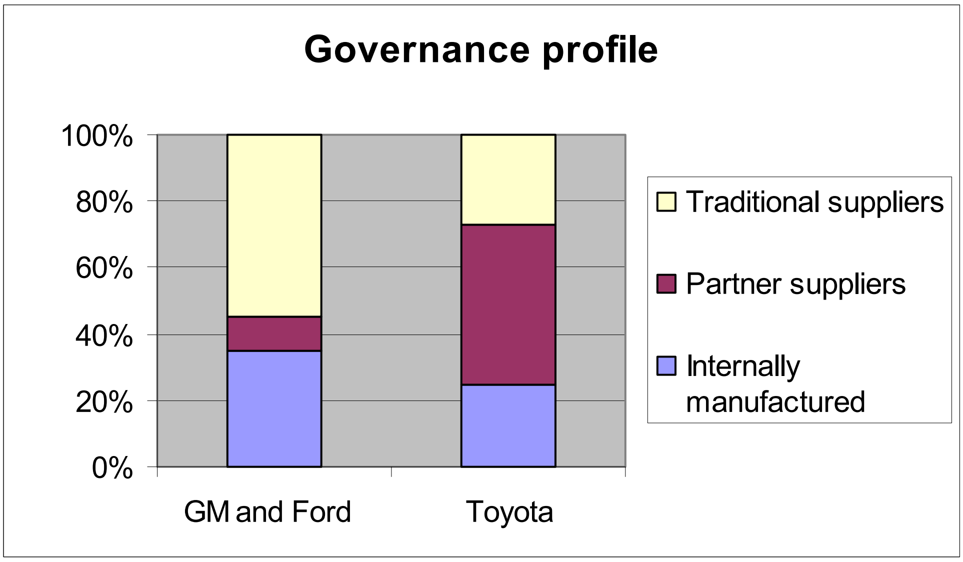
Typically benefits are the ones of a successful partnership, not any partnership. Some of the advantages mentioned can also be obtained through improved supplier management and cooperation and supply chain coordination, not necessarily only through official partnerships. Partnering efforts can also end up being non-value adding or they also might even have a negative impact on supplier relationship management by making either party complacent with the situation. The theories do not mention the company internal decision-making process concerning partnership activities. Based on the supply chain management theories, the decision should be unanimous as cross functionally as possible to gain commitment from the whole organization. Metrics for measuring the value added and successfulness of the partnering efforts were not identified in the literature reviewed.

There are several different methodologies in building a strategic partnership. The models proposed by Goldfed (1998) and Schorr (1998) vary in the approach to forming partnerships. Goldfeld's process is very fact based whereas Schorr takes a softer, good will based approach. Another, complementary method is presented by Van Mieghem (1996). Based on Dyer's theory, partnerships create competitive advantages only as they move the relationship away from the qualities of a standard market relationship. The key factors are: dedicated and joint assets, knowledge sharing routines and trust. The statement concerning joint assets can, however, be argued. Dyer (2000) summarizes the trends that favor partnershipping.



Picture 7: Trends that favor network partnershipping (Dyer, 2000)

An example of different kinds of mixes of supplier relationships at GM, Ford and Toyota are presented below.



Picture 8: An example of governance profile of supplier management within automotive industry (Dyer).

The decision whether to move towards partnerships or to stay in the existing mode of supplier management and purchasing depends on the market, risks, problem areas and competitive situation. The arm's length model refers to levels one (price competition) to three (close cooperation) in sourcing function maturity levels presented by Hines (1994) or operational and/or strategic sourcing approach presented by Pearson, Gritzmacher and Karen in 1990.

Table 7, conditions for effective use of different governance models (Dyer, 2000).

Traditional supplier management	Partnership model
Low volumes of exchange	High volumes of exchange
One-time or infrequent purchases	Recurring purchases
Low degree of supplier-buyer interdependence	High degree of supplier-buyer interdependence
Stand-alone inputs	Inputs with multiple interaction effects
During a recession	During an expansion
Short-term cost reduction	Long-term value creation

The term partner is used quite loosely within the electronics industry today when addressing key suppliers or even potential suppliers. If a company wants to be careful when using the terminology, this distinction needs to be done on a supply chain level by determining what level of cooperation could be called a partnership.

The alternative approaches presented in this chapter represent the main theories in the area of supply strategies. The purpose of the review was to find the best possible approach to creating supply strategies and managing suppliers within the electronics industry to ensure availability of materials and products in a fluctuating demand environment. Coordinated and carefully managed supply strategies will contribute to ensuring the timely supply of high-quality, lowest total cost components and raw materials. As a conclusion, it could be suggested based on the theory review that the purchasing function of each supply chain company needs to be on a sufficient level to be able to create a supplier strategy and to manage the supply chain accordingly. A sufficient level refers to the strategic approach defined by Pearson, Gritzmacher and Karen in 1990 or stage three or four of sourcing function maturity level presented by Hines in 1994.

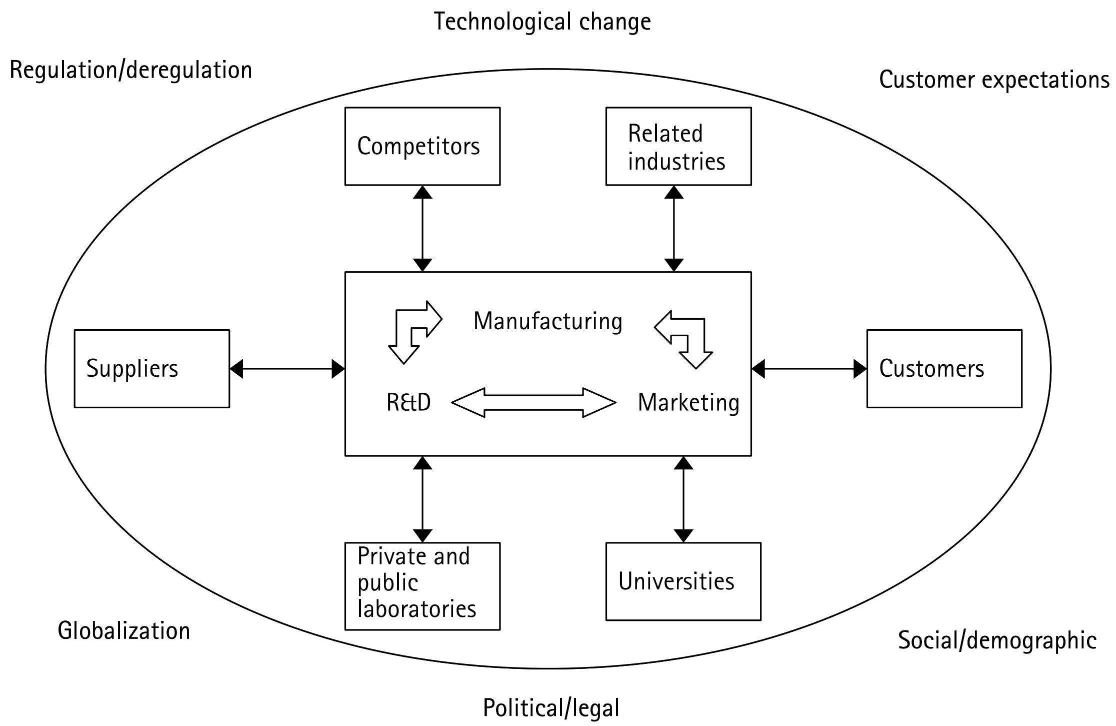
Based on the literature review, it could be proposed that the strategic positioning model proposed by Goldfeld (1998) would be the best alternative to categorize the existing suppliers based on pre-determined criteria in order to form a supply strategy and supplier management strategy, including the risk management aspect. However, the axes of the matrix should be reconsidered. Technology criticality could be mentioned in one of the axis, whereas the other axis addressing the influence on company results, i.e. costs and volume. The purpose of emphasizing technology in supplier strategy creation is clearly due to the importance of new technologies in the electronics business and the need for the speed of implementation of new technologies into end products. That is why supplier strategies should foresee the future and the capabilities of the supply chain long-term.

3.3 Technology cooperation

Innovation is the use of new technological and market knowledge to offer a new product or service to customers. The product is considered new in that its costs are lower, its attributes are improved, it now has attributes it never had before or it never existed in that market before (Afuah, 1998).

Each company's innovation strategy can be divided into being offensive, defensive, imitative, dependent, traditional or opportunistic. Depending on the strategy, a company's approach to developing innovations can be either internal or external. If a company chooses an external approach, technology cooperation becomes an alternative. The major functional sources for innovation for a firm are (Afuah, 1998): its own internal value chain functions, its external value-added chain of suppliers, customers and complementary innovators, university, government and private laboratories, competitors and related industries and other nations and regions.

Bidaut and Cummings (1994) suggest that cross-industry alliances are likely to be more innovative than alliances with competitors.



Picture 9: Sources of co-opetitors and variables in operating environment (Afuah, 1998).

The models of cooperation described in the following chapters can be used with all the above-mentioned external parties. The decision of who to co-operate with depends on the type of technology and market, the timing and cost of innovation and co-operator's competencies and endowments (Afuah, 1998). A company can build strength in four ways: internal activities, acquisitions, arm's length transactions and strategic alliances. Strategic alliance partners are typically found through effective scanning within the before mentioned framework of companies and institutions (Lewis, 1990).

The overall purpose of interorganizational relationships is to maximize profit or contribution by producing higher value than the competition. The higher value is defined by product functionality (meeting market needs), low cost, high quality, and minimal time to market (Ashkenas, Ulrich, Jick, Kerr, 1995). A survey conducted by Dataquest and Arthur Young in 1991 among 700 start-up and fast-growth companies showed that nearly 90% reported forming some kind of strategic alliances with other companies (Ashkenas, Ulrich, Jick, Kerr, 1995). Whereas the data collected by Hagedoorn (1993) shows that during 1980-1989 consumer electronics was the field of technology that had a very small number of alliances.

This difference clearly suggests, and this is also stated by Cainarca, Colombo and Mariotti (1992), that the propensity for cooperation depends on the growth rate of the market, technological evolution and the strategic conduct of the companies within the industry branch. Also, according to Hagedoorn and Schakenraad (1994), rapid changes and uncertainties in technology environment attribute to willingness to form alliances with other companies. The key success factors for successful collaboration have been defined by Littler, Leverick and Bruce (1995). The factors include: process management, allocation of resources, assessing external factors, trust between parties, attention paid to marketing issues, flexibility of management systems and style and frequent communication. These factors are quite similar to the one mentioned by Kneeland (1996) as critical success factors for partnering in the previous chapter. An example of a technology cooperation network is the one around Sun Microsystems. The company has opened its standards around the products in its workstation business as widely as possible (Doz, Hamel, 1998). Also in the telecommunications industry the direction is towards open standards around which various products and applications can be developed. Other success stories worth mentioning are Canon, Honda and NEC (Prahalad, Hamel, 1990).

3.3.1 Reasons for inter-company technology cooperation

There are some general prerequisites for innovation cooperation (Bidault, Cummings, 1994): understanding of users' needs, knowledge of marketing and distribution of a new product, project "sponsor", metrics (controls), clear and speedy communication channels and the right mind-set of a project team. When entering cooperation, the possible dissolution of the cooperation also needs to be taken into account through definition of possible exit strategies. Different exit strategies are described by Alajoutsijarvi, Moller and Tahtinen (2000): indirect or direct exit and voice.

The main reasons for inter-company technology cooperation can be categorized to three broad categories business environment, intercompany reasons and research-related reasons (Ashkenas, Ulrich, Jick, Kerr, 1995), (Hagedoorn, 1993), (Cainarca, Colombo, Mariotti, 1992), (Avery, 1998), (Hagedoorn, Schakenraad, 1994), (Spekman, Forbes, Isabella, MacAvoy, 1998), (Bidaut, Cummings, 1994), (Millson, Raj, Wilemon, 1996), (Dosi, 1982). (Deeds, Hill, 1996), (Littler, Leverick, Bruce, 1995), (Lewis, 1990), (Hagedoorn, Sadowski, 1999), (Doz, Hamel, 1995), (Harrigan, 1995), (Simchi-Levi, Kaminsky, Simchi-Levi, 2000) and (Keil, 2000). The reasons presented in this study are also well in line with the motivations presented by Nurmi (1998).

Strategic alliances have at least three key purposes based on the theory presented by Doz and Hamel (1995 and 1998): co-option, i.e. neutralizing rivals, co-specialization, i.e. synergistic value creation and learning and internalization. This is an alternative way of categorizing the reasons. Keil (2000) touches the subject of technology access in his Thesis by categorizing the reasons for corporate venturing in two: exploration, namely experimentation and exploitation, i.e. ensuring rapid entries. This categorization can be used more broadly in technology cooperation in general to understand the reasons for such cooperation, especially now in 21st century.

The reasons found in the literature review in the area of business environment are well in line with the current state of the business environment described in chapter 2.1 and the data collected from the survey presented in chapter 2.2. However, some contradicting information can also be found in the related literature. Bidault and Cummings (1994) suggest that development times become longer with cooperation activities compared to internal development. Another source, Deeds and Hill (1996) suggest the contrary: a firm's rate of new product development is a positive function of the number of strategic alliances that it has entered, until the number of alliances becomes so high that the benefits tend to decrease. Bidault and Cummings also state that development costs are more difficult to control in joint development and thus result in being higher than in internal development. Only one of the references mentioned access or availability as one of the reasons for technology cooperation. This might be due to the fact that most of the literature reviewed was from late 1980's and early 1990's. Also, Hagedoorn (1990) suggests that technological complementarity and reduction of the innovation period are less relevant motives for technology cooperation within consumer electronics and automotive industries. This statement might have been true during 1980's but clearly not now at 21st century.

3.3.2 Forms of strategic alliances

The following chapters will review different forms of technology cooperation in more detail. A decision-making matrix will be presented to propose the ideal cooperation model in different technology and market environments. The definition of strategic alliance is presented in the definitions chapter of this study by Hagedoorn (1993), Lewis (1990) and Spekman, Forbes, Isabella, MacAvoy (1998). Strategic alliances are also typically agreements used for defining important aspects of standards for architectures and interfaces of systematic products (Cainarca, Colobmo, Mariotti, 1992). These alliances can be equity sharing or non-equity, contractual agreements (Hagedoorn, Narula, 1996). The forms of strategic alliance in the area of technology cooperation presented in this research, based on the data collected in the literature review, are:

Non-equity, contractual alliances:	Technology exchange
	Joint development/R&D agreements
	Licensing
	Research consortia
	Technology partnership
Equity sharing cooperation:	Vertical and horizontal integration, including virtual integration (non-equity)
	Equity investments
	Joint ventures

Mergers and acquisitions will not be addressed as a part of this research. These refer to cases where two separate companies are combined into one company, either by means of a combination of the economic interest of equals, or through an acquisition where one company obtains majority ownership over another company (Hagedoorn, Sadowski, 1999). The main focus of this study is to review the non-equity investment forms of cooperation. This decision is supported by statement from Hagedoorn and Sadowski (1999): rapid technological change in sectors of industry induces the formation of informal forms of cooperation such as non-equity agreements. Killing (1988) supports this statement. Based on the consumer electronics industry review in chapter 2 it can be stated that consumer electronics is a rapidly changing technology environment. Jones (1987) and Williamson (1985) give a slightly contradictory point of view: one quasi-hierarchical form of governance structure is preferable for international joint R&D because it allows greater control over complex judgmental tasks, and aids the transfer of non-codified technology know-how. Osborn and Baughn (1990) assume that contractual arrangements would not be a preferred way of cooperating in technologically intensive product areas. These comments can be partially explained by the timing of these studies, most of which date back to the 1980’s. Company size may be a factor in making these decision concerning governance models (Osborn and Baughn, 1990).

One-directional technical flows and customer-supplier agreements (Hagedoorn, 1990) will be excluded from this study, as these forms of cooperation are considered to be part of ensuring availability of existing technology through purchasing agreements. Contractual forms of cooperation have typically quasi-market characteristics, whereas equity-sharing contracts are typically more hierarchical in nature (Hagedoorrn, Narula, 1996), the first alternative being recommended to companies in the awareness or exploration phase of joint development efforts (Millson, Raj, Wilemon, 1996). As industries become more mature, more formal modes of cooperation typically become preferred (Hagedoorn, Narula, 1996). More R&D intensive and uncertain market environments require more organizational flexibility leading to a preference towards contractual agreements instead of equity investment (Hagedoorn, Narula, 1996). Most forms of technology cooperation are strategically motivated; according to Hagedoorn (1993) the percentage would be 85%. Hagedoorn and Narula (1996) also propose that the split between contractual and equity agreements in consumer electronics industry was 60%/40% during the 1980’s and early 1990’s.

As proposed by Millson, Raj and Wilemon in 1996, all strategic alliances have a maturation process with different stages: awareness (scanning), exploration, commitment and dissolution. These different stages have been determined to be outside the scope of this study. The partner selection criteria, both technical and commercial, apart from the cooperation model selection criteria, will also be excluded from this study. However, both topics could present ideas for further research.

Possible problem areas within technology cooperation are not widely discussed in the literature. Some potential problem areas are described by National Research Council in their fourth report of the Research Program of the Partnership for a New Generation of Vehicles (1998): different opinions concerning technological direction, project funding related disagreements, project cost and schedule misunderstandings, agreeing the target levels, resourcing and differences in competency levels. Additional risks have been brought up by Littler, Leverick and Bruce in 1995 and Lewis in 1990: leaking of confidential and/or “tacit” information, reduction of direct control, additional financial and time costs, increased development times, lack of commitment, too specific results in terms of products, capability gaps between companies, and costs of maintaining the relationship. Also, based on a study conducted by Madhok and Tallman (1998), the failure rate of inter-firm collaboration efforts is quite high due to some managers typically under appreciating and underestimating the transaction specific expenditures and investments. Also, costs and returns are typically skewed toward different periods of relationship. Some literature even suggests (Lewis, 1990) that all company know-how should not be exposed to alliance partners. This statement can be argued based on the data collected for the reasons for inter-company cooperation.

3.3.2.1 Technology exchange

Technology exchange typically is the loosest form of technology cooperation between companies. The purpose of technology exchange typically is to learn from other organizations, cost economizing and exchanging strategies to increase the certainty of the technology roadmaps of the firm. Technology exchange agreements cover technology sharing agreements, possible cross-licensing and mutual second sourcing of existing technologies. Technology exchange is not typically defined as being a long-term undertaking; companies typically negotiate the allocation of the established knowledge or artifacts generated either by one partner or through collaborative efforts (Hagedoorn, 1990, 1993).

3.3.2.2 Joint development and R&D agreements

Joint R&D agreements refer to joint research pacts and joint development agreements, which establish joint undertaking of R&D projects with shared resources (Hagedoorn, 1993). Joint development agreements can be established between two or more companies, either competitors or supply chain companies, or with national or international governmental programs or with university research projects. These projects are most typical in the product development phase of the product life cycle, whereas research consortia are aimed more at the pre-competitive phase of the life cycle (Cainarca, Colombo, Mariotti, 1992). Joint R&D agreements cover agreements that regulate technology and R&D sharing and/or transfer between two or more companies to reduce costs, minimize risk and allow synergy among firms pursuing similar innovations (Hagedoorn, 1990). Joint development and R&D agreements, non-equity agreements are most typical and valuable in rapid change technology environment with short product life cycles, where R&D intensity and market instability are high. This is due to the fact that the environment requires more organizational flexibility (Hagedoorn, Sadowski, 1999).

Formal agreements provide a frame of reference for the cooperation. Informal interfaces, however, hold the alliances together. These interfaces reinforce personal commitment and trust and provide access to personal information and contacts (Spekman, Forbes, Isabella, MacAvoy, 1998). Formal technology agreements typically address the topics such as intellectual property rights, technology access, exclusivities, volume commitments, design ownership, development responsibilities, cost sharing and time schedules. The types of contracts can be letters of intent, contingency agreements, project agreements with milestones and options for technology licenses or joint ventures. Exclusivities place some critical resources or technologies beyond the reach of others. For competition, this type of situation may result in costly licensing fees or having to use an alternative technology. Considering industry's technology development overall, exclusivities are not necessarily the best way of ensuring technology access for the future to a particular company (Lewis, 1990).

3.3.2.3 Licensing

Licensing is one of the easiest ways of gaining access to a particular technology, at a cost. Under a licensing agreement, a company purchases the rights to use another organization's patents or a technology for a single payment and/or royalties of the sales, depending on the terms of the agreement made between the companies (Steensma, 1997). Different types of licensing include: traditional licensing, cross licensing between companies, sub-licensing, have-made-rights and royalty-free licensing. Single-licensing usually concerns the transfer to partners or somewhat older technologies and products. In licensing for reciprocity and cross licensing, companies exchange licenses to supplement their own research with licensed technology or to avoid patent protection. Typically the value of both licenses or packages of licenses is calculated for swapping (Hagedoorn, 1990).

The positive aspect of licensing is a quick and relatively low-investment access to new technologies. The main shortcoming is that if a company does not develop its' own technologies, it may be caught stranded when the licensor decides not to renew the contract and cuts off the licensee from important new and compatible technologies. A not-invented-here-syndrome may also occur within internal product development departments (Afuah, 1998). Generally, a patent portfolio is extremely important in today's competitive marketplace. In supplier/customer relationship, especially in case of joint R&D efforts, it is important to agree the IPR policies prior to starting joint efforts that might lead to patentable outcomes. Management of patents can significantly enhance a company's success in three ways: by establishing a proprietary market advantage, by improving financial performance and by enhancing overall competitiveness. Patents can also be used to protect the proprietary technologies that give their products and services an advantage over those of the competition (Rivette, Kline, HBR, 2000).

3.3.2.4 Research consortia

A key reason for forming research consortia is to minimize the risk of an individual company in new technology research and to share the costs between a number of companies. Also, standardization plays a major role in research consortia together with either national or international governmental program support (Cainarca, Coloblo, Mariotti, 1992).

Research programs typically focus on the development of significant new products and/or process technologies. The longevity of consortia alliances typically is based on the duration of a particular research program. In addition, consortia can be used as a tool to accumulate capital, and acquire human, technological and physical resources (Millson, Raj, Wilemon, 1996). Business-university activities could be broadly categorized as research consortia, and in more detail, into following categories (Lewis, 1990): university group research, outside group sponsorship, individual projects, and individual faculty contacts and shared facilities.

3.3.2.5 Technology partnerships

Technology partnership is one of the most common ways to cooperate due to its flexible form. Technology partnership can be a faster access to new technologies than internal product development (Millson, Raj, Wilemon, 1996). The UN Meeting of Experts on Technology Partnerships (1996) has defined basic criteria that need to be fulfilled by all companies striving towards successful technology partnership. This criteria is similar to the one defined for partnerships overall (Kneeland, 1996) and for technology collaboration (Littler, Leverick and Bruce, 1995). Companies can enter into technology partnerships with existing key suppliers, potential suppliers, customers, potential customers and even competitors making partnerships in some cases even three-to four party partnerships. These partners could be private or public entities, other enterprises, governmental research institutes, universities, private research institutes, investment funds, start-up companies or ministries in different countries (UN, 1996).

A practical example of a multi-party technology partnership is ARM Inc. case. The mission of the partnership was to become the de facto standard for embedded RISC processing across the communication, networking, consumer, portable, automotive and multimedia application markets. Restructuring of the value chain to create a value web around its architecture for semiconductor, software and end user companies, the companies being Gemplus, HP, Nokia, Sony and Psion (Extending your Reach – Networked Product Creation, 2001 with collaborators from INSEAD Faculty Peter Williamson and Yves Doz).

3.3.2.6 Vertical, horizontal and virtual integration

The definitions of vertical and horizontal integration have been defined by UN's Meeting of Experts on Technology Partnerships (1996). Vertical collaboration occurs throughout the chain of production from the provision of raw materials to distribution and after-sales servicing. Horizontal collaboration occurs between competitors operating at the same level of the production process, who extend their expertise by sharing knowledge, skills and personnel (UN, 1996). Generally, vertical and horizontal integration adds value if a company can lower the transaction costs by internalization (Afuah, 1998) or if key suppliers are controlled or owned by rivals (Lewis, 1990). Virtual integration means that partners' businesses are joined with OEM's and the suppliers are treated as if they were inside the company.

According to Dyer (2000), vertical integration should only happen if integration is critical for product differentiation. Based on other literature reviewed (Fine, 2000, Doz, Hamel 1998), this seems to be a valid statement. Integration vertically backward can take place to gain critical inputs and forward to gain access to scarce distribution channels in order to reduce competition and allowing a firm to have more control over its prices (Afuah, 1998). Vertical or horizontal integration can be used to gain bargaining power and to avoid opportunistic strategic behavior by suppliers or other complementary innovators (Afuah, 1998). Transaction cost theory states that when inputs are highly customized and involve transaction specific or dedicated assets, firms should vertically integrate. In contrast, when inputs are highly standardized, or do not involve transaction specific assets; firms should use arm's length relationships with outside suppliers who can specialize and achieve economies of scale. Partnership falls between vertical integration and traditional supplier relationships (Dyer, 2000). Similar theory has been proposed by Picot (1991):" The more a transaction requires investments that can not be re-deployed to other users, the lower are the incentives for an external party to make these investments. Asset specificity suggests that an activity should be conducted within boundaries of an organization". These statements made by Dyer (2000) and Picot (1991) can be argued based on other theories and practical examples presented in this research. Vertical integration could be replaced by virtual integration. The decision of the investment within a supply chain is typically based on risk sharing decisions either by the buying company or inside the supply chain. The investor and the holder of the physical assets do not necessarily need to be the same company. The approach towards integration could also be the one of "engineering supply chain" (Miller, 2002) within the concept of extended engineering team.

A different approach has been taken by Christopher (1998) stating that vertical integration is not necessarily promising speed and flexibility required in today's business environment. Virtual integration would most likely be a better alternative for that environment. Within cellular terminal manufacturing there is a two-fold approach: some OEM companies are still investing in component manufacturing and some are divesting from that business. During year 2000 Ericsson stopped manufacturing screen driver IC's and started using the Sony Semiconductor Company's fab as a chip foundry. On the other hand, Philips Electronics NV still had its driver IC operations both for internal consumption and sale on the merchant market (Robertson, Electronic Buyers' news, March 2000). Many Japanese electronic manufacturing companies are still vertically integrated. Companies such as NEC and Fujitsu, making both chips and mobile phones are preparing for the 3G explosion by expanding chip manufacturing capacity and developing new process technologies, whereas Sony is relying on Texas Instruments' 2G/3G enabled chip architecture (LaPedus, Seeking Riches in 3G chips, Electronic Buyers' News, May 2000). A study conducted by Forrester Research in December 2001 (Harris, 2002) states that integrating internal systems within companies and integrating systems with company partners was a major priority for businesses. The study also shows that supply chain integration projects cost more than expected and take longer than expected, with typically not very successful integration results.

The positive effect of internal sourcing, manufacturing components internally, seems to be the ability to keep sight of emerging technologies and expertise in the long run, which could be incorporated into the development of new manufacturing processes as well as new products thus enhancing cost competitiveness and global competitiveness. On the other hand, sourcing from independent suppliers enables companies to fully exploit changing market conditions and develop supplier relations (Kotabe, 1992). New logistics arrangements can bring virtual integration closer. As another example, during 2000 Ericsson wanted Lucent to deliver chips it used to power its mobile phones within 48h of an order. The connection between Ericsson and Lucent was over a value-added network, but it was expected to migrate to the Internet by the next year. On average, DHL delivered the chip shipments to an Ericsson plant in Sweden about 56 hours after Lucent received its order (Chabrow, EBN, April 2000). Another example could be Dell, whose inventory velocity has been one of the key performance measurements. Real-time information is given to suppliers on what the demand is and the supplier has to get the product to OEM's on time. BTO means only five to six days lead-time and inventory needs and replenishment needs are communicated to suppliers even hourly (Magretta, The Power of Virtual Integration, HBR, 1998).

3.3.2.7 Equity investments

Equity investments are closely related to vertical and horizontal integration. Based on the theories described earlier in chapter 3.3, the level of commitment and risk becomes higher in equity investments, when actual monetary commitments are being made. This form of cooperation typically affects the technological performance of at least one partner (Hagedoorn, 1990). Alliances are not universally preferable to acquisitions. Both small acquisitions and alliances leverage company resources, particularly for a large company. Equity investments or full acquisitions may be the best approach when a competitor is moving faster, when the acquired company needs to be actively rescued or when new competencies need to be obtained fast (Doz, Hamel, 1998). Minority investments make most sense when the investee's business is sharply focused on products and markets with clear strategic value for its partner (Lewis, 1990). According to Lewis (1990), a rule of thumb in minority investments, in order to stay independent, is to acquire maximum of 30% ownership.

3.3.2.8 Joint ventures

The motivations for joint ventures are well in line with the overall motives for technology cooperation, more specifically evasion of small number bargaining, i.e. minimizing transaction costs, enhancement of competitive positioning and mechanisms to transfer organizational knowledge (Kogut, 1988). Joint venture results in high levels of uncertainty over the behavior of the contracting parties when assets of one, two or all parties are specialized to the transaction. For small innovations a joint venture is a mechanism to guarantee the entry-deterring investment. In general, joint venturing is being used more as a tool for competitive positioning of parties and for strategic motivations than for minimizing transaction costs (Kogut, 1988). The starting conditions of a joint venture can be categorized as (Lewis, 1990): startup, buy-in and merger. The main reasons for failures in joint ventures are typically found in different views of participating companies on strategy and lack of agreement in advance on how to run the venture (Hagedoorn, 1990).

The main advantages of joint ventures are associated with the spreading of risks, sharing of fixed costs, capturing economies of scale, access to new markets, competitive positioning and sharing of research efforts. Problems may arise from sharing proprietary know-how, coordination of time-horizons and disagreement on design specifications. (Hagedoorn, 1990). The key difference, according to Doz and Hamel (1998) between traditional joint ventures and new strategic alliances, is the focus on fundamentally new markets and technologies and thus the level of uncertainty both in resources and in the external turbulence the alliance could face. As joint ventures usually are bilateral, strategic alliances can easily be multilateral and a company can manage several multilateral alliances simultaneously. Typically alliances are not built to co-produce a single product, but to increasingly develop complex systems and solutions that call for resources of many partners.

Joint ventures are typically considered as relevant forms of cooperation especially after the first phase of joint experimenting with technology exchange agreements. Sometimes joint ventures are established with smaller, but promising companies that are on the outskirts of larger companies' fields of interest (Hagedoorn, 1990). Hagedoorn and Sadowski (1999) state that the industries where technological change is less pervasive, more formal modes of cooperation such as joint ventures are the preferred form of collaboration. Some companies decide to proceed with a joint venture in order to cut risks in uncertain new markets (Doz, Hamel, 1995).

3.3.3 Summary of the forms of technology cooperation

There are a few different literature references for the selection criteria of a technology cooperation model. Hagedoorn (1993) presents a criteria based on the assumed relation between modes of technology cooperation and their strategic content and Cainarca, Colombo and Mariotti (1992) criteria is based on the typology of agreements during the phases of the technological life cycle. UN Meeting of Experts on Technology Partnership presents a summary of models of inter-firm cooperation and their content (UN, 1996). Chesborough and Teece (2002) propose guidelines for selecting between decentralized and centralized innovation. Based on the literature review, it can be stated that the main market related criteria for selecting a form of technology cooperation are: technological life cycle, design dominance, specificity of the application, criticality of the technology in question, the level of uncertainty, level of asset specificity and the market growth in a particular consumer market affecting volumes and availability (Hagedoorn, 1993), (Kogut, 1988), (Cainarca, Colombo and Mariotti, 1992), (Tushman, Andersson, 1997). Company internal criteria also have an impact on a cooperation model selection. These criteria include: level of alliance control, willingness to invest, risk taking ability and level of flexibility wanted (Millson, Raj, Wilemon, 1996 and the above mentioned references). Asset specificity was excluded from the criteria due to the before mentioned fact of asset ownership and asset location being separate issues.

The table describes the cooperation models reviewed in this study and their applicability compared to each of the above-mentioned criteria. The scale used in the table is from one (1) to four (4), meaning that the suitability is higher with numbers closer to four (4) and lower with numbers closer to one (1). This table is a summary of theories reviewed for chapter 3.3.

Table 8: Technology cooperation model correlation to key criteria.

	Access to future new technology	Specificity of application	Criticality of technology	Suitability for uncertainty	Market growth	Alliance control	Investments	Risk	Cooperation flexibility
Technology exchange	2	1	2	4	1	2	1	1	4
Joint development and R&D agreements	2	2	3	4	2	2	1	2	4
Licensing	2	1	2	3	2	1	1	1	4
Research consortia	4	1	3	4	1	2	2	2	3
Technology partnership	3	2	3	3	2	2	2	2	2
Vertical and horizontal integration	4	3	3	2	3	4	4	3	1
Virtual integration	3	3	3	4	2	2	2	1	4
Equity investment	4	4	4	2	3	3	3	3	2
Joint venture	4	4	4	2	3	4	4	4	1

The key criteria selected for evaluating different cooperation models are criticality of technology and understanding of market and volume. These two criteria were selected due to the fact that they were the most commonly mentioned criteria in the literature review and they reflect the current market environment. Based on the literature review, a company needs to make a decision whether to favor risk management or flexibility of operations in the decision-making process. This study emphasizes flexibility because of the current cellular terminal market environment. These two key areas are also key reasons for technology cooperation in general: business environment and access to technologies. Criticality of the technology typically drives the cooperation efforts, willingness to invest and the number of resources assigned to development and scanning activities. Market and demand certainty drive the risk taking level required, the level of cooperation needed and the flexibility requirements that a given company wants.

The illustration below presents each of the cooperation models based on both criteria within the matrix. Market and demand represent the risk aspect, whereas the technology axis represents the flexibility dimension of the decision making process. This data has been put together based on the information provided in table 9 and the following references: Hagedoorn (1993), Kogut (1988), Cainarca, Colombo, Mariotti (1992), Tushman, Andersson (1997), UN Meeting of Experts on Technology Partnership (1996), Chesborough and Teece (2002) and Harrigan (1995).

MARKET AND DEMAND	EXISTING	NEW BUT FAMILIAR	NEW AND UNFAMILIAR
NEW AND UNFAMILIAR	Joint venture Horizontal/Virtual integration	Horizontal/Virtual integration Licensing Equity investment	Equity investment Joint venture Research consortia
NEW BUT FAMILIAR	Supplier integration Short and medium-term purchasing agreements	Vertical/virtual integration Licensing	Technology partnership Standardization efforts
KNOWN	Internal development Long-term purchasing agreements	Supplier integration Joint R&D Licensing	Technology exchange Technology partnership Research consortia
	TECHNOLOGY		

Picture 10: Strategic alliance model decision-making matrix.

Companies tend to prefer flexible forms of cooperation early in the technology life cycle, i.e. when technology is new and unfamiliar (Osborn, Baughn, 1990) referring to Harrigan 1988). On the other hand, when a new technology is completely unfamiliar, companies may want to share the risk with others. When technology becomes a little familiar to the industry, standardization efforts begin. When technology still is new, but known, companies may be willing to carry more risk and invest more in technology development. When the technology exists, further development can be an intra-company activity, if that was originally the case. Alternatively, if technology is purchased, these agreements can be continued either short or long term depending on market and volume certainty. When risk levels concerning volumes and market increase, companies may want to share the risks associated.

To give a fair and objective picture of technology cooperation activities, it must be stated that the overall literature addressing technology cooperation has a positive tone emphasizing the value added of cooperation. However, some sources of difficulty have been mentioned in the literature (Spekman, Forbes, Isabella, MacAvoy, 1998) and (Harrigan, 1995). These potential sources of difficulty need to be taken into account when selecting a cooperation method, partner and when developing the relationship further. In addition, each company's internal capabilities need to be assessed prior to deciding on a cooperation model (Chesborough and Teece, 2002).

3.4 Supplier integration and design collaboration

Supply chain and supplier integration implies to process integration both up-and downstream. Process integration means collaborative work between buyers and suppliers, joint product development, common systems and shared information flow (Christopher, 1998). Supplier integration can be seen as one of the possible future business models for technology cooperation, with the goal of reducing the time consumed in the product development (Reese, iSource Business, 2001). The level of supplier integration can be defined on four levels from no cooperation to full integration of supplier designing the parts to an interface specification: none, white box, gray box and black box (Simchi-Levi, Kaminsky, Simchi-Levi, 2000). Black box design refers to the situation where supplier has the full responsibility of designing the product, and only the interface to other products has been specified.

Supplier integration is growing in importance as a means to achieve competitive advantage and speed. Monczka (2000) advises that the process should be guided by strategic plan that is supported by the overall company structure and culture. Companies whose development plans are or will be well-aligned with those of their suppliers can utilize the supply chain resources to minimize design and development cycle times, reduce product cost, improve quality level, improve product design, minimize the number, complexity and the cost of design changes and speed the time to market of the product (Monczka, 2000), (Whyte, iSource Business, October 2001). This can be accomplished through (1) use of pre established development plans, (2) use of products and processes developed in advance of new product development efforts (bookshelf technologies), and (3) concurrent development and testing of assemblies, subassemblies, and piece parts (Monczka, 2000). The motives for supplier integration and design collaboration activities are almost identical to the reasons behind technology cooperation apart from the research activities in the early stages of technology development. However, the situation with many companies' project management still is that suppliers are treated as stakeholders instead of partners and project management focus is concentrated in intra-company activities (Cleland, 1994). An example of supplier integration activities are the activities coordinated by Lucent Technologies, where suppliers are brought into product design process to influence the architecture of Lucent's products. The advantages of this approach have been eliminating the cost from being built into design of a particular product and the fact that supplier is willing to invest more in a particular technology required in a supply chain in light of more overall business for the given technology (Carbobe, 2002).

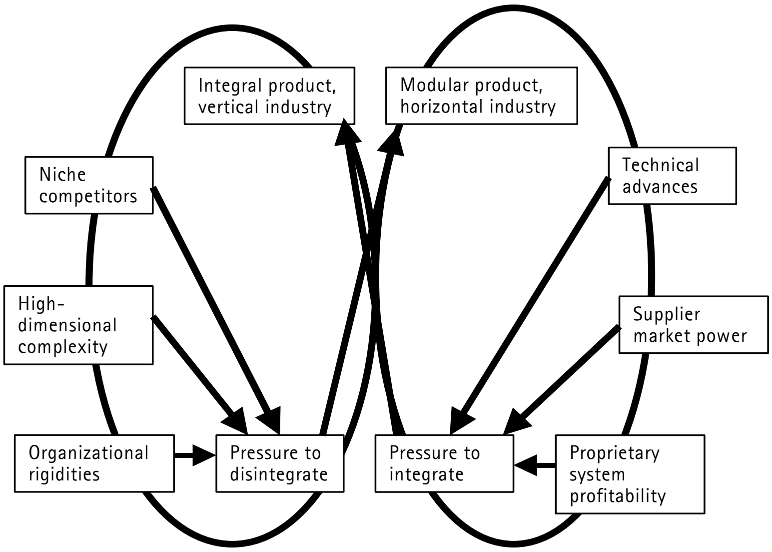
Monzcka (2000), Avery (1998) and Afuah (1998) describe strategic elements for integrating suppliers into a new type of product development process or including new suppliers in the existing process. Elements include having the focus on core technology development process, information and tacit knowledge sharing, resource optimization and joint specification work and technology planning. According to Laseter (1998), the three key concepts in integrating suppliers' in new technology development are: defining the scope, planning the technology and defining the target costing. This approach is different from Monzcka's. His approach concentrates on company internal issues prior to integration, whereas Laseter's approach is more supplier development and joint objectives-related approach. Product development activities and responsibilities proposed by Monzcka (2000) can be classified into three categories: core, leveraged or built-to-print design. For core items company retains all design and development responsibility. Core items define the company's products and are fixed across all products and platforms.

Leveraged items are sourced from a supplier with full design, development and production capabilities. Build-to-print items are usually simple and involve no design responsibility for the supplier. This classification proposed by Monczka can be argued; even core items are being developed in cooperation with key suppliers or partners.

Another way of categorizing the development activities can be done based on the criticality of the supplier and the supplied part or technology. Whyte (Forrester Research) identifies three different levels of collaboration for suppliers (iSource Business, October 2001): involved, integrated and interdependent.

Approximately 60% of the companies fall under the first category, whereas 30% of the companies typically should be in the integrated-category. These companies should be full members of development teams for specific projects. Then, 10% of all suppliers belong to the category of Interdependent. These suppliers should be empowered in every part of the development process (Whyte, iSource Business, October 2001). This categorization carries similarities to the model presented by Monzcka (2000). The main difference between these two approaches is that Monzcka suggests that the design of core parts should remain in-house, whereas Whyte (Forrester Research) proposes an interdependent integration model based on the competencies and criticality. Theory presented by Monczka (2000) on how supplier integration takes place is quite comprehensive, especially when complemented with the supplier categorization presented by Whyte. However, it is hard to collect technologies on a “bookshelf”, when market environment and even supplier capabilities change constantly, cost targets are becoming stricter and if typically all new, cost effective or market driven technologies are productizied as early as possible in any case to gain competitive advantage. Another strategic tool that can assist in supplier integration is time-pacing strategy applied to product development. New products are introduced at a certain pace instead of linking introductions to certain events. Pacing helps communicating the schedules and targets to supply chain and managing the transitions between functions and organizations. Modular product design assists in time-pacing efforts (Brown, Eisenhardt, 1998).

Fine’s (1998) theory concerning The Double Helix provides another approach to integration activities depending on the products and the market situation. Consumer electronics industry is moving more towards modular construction of products.



Picture 11: The double helix by Fine (1998).

What is the difference between supplier integration and early supplier involvement? The difference could be seen in a way that supplier integration gives suppliers their individual tasks as a part of customer's product development process. In early supplier involvement the customer typically distributes the tasks and requirements at an earlier phase of it's own development process. When integrating suppliers to development processes, they become an integral part of the development team. Naturally this is a matter of definition that needs to be done internally by the participating companies. The literature does not address the problematic related to joint project set-up, management, integrated design processes and measuring the success of the team. An alternative, novel way of approaching process and supplier integration is outsourcing a portion of the innovation task to customers to speed up the development process through fewer iterations and versions and by providing products better suited to customer needs. Companies (suppliers) need to provide their customers with proper toolkits for the customer innovation design work such as simulation and prototyping tools. An example of customer innovation approach can be found, for instance, in the semiconductor business. This type of approach is especially beneficial in environments of increasingly customized product requirements, where several iterations/versions of products are created in the product development phase and the use of computer-based simulation tools is wide spread within the company (Thomke and von Hippel, 2002).

3.5 Metrics

A key requirement for efficient inter-company collaboration is a common score keeping and incentive system so that the value chain works from the same numbers and aims toward the same set of goals. Successful value chains have jointly accepted methods of determining costs, margins, and investments (Ashkenas, Ulrich, Jick, Kerr, 1995). Schorr (1998) proposes that the key metrics for effective supply chain should cover eight (8) different areas: delivery, quality, price, lead times, inventory investment, schedule completions in the plant, cost reduction/value analysis and inbound freight cost reduction. Some additional metrics were proposed by Poirier (1999) and Field (iSource Business, November 2001): number of stock outs, turnaround time on materials returned, order lead-time, customer satisfaction ratings, number of sourcing events conducted, percent of savings, the level of Web-enablement of supply base and number of collaborating companies. The metrics tend to be fairly intra-company focused.

The target setting and measurement should be in place from the beginning of the joint activities to measure the value added of the extra effort put into this type of cooperation. The measurements must be presented in terms of concrete, measurable quantitative goals and results. Only subjective and generalized feedback cannot lead to improvement. A pre-cooperation survey could be conducted to collect information and to set the baseline for the measurement (Kneeland, 1996), (Avery, 1998). According to the theories presented by Van Mieghem (1996), Kneeland (1996) and (Extending Your Reach-Networked Product Creation training module, 2001), the most important metrics for determining the success of a partnership are: relationships and attitudes, reducing total cost, meeting profit targets, competitive position, latest technology, investments, flexibility, level of communication attitude, spend, time schedule, issue resolution, communication, savings, quality, market access, legal balance of equity, risks taken, key positions, governance process, relative criticality of inputs, relative success at learning, willingness to invest and design intent.

When establishing metrics and targets for supplier integration, the key elements to be measured are (Monzcka, 2000): cost, product specific metrics such as weight and size, speed and product development time. In addition, long-term relationships should be measured for intangibles such as loyalty. Satisfaction metrics are a good measure in cooperation, but customer and employee retention rates are equally important, as they track behaviors with real financial consequences. A proposed solution found in the literature is the loyalty acid test, which is a set of surveys that measure the loyalty of customers, employees, suppliers, and other corporate stakeholders. The test basically examines a simple question of “does the company deserve your loyalty?” (Reichheld, 2001), (www.loyaltyrules.com). Another tool in addition to metrics that can be used for measuring the performance of an individual department, company or supply chain is benchmarking. Benchmarking can be defined as the search for industry best practices that lead to superior performance (Camp, 1989). Analytically there are three different types of benchmarking: internal, external and operational (Karlöf, 1993).

An area not addressed into detail in the literature review concerning metrics is the fact that some sales and R&D related metrics could be used to evaluate the effectiveness of the supply chain and cooperation: overall sales, sales from new products, discounts and allowances, gross profit, customer satisfaction, quality of end products in terms of returns from customer, obsolescence and market share. Also, the timeliness of new product introductions could be measured, ramp-up speed, number of new technologies being introduced prior to and compared to competition and product development time and costs. The metrics identified in the literature review together with some of the above mentioned metrics have been categorized according to research question and the different theories addressing the particular research question. The theory does not really address the fact whether the metrics are objective or subjective; so researcher has added her own understanding of the quantitativeness/qualitativeness of each metric to the summaries. All possible metrics have not been identified in this study; the metrics proposed are on an aggregate level. The purpose of the metrics review is to present some alternatives in terms of measuring availability and technology cooperation in a supply chain. The formulas for each metric have been defined in appendix 1. The formulas illustrate the usability and practicality of each of the metric.

Table 9: Summary of metrics for theories addressing research question one

Area of theoretical review	Key metrics	Subjective/objective
Availability of supply/sourcing strategies	Lost sales Sales, sales from new products Customer satisfaction On time delivery to customers Market share	Quantitative/qualitative Quantitative Quantitative/qualitative Quantitative Quantitative
Improving demand/supply visibility	Forecasting accuracy	Quantitative
Collaborative planning	Number of collaborating companies Overall supply chain lead time Supply chain inventory investment Customer order lead-time	Quantitative Quantitative Quantitative Quantitative
Supplier coordination	Transaction cost reduction Gross profit	Quantitative/qualitative Quantitative
Scalability of operations	End-product cost reduction Obsolescence Level of excess capacity	Quantitative/qualitative Qualititative Quantitative
Risk management	Quality of end products/customer returns Discounts and allowances Ramp-up speed	Quantitative Quantitative Quantitative
Creating supply partnerships	Partnership satisfaction index	Quantitative

Table 10: Summary of metrics for theories addressing research question two

Area of theoretical review	Key metrics	Subjective/objective
Reasons for technology cooperation	Reducing total cost of end product	Quantitative
Strategic alliances	Reducing total cost of product development Number of new technology introductions Timely new product introductions	Quantitative Quantitative Quantitative
Supplier integration	Product development time Ramp up speed	Quantitative Quantitative
Design collaboration	Size of project team Innovativeness Quality of end products/ customer returns Customer satisfaction Market share Gross profit Sales, sales from new products Speed of change management	Quantitative Quantitative/qualitative Quantitative Quantitative/qualitative Quantitative Quantitative Quantitative Quantitative

3.6 Summary of the theories

The theories, presented to find alternative solutions to address the problematic of ensuring availability of materials short and long-term, address reasons behind availability problems, methods for improving visibility within supply chain such as demand marketing, limited editions-approach, keeping inventory, forecasting models, collaborative planning, consensus forecasting, point-of-sale driven demand management and efficient supply chain management. Different types of supply chain model alternatives have been presented for reference, the recommendation being a model including the end-customer interface representation for improved visibility to the market environment within the chain (Dyer, 2000 and Poirier, 1999). Some ideas are presented for developing existing supply chains into a more customer responsive mode of operating such as S^3-approach (Reese, 2001), BTO-mode (Banham, 2001), risk based profit distribution model (Jarillo, 1988), Poirier's optimization model across supply chain (1999) and supplier coordination (Hines, 1994 and Dyer, 2000).

Four different supply chain management strategies and supplier categorization models have been presented for supplier prioritization and segmentation purposes. All suppliers within a supply chain cannot be managed in a similar manner, so these different models are provided to assist in the categorization and risk management efforts. These models have been presented by Goldfeld (1998), Pearson, Gritzmacher and Karen (1990), Hines (1994), Dunn (2001) and Laseter (1998). As partnerships seem to be the norm today in the consumer electronics business at least theoretically, some theories in the area of creating partnerships have been presented. The main references are to Avery (1998), Kneeland (1996), Goldfeld (1998), Erridge (1995), Doz and Williamson (2001), Dyer (2000) and Van Mieghem (1996). Some guidelines were presented when partnerships add value together with the potential benefits of partnerships. References did not really present data for measuring the value added of partnerships and did not really challenge the concept of partnerships.

The theory review to find solutions to the second research question started with an overview of the concept of innovation strategy (Afuah, 1998 and Bidaut and Cummings, 1994). Reasons for inter-company technology cooperation were collected from several literature references and different forms of technology cooperation were presented. Vertical and horizontal integration was considered as one form of technology cooperation in this study. A model was built based on this data to link the different cooperation models and market related key criteria together to guide the decision making process. Two key criteria, demand and technology, were selected as a basis for a decision-making matrix to determine the most suitable technology cooperation model (Picture 10). Flexibility was seen as a guiding principle in this matrix based on the data presented in the current state analysis of the electronics industry and the practical examples presented in the referenced literature. Supplier integration was proposed as an alternative approach for technology cooperation in the future for driving shorter development times and resource optimization with the supply chain.

The last chapter addressed a number metrics identified throughout the theory review for the different areas covered in this research. All the metrics have been categorized per theory and per research question. The qualitative or quantitative nature of the metrics has been identified per metric.

4. THE SURVEY AMONG OEM SUPPLY CHAIN COMPANIES

The purpose of the survey was to collect the best practices and as much tacit knowledge as possible across the cellular terminal for this study. The data from the survey will be used to add the tacit industry knowledge to the model of constructs that is defined based on the literature review. The survey was conducted within a cellular terminal OEM's supply chain including nine (9) companies from different domains of the electronics industry: OEM's, CM's, component manufacturers, manufacturing equipment suppliers and process material suppliers. The companies were typically first or second tier suppliers to the OEM and had at least one customer in common. The informants were either Key Account Managers from the Sales Department or Managers from the R&D or Logistics Department in each company. The sizes of the companies in terms of personnel and annual sales varied substantially. The smallest company's number of personnel was 300 and sales 80 M USD, whereas the biggest company had over 60000 employees and sales of 13000 M USD. The majority of the companies were in the middle of the range with approximately 15000-30000 employees and 4000-10000 M USD sales annually.

Table 11: Interview schedule and participants of the survey.

Company	**Date**	**Interviewee**
D1	2.2.2001	Key Account Manager
D2	12.2.2001	Key Account Manager
D3	1.3.2001	VP, Research and Development
D4	8.3.2001	Durector, Sourcing
D5	9.3.2001	Director of Operations
D6	26.3.2001	Project Management and Logistics Department
D7	30.3.2001	Key Account Manager together with Logistics Coordinators
D6	30.3.2001	Director of Technology Research
D8	11.4.2001	Regional Sales Manager
D9	14.4.2001	Key Account Manager

4.1 Methods of the survey

The method of the survey was interviews based on a questionnaire (Appendix 2). The questionnaire consisted of four sections: background, new technologies, demand planning and customer-supplier relationship. Interviews were conducted anonymously, so neither the companies nor the participant names will be published. The questions were open ended to collect as much qualitative data as possible. The interviews lasted typically from ninety (90) minutes to three (3) hours and the number of participants ranged from one to three per interview. The questionnaires were sent to the main participants in advance, and it was their decision to invite additional people to participate in the interview session. Some participants also collected information internally from other departments than their own prior to the interview to answer the questions as broadly as possible. Companies were selected based on their reputation and position within their industry, the companies were typically among the industry leaders and had been in the electronics manufacturing business for several years. Some companies were more dependent on fewer customers than others. Attention was also placed on choosing the case companies that would represent as wide a spectrum of the electronics industry as possible and several different countries of origin.

4.2 Key findings

The findings of the survey are presented in three categories: demand planning, technology cooperation and creating partnerships.

4.2.1 Demand planning

According to some survey sources the demand visibility should take place both from top down and bottom up within the supply chain to gain the necessary speed of information sharing, change management and cost savings. The supply chain companies should gain a deeper understanding of the underlying reasons behind demand fluctuations, modifications and possible change patterns rather than getting periodic forecasts from the chain “Nucleus Company”. Companies generally preferred receiving the demand information as raw data, without any flexibility adjustments or buffer percentages. Most companies wanted on-line information on demand changes, but others felt that monthly updates on demand information would be sufficient for their type of operations. Due to the constantly changing end-product demand, participants had difficulties in believing the demand information provided by OEM’s or CM’s and thus they did not necessarily start building/downsizing capacity to correspond to the predicted level of demand due to the fear of over- or undercapacity. The product development and capacity building lead times became longer upstream in the supply chain (for example semiconductor business, customer specific parts). The interviews stated that building extra manufacturing capacity takes six (6) to eighteen (18) months depending on the technology. The extra capacity needs to be in place if the OEM or CM wants to have substantial upward demand flexibility by the time of the ramp-up of a new product. Joint investments, in some cases, show long-term commitment from OEM's side, at least from suppliers' perspective. Some companies mentioned that they would not have knowledge for downsizing capacity, because that has not been a requirement for a very long time especially due to growth in the cellular terminal business. It is also far more difficult and painful to manage downsizing than increasing capacity and most companies preferred having some overcapacity as a buffer against demand fluctuations. A general statement was that different e-business and collaboration related tools are now being investigated, but not yet implemented within the industry, especially among mid-size companies.

One case study participant mentioned PC-industry as an example for a limited editions-manufacturing approach. It could be used as a benchmark to the approach of building a certain quantity of a product into inventory. When those products are sold, the build for next version would start. Another aspect that surfaced was ramping up production for a new product. Several companies in the chain use similar kinds of manufacturing equipment and materials and typically there is no coordination between companies inside the supply chain on aggregate equipment requirements and possible shortage and allocation situations. In reality, supply chain companies are competing against each other in shortage situations. Forecasting as such does not improve or optimize the availability in the chain. Proactive capacity implementation and materials management using the forecast information can help to optimize availability. In the survey forecasting accuracy requirements varied from 50% to 90%, forecasting accuracy formula being the same as described earlier in the study, and the inputs concerning the optimal forecasting time line varied from a one-year period to a period of three years to the future.

4.2.2 Technology cooperation

The survey companies endeavored to gain access to new technologies through several different channels. The main sources of new technology access were:

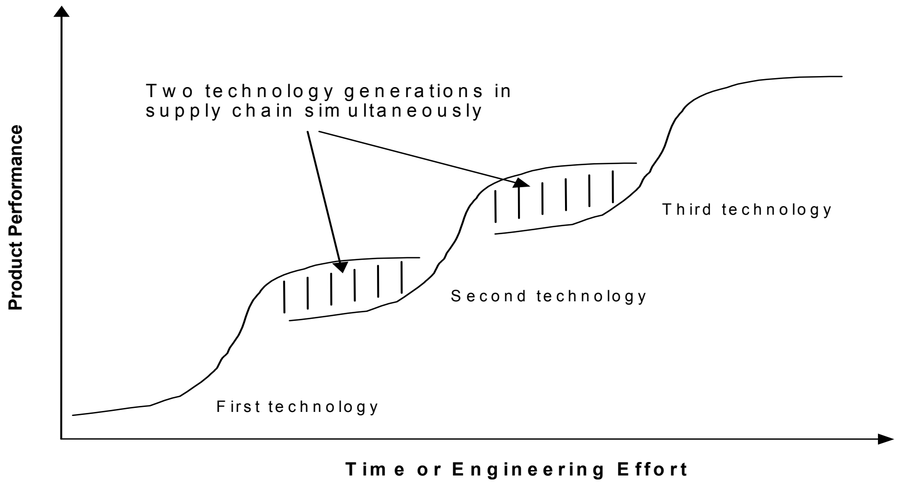
- Joint research with their customers or suppliers
- Start up company cooperation or acquisitions

- Joint research or funding of a specific research at universities and research institutes
- Transfer of ideas from another industry or business area, for instance from automotive business to cellular manufacturing
- Joint research activities with either two or more supply chain members
- Bringing new companies into the supply chain as technology providers

The scope of technology scanning activities was usually two (2) to five (5) years into the future. It was generally stated that the organization doing the scanning needs to be close to the Business Development department so that scanning efforts would not be random, but organized based on future business needs, customer expectations and subject to a cost/benefit analysis. Business Development and Marketing should actually drive the technology scanning process to avoid unnecessary and random scanning. The availability of a promising, new technology was ensured through patents, licensing, and acquisitions, taking equity in a technology provider or co-ownership. Availability towards customers was typically ensured through some initial extra manufacturing capacity. Participation in standardization committees was a common way to guarantee a solid base for future technology development especially for larger survey companies. Other ideas in the area of technology cooperation were:

- Modularity and open interfaces in product design would help joint development efforts and combining supplier-developed parts into OEM's end products
- Multi-disciplined steering team guiding the joint the technology efforts and prioritizing the activities would be beneficial to help meet the development cost and time schedule targets
- One primary technology message from customers to supply chain
- The number of new technologies introduced per product should be controlled based on technology maturity to avoid too high risks when bringing a new product to market
- Customer input collection for new technology development through focus groups

One of the major challenges mentioned in managing and developing a technology portfolio was the fact that different customers are using different technologies. Some continue using "old" technologies in their products when others move immediately towards the latest technologies, when available. It is not cost efficient either financially or resource-wise for a company to manufacture and maintain support for several different generations of technologies simultaneously. This observation ties together with the theory on technology S-curves (Chirstensen, 1997).



Picture 12: The conventional Technology S-Curve (Christiansen, 1992).

Technology roadmap sharing between key suppliers and customers was seen as an essential tool for the whole supply chain to know which technologies are the most prominent ones, according to their end customers, to develop in a certain timeline and also to create a shared picture of the future throughout the chain. One comment was that each company needs to understand their own roadmap thoroughly internally first prior to communicating externally to avoid misunderstandings. New, potential technologies should be analyzed and challenged by customers and suppliers; the companies interviewed felt that technology discussion overall should be more active and challenging inside the supply chain. A frequent comment was that more front-end research people should be involved in the joint research activities from all parties and communication should be constantly ongoing and taking place on the several levels of the organization, not tied to annual or semi-annual technology review meetings. Survey suggests that R&D and research organizations are very careful with information sharing, even too careful. It would also be ideal if new development projects could have joint investments, shared between participating companies and a common, open business case with joint resources and combined competencies to avoid overlap and overlapping activities.

Another typical comment in the survey was that OEM’s and CM’s do not include suppliers in product development early enough and are not necessarily open to new ideas. The processes and working practices within product creation are not typically designed for supplier or third party inclusion to the innovative process. It was pointed out that the scope of the joint development efforts should be fairly broad, exchange should include system and interface understanding in addition to core technology sharing. Development teams should be small enough to be able to familiarize themselves with each other and to come up with innovative solutions in a speedy manner. If the actual manufacturer of the end product is a contract manufacturer, these companies should be involved in product design as early in the process as possible. An usual bottleneck in the development process today is the equipment or a tooling supplier who was not involved in the development process early enough, resulting in long tooling design and manufacturing lead times, especially upstream in the supply chain. Companies interviewed tend to concentrate on technology exchange and development with their customers instead of their suppliers. This makes sense business wise, but it is also equally important to engage in technology exchange and development with second and third tier suppliers to keep the technology related promises to customers and to be able to introduce new technologies in an efficient manner. The same is true with demand planning. Another discovery from the interviews was that it is important to keep in mind that a new technology learning curve can be up to twelve (12) months. With product life cycles getting shorter, some technologies might never reach maturity, as products are phased out before the whole supply chain is optimized for the new technology.

4.2.3 Creating partnerships

Based on the interviews partnership meant creating a common strategic intent up to three to four years into the future. In practice it meant aligning product and technology roadmaps and having joint research activities with common goals and targets. Generally opinions were that partnership efforts need to be performed both in the area of logistics and technologies. These areas have to be developed simultaneously to ensure future supply of technologies, components and equipment. Trust and openness were considered key areas of the relationship together with a win-win approach: what can we do together to make customers satisfied and to create value? Fairness was another value that was frequently mentioned in the interviews: companies expected the value added or the extra revenue to be shared in a fair way between the partners. Companies entering partnerships expect to gain demand visibility through streamlined processes, long-term commitment, joint development and research activities, improved understanding of business requirements, collaborative planning and the ability to generate cost savings through efficiency in using this information. This information is well aligned with the concept of “Social Contract” introduced by Fortgang, Lax and Sebenius (2003). Some participants also saw value in partnerships through positive associated publicity.

Some downsides mentioned for creating partnerships were the emphasis on costs only and customers or suppliers moving away from partnership activities when demand starts to decline or when profit margins are reduced. Some saw partnership as a tool for ensuring availability in high growth times, but not as a tool for continuous development effort in a fluctuating or declining market environment. The balance between price negotiation and partnership has been mentioned in the literature by Baker and Laseter (2002). From the customers’ perspective one of the challenges of partnerships was ensuring the continuous competitiveness of the chosen partners. Few of the case companies stated that typically the partners are in the forefront of technology for one product generation, but their competitiveness often drops for the next generation. Then, in the third following generation the partners are back with the latest, most competitive technology. This pattern suggests that technology competitiveness of companies’ shifts with every technology generation.

The survey results presented in the last few chapters do not really conflict with any of the theories presented in chapter 3. The interview results clearly show that in practice the management of supply chain and technology cooperation is much more complicated than the theories suggest. This difference has been pointed out by literature as well. Spekman, Forbes, Isabella and MacAvoy (1998) address these problematic in their paper on Alliance Management.

As a summary, the most interesting new findings in the area of demand planning that were not widely mentioned in the literature review were:

- Online visibility of end product demand is needed up and downwards in the supply chain
- Sales and/or marketing involvement is required in the supply chain demand planning to increase credibility
- Capacity implementation lead time increases upstream in the supply chain
- Downsizing capacity is perceived as more challenging than increasing capacity
- E-tools are not commonly implemented across the supply chain

- Aggregate requirements of components and equipment should be collected and estimated across the supply chain especially for ramp up situations

These findings are well aligned with the background information presented in chapter 2. Some of the findings can be regarded as statements of the current state in the cellular terminal business, others are recommendations for the future.

The main findings in the area of technology cooperation were:

- Technology scanning activities need to be aligned with Business Development department's vision and cost targets
- Multi-disciplined steering teams should be in place to guide technology cooperation and development within supply chains
- Uniform technology message should be communicated across the supply chain
- Customer input to technology scanning activities could be collected through a focus group approach
- Knowledge transfer should take place between industries and business areas
- Several technology generations are being used in a supply chain simultaneously
- New technology learning curve can be up to twelve (12) months
- There is a tendency to cooperate downstream in the supply chain
- Partnership is envisaged as a tool in high demand growth environment only

These findings comply with the theory presented in chapter 3 and also provide some insights to how technology cooperation is being performed in cellular terminal business. All findings will be taken into account in the model of constructs.

5. BUILDING THE MODEL OF CONSTRUCTS

The findings from the literature review and from the industry survey constitute the model of constructs for this research to find solutions to the problematic addressed in the two main research questions. The constructs related to availability, supply chain management and sourcing strategies are formed to find alternative solutions to the research problem addressed through the first research question: how to ensure availability of components and manufacturing tools? The constructs related to technology cooperation and new technology development are aimed at finding approaches to the second research question: what are the possible, practical guiding principles in developing new technologies in supply chains? Some examples of metrics presented in chapter 3.5 will be linked to each construct as a suggestion for relevant metrics for performance improvement. The metrics proposed for each of the constructs are practical of nature. The selection criteria have been usability in practice and the availability of measurable data. The formulas for the selected metrics are defined in Appendix 1.

The research questions can be detailed based on the literature review and the survey and few sub-questions could be added to refine the scope. The purpose of the refining questions is to narrow the scope of the original research questions to facilitate the model building. The additional questions for the first research question are:

- How to ensure availability in the overall supply chain, not only from OEM perspective?
- How to manage ramp-up and ramp-down situations in the supply chain?

Some sub-questions can de identified to the second research question as well to refine the scope of guiding principles addressing the research questions.

- What are the most beneficial forms of technology cooperation in a given business domain and environment?
- How can product development processes facilitate technology cooperation with third parties?

The purpose of the model of constructs overall is to find alternative, practical and implementable approaches and ideas to the challenges identified in the research questions and in the sub-questions.

5.1 Building a model to answer research question one (1)

As inventory management tools and forecasting models do not provide accurate and timely enough information for demand planning within a supply chain, end-to end demand visibility within the chain is the only alternative for ensuring availability of materials and tools on all levels of the chain. The most critical phases in a product life cycle management are ramp up and ramp down, and overall visibility up and downwards in the chain provides a tool for managing these situations.

Construct 1: To ensure materials availability in a supply chain, demand management should work on-line, providing demand and supply end to end visibility both up-and downward in the supply chain including inventory related information to be used in ramp-up, mass production and ramp-down phase decision making. Proposed metrics: demand planning accuracy and ramp up speed.

This construct is supported by the overview of the current state of the electronics industry presented in chapter 2.1, together with theories presented by Poirier (1999), Christopher (1998) and Greenbaum (2001), Ashkenas, Ulrich, Jick and Kerr (1995), Makridakis and Wheelwright (1990), Lancaster and Lomas (1985) and data collected by Forrester Research (Whyte, 2001). The metrics refer to theories presented by Schorr (1998), Van Mieghem (1996) and Kneeland (1996). Butman (2002) states that a company that does not track actual demand cannot be successful. This does apply to overall supply chain. A research were conducted by Stanford University and Accenture in 1998 stating that companies that shared information extensively withy their supply chain partners enjoyed higher than average profit margins. The survey identified the need to improve demand-supply planning activities within supply chains through shared processes, procedures and information sharing tools. Some product categories could be managed through periodic forecasting, whereas for others shared information systems with 24h visibility are required (Butman, 2002). Industry satisfaction surveys conducted within cellular terminal business during 2000 and 2001 also indicate that continuous updating of forecasts is the most important area of improvement, as according to the participants, the accuracy of the forecasts has been deteriorating since Y2000.

Survey participants stated the preference of using “raw data”, actual demand information, instead of demand data with flexibility requirements and survey also identified the need for overall ramp-up coordination of materials and equipment within the supply chain. Lack of visibility in these situations typically results in sub-optimization within the chain. This finding is supported by theories presented by Shah-Baljko (2000) and Poirier (1999). Gaining supply chains’ commitment to end-product sales plans, especially in case of new products, is difficult due to historically inaccurate forecasts and the fear of overcapacity, so having the end-customer interface involved in collaborative planning across the supply chain will build confidence and commitment within the supplier base.

Construct 2: The end-customer interface of a particular supply chain should be involved in the supply chain collaborative demand planning to increase future market understanding within the chain and to communicate the demand fluctuations in a timely manner across the supply chain to gain trust and commitment. An active demand marketing approach is often required to convince the supply chain to act according to the up-and downward trends in the market demand to ensure materials availability in the long-term. Proposed metrics: sales, sales from new products and gross profit.

Goldfeld (1999) suggested that the strategy should be created and managed by a cross functional team. The survey supports this, as several interviews show that companies feel that there is not enough contact with sales and marketing functions of buying companies to gain market understanding of future demand and new technologies. The customer fulfillment network (CFN) presented by Hines (1994) is a viable approach, as the purpose of CFN is to include end customer interface with the supplier and demand management activities. Poirier (1999) addresses the same problems in his four-level supply chain optimization model. Baily, Farmer, Jessop and Jones (1994) identified the demand planning credibility problems in their theory on demand marketing. Murphree (2003) points out the need for consensus-forecasting and point-of-sale driven demand management. Demand fluctuations and uncertainties in current forecasting methods are the reasons why OEM’s and CM’s need to convince suppliers to believe the demand estimates through supplier forums, top management meetings, supplier associations and through partnership activities. Having the capacity for substantial upward trend in demand is clearly a business decision for the OEM’s. Extra capacity means extra cost and OEM’s need to decide how much are they willing to pay for having the extra capacity on hand. An industry satisfaction survey conducted both in 2000 and 2001 indicate that suppliers do not think that the forecasts given today are reliable and that there is a need for more timely information sharing. It can be stated based on the theoretical background of this study and the survey results that forecasting and collaborative demand planning do improve availability of materials within supply chain. This has also been stated by Sahlin (2001). The metrics have been identified by Poirier (1999) and Field (2001).

In some cases the planning of sales of a particular product may prove to be impossible especially in ramp up and ramp down situations. Alternative approaches need to be identified for these type of situations, limited editions-manufacturing being one.

Construct 3: Limited editions approach can be used for extremely “difficult to forecast” or “erratic demand” –products to ensure the aggregate availability within a supply chain for a given commodity and/or end product. “Limited editions” are also a viable tool for product ramp down management. Proposed metrics: obsolescence discounts and allowances.

Based on the survey, limited editions are being used as a lifecycle management tool within the electronics industry, for example in watch-making, equipment and car industries.

Managing the existing supplier base, from the buying companies’ perspective, is an important aspect in ensuring the overall availability of materials and equipment. All suppliers do not require the same level of attention in supplier management activities to ensure a solid performance.

Construct 4: Supply strategy is a critical part of materials and equipment availability in the long term and the two most important criteria to categorize companies for OEM-driven supply chain are: technology (provided) and (future) volume of each commodity. Proposed metrics: overall supply chain lead-time and on-time delivery to customers.

Sourcing function maturity level theory by Hines (1994) proposes that all suppliers within a supply chain cannot and should not be managed in a similar way. This has also been stated in the supply strategy models developed by Goldfeld (1998) and Pearson, Grizmacher and Karen (1990). Cavinato (1983) emphasizes the number of suppliers being critical in ensuring the availability of the supply. This can be argued, as companies are looking for tighter, collaboration-based relationships with a limited number of selected suppliers (Poirier, 1999 and Harrigan 1995). Similar metrics to the ones presented in this construct have been identified by Schorr (1998), Poirier (1999) and Field (2001).

All companies in the survey did not have the same requirements concerning supply chain management practices. Some criticism was also presented in the survey for partnering being used as a tool for volume growth market environment, but not during the times of declining demand. Harrigan (1995) identifies the problematic: vertical alliances can be threatened by price wars in downstream partner's market. This suggests that collaboration strategies vary depending on end-product market situation.

An interesting finding in the research was that typical bottlenecks in ramp up and capacity implementation situations were the second and third tier suppliers of components and tools.

Construct 5: As investment intensity, the bullwhip effect and capacity building lead-times increase upwards in the supply chain and the speed of information sharing decreases upwards in the supply chain driving verticalization and cooperation preference downstream, all supply chain companies, regardless of their tier, should be on an acceptable level in supply chain management activities to optimize overall availability. Proposed metrics: level of excess or missing capacity, customer satisfaction and customer order lead-time.

Transaction cost theories presented by Dyer (2000) and Picot (1991) suggests that vertical integration is the best alternative within a supply chain, if investments within the chain are very specific. This can be argued, because theoretical background of this study suggests many alternative approaches to vertical integration, such as partnerships, virtual integration (extended enterprise), horizontalization and strategic alliances (Afuah (1998), Dyer (2000), Magretta (1998) and Lewis (1990). Poirier (1999) refers to "deverticalization" stating that critical processing actions should be performed by the best possible chain partner. Asset specificity is a risk management and capacity investment related decision, which is not necessarily tied to company ownership issues. Quasi-integration aspects of vertical strategic alliances can be among the most effective forms of vertical integration strategy due to the involvement of the continuous processes of redesigning task responsibilities in collaboration with suppliers and customers to create more value internally (Harrigan, 1995).

An interesting finding from the survey was that supplier management is typically more professional downstream in the supply chain. It seems that companies are measured primarily for customer satisfaction, as customer interface is managed the most efficiently of all the company interfaces and both demand and design collaboration is preferred with downstream companies, i.e. customers. Survey participants openly admitted that the most of their communication and integration efforts are spent with either existing or new customers instead of suppliers. Harrigan (1995) states that downstream alliances tend to be more risky than upstream ones. This correlates to the purchasing function sophistication model proposed by Pearson, Gritzmacher and Karen (1990). Many companies, especially first and second tier suppliers in an OEM supply chain, still have an operational approach towards their suppliers. Acknowledging this problematic, the theoretical scope of supplier association remains unclear: which suppliers should these activities include, first, second and/or third tier? Theory presented by Doz and Hamel in 1995, using alliance networks as the competence leverage multipliers, applies to this problematic.

5.2 Building a model to answer research question two (2)

The scope of the research question of ensuring long-term technology access within and outside the existing supply chain has been refined with a few sub-research questions. The main purpose of the constructs is to find methods to facilitate technology cooperation within a supply chain and inside each supply chain company.

Sometimes technology scanning and cooperation activities within a company or even within a supply chain are random, engineering-driven, with no real business opportunities. All supply chain companies are not necessarily even aware of the future end product expectations and technology requirements to align the new technology development activities with.

Construct 6: Sales and/or product marketing involvement from the buying company's side in technology cooperation is essential in ensuring the alignment of technology scanning and cooperation activities with the market expectations concerning cost/benefit, product features and introduction time schedules. Proposed metrics: product cost and timeliness of new product introductions.

The prerequisites mentioned in the survey for technology cooperation such as participation from sales and marketing function, roadmap understanding, steering team approach and clear communication guidelines at all levels of organization comply with theory presented by Bidault and Cummings in 1994. The customer fulfillment network (CFN) presented by Hines (1994) applies to this construct as well, the purpose of CFN being to join end customer interface with the supplier management, including technology coordination activities. Industry satisfaction surveys (2000 and 2001) also stated sharing business related information and roadmaps as essential areas in early supplier involvement.

Technology development has traditionally been an in-house activity for most companies. The development process improvement, resource optimization and cost efficiency activities have concentrated mainly on intra-company activities.

Construct 7: To enable cost efficient and speedy design cooperation in each company, inside and beyond supply chains the following prerequisites need to exist inside a supply chain: streamlined development processes, facilitated third party participation in company internal processes, resource optimization and modularity, standardization and open interfaces in product design. Proposed metrics: product development time and cost.

Littler, Leverick and Bruce (1995) and Spekman, Forbes, Isabella and MacAvoy (1998) indicate that clear processes, rules, procedures and allocation of resources are critical to successful design collaboration. The statement is supported by Monzcka (2000) and Whyte (2001). The need for joint product development teams between companies has been identified also in a case study conducted by Lam (1997). Doz and Hamel (1998) address the value added of standardization efforts to enhance the cooperation network and Monzcka (2000) refers to the importance of modularity in optimizing development resources, time and costs. Lewis (1990) states that standards development becomes easier when it applies to large technological changes that require major investments within the industry. This statement supports the criticality of standardization work. According to Meyer and Lehnerd (1997), products can also be designed so that it is easier for external resources to participate the design work, i.e. through platforms and design modularity. Metrics for this proposition can be referenced from theory presented by Monzcka (2000). In supply chains, openness for sharing ideas, opportunity to give input, open interfaces and system design are necessary to gain efficiencies in the overall product development. This has also been emphasized by Christopher (1998). Early supplier involvement needs to be emphasized and the strive in OEM product design should be towards interfaces where the plug and play type of use of third party designed technologies would be possible. Early supplier involvement in part ensures the optimal design also from the suppliers' perspective and helps lower the future logistics and unit costs within the supply chain. These efforts can also optimize the new technology and/or end product development resources needed throughout the supply chain and bring the optimal competencies together that none of the companies possess on their own. The data from industry satisfaction surveys (2000 and 2001) indicates that design collaboration is not as commonly used as it could within supply chains.

The survey suggests that companies want to be more involved in OEM's product design and in an earlier stage than at present, so the survey supports this proposition. Yet it needs to be understood that the overall supply chain needs to comply with common product architecture and design processes to make the cooperation most beneficial. Architectures should optimally be either integral (example Toyota City) or modular (PC's, phones and service) to be mutually reinforcing (Fine, 1998). Standardization work was mentioned in the survey as a tool for technology access. Teams of rotating experts could be used inside the supply chain to coach in shared development work (Harrigan, 1995) and this type of engineer exchange was also mentioned in the survey. Fine's theory (1998) simplifies the supply chain architecture a little: modularity does not necessarily mean slowness and the integrated supply chain is typically not possible to set up either due to geographic, competency or cost reasons. As the survey suggests, flexibility of the supply chain is one of the most important factors in today's business environment, and this can not be obtained with a very tight supply chain design, especially in the situation wherein shifts between OEM manufacturing locations, the use of CM's and changes in the product manufacturing mix and volumes happen fast. The flexibility requirements have also been emphasized in a study conducted by Forrester Research (Beard, iSource Business, 2001).

Consistent and constant information sharing is a basic prerequisite for any cooperation. The reason for emphasizing this in the model of constructs was the fact that information sharing was brought up frequently both in the theories reviewed for this research and in the survey.

Construct 8: End product design and manufacturing process related information is a prerequisite for optimizing the design, quality and costs of end customer products.

Consistent and uniform communication needs to take place on all levels and in all functions of the organizations within the supply chain and management needs to educate personnel on what should and should not be communicated within supply chain. Proposed metric: satisfaction surveys.

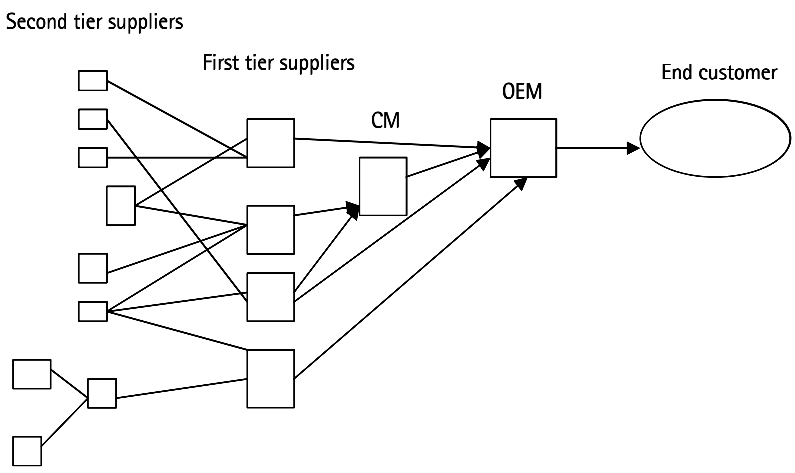
Increased need for communication has been mentioned as one of the key reasons for inter-company technology cooperation. The importance of product development related information sharing within supply chains have also been emphasized by Avery (1998) and Afuah (1998). Forrester Research (Beard, 2001) indicates that poor information sharing is one of the main obstacles for effective design collaboration. Level of communication as a metric has been presented both by Van Mieghem (1996) and Kneeland (1996). Industry satisfaction surveys (2000 and 2001) emphasize the information sharing and openness, or the lack of thereof, in the technology cooperation within a supply chain.

Lewis (1990) supports this construct by stating that inter-firm contacts should happen directly between people with relevant technical, market or other information. These problematic are also similar to theory by Meyer and Lehnerd (1997) concerning supply chain globally being as a source for new ideas and technologies. Survey participants also recommend that communication needs to take place on all levels and in all functions of the organization, especially in research and development organizations in a coordinated manner to communicate a uniform message from each company to another. Management needs to clearly communicate in all companies involved what can and should be discussed with third parties and what should not. Typical proprietary information includes manufacturing volumes, new end product designs and launch dates, certain new technologies and information related to other suppliers. As product lifecycles are shortening and new cellular terminal products are expected to appear in the market on a constant pace, the traditional one-on-one technology cooperation is not the most efficient way of scanning and developing new technologies.

Construct 9: The supply chain's "nucleus company" has an essential role in bringing existing suppliers and new, third party companies together in strategic alliances to coordinate the creation of new, innovative solutions for end-users within the concept of extended enterprise. Proposed metric: number of new technologies introduced prior to and compared to competition.

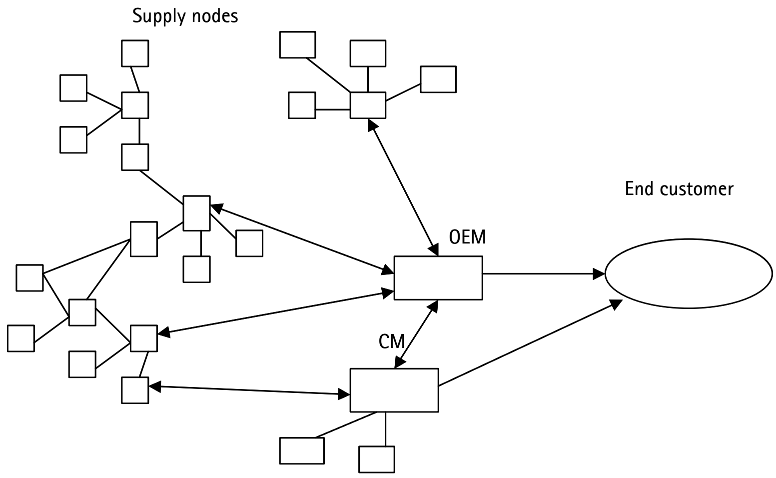
Survey participants commented the buying company, i.e. network "orchestrator" does not need to cooperate with all companies or to develop innovations on its own, but to bring new companies together with nodal companies to create applicable new technology solutions and to encourage suppliers and third parties to cooperate to develop new technologies. This input came mainly from OEM and CM participants of the survey. Naturally traditional type of one-to-one technology cooperation will exist simultaneously. Technology network emphasis is more and more towards horizontalization of efforts to add value instead of driving supply chain companies to integrate (virtually) vertically. These overall "orchestrating" efforts could be called supplier coordination as a form of technology cooperation. Coordination will also encourage companies to cooperate more upstream.

The pictures will illustrate the approach of the "nucleus company" coordinating to bring suppliers and third parties together to create new ideas and applications. The pictures demonstrate the fact that technology alliance management today is more related towards managing a network of alliances instead of multiple individual alliances. At the same time, alliance networks can be used as a competence leverage multiplier (Doz and Hamel, 1995). A study conducted by Vilkamo (2000) concerning cellular OEM technology cooperation supports the idea. The theories presented by Afuaf (1998), Lewis (1990) and Bidault and Cummings (1994) concerning sources for technology innovation support this construct. Prahaland (1990) also identifies ability to build alliances within supply chain as a core competence for especially Japanese companies.



Picture 13: Traditional technologies supply chain within an electronics industry.

This model was constructed based on the information collected from the theoretical background on supply chain management and the survey.



Picture 14: New technology supply model. Technology cooperation nodes are supplying innovations to OEM's or developing them with OEM's and CM's.

The technology cooperation model selected has an impact on the cost of the new technology, future availability and speed of the development, so it is critical to select the right cooperation method in a given timeframe and a particular market situation.

<u>Construct 10</u>: The technology cooperation model selection for new technology creation should depend mainly on two key criteria: market and demand certainty, i.e. risk and novelty of technology and the understanding of future demand. Proposed metric: partnership satisfaction index.

Picture 10 describes the criteria for selecting a technology cooperation model. The picture has been put together based on references from: Hagedoorn (1993), Kogut (1988), Cainarca, Colombo and Mariotti (1992), Tushman and Andersson (1997), Harrigan (1995) and UN Meeting of Experts on Technology Partnerships (1996). Metric used for this construct has been referenced from Reichheld (2001), Van Mieghem (1996) and Kneeland (1996). An increasing amount of OEM and CM product development will and is being done by suppliers and third parties. There are numerous models for technology cooperation the use of which needs to be determined individually the key criteria being, based on the literature review, market and technology certainty. The formality of the cooperation depends on the model selected and the agreements put in place.

The survey participants commented technology cooperation stating that both logistics and technology aspects need to be taken into account in any cooperation. This statement supports the construct stating the two criteria for technology cooperation model: demand certainty (logistics) and technology. Survey participants emphasized fairness, equal risk and profit sharing across the supply chain. This problematic has also been addressed by Kogut (1988) and Jarillo (1988). The survey also suggests that supply chain companies prefer long-term technology cooperation rather than separate, individual technology projects that tend to put the most emphasis on the cost of the technology being developed.

5.3 Summary of the constructs

The charts will summarize the models of constructs and the proposed metrics for both main research questions.

Table 12: Model 1A of propositions to address research question one (1).

Proposition model 1A	**Metrics**
Construct 1: To ensure materials availability in a supply chain, demand management should work on-line, providing demand and supply end to end visibility both up-and downward in the supply chain including inventory related information to be used in ramp-up, mass production and ramp-down phase decision making.	Demand planning accuracy and ramp-up speed
Construct 2: The end-customer interface of a particular supply chain should be involved in the supply chain collaborative demand planning to increase future market understanding within the chain and to communicate the demand fluctuations in a timely manner across the supply chain to gain trust and commitment. An active demand marketing approach is often required to convince the supply chain to act according to up- and downward trends in the market demand to ensure materials availability in the long-term.	Sales, sales from new products and gross profit
Construct 3: Limited editions approach can be used for extremely “difficult to forecast” or “erratic demand” –products to ensure the aggregate availability within a supply chain for a given commodity and/or end product. Limited editions are also a viable tool for product ramp down management.	Obsolescence, discounts and allowances
Construct 4: Supply strategy is a critical part of materials and equipment availability in the long term and the two most important criteria used to categorize companies for OEM-driven supply chain are: technology (provided) and (future) volume of each commodity through end product market changes.	Overall supply chain lead-time and on-time delivery to customers
Construct 5: As investment intensity, the bullwhip effect and capacity building lead-times increases and information sharing decreases upwards in the supply chain driving verticalization and cooperation preference downstream, all supply chain companies, regardless of the tier, should be on an acceptable level in supply chain managemet activities to ensure overall availability.	Level of excess or missing capacity, customer satisfaction and customer order lead-time.

Table 13: Model 1B of propositions to address research question two (2).

Proposition model 1B	**Metrics**
Construct 6: Sales and/or product marketing involvement from the buying company's side in technology cooperation is essential in ensuring the alignment of technology scanning and cooperation activities with market expectations concerning cost/benefit, product features and introduction timeschedules.	Product cost and timeliness of new product introductions
Construct 7: To enable cost efficient and speedy design cooperation in each company, inside and beyond supply chains the following prerequisites need to exist: streamlined development processes, facilitated third party participation in company internal processes, resource optimization and modularity, standardization and open interfaces in product design.	Product development time and cost
Construct 8: End product design and manufacturing process related information is a prerequisite for optimizing the design, quality and costs of end customer products. Consistent and uniform communication needs to take place on all levels and in all functions of the organizations within the supply chain and management needs to educate personnel on what should and should not be communicated within supply chain.	Satisfaction surveys
Construct 9: The supply chain's "nucleus company" has an essential role in bringing existing suppliers and new, third party companies together in strategic alliances to coordinate the creation of new, innovative solutions for end-users within the concept of extended enterprise.	Number of new technologies introduced prior to and compared to competition
Construct 10: The technology cooperation model selection for new technology creation should depend mainly on two key criteria: market and demand certainty, i.e. risk and novelty of technology and the understanding of future demand. Proposed metric: partnership satisfaction index.	Partnership satisfaction index

6. CASE STUDIES

Three different case studies are presented to test and to validate the model of constructs created based on literature review and the tacit knowledge presented in the survey. The cases will be presented one by one followed by a cross-case analysis. The main findings supporting the constructs have been underlined in the following chapters for easy identification and reference. The evidence validating the overall model of constructs is presented after the cross-case analysis in chapter 7. Findings per case study, if applicable, will be presented to support each of the constructs separately. This approach has been selected to avoid repetition, as all case studies present evidence to validate most of the constructs.

When conducting a case study, as stated by Eisenhardt (1989), material can and should be collected from several sources. Data collection questions can be presented either to an individual (interview) or an organization (documentation, archives). Other sources of evidence can be observations and physical artifacts. All these sources of evidence have strengths and weaknesses, so multiple data collection methods should be used (Yin, 1994). The main data collection methods have been project meeting memorandums, companies' strategy material, policies, action plans, existing metrics, project plans and updates, interviews, existing process descriptions and participant-observation techniques.

6.1 Selecting the cases

The case studies have been selected due to their applicability to the research based on their contemporary nature and an interesting before and after supplier development analysis opportunity. The case studies also endeavored to capture the tacit knowledge from the cellular terminal business in the theoretical areas of the research. The main criteria for selecting the cases were: accessibility to cellular terminal business related information, recent and actual project, scope of the case, internationality, fairly typical example of technology cooperation and/or supplier development project and related to research questions of this study. The two first cases describe a supplier development project, the background, concrete actions taken to improve the existing situation between an OEM and a supplier and then the measures and feedback concerning the successfulness of the implementation. The before and after approach in the two first case studies profound the understanding of the current challenges in the cellular terminal manufacturing industry and the solutions proposed demonstrate the tacit knowledge available within the industry in the areas of supply chain management and technology cooperation. Similar approach, supplier development teams, has also been described in the literature by Christopher (1998). The third case study describes an actual technology cooperation project between an OEM and an electronics material supplier. It also demonstrates the possibilities of bringing third parties into a cooperation project. The timeframe of the events in all three cases is approximately the same, from 1999 till 2002.

The criteria were selected according to Yin's theory (1998) and based on the requirements of the study. The companies involved in the case studies are a cellular terminal OEM, a global material supplier and two equipment suppliers. The OEM company is the same in all three case studies. All before mentioned companies have been working with the OEM for several years, and there is a supply relationship among all of the companies vertically with the OEM but typically not horizontally.

6.2 Data collection methods

The case study protocol for the first two cases, supplier development projects, was a review of an actual project documentation collected mainly from the OEM. The case study material consisted of management meeting memorandums, executive summaries, project team meeting memorandums, factory feedback documentation, project plans, strategy material, supplier rating results, company level action planning, audit results and follow up documentation, process descriptions and supplier management meeting memorandums. Both participating companies created and archived their own documentation. Participant-observation was used together with informal interviews of the project management teams to increase understanding of the project. The main case study protocol in the new technology cooperation case study was interviews. The interviews were conducted either personally or via teleconference. Some project related documentation such as project plans and project reports were reviewed. The interviews were based on a pre-designed questionnaire. The questionnaires were distributed to participants prior to the interview together with basic information concerning the overall research and objectives of the case study to allow the participants to familiarize themselves with the questions as proposed by Bulmer (1988). The questionnaire is available in Appendix 3.

The time schedule of documenting all three case studies was the spring of 2002. The actual projects took place between 1999 and 2002 and some spin-off or complementary projects were still ongoing in late 2002. The table below describes the different types of data available per case study.

Table 14: Main types of data collected for the case studies

Type of data available	Case A	Case B	Case C
Project plan	X	X	X
Process descriptions	X		X
Project meeting minutes	X	X	X
Management meeting minutes	X	X	X
Steering team meeting minutes	X		X
Supplier rating data	X	X	X
Reported metrics	X	X	
Strategy material	X	X	X
Documented feedback	X		X
Improvement plans	X	X	
Formal interviews			X
Final report	X	X	X
Participant-observation	X	X	
Informal interviews	X	X	X

6.3 Company A supplier development project

The participants of the project were a cellular terminal OEM and one of its' suppliers. The OEM was experiencing high growth in end product demand at the time of starting the project, which later declined due to market environment changes. The supplier had been an important supplier to the OEM since the early 1990's specializing in manufacturing equipment and services. The company had been growing together with OEM and went international during the 1990's to be able to support the OEM on a worldwide basis and to expand their business. During the time of the project the supplier went from insufficient capacity, personnel and components to serious overcapacity situation both in terms of manufacturing capacity and personnel.

It was decided in the regular management meetings held between the two companies in late 1999 that the existing cooperation needed to be taken to a more detailed level to develop the existing business relationship and possibly move towards partnership. The participants of the management meeting were senior managers and commercial personnel from both companies. It was agreed that a two-year supplier development project would be started to develop certain, predetermined areas of cooperation between the companies to strive towards a more systematic and controlled method of working together, to minimize market environment generated risks and to ensure continuous flow of necessary equipment, service and support to OEM manufacturing facilities worldwide. The ultimate goal of the joint undertaking was to develop a joint supply and technology strategy for the given technology area for these two companies. The supplier readily adopted all changes and ideas presented by OEM, largely due to the fact that OEM represented a significant part of company A's overall turnover.

The start of the project took place during the growth period of cellular terminals, late 1999. Many suppliers, including the supplier in question, had difficulties meeting the increasing demand of the equipment and services globally. By the time the project was determined to be completed, the growth had basically stopped and the amount of business between the two companies had started to decline dramatically. This fact adds an interesting aspect to the overall case study, <u>how to execute supplier development and cooperation activities with a critical technology provider in a declining growth environment. In addition, should the supplier management practices remain the same or vary based on the market changes?</u>

6.3.1 Drivers for supplier development

The main input for starting the development project came from several sources on the OEM side: factories, new product development programs, commercial personnel managing suppliers, quality department, corporate communications and the risk management team. OEM management felt the portion of the supplier's overall business with the OEM was too great and was becoming a risk, as <u>the supplier was a single source for the OEM in the area of certain technologies</u>. Factories and product development teams felt that <u>equipment development and delivery lead times were too long</u> and that the equipment <u>deliveries were often late</u> jeopardizing the OEM product ramp-up efforts. The OEM management also stated that <u>equipment quality was not on a satisfactory level</u>, as equipment were not always working when it arrived on the production floor and a lack of common equipment development processes between the companies was making communication more difficult and slowed the development process.

The issues OEM factories, sourcing department and the technology organization saw as areas for improvements were: price breakdowns were not available, delivery accuracy and quality level poor, joint projects were not effective, supplier's service effectiveness was not on a sufficient level, the latest technologies were not available in sufficient quantities, trust between companies was missing, there were too many open, unresolved items ongoing, time schedules in projects and deliveries were slipping, new product information sharing was poor from the supplier, the roles and responsibilities in the supplier's organization and in joint development projects were unclear, development and implementation projects took too long a time and too many resources were required in projects from the OEM side. There were also concerns in the areas of contracts and pricing agreements and information safety. OEM perceived that the costs were not aligned with the quality and performance of the equipment.

The supplier felt that OEM requirements were often contradictory, projects were not well organized and that there was no mechanism to give an early warning of future requirements project or demand-wise, so they were not able to plan the production or project resources properly. The projects were not prioritized from the OEM's side; project requests from the OEM were ad-hoc, un-approved internally and not communicated centrally. The attitude of some OEM employees was not respectful towards them and they were asked to perform non-value adding tasks for the OEM without compensation. The supplier was not involved in development projects early enough and enough information was not shared with them concerning the project requirements and overall development interfaces. This resulted in a situation where both companies were using their own development resources separately instead of cooperating fully and thus adding overhead cost.

As a summary, the overall drivers for the company A supplier development during year 2000 were: OEM's big percentage of supplier's sales, company A's role as a key supplier, sourcing targets for cost, quality and lead times, supply strategies and risk management, feedback from factories concerning supplier's products and services, unclear roles and responsibilities between the companies, some undefined processes, lack of trust on both sides, no demand planning, mismatches in communication, lack of early supplier involvement and information sharing in customized equipment development projects and inefficiencies in project work.

The drivers for cooperation started to shift gradually towards new business requirements, and during spring of 2001 the OEM presented a few new focus areas: reusability of existing assets, minimizing excess asset inventories, increasing emphasis on service and support and optimizing the number of resources for equipment development projects. The required OEM capacity was in place, and major new investments were not necessary. The OEM indicated that the future business areas for the supplier would not be the same as they had been in the past, but rather a narrower scope of equipment and low-cost solutions. OEM factories focus were also changing; the majority of capacity increases were made in countries that did not require the same amount of manufacturing equipment as higher labor cost countries. End customers' requirements towards the OEM started to change as well: order lot sizes became smaller and the number of variant end products required increased. So the overall manufacturing, at least partially, needed to move towards more flexible solutions. This resulted in a major decrease in business between the OEM and the company A.

6.3.2 Project organization and set-up

The project was officially started during first half of 2000 when a project plan was initiated and approved by the OEM and the resources were nominated from both companies. The responsibility of the project team was to find solutions to the focus areas identified as drivers for the project through current state analysis, develop and integrate existing processes, share best practices and implement in both companies efficiently. The project team was also responsible for setting up and reporting metrics to monitor the progress and the value-added of the development project. The Project Manager was an OEM resource. All resources selected for the project team were people working in the customer/supplier interface on a daily basis either commercially or in technology development projects. Participants represented commercial, quality and technical functions. The project tasks were split between teams consisting of pairs, each pair having a participant from both companies. The number of pairs depended on the timeframe, during 2000 there were 4-6 pairs involved in various project related tasks, whereas during 2001 there were 2-3 pairs carrying out the tasks. Project reviews were held quarterly by the management of both companies in conjunction with the regular management meetings, so the management team acted as a steering team for the development project. The Project Manager was also part of the steering team. Rough company A's supplier development project related meeting schedule is outlined in the table below.

Table 15: Company A supplier development project meetings schedule

Time	Management meeting	Project team meeting	Quality review	Other
1999	14/9			
2000	29/2, 31/5,	13-14/4, 13/6, 26/6, 24/8	17/5, 20/6, 18/7, 17/8 10/11, 19/12	24/5 project approval
2001	26/2, 12/4, 27/11	9/1, 25/3, 3/4, 22/5, 4/6 11/6, 18/6, 30/8, 18/9, 10/10	12/1, 23/4, 25/11	25-26/1 management seminar 13/3 strategy workshop 2/4 communication meeting 11/9 process integration day
2002	23/1	23/1		

6.3.3 Focus areas

Towards the end of 1999, it was decided in a joint management meeting that there would be three main focus areas for the supplier development project with company A. The decision was based on the drivers described earlier. The areas selected at that time were:

- Joint equipment development process
- Demand/supply planning process
- Quality (especially for customer-specific equipment)

Some improvement ideas and procedures implemented during 2000 were:

- Written project agreements (to clarify scope, cost sharing, ownership and responsibilities in technology projects)
- Project steering groups (to guide decision making, specification change and gap management)
- Use of monthly forecasts to reduce delivery lead times and plan supplier manufacturing and materials capacity
- Use of a common development process for customer specific equipment development
- Specification change management process for customer specific equipment
- Having supplier's engineers in OEM facilities as part of project teams
- Increased information sharing through technology roadmaps
- Standardization efforts in equipment development
- Modular approach in customer specific equipment development (idea presented in 2001)

During spring 2000, after the project work had already started, the focus areas were refined in more detail after new information was gained through the current state analysis. The project plan outlined the new key focus areas:

- Quality improvement for mainly customer-specific equipment
- Total cost of owning and running the equipment
- Process integration for four key processes:

1. New equipment engineering process
2. Product delivery process
3. Change management process
4. Feedback process

The targets defined in the original project plan do not really differ from the refined ones. The tasks have just been split into more manageable pieces. The cost aspect has been prioritized more than initially, as cost was one of the project drivers originally identified from several sources. The discussions concerning an electronic information sharing system were started during spring 2000, when the supplier started working on an Extranet-solution that could be accessible to certain OEM employees. The initial scope of the solution to be developed was purely commercial, but evolved later towards a project information-sharing tool.

The following targets were added to the project in 2001, mainly due to the changing business environment as described in first chapter of this case study: reusability of existing products, minimizing excess equipment inventories and increased emphasis on worldwide service and support. Some other new ideas were also presented during 2001, such as moving towards supplier provided consulting services to replace OEM in-house activities in the areas of manufacturability, and after-market planning, i.e. life-cycle management of equipment. These two ideas were never thoroughly followed-up.

6.3.4 Project progress in quality improvement

In quality, the baseline for process and product quality was set through quality system audits and current process reviews for both companies. Problem areas were identified being customer specific parts and equipment development. One of supplier’s facilities was selected as a pilot factory for the efforts. Supplier audit non-conformances were followed-up, and measuring of on time delivery (OTD) and dead on arrival (DOA) continued against a baseline defined earlier in the project. On time delivery was measured against OEM requested date with an error margin of three (3) days up and downwards and compared to all deliveries in a particular time period. Dead on arrival was measured as ratio of equipment that did not function immediately after delivery and installation compared to the overall delivery quantity over a period of time. There were challenges: the supplier did not always think closing the audit non-conformances would add value to them, and the OEM addressed some of the quality related issues on a too theoretical level. Project resources lost interest in the project for a while due to the before mentioned issues. The project was revisited in late 2001 to measure the successfulness of the quality and the process improvements through OTD and DOA measurements. Factory feedback helped to start factory-level quality meetings. Quality reviews we initiated with the supplier and the main customer factories regularly to address product and process quality related issues and to agree on actions on a systematic manner.

The metrics defined for quality improvement were on-time delivery and dead-on-arrival (DOA) rate. The baseline for on time delivery was 97% for standard products and 50% for customer specific products during January-May 2000 time period, meaning that 97% and 50% of the deliveries were on time within a three-day window. The targets set were: 100% on time delivery and 0% DOA. Actual OTD for standard products reached 100% in early 2002, and the OTD for customer specific parts was around 96% in early 2002. DOA rate was 1,6% during the same time. Naturally OTD and DOA varied during the project, in year 2000 standard equipment OTD was between 98%-99% and custom specific equipment OTD was between 82%-100%. However, the targets of 100% OTD and 0% DOA were almost met, and this demonstrates the value added of demand planning and process integration.

6.3.5 Process development

It was noticed at the very beginning of the project that the change management process was driving the quality improvements; many quality related challenges were due to a poor change control and management between the two companies. The development change requests and the changes executed were not always documented and as a result, the end products shipped to the factories were always different. The possibility of errors was increased by the lack of open dialogue between separate development teams, and the lack of understanding of the interfaces in the overall development. The purpose of the change management process was to help the supplier control customer proposed changes during the product development and life cycle and to enable copy-exact product deliveries of customer specific equipment to OEM factories. The purpose of this process is to have controls in place for change approval, execution and documentation by OEM as a requestor. On both the OEM and the supplier side, clarifying and implementing a change management process helped in making the internal development projects in that particular technology area more systematic and helped improved the quality and on-time delivery of customer specific equipment. In addition, an integrated process enabled companies to work more closely together and also helped OEM to understand the value added of early supplier involvement (ESI) and common processes in customer specific equipment development.

At the same time the supplier was working on improving the feedback process between the two companies. An official process for receiving and processing feedback was defined and communicated to all OEM facilities. Response times were predefined to give timely solutions to feedback presented by customers either through e-mail, phone or the Internet. The feedback process was used as one of the tools to improve communication between the two companies on various different levels and between different organizations. The feedback process implementation and the OEM factory quality meeting practice increased the customer satisfaction on the OEM side. This can be seen in the OEM supplier rating results, as service effectiveness score is 100% better during 2001 compared to the previous year.

The process integration team started off by defining the best practices at both companies to determine which processes to adopt and integrate. It was decided that the OEM's equipment development process would be followed and the supplier adjusted its' internal development process to reflect that. It was decided in the spring of 2001 that the supplier would have the main responsibility for the equipment development and the OEM's primary role would be reviewing and guiding the progress of the development. The responsibility of the development was given to the supplier to save resources on the OEM side and to avoid duplicate efforts. Emphasis was put on the fact that as many solutions as possible should be standard, usable by several of supplier's customers. The OEM also took a role in bringing third parties, i.e. other equipment suppliers or technology providers together with company A to develop standardized solutions, company A acting as a technology integrator. Standardization was enabled through commonly agreed parts lists for equipment to facilitate the supplier's component sourcing process. The OEM gave company A insight, in a sense consulting, to process development especially in the area of customer project planning and management, R&D processes, product creation manuals, change management process and customer feedback processing. The development work that was carried out during the project will be a solid ground for future process development and improvement in both companies. Even if the joint equipment engineering process did not end up being used, a lot of progress was made in the area of equipment and component standardization, customer specific equipment modularity and development project resource optimization. The data provided by the supplier show that standardization efforts were able to cut the development and manufacturing costs by 15%-25% and bring the reusability rate up to 80%. These efforts also reduced the number of company A's suppliers and made the supply base more manageable.

A monthly forecasting process was established so that supplier would get information on the future requirements to prepare the capacity for the deliveries and to pass the information to its' suppliers. The intention was that the forecast would act as a non-binding blanket order for six (6) to twelve (12) months to the future, and actual purchase orders (PO's) would be call-off's based on the blanket order with as short lead times as possible. Due to the inaccuracy of the forecast, it was not used as a blanket order, but capacity was reserved based on the estimates, and lead times for standard equipment were reduced by 30-50% with the target delivery lead-time being four to six weeks. Forecasting accuracy from OEM side varied between 30% and 80% with forecasts being more inaccurate for custom designed equipment. This was measured against an actual order book provided by the supplier. Due to improved forecasting and general downturn in OEM orders, there were no real capacity constraints during 2001.

As a demonstration of the work done in the area of process integration, a joint OEM and supplier process integration day was held during the fall of 2001. The process areas reviewed included RFQ management, the engineering process, the order fulfillment process, the change management process and feedback process. The intention was to raise the awareness of the common processes outside the project team, educate and encourage people to work according to the commonly agreed processes.

6.3.6 Total cost of ownership

The use of project agreements and steering teams did clarify the roles and responsibilities within the development projects. The plan was to optimize the number of resources needed in common development projects by relocating supplier's engineers at OEM premises or giving the supplier more responsibility for the overall development. Another reason was to avoid double resourcing, i.e. having one full project team on OEM side and another at the supplier. This relocation actually never happened during the supplier development project. OEM engineers were also educated about information sharing guidelines and limitations and courtesy when dealing with suppliers, and about bringing them earlier to the OEM end product development.

Common cost model development started in late 2000 with the intention to build a generic price breakdown model for customer specific product development project quotations and pricing. At the same time, discount targets of 25% had been determined for standard products on an annual basis. The cost reduction target of –25% was not quite met, and by the end of year 2001 a level of –15% to –20% was maintained off the supplier's standard prices. It was stated that this level of discount was sufficient with the decreased sales between the two companies. The progress in the area of the common cost model was extremely slow, due to differences in company cultures concerning sharing cost related information, lack of trust, misunderstandings in the level of detail required and changes in the responsibilities. General discount levels and project discounts had been agreed in 2000, and the cost breakdown model was finally agreed to in late 2001. This model outlined the costs related to materials, different kinds of labor, administrative overheads and profit. The purpose of the cost breakdown model was to demonstrate the cost savings through standardization and to increase understanding of the cost implications of specification changes and over specifying. It was also used as a tool for decreasing equipment costs. As described earlier, more emphasis was also put on global service and support, and service and spare part logistics and costs were agreed in late 2001. The standardization efforts done in equipment development also facilitated the spare part logistics.

6.3.7 Partnership efforts

Both companies' management met in early 2001 to discuss partnership strategies with proposals for joint company culture, a competency pool, communication models and existing challenges. As a result of this third-party facilitated session, the official joint supply and technology strategy creation work started. Joint strategy creation was seen as the next step after the supplier development project in proceeding towards partnership. A common strategy exercise was started covering six areas: business processes, organizational integration, technology leadership, quality, responsive supply and cost. The groundwork was done by reviewing both companies' existing strategies in these areas, keeping the particular technology scope in mind, finding common goals and targets and identifying areas where joint activities and strategy could add value. The joint strategy outline included: strategic intent, scope of joint activities, value creation to both companies, core competencies and processes of both companies, key interfaces, organizations, costs and the action plans.

These areas are well aligned with the overall drivers and activities addressed at the beginning for the supplier development project. Once the strategy document was created, the overall development project slowed down due to the changes in the business environment and the strategy work was never officially completed. As described throughout this case study, substantial progress had been made in implementing various areas of the actual strategy, although the final target of true partnership was never accomplished. Joint strategy creation was meant to improve mutual trust, show OEM commitment and involve the supplier in collaborative planning. Overall project progress was decelerated during second half of 2001 due to changes in both companies' management. New people who became involved in the activities did not quite understand the scope and purpose of the project. This problem was overcome by reviewing all drivers and project plans again with the new management and the new project team members. Senior management support helped in overcoming the discontinuities.

6.3.8 Communication

Due to changes in both companies' ways of working and key personnel, communication remained as a topic in all the project meetings. OEM engineers sent development requests, sometimes un-approved by management, to the suppliers that tied their resources and did not result in anything concrete. This wasted supplier's resources and added to the overall costs. During 2001, the scope of the initially proposed Extranet solution included contacts, pricing, demand planning, project related items, scorecards, open actions, product information and change management related items. The work on joint information systems was cancelled due to the potentially high cost of the application.

6.3.9 Changes in project drivers and metrics

The metrics of the overall supplier development project evolved as the project progressed and when new drivers were added. The use of a quarterly scorecard started in Q3/2001. Due to various reasons, progress was not made during second half of 2001 and the scorecard was never effectively used. The focus remained in defining good and efficient metrics that could have been useful in managing the relationship, but baselines were not really set for most of the metrics. A table in the next page will illustrate the changes in project drivers, focus areas and metrics during the length of the project.

An OEM supplier rating system was developed for the particular technology area suppliers regardless of the project in question. The data collected from that rating system was used as a metric in the project. The rating system was the official feedback mechanism that the OEM used in providing both objective and subjective feedback to main suppliers semi-annually. The rating results for company A do show some progress in different areas of cooperation. The score is from zero (0) to four (4), zero (0) being the lowest and four (4) being the highest. The rating system addresses most of the areas of company A supplier development, and the data clearly shows the need for improvement in the areas outlined for the project such as cost, quality and delivery. One of the reasons that the use of metrics was not implemented could also be the fact that one system, the rating system, existed already, so separate metrics were seen as duplicate work.

Table 16: Company A supplier-rating scorecard

ITEM	Weight	Score Q2/2001	Score Q4/2000
QUALITY			
MTBF		2	3
Assessment results		3	2
Customer complaints		4	1
Quality system		3	3
COST			
Total cost of ownership		2.7	2.1
Equipment price competitiveness		1	2
Terms of payment		0	0
DELIVERY			
On time delivery		0	0
Lead time		2	4
Use of forecasts		2	2
SERVICE & SUPPORT			
Service effectiveness		2.8	1.9
Global support		3	3
Quality of LSA		2.2	2.0
TECHNOLOGY			
Technology roadmap		2.2	2.0
Latest technology		2.3	2.0
Effectiveness of specific product development		2.1	2.2
		2.14	2.00

As the results show, progress in many areas had not been very rapid, but improvements could be identified in the area of total cost of ownership, the level of customer complaints and the service effectiveness. The overall rating for company A was below average compared to the other main suppliers in that particular technology area. This is partly because the supplier provided customer specific equipment instead of standard equipment, and that was reflected in the customer satisfaction and the equipment lead times.

Table 17: Summary of case study drivers, focus areas and metrics based on a project timeline.

	1999	2000	First half of 2001	Second half of 2001
Drivers	Lowest total cost Delivery accuracy 100% Quality level 100% Project effectiveness Service effectiveness Latest technology Improved information sharing	Lowest total cost Delivery accuracy 100% Quality level 100% Project effectiveness Service effectiveness Latest technology Improved information sharing	Reusability Excess asset management Service and support Resource optimization	Reusability Excess asset management Service and support Resource optimization
Focus areas	Joint equipment development Demand/supply planning Quality improvement	Quality improvement for specific eq. Process integration: Equipment engineering Demand/supply Change Management Feedback Total cost	Excess asset management Standardization work Service and support	Excess asset management Standardization work Service and support
Metrics		OTD to customer req. date OTD to supplier confirm. date Number of customer complaints Troubleshooting response time First time quality Production downtime Product return rate	Set-up times Minimize excess assets Supplier rating score Factory open items OTD to customer req. date Dead on arrival	Standardization rate Price reduction Minimize excess assets Depreciation cost Factory open items Supplier rating score OTD to customer req. date Dead on arrival Ramp-up speed Set-up times Change mgmt control Service level improvements

6.3.10 Results

Table 21 summarizes the key accomplishments of the company A supplier development project. Regardless of the results, there are areas that could be further developed in the cooperation between the two companies. These areas include: early supplier involvement in customer specific product development, overall communication, total cost of ownership-understanding, increasing modularity and reusability of equipment and the role of the equipment supplier inside end product supply chain.

As company A is a main supplier in the particular technology area, this development work will continue after the closeout of the official project. The project team members stated that even if the downturn in cellular terminal demand slowed the project time schedule and implementation, it gave both companies the possibility to review and improve existing processes and ways of working together. When the demand soars, both companies are better equipped to take the challenge.

Table 18: Key results of Company A supplier development project

Key results of Company A supplier development project	
Actions	**Concrete value-added**
Company A internal process development	Improved internal product development process Equipment standardization and modularity Regular technology exchange More efficient project planning and resourcing
Forecasting process implementation	Shorter lead-times for standard equipment Less capacity constraints at supplier Better visibility to supply chain (OEM) Equipment rotation between OEM factories Improved On-Time-Delivery from supplier Increased OEM factory planning
Change management process implementation	Process integration between two companies Clear interfaces in equipment development Improved communication in equipment development Improved product quality Understanding the value added of ESI
Feedback process	Systematic process for giving feedback Improved response times Increased customer satisfaction Factory quality meeting practise
Total cost	Common agreement on volume discounts Cost breakdown model for project pricing Reasonable service and spare part pricing
Other areas	More open communication in all areas of cooperation Building trust

6.4 Company B supplier development project

The case study describes a supplier development project that took place between two major electronics companies, cellular terminal OEM and a test instrument supplier during 2000-2002. Company B is the biggest supplier of test instruments for the OEM based on the overall annual OEM spend. Its' status as the equipment supplier with the largest spend has remained during the past several years from the mid 1990's until 2002 and beyond. Company B provides OEM with standardized test instruments and related services globally to most factories and R&D centers worldwide. The supplier is critical in developing test instruments and methods for testing future generations of OEM end products. Company B initially started custom test equipment development and manufacturing based on a request from OEM. The relationship between the two companies has been good, but a little distant and very headquarters-driven. Company B is not a single source supplier, but clearly a key supplier to the OEM. Company B is a hierarchical company, where decision making and implementing new ideas take a fairly long time. OEM is one of the largest customers of company B, but it is not dependent on the business coming from the OEM. It also needs to be noted that company B supplies equipment to OEM's suppliers' and customers as well within OEM's overall supply chain.

The fact that customer-supplier relationship had remained on an arm's length level and to ensure availability of future technological requirements, OEM wanted to start a supplier development project. The target was to improve the relationship, build trust, to address a few problem areas in the existing relationship and to build a systematic way to exchange information on future technological requirements concerning product testing. A quality system audit held in early 2000 at several of company B's manufacturing plants triggered the need to improve the relationship and working practices between the two companies. Another key trigger for deeper cooperation were the availability problems experienced during 2000 with company B's new generation products. The new instrument in question was in allocation due to limited availability for more than six (6) months causing a lot of concerns to OEM, who was at that time upgrading factory test systems to that new generation of instruments. The decision to proceed with the supplier development project was made in a joint management meeting held during late 2000.

It needs to be noted that the business environment changed quite dramatically between 2000 and 2002, so the drivers of the cooperation in early 2000 were not necessarily the same in early 2002. The growth in the area of cellular terminal sales had started to decline, and clearly reflected to the new equipment demand, as new capacity was not necessary. Issues like availability of standard equipment was not as critical towards the end of the project as it had been in the beginning. Short-term fluctuations in demand still remain a major challenge. This phenomenon is aligned with some of the constructs of this study stating that supplier management activities are subject to demand environment changes. Ramp up and ramp down availability and excess inventory still need a lot of attention.

6.4.1 Drivers for supplier development

The key drivers will be divided into two different categories, OEM and supplier identified reasons for development activities.

6.4.1.1 OEM drivers for development

The key drivers from the OEM side were clearly the annual spend on company B's test instruments, ensuring the availability of equipment and services long-term, optimizing the existing resources in equipment development, ensuring the future technological requirements in the area of test and improving the supplier's response times for inquiries. OEM felt the annual spend should give them better pricing and priority in allocation situations, and by working together, the development costs of the customer specific test equipment should decrease or be more equally shared instead of OEM feeling of having to carry the main responsibility for the costs occurred. OEM assumed the reason for the equipment being so expensive and slow to develop was the fact that they were over engineered. Company B did not really challenge the OEM engineers in the specification phase of the projects and OEM engineers typically over specified features and performance requirements of the equipment. Traditionally, there had not been any commercial people involved in the development projects, so the project cost targets were typically exceeded. Company B had been a supplier for complicated standard instruments, so they did not even initially have the competencies to challenge OEM engineers in the technology area of custom equipment. OEM also wanted to set up a forum to share technology related information in a systematic manner, challenge the future plans of both companies in the area of that particular technology and to ensure that OEM future requirements concerning product testing were taken into account in supplier's standard equipment development concerning features and time schedules. An additional driver from the OEM side for the supplier development was the overall relationship. As mentioned in the beginning, the relationship had remained on an arm's length. Information was not shared openly, the decision-making process was hierarchical and slow and implementing new ideas or ways of working was time-consuming and sometimes frustrating for the OEM people. OEM's business environment required fast responses to changing end-product demand and other business requirements, like new technology development requests.

Towards the middle of 2001 another driver for the project emerged. As OEM manufacturing and testing capacity was already in place, and more cost efficiencies were required, OEM wanted to address the issue of existing equipment reusability and life cycle management. A large in-house equipment base, end-product generation changes, declining growth in demand, and increasing need to dispose of the older equipment in an economic way drove this requirement. Two risks were identified from the OEM side for the overall development project: time schedule and supplier commitment. The risk of lack of commitment was mainly attributable to supplier's project team nominations.

6.4.1.2 Supplier drivers for development

The key drivers from company B's side were to improve communication especially on management and technology exchange level. Supplier felt that there was not enough visibility concerning the future of the OEM business, equipment demand and long-term technology direction. Supplier felt that they were getting conflicting information and requests from OEM's different organizations and locations and did not really know what the official OEM direction was. They wanted to see the communication filtered through certain contact persons to avoid unnecessary work. They also wanted to emphasize the importance of early supplier involvement to really influence the testability of the OEM end product instead of just building products to OEM specification or standard equipment upon request. Company B wanted to improve the existing demand planning system so that equipment shortage situations could be avoided in the future. The quality system audit held in early 2000 was an area that company B wanted to address. They wanted to close all remaining open items and get guidance from the OEM on some areas of the audit. As OEM-driven supplier rating system was put in place, supplier wanted to address the issues identified in the rating. This work was done as a part of the overall development project.

6.4.2 Project organization and set-up

A project team was set up for the supplier development project. Project manager was an OEM employee, and four separate sub-teams were formed with one participant in each team from both companies. Project team members were involved in the supplier development project on top of their everyday duties. OEM nominated people that worked with company B on a daily basis, whereas company B nominated people that had not really been exposed to the challenges identified. The project team was responsible for creating ideas to solve the existing issues and for implementing processes and new ways of working within the two organizations. Project steering group consisted of senior management from both companies to monitor the progress of the development project and to support the implementation of the new ideas. Project Manager was part of the steering team. The official time schedule of the project was from early 2001 till the end of first half of 2002. Project was managed through regular face-to-face or teleconference meetings. Memorandums of the meetings were kept diligently and action lists were created to follow up on actions assigned to different team members. Both companies kept their own documentation, only memorandums of the meetings and presentation materials were shared. Project steering group meetings were not held during the overall project. The management of both companies was aware of the progress of the project at least to a certain extent through reporting and overviews given in internal meetings. The management support for the overall project was not as good as anticipated at the beginning of the project.

Table 19: Company B supplier development project meeting schedule

Time	Meeting type
26-27/10/2000	Supplier development project kick-off
13/11/2000	Metrics, audit follow-up and supplier rating
18/12/2000	Communications team meeting
4/1/2001	Communications team meeting
5/2/2001	Overall project team meeting
28/3/2001	Project team meeting for cost initiative
19/4/2001	Project team meeting for early supplier involvement
12/6/2001	Metrics and supplier rating
12/6/2001	Web security meeting
13/6/2001	Communications team meeting
20/6/2001	Project team meeting for cost initiative
21/6/2001	Project team meeting for early supplier involvement
10/8/2001	Management meeting
13/8/2001	Project team meeting for cost initiative
14/8/2001	Overall project team meeting
24/8/2001	Metrics and supplier rating
25/9/2001	Project team meeting for cost initiative
4/10/2001	Project team meeting for cost initiative
5/11/2001	Management meeting
7/11/2001	Project team meeting for cost initiative
13/12/2001	Project team meeting for cost initiative
Early 2002	Technology day
4/3/2002	Metrics and supplier rating
12/3/2002	Project team meeting for cost initiative
18/2/2002	Technology steering team meeting
25/4/2002	Project team meeting for cost initiative
30/5/2002	Regional technology day

6.4.3 Key focus areas

Four key objectives and deliverables were defined for the overall project based on the key drivers identified by both companies. These four key areas were: communication, total cost of ownership, early supplier involvement and technology exchange.

Timely information sharing concerning new products, projects, existing products, open purchase orders and future orders was seen as essential but not very efficient due to the size of the companies' global operations and the width of the existing interface. The project team wanted to establish an official, formal management team and technology exchange seminar culture between the two companies. On a practical level, the improvements in the area of communication were supposed to provide processes and mechanisms to share secure information and future roadmaps, enable active, closed loop communications, identify the key points of contact, communicate key business commitments, track business based metrics and gain faster access to a large number of people and information.

The cost target was to reduce the total cost of ownership by 25% from the Y2000 cost level. Some tools were identified for cost savings such as monthly forecasting routine and order book follow up to monitor the accuracy of the forecasts and to prioritize the orders. The purpose of the forecasts was to ensure the availability and to shorten the delivery lead times of standard equipment. It has to be noted here that forecasts were already being distributed to the supplier during the time of the availability problems, but they were not used to the full extent possible and not distributed to second- and third tier suppliers to ensure component availability. Forecasting process was refined, a new template created, and company B accepted the responsibility to use the forecast information for capacity and materials planning purposes. They also committed to provide OEM monthly with an open order book report and an Internet solution for tracking existing order status worldwide. The effect of these changes to the use of forecasts or availability was not really measured in the project, partly due to the fact that there were no availability issues due to decreased overall demand. The overall allocation for the whole supply chain was not done, as OEM was not aware of orders placed by its first and second tier suppliers who were company B customers as well. So without knowing the supply chain demand OEM could have sub-optimized the availability by allocating its own equipment demand only.

Another very basic concern in the total cost team was whether the agreed discounts and terms and conditions of doing business together were actually distributed to all supplier and OEM locations worldwide and being fully taken advantage of. OEM wanted to pass the cost advantage given to them to certain third parties such as CM's or third party service providers to optimize the total cost.

The overall purpose of early supplier involvement efforts was to shorten the delivery time of customer specific solutions, and in a sense also the time-to-market of OEM end products. Driving lower development costs and end-product prices was another objective of this initiative with promoting the cost awareness among the engineering staff of both companies. Company B used some project management methods that could have been too rigid for development. Both parties also wanted to give the supplier more responsibility in envisaging the overall testing of OEM end products and for developing customer specific and standard equipment together with other suppliers and third parties at a certain cost. The purpose of the technology exchange between the two companies was to ensure both companies' competitiveness in the future and a common understanding concerning the future technology requirements and timelines of OEM business.

6.4.4 Project progress

A lot of new ideas to improve the relationship between the two companies were collected in three out of four areas of the cooperation. Some of these ideas were actually implemented during the project, some remained as ideas for future development. Communication related ideas were the joint website, agreeing roles and responsibilities, regular contact list updates, structure for key meetings and action lists with responsibilities and deadlines. Ideas in the area of decreasing total cost of ownership were order book follow-up in the Internet, monthly forecasting from OEM, price breakdown model for customer specific equipment, periodic invoicing, three-year total cost model, decreasing order entry points, monthly communication of existing discounts and agreed terms to all sites and renegotiating annual discounts for standard and custom products. Early supplier involvement ideas presented were: combining project teams to optimize development resources, more communication and challenging the specifications within project teams and commercial participants in technology development projects to monitor costs.

The first technology exchange day was held in the summer of 2001, and the results were promising, however not quite what was expected by both companies. Participants were still hesitant with a lot of information and technology roadmaps were not shared on a very detailed level. Annual senior management meeting practice was also set up. These two separate meetings, after being held for the first time, resulted in a clear need to set up a separate technology steering team. The official goal of the steering team was “to make sure that the supplier has up-to-date information of OEM’s current and future technology needs, define the right technology development areas, start joint projects and prioritize the projects”. Headquarters-level organizations of both companies started using action lists to follow-up on progress made with different commercial tasks and assignments, but the practice was not systematically implemented on factory or R&D site level. Key contact persons from both companies have now been clearly defined, but there still were challenges in the timely troubleshooting on a site level. A web-application for information sharing between the two companies was studied thoroughly, but never implemented. This was mainly due to the costs associated with ensuring the sufficient security level of the application.

At the beginning of the project, there was no real understanding of the total cost of test equipment ownership. A cost breakdown model was proposed to understand the cost implications of OEM equipment specifications and specification changes in the equipment development. The level of detail required for the custom equipment cost breakdown model were material cost including mark-up percentage, labor rates and hours required per task, administrative overhead, supplier profit and total engineering/development cost. Initially it was difficult for the supplier to understand why OEM would require a breakdown of costs. OEM reason for the request was to help the design engineers understand where the costs originated from, to be able to influence the cost with certain design related decisions and to be able to determine the possible ownership and IRP issues based on the division of the development costs. The cost breakdown model was finally agreed in the last cost – team meeting in early 2002. Parties agreed to a certain level of cost breakdown that both companies felt comfortable with, which would still add value for new development projects. Both parties were responsible for distributing pricing and contractual information to all the relevant sites worldwide on a monthly basis for all the products to ensure contract implementation.

An analysis of different order entry points OEM uses with company B was made, and it was determined that only one point per region would be needed with a few exceptions.

OEM took the responsibility to start working towards diverting all existing orders to those selected points of ordering to cut transaction-related costs. Periodic invoicing is still under consideration at OEM. Different alternatives for semi-automatic ordering and invoicing were investigated: the approach will most likely be email - based system for the time being. Company B spent time in analyzing the cost of a technology and developing three-year total cost models, but these models were never really implemented due to some OEM' internal accounting practices and lack of interest from OEM factories and the technology development organization. Some ideas were too novel to be implemented in the short-term.

The main difficulty in the area of early supplier involvement was to find a pilot project for testing the new ways of working. The supplier development project took place after the equipment development for the latest generation of OEM products had been completed, and new projects where the supplier could participate had not started yet. The situation was also influenced by the volume decrease in OEM business, so building new capacity and developing new equipment was no longer the first priority between the companies. There were some projects ongoing most of the time, so the challenge was partly the lack of interest and commitment especially from the OEM technology and project organization. Technology exchange project was never started, so no progress was made during the overall supplier development project. However, annual technology day practice and technology steering team certainly were the first steps towards technology cooperation.

6.4.5 Metrics

Following up on the remaining open items in the quality system audit and the semi-annual communication of the supplier rating results were parallel to the supplier development project. Due to the fact that there already was a measurement system in place, the metrics proposed for the development project were never implemented. The lack of resources and the interest within the project also influenced this decision. However, the separate metrics proposed by the overall project team will be summarized for reference.

Early supplier involvement	Time-to-market of custom equipment
	Total number of resources required in projects
Total cost	Depreciation cost per produced OEM product
	Forecasting accuracy

	Lead-time accuracy
	Disposition and reusability of excess assets
Project in general	Number of project team actions open vs. closed
	Supplier rating score
	Responsiveness to OEM feedback

An example of supplier rating score development over time is presented in the picture below.

Table 20: Company B supplier rating scorecard

ITEM	Weight	Explanation	Score Q2/2001	Score Q4/2000
QUALITY				
MTBF		Mean Time Between Failures	3	1
Assessment result		Compliance to OEM Supplier Requirements	4	4
Customer complaints		Effectiveness of customer complaint system	4	1
Quality system		Supplier's Quality Management System in place	2	2
COST				
Total cost of ownership		Trend of total cost of using the equipment	3.3	2.1
Equipment price competitiveness		Price reductions from the general price list	1	1
Terms of payment		The agreed payment terms as defined in the contract	3	3
DELIVERY				
On time delivery		The On time delivery result for the defined period	0	0
Lead time		Average lead time of the supplier's equipment	3	3
Use of forecasts		Ability and effective use of OEM provided forecasts	3	2
SERVICE & SUPPORT				
Service effectiveness		Effectiveness of repair, maintenance and corrective actions	3.0	2.5
Global support		Global presence of service and support in regard to OEM sites	3	3
Quality of LSA		LSA = Local Support Agreement	2.3	1
TECHNOLOGY				
Technology roadmap		How well supplier's roadmap match with OEM technology roadmaps	2.7	2.5
Latest technology		Capability to implement and use latest technology	2.8	3.1
Effectiveness of OEM specific product development		Specific product development project management and cooper ation	2.7	2.8
		Supplier Total Score	2.65	2.08

Company B addressed the supplier rating results with great detail. All metrics were reviewed separately on a quarterly basis with a corrective action plan. The improvements in rating results are presented in the following chapter. Supplier had problems with agreeing to some of the OEM-driven metrics used in the rating system. It might have been value adding to create the rating system for the supply chain together with suppliers to gain commitment from the beginning of the process.

6.4.6 Results

The results are presented per the development area. The main accomplishment in the area of communication clearly was that the project team was successful in implementing the regular senior management meeting and technology day culture between the two companies. Even if the technology day concept still needs fine-tuning, the groundwork has been done. The project also was successful in determining the key contact persons for different areas of cooperation and succeeded in implementing a technology steering team to monitor the cooperation progress and to prioritize the different new technology related projects. The action list and follow up practice helped to shorten the response times at least to a certain extent. The quality related communication between OEM sites and company B needed fine-tuning.

In early supplier involvement no real progress was made because there were no real projects to test the new ideas with. The management and commercial functions in both organizations did understand the importance of ESI, but the real ownership for the new way of working still remained in technology projects. It was agreed that commercial function needs to be involved in the development projects to review development costs and cost allocations at the beginning of the project. A development project change management process was also defined and documented in a project agreement template as it was identified that changes to the original specification were the root cause for over specification and to the increased development and end product costs.

Technology exchange project was not really ever started; the technology function from the OEM side was not able to give a resource to start brainstorming about new ways of doing technology exchange. Supplier did have a resource appointed, but the initiative was never started. As with ESI, the project steering group was not addressed with the issue, so no management support was gained. At the same time, regardless of the project, company B was working towards the standardization of its' product platforms in order to improve upgradeability and usability of future product generations. The main reason for the lack of efforts in the area of technology cooperation was the fact that towards the end of the project it became clearer that the supplier would mostly concentrate on developing and delivering standard instruments to the OEM, so the need for deep technology collaboration did not exist. A steering team was established to provide an input channel for the OEM concerning the supplier's future technology choices.

The most progress was made in the area of cost. The existing forecasting process was refined, a template was taken into use and OEM started sending forecasts to Company B. OEM forecasting accuracy has remained in the level of 30-60% compared to the actual existing order book. There has been a clear improvement in the area of on time delivery from company B. The first OEM supplier rating result dating back to November 2000 – April 2001 timeframe show OTD results of 29% to customer requested delivery date. This data clearly shows the availability problems of company B during year 2000. Supplier internal delivery accuracy during February-July 2001 shows delivery accuracy of 63-87% from the supplier confirmed delivery date. There were a lot of misunderstandings at the beginning concerning on time delivery. Company B felt that OTD should not be measured from customer requested date, but from supplier confirmed date, as they did not have an information system that could measure on time delivery from customer requested date. Company B felt that being early in delivering instruments couldn't be as bad as delivering late, whereas OEM felt differently about this stating that both early and late deliveries mean that deliveries are not on time. Open order book delivery process to OEM started on a monthly basis for monitoring purposes and the status of existing orders can also be monitored through an Internet application. The improvement in the OTD is also due to the fact that the number of OEM orders decreased thus making availability less of an issue.

The discount level obtained for years 2001 and 2002 remain below the target of 25%, the existing discounts varied in the range of 10-25% from Y2000 pricing depending on the type of products and promotions. Bigger discounts were given in a situation where company B built standard equipment to inventory to either meet uncertain demand or to manufacture an end-of-lifecycle lot prior to the next generation products. Some third parties were given the possibility to use OEM negotiated company B prices in OEM related production or equipment supply. Price breakdown structure was extended to three levels of the project costs and the cost sharing method and the product ownership were linked together in the cost breakdown model. Based on the improvements made in the supplier rating scores, progress has also been made in the area of effectiveness of the customer complaint system. This data is collected and reported quarterly to OEM with action and follow-up information. The summary of the results of the supplier development project is presented in the table.

Table 21: Key results of company B supplier development project

Key results of Company B supplier development project	
Focus areas	**Main results**
Communication	Key contact persons identified
	Action list approach to shorten response times
	Regular management meeting structure
	Technology day roadmap sharing structure
	Technology steering team set up
Total cost	Forecasting model refined for ensured availability
	Order book follow-up monthly for accuracy review
	Internet order follow-up
	Cost breakdown and development cost division model for projects
	Improved understanding on volume discounts, implementation of contracts
	Improved communication on pricing arrangements
	Fewer ordering points, lower transaction costs
	Email based ordering and invoicing under review
ESI	Common change management process proposal submitted for development projects

As a conclusion it can be stated that the project team did not have enough authority to create results in all the identified areas. Especially OEM lacked resources and commitment from the technology organization meaning that the cooperation project was not a priority to the OEM technology organization, whereas the lack of decision-making authority was a challenge with company B. Some of the people involved had not been dealing with the OEM earlier, so the problems addressed were unfamiliar to them. Another area for speculation is the custom equipment development. Did OEM make the right decision in promoting the possibility of company B developing custom mechanics for OEM in the first place? Could a more custom development oriented third party been a better alternative instead of encouraging company B into diversifying to a new domain?

6.5 Company C new technology development project

6.5.1 Background

The purpose of this case study is to describe and review a series of technology cooperation projects conducted within cellular terminal business starting year 2000. This case study concentrates mainly on one cooperation case to validate the model of constructs mainly for research question two (2). A new technology cooperation project was started between a cellular terminal OEM and one of its' main suppliers in the area of electronics materials to develop a new material for a particular manufacturing process. The OEM is a global cellular terminal design and manufacturing company. Company C is a global supplier for the OEM in the area of diverse materials, not dependent on the OEM's business, even if OEM is an important customer. The requirement to develop a new technology came from gradual changes in the consumer market legislation and the market requirements. OEM started a technology scanning and research project to identify the different technologies available in the marketplace to fulfill the new legislative and market requirements and the OEM project management came to the conclusion that the new technology in question needed to be developed together with another company. There were not many alternative technologies available or even to be developed within the given timeframe, for the particular process, with the targeted reliability and cost metrics. So OEM made the decision to move ahead with a certain approach together with a third party. At the same time company C had been slowly developing their own solution for their core competence technology area resulting in a technology development that OEM was looking for. Supplier's initial project did not have a definite customer, so the application development had been slow. The approach the company C wanted to take for risk management purposes was to find customers for the particular technology application from several different domains of the electronics industry. This makes the future customer base for the new product to be wider with more solid demand patterns.

The different alternatives for acquiring the new technology were reviewed by both companies and, based on the information collected in interviews among the project participants from both companies, these alternatives included cooperation with suppliers, customers, universities or within consortiums. Both companies also considered internal technology development and technology licensing as alternative means of access to a new technology. Most interviewees felt that in general terms, the most value added for technology cooperation would be found in the cooperation between OEM and existing suppliers due to familiarity of the people and the ways of working. Technology cooperation in that particular technology area in the future will move towards supplier coordination where suppliers or groups of suppliers would bring new technologies to the OEM to be tested and verified. OEM wishes to limit its' participation in projects in the long-term to few key people and practice technology development steering and guidance in supply chain through roadmap sharing, early supplier involvement and joint technology steering teams with suppliers. This decision was made in order to optimize the development resources in the supply chain, to avoid duplicate development work and also to distinguish and prioritize between core and non-core activities.

The technology cooperation project was started in late 1999 and completed in the middle of 2001. The technology scanning and research cooperation project was followed by an implementation project, where the new material's manufacturing process specification would be created and implemented to OEM's manufacturing process for predetermined end products. Teams for projects were different, but the best practices were shared between the teams through a common team members and reporting structures. The third parties participating with the OEM varied as well. The first, research oriented project was between one supplier and OEM and then OEM started a similar cooperation with an alternative supplier for the same new technology towards the end of the original research project to obtain a dual source situation for the new technology. Equipment suppliers were also introduced to the initial cooperation project during the same time. The implementation project was mostly an intra-company project at OEM. The focus in the case study will be on the initial research project for a new technology, as it is most related to the research questions of this study. Due to the timing of the research project, the most data was available. Some project participants were interviewed for the case study.

Table 22: Case study interview schedule

Time	Interviewee
10/12/2001	OEM Sourcing Department
21/12/2001	Supplier Key Account Manager
10/1/2002	Supplier Technology Director
17/12/2001	OEM Project Manager
18/12/2001	OEM Technology Director
19/12/2001	OEM Project Manager

6.5.2 Drivers for technology cooperation

The key drivers have been collected in the interviews from the participants from both companies: market push, competition, legislation, quality improvement, single source situation, manufacturability improvement, optimizing resourcing, speed of the development, commitment from customer and becoming an early adopter of a new technology.

These drivers are well aligned with the ones presented in the chapter 3.3.1. Cost was not clearly mentioned in the interviews as one of the drivers for the joint development, and quite the contrary, mentioned as a project risk due to the OEM push for cost reduction.

The supplier brought up this concern. Return on investment for the development was seen as a risk due to uncertainty of the demand and the lack of volume commitment from OEM. Increased use of contract manufacturers could also affect technology cooperation practices in the future, as especially the second tier suppliers believe that CM's would not invest as much in new technology development and supplier cooperation as OEM's do.

6.5.3 Project targets

Since the beginning the project was very process and material oriented, so all the targets were process and material specification related. Both companies had their internal target setting and reporting system and the only targets shared were the specification and the time schedule. Most participants agreed that cooperation would have been more systematic if there were joint targets and metrics for the management and steering team monitoring and review. OEM had a project steering team in place that reviewed the OEM targets regularly. The project targets for OEM were to develop a new material to meet legislation requirements, improve the reliability of the new material and process, ensure the reliability of the process mixing old and new technologies, to create a new technology demonstrator end product and to define an implementation plan for the selected end product programs.

The reason behind the target for mixed process was the fact that only some new end products would initially use the new material for risk management and the market requirements purposes. The final project report indicates that the project team felt that more emphasis could have been put on dealing with related suppliers and to the new manufacturing process in the target prioritization. Targets on the company C side were more cost-driven; one of the key targets for the project was return on investment (ROI). Risk management and efficient implementation were also identified as targets. The metrics that were used separately by both companies and reported to either OEM's project steering team or supplier's management team were: keeping the time schedules, staying within the budget, increased cost per end product/new product, failure rates in both companies' manufacturing, customer satisfaction (internal and external), meeting the specifications, managing the project with predetermined resources and the reliability of the solution.

One of the underlying targets for both companies in the cooperation process was to be able to standardize the end product of the cooperation process. The reasons behind the standardization efforts were ensuring availability of raw materials and manufacturing capacity together with being able to contribute to the electronics industry in general. OEM wanted the developed material to be as standard as possible to ensure availability and to optimize the cost, whereas supplier felt that it was difficult to come up with a generic product due to the specificity of the OEM's and typically all customers' manufacturing processes. The supplier also wanted to develop a standard product to be able to offer the same product to customers in different domains of electronics industry with as little modifications as possible to obtain economies of scale. Supplier could also have chosen product differentiation and price differentiation for various customers, but the competitive strategy chosen by the supplier was that of product standardization.

6.5.4 Cooperation process

Project team at OEM included project manager, process specialists and a sourcing representative. OEM steering team participants were senior managers from the relevant organizations. Company C's project team included sales representation and technology specialists. Technology steering team was set up with senior participants from both companies' technology organizations to monitor and create new ideas and projects for technology cooperation and development. The purpose of the steering team was also to influence the material supply chain by optimizing the number of suppliers and technologies.

Project reporting took place in both companies according to each company's documentation guidelines, and meeting memorandums were the main form of joint documentation. Project documentation included project plans, project status reports, final reports, test reports and meeting memorandums. OEM project steering team meeting memorandums were available together with the memorandums from joint technology steering team meetings. In practice the parties worked quite separately throughout the cooperation process. Company C did most of the material development work and OEM used its product and process to test, verify and give feedback on the new technology. Project participants had mixed feelings concerning using a joint process for new technology development. Some felt that there would be no value added especially if OEM was moving from joint development with suppliers towards supplier coordination and evaluation of third-party-developed new technologies. Others felt that joint process with pre-determined responsibilities would be helpful especially for the less experienced project managers and team members and with new third parties. It was also pointed out that the joint development process does not necessarily need to be the one used by the OEM. A project plan with jointly agreed and documented targets, resources and metrics would facilitate and clarify the cooperation especially on a management level. It was also indicated that joint planning would help both companies to gain visibility to the other party's internal processes, resourcing and decision making channels. The visibility was regarded as important in understanding the cost of resources to avoid unnecessary work and non- value adding research requests.

The concerns were actually experienced in practice when OEM started the technology cooperation with a new company, which had not been a supplier previously. It took the team members some time to identify the ways of working and communicating together. Initially there were a few misunderstandings and some confusion due to unfamiliarity of the people and the different development processes and practices.

The demand supply planning process was not considered being important in the development project. The commercial participant of the OEM project team was responsible for communicating long-term forecasts to the supplier. OEM did not, however, see availability being an issue due to the past experience with company C's current products, through familiarity with the supplier's manufacturing process and due to a dual-sourcing situation. Informal estimates were given for the future purchasing volumes, but supplier's participants felt the lack of demand related information and commitment were a major problem both for the development time schedule and internal planning of the ramp-up for the manufacturing capacity. Supplier could not fully estimate the return on investment for the new technology development and this complicated the definition of the pricing structure of the new product. In the same subject, OEM did state in the final project report that marketing department should become more involved with the project to be able to get the latest information on market requirements for the new technology to drive the development schedule and implementation.

Both supplier and OEM agreed to bring third parties into cooperation process towards the end of research project and during the implementation project to facilitate the manufacturing implementation and ramp-up of the new material. Equipment suppliers were introduced to the project towards the end and one of the reasons for doing this was that some of the equipment used in the manufacturing process needed a review or adjustments because of the new technology. The implementation was planned to progress gradually, from one OEM factory to another and even from one end product to another to reduce the risks.

6.5.5 Risks

Project team members from both companies mentioned information sharing as the biggest risk in research project and in technology cooperation in general. OEM saw the confidentiality of the information shared in developing a new technology for future end products as a major risk. It was mentioned that typically the commercial participants of the development projects share information more openly than the technical members of the team. Similarly, more information is being shared on a management level than on operational levels of the organizations. Willingness to share information also depended on a singe/multiple source situation: supplier felt that as long as they were the only company doing cooperation with the OEM in the technology area and application, information sharing was more open. Supplier also mentioned that they received some contradictory information from different OEM sources, and that they were occasionally requested to perform non-value adding tasks. Other factors that contributed to the level of information sharing in the project were familiarity of the participating people, trust and the status of the supplier (new or existing).

Another area the supplier identified as a risk was the coordination of ramp up. Joint ramp-up plan could have helped to avoid extra inventory, scrap and optimize the number of resources required from each participant. Supplier felt that OEM ramp-up and implementation planning was concentrated too much on intra-company activities instead bringing the whole supply chain together in a coordinated manner. On the other hand, OEM had a major task in the intra-company implementation due to multi-factory, multi-product and a mixed process approach. Some additional risks were identified by OEM in the area of third party capabilities and competencies of developing new products, materials and equipment to fit to the new process in a given time schedule.

6.5.6 Results

Both companies considered the results of the new technology cooperation project extremely positive as the targets of the project were met. All participants agreed that cooperation definitely did add value to the new technology development and the fact that the companies had been working together in the past as well facilitated the cooperation and information sharing between the companies. Supplier definitely wanted the new technology to become a commercial success in medium to long term, and OEM wanted the new technology to be as reliable as possibly in the manufacturing process. The key results of the technology cooperation project were: a new process material technology was available for timely implementation, the application development time was shorter, development costs and risks were shared, relationship between the two companies was improved, communication on different levels of organization was improved and the third party involvement brought a wider scope to the activities.

These achievements are well in line with the areas covered by the literature review chapters, for example 3.3.1 addressing value added of technology cooperation. Some lessons learned were collected from the project participants. The two areas mentioned were communication and commitment. Communication could have started earlier in the overall cooperation and supplier identification process, and the information sharing could be more efficient in the implementation phase of the projects. The feedback from company C suggested that the main technology message from OEM should be uniform across the supply chain and from different sites without contradicting information and conflicting demands on the other cooperating parties. Some tasks given to suppliers from various OEM locations were clearly non-value adding and did not result in anything.

Another area for improvement that was mentioned by the project participants from the supplier's side was the fact that more commitment would have been required from the OEM side to enable more efficient and timely development and to ensure a reasonable return on investment for the supplier. The participants from the both companies mentioned the possibility of joint investments or even future profit/loss sharing based on OEM end product sales being possible scenarios for risk sharing in the future especially for high risk development projects.

6.6 Cross case analysis

The purpose of a cross-case analysis is to generalize the results of the three case studies to validate the model of constructs. The tacit information collected through the case studies will also be used for refining the model of constructs. As most of the data presented in the case studies is qualitative of nature, the cross-case analysis is more of a case survey (Yin, 1994). A cross-case analysis through pattern-matching and explanation-building techniques shows that a lot of the drivers, targets and development areas mentioned in the three cases were common to them all. The main drivers for change in all the three cases were:

- Change in the business environment
- Shortening time-to-market
- Need for timely and consistent information sharing
- Lack of emphasis of early supplier involvement
- Criticality of demand planning
- Inaccuracy and inconsistency of forecasts
- Long new equipment/material development times
- Discontinuities in development and planning processes
- Duplicate resourcing in development projects
- Supplier performance issues: quality, deliveries, efficiency
- Lack of visibility to the future
- Increased cost
- Strive towards recycling of materials and assets

These drivers are well aligned with the current state analysis of the consumer electronics industry and the future challenges of the electronic industry presented in chapter 2. The first two cases tried to find solutions for the main drivers of the projects, and in the third case study the technology cooperation mode was selected due to the changing market environment, cost and flexibility. Similar business drivers have been identified in the literature review as well (Christopher, 1998).

The two first case studies illustrate the communalities in supply chain management challenge: both cases address similar problematic, and also offer similar solutions to these problem areas. Ensuring materials and equipment availability is the main challenge, and the solutions offered are forecasting, demand visibility, regular management and technology meetings, increasing understanding of the business environment with the suppliers, standardization and modularity of products to shorten development and delivery lead times, improving communication and clarifying the roles and responsibilities between companies and within project teams. Both projects spend the majority of the time to improve the visibility to technology and volume demand both medium and long term. OEM was basically in a single source situation with Company A and B, and this increased the need for cooperation and supplier development. Cost also was a main concern for OEM due to the changing business environment and the existing supply strategy. An interesting aspect in both case studies was the shifting focus of the cooperation efforts depending on the changes in the business environment. This resulted in changing drivers, metrics and actions and also contributed to the lack of interest from both parties in some particular phases of the projects.

In the third case study, the drivers for the technology cooperation are well aligned with the reasons identified in the theoretical review of this research. Also the technology cooperation model was selected along the guidelines presented in the theoretical review. The case study illustrates well the problem areas: cost and resource sharing, information sharing, lack of trust, future demand planning challenges and changes in time schedules. As both participants kept their own project teams, processes, documents and metrics for the successfulness of the project, overall coordination of the project became a major challenge. The second case study proposed a solution to this problematic: a technology and project steering team within the supply and technology area. This is a concrete idea of new tacit knowledge collected through the case study.

The common areas identified between all three case studies were the importance of demand planning, standardization efforts and the lack of information sharing and coordination in development projects. An area not addressed in the theoretical background of the study was the non-value adding tasks from OEM that all three companies mentioned in the case studies. The problem is most likely due to lack of project and technology coordination and prioritization within supply chain and also due to the lack of consistent and coordinated information sharing. Another interesting finding in all three case studies was the approach to partnership. Real partnerships were really not addressed in the case studies at all, whereas the literature review emphasizes the need for partnerships quite extensively. This demonstrates that there are alternative forms of supply and technology cooperation to partnerships. The overall approach in all three case studies for problem solving was very concrete: challenges were identified and the project teams started addressing the areas directly with possible solutions. The solutions were meant to be long-term fixes, but in some instances they turned out to be quick fixes for the immediate future only. Most of the solutions were improvements to existing processes and the ways of working, not really new supply chain management practices. Long-term follow up was not designed or executed through the project metrics: the only follow up tool was the supplier-rating tool. This tool is sufficient for the follow-up of the ideas implemented, but at the same time, the tool made the project metrics redundant.

The solutions offered in the case studies correlate with the research questions. As a summary, the main solutions offered to the first research question of ensuring availability were:

- Increasing supply chain visibility with regular management and technology meetings
- Monthly forecasting from OEM to supplier and from supplier to 2nd tier
- Sales and marketing function involvement to increase market understanding in the supply chain
- Product standardization and modularity
- Coordinated ramp-up efforts within the supply chain
- Improved cooperation through partnership efforts
- Existing order book follow up and prioritization
- Reusability of equipment
- Improving forecasting accuracy through follow up
- Metrics for availability, like supplier rating
- Consistent information sharing, prioritization of efforts
- Changing focus in supply chain management due to market environment

These solutions apply to the overall supply chain, and emphasize capacity implementation phase of the new product lifecycle. It can be stated that these solutions support the sub-questions defined for the first research question as well. Similar topics were also identified in the literature review especially in the area of demand planning and supplier development. The case studies brought up some novel ideas that will be added to the final model of constructs. The summary of the solutions offered to the second research question concerning guiding principles in technology cooperation were:

- Emphasizing the importance of early supplier involvement

- Sharing development resources within the supply chain
- Supplier coordination as a form of technology cooperation
- Bringing companies together to innovate, 1st and 2nd tier
- Standardization and modularity of products to enable wide usage and easier development interface
- Reasonable cost and risk sharing to reach a reasonable ROI
- Joint development processes
- Systematic and uniform information sharing
- Prioritization and guidance of technology projects through steering teams

Especially the third case study emphasizes the supplier coordination through technology steering teams as a viable model for technology cooperation in cellular terminal industry due to the flexibility and the company level independency of the model. All three case studies put the main emphasis on tools, processes and standardization in facilitating the collaborative planning in product demand and new technologies. Literature review addresses similar topics in the area of technology cooperation, and the case studies presented some tacit knowledge in this area not emphasized in the literature.

6.7 Evaluating the quality of the case studies

The three case studies brought a completely new dimension to this research that was not anticipated at the beginning of the research. The theories presented in this research did not address the fact supplier management practices, supplier cooperation and partnership activities would be dependent on end product market environment, namely end product demand growth, stability or decline. This phenomenon was clearly visible in the two first case studies describing supplier development projects between companies A and B and the OEM. The scope of the development activities with suppliers was broadest and the cooperation projects were most active during the time of increasing demand. When end product demand started to decline, project scope became more cost driven and activities were pushed to the suppliers with limited OEM involvement. Based on this input, the effect of the market environment on supply chain management practices was added to the final constructs of this study. All of the projects were conducted during a period of three to four years, from 1999 to 2001. During this time, a major change took place in the cellular terminal business environment. The growth in cellular mobile demand started to decline affecting all companies within the supply chains. This is clearly visible in the two supply chain management related case studies in terms of changing drivers, focus areas and metrics and eventually even in the lack of overall commitment for some of the development efforts. It is very noticeable in the case studies that availability was the main driver of the development efforts. When there no longer were problems with availability, interest in other areas of development declined. It could be argued whether availability was overemphasized on the account of for instance quality and cost during the exponential market growth environment.

All three projects were related to one domain of cellular terminal development and manufacturing. This fact can be regarded as a shortcoming for the overall case study, but different types of companies and challenges were addressed in the studies to ensure a broader scope for the case studies and to the overall validation of the research questions. One project dealt clearly with research environment and technology cooperation, whereas the two other projects addressed supply chain management and cooperation related issues. Many of the cellular terminal business related supply chain management and technology cooperation issues could be generic to the consumer electronics business, but due to recent volume explosion in that particular business domain, challenges were more clearly identifiable and concurrent than in other, more stabilized fields of consumer electronics.

Three case studies were presented in this research due to the fact that a smaller number of cases would not present enough evidence to support the constructs of this study. On the other hand, the evidence from the case studies was similar in nature, so the researcher decided that a total number of three case studies would be sufficient. The case studies were fairly easy to put together, analyze and present with sufficient documentation. The data was also recent, and the people participating the projects were still with the companies involved in the projects or even in the same positions as during the time of the research, so the researcher was able to ask for more detailed information and for clarifications to the existing data. The only shortcoming identified, common to all three projects, especially the case studies with companies A and B, was the lack of follow-up in the implementation and the objective measurement of the project achievements both short-and long-term. Metric related follow-up data from a longer period of time would have helped in evaluating the long-term impact of the supplier development projects on the predetermined development areas. This data would also have been useful in presenting the evidence to the model of constructs of this study.

Information collected through the case studies does not contradict the information presented in the survey. The information found through the different data sources are well aligned with the theoretical background presented in chapter three (3). The case analyses show that the number of cases presented is sufficient for validating the model of constructs. It can be stated in the cross case analysis that the findings in all the cases are quite similar so increasing the number of cases would not necessarily have created any more validation data for the model of constructs.

7. VALIDATION OF RESEARCH CONSTRUCTS

This chapter will present the evidence to validate the model of constructs (1A and 2A) and refine the constructs with the findings from the case studies. The changes to the model of constructs have been underlined for clarity and the numbering of the updated model of constructs (1B and 2B) is the same as in the previous model (1A and 2A). The evidence is presented per construct. However, all the three case studies did not present evidence to validate all of the constructs in the model, so all the case studies are not mentioned with each construct.

7.1 Final model of constructs for research question one (1)

Construct 1: To ensure materials availability in a supply chain, demand management should work on-line, providing demand and supply end to end visibility both up-and downward in the supply chain including inventory related information to be used in ramp-up, mass production and ramp-down phase decision making. Proposed metrics: demand-planning accuracy and ramp up speed.

Case study A evidence: the monthly forecasting system presented to reduce lead times and to plan supplier capacity supports the construct. OTD improvement through forecasting on customer specific equipment from 50% to 96% within one year also suggests that forecasting does improve availability. A controlled product development change management also attributed to the improvement. On the other hand, a manual forecasting process from the OEM was not very accurate and the delivery of the forecasts was not consistent, so a more consistent process would be required for effective demand planning. A metric of on-time delivery (OTD) to end customer proposed delivery date was used in the case study. Ramp-up speed was being measured from the OEM side.

Case study B evidence: the overall OEM effort to generate and use forecasts in the supplier development project to improve availability and avoid shortages agrees with this construct. Forecasting, typically periodic, also shows improvements in on-time-delivery statistics demonstrated in the supplier rating data. However, the use of forecasts and the market information behind the forecasts need to be communicated effectively within the overall supply chain to ensure the maximum use of the forecasts and the overall availability. Supplier also felt that OEM gave more visibility to the end-product market through forecasting and improved communication regardless of the fact that forecasting and communication was not consistent across all the periods. The overall understanding of individual companies' equipment demand in a given time period across the supply chain in ramp-up situations would have helped the OEM and the supplier to allocate the scarce equipment where they were needed the most. The metrics used in the case study to measure demand and supply planning are forecasting accuracy and on-time delivery.

Case study C evidence: company C wanted to get as much information as possible concerning future volumes of the new product being developed to be able to determine return on investment for the project and to estimate the price of the future product. They also needed the demand data for manufacturing ramp up and capacity implementation purposes. OEM did not see demand planning being as critical in the technology development phase due to past availability experience and dual sourcing situation. Availability related metrics were not used in the project.

Construct 2: The end-customer interface of a particular supply chain should be involved in the supply chain collaborative demand planning to increase future market understanding within the chain and to communicate the demand fluctuations in a timely manner across the supply chain to gain trust and commitment. An active demand marketing approach is often required to convince the supply chain to act according to the up-and downward trends in the market demand to ensure materials availability in the long-term. Proposed metrics: sales, sales from new products and gross profit.

Case study A evidence: the overall supplier development project is part of an OEM demand marketing approach, where the OEM and the supplier tried to find alternative approaches to improve the existing ways of working and gain each other's trust. Regular management meetings and technology exchange sessions were part of this approach. Working with supplier development related activities during declining growth, even with limited interest, was demonstration of demand marketing and relationship management efforts. Forecasting accuracy was a metric that the OEM endeavored to measure throughout the project.

Case study B evidence: more active demand marketing with management and sales department involvement might have helped in "selling" the forecasted quantities to company B from early on and triggered them to act according to the forecasts and to communicate the information to the second and third tier suppliers as well. Demand marketing approach through systematic management communication and a timely forecasting system implementation might have helped to avoid the shortage situation. The case study used forecasting accuracy and use of forecasts as metrics for demand marketing.

Construct 3: Limited editions approach can be used for extremely “difficult to forecast” or “erratic demand” –products to ensure the aggregate availability within a supply chain for a given commodity and/or end product. Limited editions are also a viable tool for product ramp down management. Proposed metrics: obsolescence discounts and allowances.

Case study B evidence: supplier’s manufacturing strategy of build-to-inventory and end-of-life cycle management practices correlate to the limited editions-approach in manufacturing. Company B used limited editions as an end-of lifecycle management and version control tool and as a way of ensuring availability and reasonable cost of standard equipment for customers. No metric was defined for the approach in the case study.

Overall, there is substantial amount of tacit knowledge within the electronics, automotive and watch making industry to support this construct.

Construct 4: Supply strategy is a critical part of materials and equipment availability in the long term and the two most important criteria to categorize companies for OEM-driven supply chain are: technology (provided) and the (future) volume of each commodity through end product market changes. Proposed metrics: overall supply chain lead-time and on-time delivery to customer.

Case study A evidence: the criteria for the decision to start supplier development activities comply with the criteria of technology and volume. When the project was started, company A was supplying a critical technology, customer specific equipment in a single source situation during an end product demand growth phase, and supplier was highly dependent on the OEM, so both technology and volume were taken into consideration. The case study demonstrates the drivers, focus areas and commitment in supplier management practices vary depending on the market demand situation. Metrics proposed for the construct are applicable, but once again difficult to measure. OTD was the most commonly used metric in the case study.

Case study B evidence: the criteria for selecting company B to the supplier development project and identifying the supplier as a strategic supplier were aligned with the criteria of technology and volume. Company B supplies customer specific technology in certain quantities and standard equipment in large quantities. The technology in question will be a critical technology in the manufacturing process in the future. OEM wanted to ensure the long-term availability and timeliness of new technologies for future product generation testing. Volume of the equipment purchasing was critical to the OEM both spend and equipment base wise. Availability of test instruments, like any other materials and equipment, was especially critical in new product ramp-up situations across the supply chain. The case study also illustrated the shift in the project priorities and the commitment due to the downward trend in business volumes. On-time delivery was used as a metric in the case study as a part of the overall supplier rating system.

Case study C evidence: OEM wanted to find an alternative source for the new technology to comply with a dual-source strategy outlined in the supply strategy for the particular technology area. Supply strategy was defined due to the criticality of the technology to the manufacturing process and the demand for this technology was substantial from all OEM facilities worldwide even when the biggest growth in the cellular mobile business started to decline. Dual sourcing was also a conscious risk management decision to the OEM. The project did not define any metrics related to the supply strategy.

All three case studies suggested and demonstrated that environmental changes in the market need to be taken into account in the supplier management approach and practices.

Construct 5: As investment intensity, bullwhip effect and capacity building lead-times increase and the speed of information sharing decreases upwards in the supply chain driving verticalization and cooperation preference downstream, all supply chain companies, regardless of their tier, should be on an acceptable level in supply chain management activities to ensure overall availability. Proposed metrics: level of excess or missing capacity, customer satisfaction and customer order lead-time.

Case study A evidence: it was clear company A put a lot more effort into managing the customer interface than the supplier network. This construct applies best in high demand growth environment. When business is growing, companies want and have funds to expand to new business areas by integrating vertically. When demand starts to decline, companies are more likely to form alliances horizontally to stay competitive. More emphasis will also be put in upstream sourcing activities when the profit margins get thinner. This also happened with Company A in the case study.

Case study B evidence: communication was not effective between OEM's first and second to third tier suppliers and that resulted in an equipment shortage situation. Company B's materials management system was not advanced enough to handle third party assistance to correct the component shortage situation. Company B had traditionally been a standard instrument supplier and to gain more business from the OEM in a fast growing market, it agreed to start custom equipment development, which had a fairly long learning curve to company B. This is an example of one type of a diversification and/or verticalization in a high demand growth market environment. To speculate, a better approach for both companies might have been to cooperate with a third party, a supplier specializing in custom equipment development and manufacturing. Metrics were not addressed in the case study.

7.2 Final model of constructs for research question (2)

Construct 6: Sales and/or product marketing involvement from the buying company's side in technology cooperation is essential in ensuring the alignment of technology scanning and cooperation activities with the market expectations concerning cost/benefit, product features and the new technology introduction time schedules. Proposed metrics: product cost and timeliness of new product introductions.

Case study A evidence: alignment of the technology activities in the case study was ensured through technology day sessions and business-related management meetings. In technology day meetings both companies presented their technology plans in the particular technology area. This data had been collected with the help of each company's technology, sales and marketing people.

Case study B evidence: the commercial organization involved does not necessarily need to be sales, but a commercial function is required in technology development projects to give guidance on technology direction and monitor the cost implications of the decisions made in the development phase concerning the features and the specification of the future product. Commercial function will also be able to assess the tasks assigned to the suppliers for relevance and business potential. Cost breakdown model ties costs and specifications together and helps promote the cost and market expectations understanding within new technology development teams.

Case study C evidence: OEM's final project report states that sales and marketing functions should have been involved in technology scanning and cooperation activities from early on to bring input and prioritization from the end-product market perspective to the project time schedule. The initial input for the cooperation project and the technology development did come through product marketing/sales organization, so the mechanism was already being used to some extent. Latest technology is one of the metrics being measured in a sense that both OEM and supplier wanted to be early adopters for the new technology.

Construct 7: To enable cost efficient and speedy design cooperation between companies, inside and beyond supply chains the following prerequisites need to exist: streamlined development processes, facilitated third party participation in company internal processes, resource optimization and modularity, standardization and open interfaces in product design. Proposed metrics: product development time and cost.

Case study A evidence: process harmonization and process integration were key focus areas throughout the supplier development project both in the area of demand/supply planning and new equipment development and the quality of products. Implementing a joint change management process within custom equipment development helped improving DOA and OTD, so there is evidence of the joint processes between companies facilitating the product development. The case study also points out that all processes to be followed within the supply chain do not need to be the OEM processes. In some cases supplier driven processes could be used in joint development, especially if the main development responsibility is suppliers', not OEM's. Early 2001, OEM wanted to start pushing more and more development activities to the company A to optimize the resource usage and to utilize the best possible competencies in the particular technology area. Even the project management competencies do not need to reside at OEM, especially if the particular development activity is not "core" to the OEM. The drivers for standardization and modularity efforts in the case study were broadening customer base (supplier), speeding up the development (both companies), improving equipment re-utilization (both companies), declining demand (OEM), cost consciousness (both companies), increasing number of variant products (OEM) and facilitating the implementation of third party provided technologies into supplier equipment (both companies). The data from the case study shows 15-25% savings in equipment development and manufacturing through standardization and modularity. The approach improves equipment reusability by 80%. Cost breakdown model helps in understanding the value of modularity and standardization and the added costs related to specification changes.

Case study B evidence: OEM and company B endeavored to have a joint development process for future custom equipment design to cut costs, resources and the overall time of the technology development. Agreeing on a joint change management process for development projects supports this construct. OEM wanted to cut costs associated with new technology development. One of the ways to reach this goal was to optimize the overall resources involved with the equipment development projects through possible engineer exchange and by giving more responsibility to the supplier to develop the necessary technologies. The cost breakdown model facilitates standardization and modularity efforts and makes the second-tier supplier activities, i.e. sourcing of components easier. Cost modeling has been mentioned as a tool for cost structure definition in the literature as well (Baker, Laseter, 2002). To improve the total cost of ownership and the cost competitiveness of supplier's products included working towards developing more commercial, open platform type solutions to drive standardization and cost savings through economies of scale. Platform type of modular approach for different project generations shortens development times as well. Standardization and modularity also enables more efficient life cycle management of equipment by facilitating customer upgrading and updating of existing product generations.

Case study C evidence: the comments given by the interviewees concerning the value added of joint processes stated the value added of joint development processes within supply chain with new project team members and new suppliers. Common processes facilitate third party development and technology cooperation in general and that the commonly used processes do not necessarily need to be the ones used by the OEM. The case study was an example of how resources were not being fully optimized in joint development projects. Both companies had their own project teams, project plans, metrics and reporting. OEM wanted to shift as much non-core technology development responsibility to the supply chain as possible to free it's own resources to the core activities. OEM also wanted to limit it's own participation mainly to the coordination and testing alternative future solutions and technologies. In a sense OEM was concerned with the size of project team, total cost and the product development time. The standardization was driven by both companies, but for different reasons: OEM wanted to ensure the availability through standardization, whereas supplier wanted to ensure as broad a customer base as possible.

Construct 8: End product design and manufacturing process related information is a prerequisite for optimizing the design, quality and costs of end customer products. Consistent, uniform and prioritized communication needs to take place on all levels and in all functions of the organizations to avoid overlap and redundant work within the supply chain and management needs to educate personnel on what should and should not be communicated within the supply chain. Proposed metric: satisfaction surveys.

Case study A evidence: lack of communication and trust was one of the problem areas identified at the beginning of the supplier development project. Regular management meetings were one way to improve the communication on a management level and the purpose of the regular quality meetings approach was the same on an operative level. OEM personnel were educated concerning the supplier communication. Supplier put a lot of effort in developing and implementing an official feedback system enhancing the communication on several levels of the organization and by different functions and regions of the same organization. Supplier rating system functioned as a feedback system from OEM to the supplier. Early supplier involvement was emphasized throughout the overall project. Supplier also emphasized the importance of consistency of the information sharing to avoid unnecessary and non-profitable work.

Case study B evidence: communication was identified as one of the four key areas in the supplier development project, especially the timeliness and uniformity of the information sharing to avoid supplier assignments with no real business opportunities. The case study proposed response times as a metric for communication.

Case study C evidence: the lessons learned from the case study are aligned with this proposition concerning importance of information sharing emphasizing timeliness and uniformity of the messages to the supply chain. The issue of OEM requests that do not generate any real business was identified in this study as well. Both companies identified the main area of risk in the joint development being the information sharing, due to the problems and shortcomings encountered, and especially OEM was unsure about sharing future product related information in the research and development phase. The effectiveness of the information sharing was not measured in the cooperation project.

Timeliness of the information sharing and quick responses to inquiries were one key issues in the communication initiatives of all three case studies. The issue of prioritization in information sharing to avoid overlapping and redundant work was added to the construct as it was clearly indicated in all three case studies as a major area of concern.

Construct 9: The supply chain's "nucleus company" has an essential role in bringing existing suppliers and new, third party companies together in strategic alliances to coordinate the creation of new, innovative solutions for end-users within the concept of extended enterprise. Technology steering teams per core technology facilitate the coordination. Proposed metric: number of technologies introduced prior to and compared to competition.

Case study A evidence: OEM started to push the equipment development work to the supplier during the project due to the reasons stated in the construct seven (7). OEM also facilitated the cooperation of different manufacturing technology companies to create new applications, company A acting as an integrator for the new technologies. Technology day approach was used a metric for ensuring the access to the latest technology.

Case study B evidence: technology days, technology steering group and business-related management meetings facilitate third party technology development through enhanced information sharing, using a steering team approach for monitoring and prioritizing the joint cooperation and third-party development progress and also help optimize resources within supply chain by cutting overlapping activities.

Case study C evidence: the case study was a good example of OEM acting as a "nucleus" company bringing different types of suppliers together to develop and implement a new manufacturing process. New companies were brought to the scope of the project in different stages of the project, depending on the status of the project and the type of the supplier. OEM was mainly concentrating on supplier coordination and testing the proposed alternative technologies. Coordination took place through the technology steering team set up between OEM and the individual suppliers.

Technology steering team approach for coordinating the supply chain technology development has been added to the construct.

Construct 10: The technology cooperation model selection for new technology creation should depend mainly on two key criteria: market and demand certainty, i.e. risk and novelty of the technology and the understanding of future demand. Proposed metric: partnership satisfaction index.

Case study A evidence: the criteria used for determining the cooperation model in the case study is similar to the criteria presented in the construct: market and demand certainty (single source, initially high demand) and risk and novelty of the technology (customer/product specific equipment). Due to existing problems in these areas, supplier development towards partnership was chosen as a cooperation model. OEM and supplier decided to start the project in the areas of both supply and technology cooperation due to the following reasons: technology, custom equipment development, equipment quality improvement, single-source situation and OEM's major role in supplier's overall business. Based on the case study it can be stated that the likelihood for supply partnerships becomes less likely in stable or declining market growth. End-product demand does not affect technology cooperation as dramatically. Case study did not present any metric related data to support the efforts, but based on the initial problematic presented, some partner satisfaction related metric could be appropriate.

Case study B evidence: possibly one of the reasons why project did not really succeed in the area of technology cooperation was the fact that the two criteria presented in this construct were not fulfilled. Demand certainty was on a sufficient level after initial problems, products supplied were mainly standard equipment that were replaceable by another supplier's equipment in medium-to long term and the companies were not extremely critical to each other. So the need for deeper cooperation did not necessarily exist. Companies did acknowledge the need for technology cooperation to ensure the timely availability of test instruments for future end product generations.

Case study C evidence: technology cooperation process was selected to be fairly informal but systematic with no joint investments. The criteria for selecting technology cooperation model were the criticality of the technology, future demand, time schedule and available resources. Parties managed risks by dual sourcing or by having multiple customers. The project teams did not really reflect the decision made to develop the new technology in cooperation with a supplier/customer. As stated in the results of the project, both parties thought that the project was successful, so it can be stated that a right choice was made concerning the cooperation model. No metrics were determined for the successfulness of the project outside time schedule and specification.

Overall, the case studies presented a wide variety of different metrics that were quite case specific. Metrics did guide the decision-making and target setting to some extent and, in some instances, clearly demonstrated the value added and progress of the joint efforts. However, most metrics in both theoretical review and in the case studies were difficult to apply and measure in practice. The case studies show that the classic supplier rating system is a proper tool for OEM feedback to suppliers. Even further developed, supplier rating could be used for measuring overall supply chain performance. In that case the criteria and measuring system needs to be agreed by all participants jointly. The overall metrics of the model of constructs have been refined based on the tacit knowledge collected from the case studies concerning the practicality and actual use of the metrics. An as stated earlier, the metrics proposed are suggestions on an aggregate level.

7.3 Summary of the final constructs of this research

The final model of constructs (1B and 2B) and the proposed metrics have been presented per research question in the tables 26 and 27. Constructs eight (8) and nine (9) have been refined based on the case study findings.

Table 23: Final model 2A of propositions to address research question one (1)

Proposition model 2A	**Metrics**
Construct 1: To ensure materials availability in a supply chain, demand management should work on-line, providing demand and supply end to end visibility both up-and downward in the supply chain including inventory related information to be used in ramp-up, mass production and ramp-down phase decision making.	Demand planning accuracy and ramp-up speed
Construct 2: The end-customer interface of a particular supply chain should be involved in the supply chain collaborative demand planning to increase future market understanding within the chain and to communicate the demand fluctuations in a timely manner across the supply chain to gain trust and commitment. An active demand marketing approach is often required to convince the supply chain to act according to up- and downward trends in the market demand to ensure materials availability in the long-term.	Sales, sales from new products and gross profit
Construct 3: Limited editions approach can be used for extremely “difficult to forecast” or “erratic demand” –products to ensure the aggregate availability within a supply chain for a given commodity and/or end product. Limited editions are also a viable tool for product ramp down management.	Obsolescence, discounts and allowances
Construct 4: Supply strategy is a critical part of materials and equipment availability in the long term and the two most important criteria used to categorize companies for OEM-driven supply chain are: technology (provided) and (future) volume of each commodity through end product market changes.	Overall supply chain lead-time and on-time delivery to customers
Construct 5: As investment intensity, the bullwhip effect and capacity building lead-times increases and information sharing decreases upwards in the supply chain driving verticalization and cooperation preference downstream, all supply chain companies, regardless of the tier, should be on an acceptable level in supply chain managemet activities to ensure overall availability.	Level of excess or missing capacity, customer satisfaction and customer order lead-time.

Table 24: Final model 2B of propositions to address research question two (2)

Proposition model 2B	**Metrics**
Construct 6: Sales and/or product marketing involvement from the buying company’s side in technology cooperation is essential in ensuring the alignment of technology scanning and cooperation activities with market expectations concerning cost/benefit, product features and introduction timeschedules.	Product cost and timeliness of new product introductions
Construct 7: To enable cost efficient and speedy design cooperation in each company, inside and beyond supply chains the following prerequisites need to exist: streamlined development processes, facilitated third party participation in company internal processes, resource optimization and modularity, standardization and open interfaces in product design.	Product development time and cost
Construct 8: End product design and manufacturing process related information is a prerequisite for optimizing the design, quality and costs of end customer products. Consistent, uniform and prioritized communication needs to take place on all levels and in all functions of the organizations to avoid overlap and redundant work within the supply chain and management needs to educate personnel on what should and should not be communicated within the supply chain.	Satisfaction surveys
Construct 9: The supply chain’s “nucleus company” has an essential role in bringing existing suppliers and new, third party companies together in strategic alliances to coordinate the creation of new, innovative solutions for end-users within the concept of extended enterprise. Technology steering teams per core technology facilitate the coordination.	Number of new technologies introduced prior to and compared to competition
Construct 10: The technology cooperation model selection for new technology creation should depend mainly on two key criteria: market and demand certainty, i.e. risk and novelty of technology and the understanding of future demand. Proposed metric: partnership satisfaction index.	Partnership satisfaction index

8. DISCUSSION

This chapter will summarize the final model of constructs, review the applicability of the research methods used, evaluate the usability and value of the research findings within cellular terminal business in practice, review the limitations of the overall research and make recommendations for areas of further studies within the scope of this research. The effect of the results to the existing body of knowledge has been evaluated based on the theoretical framework of this study.

8.1 Contingencies of the model of constructs

A contingency analysis has been performed for the model of constructs to define whether the model applies to a particular business environment better than to any business environment. This analysis has been performed based on the input from the survey and the case studies. Overall, the model of constructs can be applied to any business environment, but some of the constructs are more valuable and usable in certain market environments, typically in a high growth environment. More contingencies would apply in the model of constructs (1B) for the research question one (1) than in the model (2B) created for the research question two (2). This is due to the nature of the research questions. Availability of materials is typically more critical and more emphasized during a high demand growth period. Cyclical quality of world economy and business domains have an effect on demand patterns and it can be stated that either maximizing or satisfying availability will remain being a critical issue in demand management.

There are no contingencies for the first (1) construct of demand and supply management visibility, as collaborative demand planning is essential in any business environment. Demand marketing approach described in the second (2) construct applies to all business environments as well, but is most likely more useful as an approach in market demand growth environment and new product ramp-up situations. End-product market information is valuable within supply chain in any demand situation. Limited editions-approach stated in the third (3) construct can be used in most market demand situations. Construct four (4) applies to all market environments as well, but is more critical when the end product demand is growing. The same applies to the fifth (5) construct, which is also critical in new product ramp-up situations.

The model of constructs (2B) for the second research question does not really have any contingencies. The only construct that would be more beneficial in new product ramp-up situations or product ramp down situations, where the future is uncertain, is the construct number six (6) describing the need for commercial participation in technology scanning and development activities.

8.2 Applicability and usability of the research methods and solutions provided

The applicability of the research results will be analyzed through validity (external, internal and construct validity), reliability and relevance (Yin, 1994 and Kidder and Judd, 1986). The construct validity of the results has been verified through multiple sources of data: the literature, the survey and the case studies. The goal of the literature review was to use as recent literature as possible from several authors in the areas of both research questions. In addition to books, a lot of information was collected from various electronics industry related magazines, cellular terminal company’s internal surveys and training material and few web pages. After the completion of the literature review, an industry survey was conducted among nine (9) companies from various domains of the cellular industry to collect tacit knowledge within the industry based on the questions identified during the literature review. To conclude, three case studies were presented and documented: two OEM supplier development projects and one technology cooperation case. The data collected through literature review, the interviews and the case studies were generally well aligned with each other, and so it is safe to conclude that the research results are based on valid data. A chain of evidence through two versions of modes of constructs (A and B) was established between these different sources of data. Internal validity of the research was verified through pattern matching between the cases, through explanation building in the validation phase of the model of constructs and through the cross-case analysis. The domain of generalization for the research findings was established from the beginning of the research, that being the cellular terminal business. External validity of the research was ensured by using other research findings, surveys and case studies from literature as a comparison and reference to the findings of this research. The reliability of the research was ensured by following the case study protocol presented by Yin (1994) into detail.

Most of the literature reviewed was generic in nature, not limited to any particular industry or business. The cases and examples presented were electronics industry related, typically either from the cellular terminal business, electronics component business or the automotive industry. The magazines used as reference were related mainly to electronics industry with the key emphasis in cellular, automotive, semiconductor and PC-businesses. The case studies and survey interviews were conducted with companies that were mainly either first or second tier suppliers to the cellular terminal manufacturing companies, but had key customers in other business areas as well. So it can be stated that the results apply the best in cellular terminal business. However, some of the results might be more generic in nature in overall consumer electronics industry.

8.3 Limitations of the study

The limitations of the research method selected, literature review, the survey and the three case studies, were mainly volume and scope. The surveys among nine companies and three case studies do not give a very broad understanding of the overall trends in the cellular terminal business. However, similarities in the results of both the survey and the case studies together with the similar findings in the theoretical framework show that there is relevance between the findings and it can be concluded that other companies in cellular terminal business would have experienced similar challenges within supply chain management, demand and supply planning and technology cooperation. It was mildly surprising that in fact that the most companies answered the questions of the survey in a similar manner. There were also quite a few similarities between the case studies. The empirical data collected correlates well with other surveys, such as studies conducted by Forrester Research and the industry related satisfaction surveys.

The overall positive tone of the literature related to the research topic will be mentioned later in this study, but it needs to be stated here that partnerships, demand planning, supply chain management and technology cooperation related literature presented mainly success stories around these topics. The theories and the practices presented were not really challenged in most of the literature references, and some of the literature was not very practical in nature and did not provide concrete advice on implementing the theories.

Another limitation of the selected method was that all the interviews for the survey were conducted during a period of six (6) months in 2001. The timing and documentation of the case studies was similar with the projects ranging from late 1999 to late 2001 and the documentation took place in early 2002. This suggests that the data collected is more of a snapshot of the industry at a given time instead of a long-term comprehensive study. The recent downturn in economy in 2001 and 2002 might have had an effect on the answering style of the interviews. However, the industry segment in which the case studies were conducted has been and continues to be interesting and the overall phenomenon of both exponential and now saturating product demand is worth studying. The results of the case studies within this industry segment cannot automatically be generalized to be valid for the overall electronics industry in any demand situation, but other industry segments have experienced similar growth curves, which have then later stabilized to declining growth or decreasing demand, just with more moderate volumes. So some generalizations can be made based on the data collected.

An additional limitation might be the fact that during the time of the case study interviews the researcher was working for one of the major OEM's in the cellular business, which might have caused the respondents answering style to be more positive. However, this was at least partly eliminated by not disclosing any of the companies or the people interviewed by name, and by explaining the purpose of the study. The role of the participant-observer actually assisted in getting access to and collecting the data. The fact that the most companies interviewed for the research are part of one or several common supply chains within the electronics industry could have affected the answering style as well. Supply chain "nucleus companies"' strong influence on the other members of the chain was clearly visible. Key processes and working practices are typically adopted from these "nucleus" companies. The processes that are optimal to one company are not necessarily optimal to another, even if the best practices sharing is always advisable, and the best practices within supply chain are not necessarily the ones used by the supply chains' "nucleus" companies. Sometimes process integration should happen downwards in the supply chain. It was also clear that most of the people interviewed both for the survey and the third case study were working very much in the present with the focus on the present activities. All participants did, however, also have insights to the future and improvement ideas to the existing situation.

The metrics for the model of the constructs were presented on an aggregate level, so that presented another limitation for the study. The researcher noticed from early on that availability and technology cooperation related metrics could be a topic for a separate research altogether, so the decision was taken to present the metrics in this study as an overview and as examples of possible metrics to use in practice.

8.4 Comparison of the constructs to the existing theories

In most areas covered by this research, the model of constructs complement the existing theories. The main references in the literature review concerning demand management have been made to Poirier (1999), Christopher (1998), Laseter (1998) and Baily, Farmer, Jessop and Jones (1994). The data collected from the survey and case studies complies with the findings of other research like Forrester Research (Whyte, 2001). In the area of supply chain management, the literature reviewed consisted mostly of the theories presented by Poirier and Reiter (1996), Dyer (2000), Goldfeld (1999), Hines (1994), Schorr (1998), Hanna and Newman (2001) and Pearsons, Gritzmacher and Karen (1990). The findings of this study add to the existing body of knowledge by identifying new ways of working, such as limited-editions approach, and emphasizing some specific areas that require attention such as new product introduction and ramp-up.

Technology cooperation models were addressed through theories presented by Afuah (1998), Lewis (1990), Hagedoorn (1993), Ashkenas, Ulrich, Jick and Kerr (1995), Cainarca, Colombo and Mariotti (1992), Harrigan (1995), Doz and Hamel (1995) and Littler, Leverick and Bruce (1995). The theoretical background for supplier integration was presented by Christopher (1998), Monczka (2000), Laseter (1998) and Fine (1998). The findings of Forrester Research (Whyte, 2001) support the findings of this research. Metrics for the individual constructs were collected mainly from Poirier (1999), Kneeland (1996), Avery (1998) and Van Mieghem (1996) and refined with practical proposals from the case studies. The case studies and the survey showed little evidence that would contradict any of the existing theories presented in the research. The industry practices and emerging ideas in some areas might be more advanced and pragmatic from the existing body of knowledge, and that creates the contribution of this research. The current situation of the cellular terminal business changes the prioritizations of the supply chain management and the decision-making criteria compared to the criteria being used during 1980's and 1990's. These new ideas, presented through the model of constructs add to the body of knowledge in the areas of demand management and planning visibility, supplier management, technology cooperation and supplier integration. To summarize, the most interesting ideas presented were:

- Market environment changes affect supply chain cooperation and management practices especially downwards in the supply chain

- A new guiding principle for flexible technology cooperation could be technology coordination through the use of technology steering teams
- "Nucleus company" could have a role in bringing companies together within different tiers of the supply chain to create new technologies
- Sales or marketing function involvement in collaborative planning and technology cooperation/coordination to share market information and to provide direction within the supply chain
- The main criteria for sourcing strategies could be: technology and demand
- The main criteria for the technology cooperation model selection could be: the risk and novelty of the technology and future volume
- Limited editions approach could be used for extremely difficult to forecast items
- Coordinated ramp up and ramp down efforts within the supply chain to optimize availability of all materials and equipment
- Active use of metrics to monitor the progress of supply and technology cooperation
- Sourcing competencies and demand planning activities should be extended to second and third tier suppliers for optimal availability
- The most competent resources and the optimal processes should be selected for technology cooperation within the supply chain
- Strive for standardization throughout the supply chain to shorten product life cycles and enable variant management
- Communication guidelines should be defined and informed to all levels of the cooperating organizations for timely and consistent communication
- Slow information sharing and increased lead times upwards in the supply chain promote vertical integration and poses challenges for the timely investments and capacity implementation
- Consistent and prioritized communication within the supply chain to avoid duplicate and non-value adding tasks
- Collaborative planning on-line for ensuring timely availability in the overall supply chain, consensus-forecasting

Literature reviewed for this study did not really address the effect of market environment changes to supplier management and collaboration activities. The effect was clearly visible through the case studies. This finding adds to the body of knowledge in the area of supply chain management and cooperation. New guiding principles for technology cooperation within a supply chain emerged from the survey and case studies: supplier coordination. Supply chain "nucleus" companies do not need to be tightly involved in cooperation projects with all key suppliers, but, instead, act as a coordinator for technology cooperation activities within the supply chain and new third parties. This approach optimizes the resources required and helps in avoiding duplicate efforts. Theory review typically presented forms of technology cooperation that were focused on deeper, preferably joint investment type of collaboration. The surveys and the case studies emphasize the importance of Sales and/or Marketing function involvement in collaborative planning and flexible technology cooperation within supply chains. The two main criteria were proposed for supply strategy creation and the selection of the technology cooperation model: (risk and novelty of) technology and (future) demand.

In general, the literature on partnerships does not surface any potential disadvantages of partnerships. This research tried to address the possible challenges of partnership efforts in a volatile market environment. Another topic within the scope of this research, not well covered in existing literature is the metrics and the use of metrics. This study endeavors to propose metrics for the model of constructs and present some ways of using metrics in evaluating the successfulness of the activities. In addition, this research emphasizes the common process development and standardization across the supply chain both in demand and design collaboration. The need for common tools, both in the technology and demand planning, the standardization efforts, targets and metrics has been mentioned frequently, more than in the literature reviewed in general. All the abovementioned activities should be extended to second and third tier suppliers to ensure overall availability and optimal resourcing across the supply chain, especially in critical situations such as new product ramp up's and ramp downs. Consistent and ongoing information sharing was emphasized on all levels of the organizations to enable timely decision-making across the supply chain. On-line collaboration for demand management was emphasized to ensure availability. Alternative approach, limited editions, could be a solution for difficult-to-forecast products.

Will the constructs of this research be valid in the future as well, or are they relevant only in today's or yesterday's market environments? The researcher feels the results of this study are not tied into certain world economy situation or end product demand growth pattern. Most likely supplier management and cooperation practices will fluctuate between different cooperation and collaboration levels (for instance Poirier's model I to IV) depending on the overall end product demand, supply strategies and the market environment. As stated in the research, when demand is growing, the supplier management activities are more focused on the supplier development and the partnership efforts whereas during stable and declining demand, the relationship between companies is more on an arm's-length level focusing on cost and performance as also outlined by Christopher (1998). The technology cooperation environment is more stable, not so exposed at least in the short-term to the changing business environment.

To conclude, this study does not bring new theories to the body of knowledge around the research questions, but complements the existing theories by bringing the information on the latest practices from the fastest growing consumer electronics industry niche in the areas of the supply chain management dynamics and new technology cooperation principles.

8.5 Recommendations and ideas for further research

Most of the ideas presented in the constructs of this research should be implementable in practice and the successfulness of the implementation could be followed through the effective use of metrics. It is recommended that both smaller and larger cellular terminal business companies should at least investigate some of the principles identified in this research. The communication and information sharing guidelines should be relatively easy to apply in basically any type of industry with no substantial costs attached, unless specific tools would be implemented. It is also worthwhile to investigate the dynamics of the supply chain to identify the strengths and the weaknesses in the existing supply chains with the proposed criteria. This analysis should be extended to the second and the third tier suppliers for uniformity and overall risk management purposes. The joint process development and shared resources can actually save costs in smaller companies even in the short term, while in the larger companies the savings can be expected mainly in the long term.

The areas for further studies evolve in the areas of the constructs made in this research. One interesting topic would be how to improve end-to-end demand visibility in both directions within the supply chain, i.e. the concept of a glass pipeline, as traditional forms of forecasting are not sufficient. In today's environment, where the product life cycles and short and the future demand of end products is uncertain, it is difficult to make decisions concerning capacity implementation, product ramp up and discontinuities without knowing the materials situation across the supply chain. How could this visibility be improved in practice and how do we measure the benefits of the visibility? What kind of tools and investments would be needed? How could the return-on-investment (ROI) be measured? The existing literature does not give new ideas of how to manage demand in a fast growing, fluctuating or declining market environment. At the same time, there is literature available concerning e-business opportunities in terms of different types of tools and applications. As mentioned in the study, many companies are still in the investigation phase of the future e-business opportunities, so the majority of electronics manufacturing companies have not fully implemented the advanced tools available. The data from Strategy & Business review (Laseter, 1998) show the implementation levels of electronic tools within the supply chains of several different industries.

	Fully implemented	Some use
Forecast and schedule sharing	17%	27%
Order call-off	10%	32%
Request of quotation, acknowledgement	7%	33%
Automated shipment notification	12%	39%
Electronic invoicing	27%	42%
Electronic funds transfer	16%	34%

The case studies also presented interesting information concerning the supply chain dynamics that the researcher did not come across during the literature review. The tendency of companies is to integrate and cooperate vertically rather than horizontally and the fact that cooperation focuses of companies is more downstream, i.e. towards the end customer. The fact remains that capacity implementation lead-times tend to get longer and production more capital intensive upstream in the chain. Should more emphasis in the future be put on these second and third tier suppliers and their strategic management and development to optimize the overall availability in the supply chain from the new product ramp-up onwards? How is a well-coordinated ramp down with minimum excess and scrap material and/or products performed?

Another interesting area for further study would be technology cooperation and early supplier involvement. What would be the optimal process for bringing suppliers and possible third parties, when necessary, to the OEM's or other companies' product development processes? Or vice versa, how could OEM's be integrated to suppliers' development processes? How should the development teams look to optimize the use of resources and competencies within the extended enterprise? How could the value-added of these efforts be measured in practice? What type of practices and ways of working enable and facilitate the third party engineering or part integration to the development processes of end products?

The fourth interesting area for further investigation would be the true value added of partnerships. First of all, what is the real definition of a partnership? And what would be the ideal process for creating partnerships? What are the best possible metrics to measure the partnership benefits and how should the measuring be done in practice? What would be the alternative approaches to partnership? Some metrics were already proposed in this study, but the related literature should be studied further and actual cases should be researched for deeper understanding of the benefits and the shortcomings of partnership efforts. The concept of a partnership satisfaction index could be worth further research. How can goodwill and trust associated to partnerships be measured and are trust and goodwill really integral elements of partnerships?

As stated in the limitations of this study, another topic for further research is the metrics. As the survey and the case studies show, metrics were defined to review the progress and results of demand management and technology cooperation activities, but the metrics were not necessarily being implemented and followed up. What are the reasons for this? Is there a lack of tools to enable measurements? Is strategic planning in terms of target setting and follow up missing on a supply chain level? Are the results of cooperation difficult to quantify?

9. SUMMARY

The purpose of this research was to define a model of constructs to find solutions to the two research questions:

1. How to ensure availability of components and manufacturing tools?
2. What are the possible, practical guiding principles in developing new technologies within supply chains?

The research method follows the case study guideline outlined by Yin (1981a, 1982b and 1994), selected based on the type of research questions and the nature of the research problem. The research has been divided into different parts: the research methodology, the electronics industry overview, the literature review, the industry survey, the model of constructs (1A and 2 A), the three case studies, validation of the model of constructs, the final model of constructs and evaluating the quality of the final model of constructs (1B and 2 B). Areas of future research and the relevance of the results to the industry and to the existing body of knowledge have been identified. The model of constructs was build based on the literature review and the survey and the model was validated with data collected from three case studies. The survey was conducted to collect as much tacit knowledge of the electronics industry practices as possible around the topics of the literature review. The case studies were selected based on relevance to the model of constructs, availability of data and timing of the case studies. The table below presents the final model of constructs categorized per research question**.** The last chapter of this study evaluates the quality and relevance of this research, identifies possible constraints to some of the constructs and analyzes the results of this study compared to existing body of knowledge. The main contribution of the overall research is the findings in the area of supply china management dynamics, collaborative planning principles and the guidelines for technology cooperation within the concept of extended enterprise.

Table 25: Summary of the constructs of the research

Research Question	Construct
1	Construct 1: To ensure materials availability in a supply chain, demand and supply end to end visibility should work on-line both up-and downward in the supply chain including inventory related information to be used in ramp-up, mass production and ramp-down phase decision making.
1	Construct 2: The end-customer interface of a particular supply chain should be involved in the supply chain collaborative demand planning to increase future market understanding within the chain and to communicate the demand fluctuations in a timely manner across the supply chain to gain supply chains' trust and commitment. An active demand marketing approach is often required to convince the supply chain to act according to the up-and downward trends in the market demand to ensure materials availability in the long-term.
1	Construct 3: Limited editions approach can be used for extremely "difficult to forecast" or "erratic demand" –products to ensure the aggregate availability within a supply chain for a given commodity and/or end product. "Limited editions" are also a viable tool for product ramp down management.
1	Construct 4: Supply strategy is a critical part of materials and equipment availability in the long term and the two most important criteria to categorize companies for OEM-driven supply chain are: technology (provided) and (future) volume of each commodity.
1	Construct 5: As investment intensity, bullwhip effect and capacity building lead-times increase upwards in the supply chain and the speed of information sharing decreases upwards in the supply chain driving verticalization and cooperation preference downstream, all supply chain companies, regardless of their tier, should be on an acceptable level in supply chain managemet activities to ensure overall availability.
2	Construct 6: Sales and/or product marketing involvement from the buying company's side in technology cooperation is essential in ensuring the alignment of technology scanning and cooperation activities with the market expectations concerning cost/benefit, product features and introduction timeschedules.
2	Construct 7: To enable cost efficient and speedy design cooperation in each company, inside and beyond supply chains the following prerequisites need to exist inside a supply chain: streamlined development processes, facilitated third party participation in company internal processes, resource optimization and modularity, standardization and open interfaces in product design.
2	Construct 8: End product design and manufacturing process related information is a prerequisite for optimizing the design, quality and costs of end customer products. Consistent, uniform and prioritized communication needs to take place on all levels and in all functions of the organizations to avoid overlap and redundant work within the supply chain and management needs to educate personnel on what should and should not be communicated within supply chain.
2	Construct 9: The supply chain's "nucleus company" has an essential role in bringing existing suppliers and new, third party companies together in strategic alliances to coordinate the creation of new, innovative solutions for end-users within the concept of extended enterprise. Technology steering teams per core technology facilitate the coordination.
2	Construct 10: The technology cooperation model selection for new technology creation should depend mainly on two key criteria: market and demand certainty, i.e. risk and novelty of technology and the understanding of future demand.

REFERENCES

Afuah, Allan (1998). Innovation Management: Strategies, Implementation and Profits. University of Michigan. Oxford University Press.

Alajoutsijarvi, Kimmo; Moller, Kristian; Tahtinen, Jaana (2000). Beautiful Exit: How to Leave your Business Partner. European Journal of Marketing, Volume 34 number 11/12, 2000. MCB University Press ISSN 0309-0566.

Ashkenas, Ron; Ulrich, Dave; Jick, Todd; Kerr, Steve (1995). The Boundaryless Organization. Breaking the Chains of Organizational Structure. Jossey-Bass Publishers, USA.

Avery, Christopher M. (1998). Powerful Partnering Practises for OEM. Partnerworks Inc.

Baily, Peter; Farmer, David; Jessop, David; Jones, David (1994). Purchasing Principles and Management. Seventh Edition. London, UK. Pitman Publishing. ISBN 0273603191.

Banham, Russ (2001). Road Testing the Ford Supply Chain. iSource Business, July 2001. Vulcan Publications.

Baker, Hugh; Laseter, Tim (2002). The Four Phases of Continuous Sourcing. Strategy + Business, Issue 27, 2002.

Beard, Haisley (2001). Industry Trends. Statistics compiled from Aberdeen Group and Forrester Research Inc. iSource Business, July 2001. Vulcan Publications.

Bidault, Francis; Cummings, Thomas (1994). Innovation Through Alliances: Expectations and Limitations. R&D Management, 24.1, 1994. Basil Blackwell Ltd.

Brown, Shona I.; Eisenhardt, Kathleen M. (1998). Competing on The Edge. Strategy as Structured Chaos. Harward Business School Press. ISBN 0-87584-754-4.

Brush, Linnea (2000). No Shortage of Issues in Power Market. August 28, 2000. Electronic Buyers' News.

Bulmer, Martin (1988). Some Reflections upon Research Organizations in A. Byrman (ed.). Research in Organizations, Routledge, London, The United Kingdom.

Buffa, Elwood, Spencer (1979). Production-Inventory Systems: Planning and Control. 3rd edition. ASIN 0256020418.

Butman, John (2002). A Pain in the Supply Chain. Harvard Business Review Case Study, May 2002. Harvard Business School Publishing Corporation USA.

Cainarca, G.C.; Colombo, M.G.; Mariotti, S. (1992). Agreements between Firms and The Technological Life Cycle Model: Evidence from Information Technologies. Research Policy, Vol 21, 1992. Amsterdam, The Netherlands. ISBN ISSN 0048-7333.

Camp, Robert C (1989). Benchmarking: The Search for Industry Best Practices that Lead to Superior Performance.

Carbone, Jim (2001). Lucent's Supply Chain Focus Fattens Margins. Electronics and Technology Purchasing. September 19th, 2001.

Cavinato, Joseph L. (1984). Purchasing and Materials Management, Integrative Strategies. West Publishing Company. ISBN 0-314-77869-1.

Chabron, Eric (2000). Tighter Supply Chain Helps Lucent Add Speed. April 17, 2000. Electronics Buyers' News.

Chesborough, Henry W.; Teece, David J. (2002). Organizing for Innovation: When is Virtual Virtuous? Harvard Business Review, The Innovative Enterprise, August 2002.

Christensen, Clayton M. (1992). Exploring the Limits of the Technology S-Curve. Part I: Component technologies. Production and Operations Management 1, no. 4 (1992): 340.

Christensen, Clayton M. (1997). The Innovator's Dilemma. When New Technologies Cause Great Firms to Fail. Harvard Business School Press, Boston Massachusetts, USA. ISBN 0-87584-585-1.

Christopher, Martin (1998). Logistics and Supply Chain Management. Strategies for Reducing Cost and Improving Service. Second Edition, Financial Times Professional Limited. ISBN 0-273-63049-0.

Cleland, David I. (1994). Project Management. Strategic Design and Implementation. Second Edition. McGraw-Hill, Inc. USA. ISBN 0-07-011351-3.

Covell, Andy (2000). Digital Convergence. How the Merging of Computers, Communications and Multimedia is Transforming Our Lives. Aegis Publishing Group Ltd. USA. ISBN 1-890154-16-4.

Day, John (2000). Having Their Day In The Sun. July 24, 2000. Electronic Buyers' News.

Day, John (2000). Navigating the DRAM Market by Technology Maze. August 21, 2000. Electronic Buyers' News.

Deeds, David L.; Hill, Charles W.L. (1996). Strategic Alliances and The Rate of New Product Development: An Empirical Study of Entrepreneurial Biotechnology Firms. Journal of Business venturing 11, 41-55, 1996. Elsevier Science Inc.

Dosi, Giovanni (1982). Technological Paradigms and Technological Trajectories. A Suggested Interpretation of the Determinants and Directions of Technical Change. Science Policy Research Unit, University of Sussex, Brighton, UK. ISBN ISSN 0048-7333.

Doz, Yves; Hamel, Gary (1995). The Use of Alliances in Implementing Technology Strategies. Managing Technology and Innovation for Corporate Renewal, Oxford University Press.

Doz, Yves L.; Hamel, Gary (1998). Alliance Advantage, The Art of Creating Value through Partnering. Boston, USA, Harvard Business School Press.

Dunn, Jim (2001). The Matrix. Assessing Your Spend in the New Frontier. iSource Business, August 2001. Vulcan Publications.

Dyer, Jeffrey H. (2000). Collaborative Advantage: Winning through Extended Enterprise Supplier Networks. Oxford University Press. ISBN 0-19-513068-5.

Electronic Buyers' News, Cell-phone Demand Squeezing Components Supply, March 27, 2000.

Eisenhardt, Kathleen M. (1989). Building Theories from Case Study Research. Academy of Management Review, 1989. Vol 14, No. 4, 532-550.

Erridge, Andrew (1995). Managing Purchasing. The United Kingdom. Butterworth-Heinemann Ltd. ISBN 0 7506 1941 4.

Extending your Reach – Networked Product Creation. Training module 8. -9. October 2001. Collaborators: INSEAD Faculty, Peter Williamson, Yves Doz.

Field, Anne (2001). Transforming a Titan. iSource Business, November 2001. Online Supply China Solutions. Vulcan Publications.

Fine, Charles H. (1998). Clockspeed. Using Business Genetics to Evolve Faster than your Competitors. Massachusetts, USA. Perseus Books, Reading. ISBN 0 316 64834 5.

Fine, Charles H. (2000). Competing with Speed and Flexibility. Sloan School of Management, MIT. USA.

Fortgang, Ron S.; Lax, David A.; Sebenius, James K. (2003). Negotiating the Spirit of the Deal. Harward Business Review, February 2003. Harward Business School Publishing Corporation.

Gain, Bruce; Dunn, Darrell (2000). Handset Forecasts Don't Add Up. August 14, 2000. Electronic Buyers' News.

Goldfeld, Charles (1999). Supplier Strategies. PT Publications, Inc. USA. ISBN 0-945456-32-8.

Greenbaum, Joshua (2001). Evaluating the Supply Chain: The Case for Business Analytics and PeopleSoft's Supply Chain Insight. September 2001. Enterprise Applications Consulting, Daly City, California, USA.

Gulisano, Vincent (2001). Optimizing Intelligence. iSource Business, August 2001. Vulcan Publications.

Hagedoorn, John (1990). Organizational Modes of Inter-firm Co-operation and Technology Transfer. Technovation, Volume 10, No. 1. 1990. Elsevier Science Publishers Ltd.

Hagedoorn, J. (1993). Understanding the Rationale of Strategic Technology Partnering. Interorganizational Models of Cooperation and Sectoral Differences. Maastricht Economic Research Institute of Innovation and Technology (MERIT), University of Limburg, Maastricht, The Netherlands. Strategic Management Journal, Vol. 14, 371-385 (1993). Chichester. ISBN 0143-2095.

Hagedoorn, J.; Schakenraad, J. (1994). The Effect of Strategic Technology Alliances on Company Performance. Strategic Management Journal, vol 15. 1994. Chichester. ISBN ISSN 0143-2095.

Hagedoorn, J.; Narula, R. (1996). Choosing Modes of Governance for Strategic Technology Partnering: International and Sectoral Differencies. Journal of International Business Studies, Vol 27, 2nd quarater, 1996. Newark, New Jersey, USA. ISBN ISSN 0047-2506.

Hagedoorn J.; Sadowski, B. (1999). Exploring the Potential Transition from Strategic Technology Partnering to Mergers and Acquisitions. Journal of Management Studies 36:1, January 1999. Oxford, Blackwell. ISBN ISSN 0022-2380.

Handfield, Robert B.; Nichols, Ernest L. Jr. (1998). Introduction to Supply Chain Management. Prentice Hall Inc., New Jersey, USA. ISBN 0136126161.

Hanna, Mark D.; Newman, W. Rocky (2001). Integrated Operations Management: Adding Value for Customers. Prentice Hall Inc., New Jersey, USA. ISBN 0-13-258526-X.

Harrigan, K.R. (1988). Joint Ventures and Competitive Strategy. Strategic Management Journal. 9: 141-158, 1988.

Harrigan, Kathryn, Rudie (1995). The Role of Intercompany Cooperation in Integrated Strategy: Strategic Alliances and Partnering Arrangements. Advances in Strategic Management, Volume 11B, pages 5-20. JAI Press Inc. ISBN 1-55938-959-1.

Harris, Neely (2001). Strategic e-Sourcing. iSource Business, Online Supply Chain Solutions. October 2001. Vulcan Publications.

Harris, Neely (2002). Integration Frustrations. iSource Business, Online Supply Solutions. June/July 2002. Vulcan Publications.

Haughey, Jim (2002). A Mix of Sun and Clouds. Electronic Buyers' News. July 1st, 2002.

Heikkila, Jussi (2000). Developing Demand Chain Management: Case Study on the Fast Growing Cellular Networks Industry. Acta Polytechnica Scandinavica, Industrial management and Business Administration Series No. 8, The Finnish Academies of Technology, Espoo, Finland.

Hines, Peter (1994). Creating World Class Suppliers, Unlocking Mutual Competitive Advantage. Pitman Publishing. USA. ISBN 0273603000.

Jarillo, Carols J. (1988). On Strategic Networks. Instituto de Estudios Superiores de la Empresa (IESE), Universidad de Navarra, Barcelona, Spain. Strategic Management journal, Vol 9, 31-41. 1988. John Wiley & Sons, Ltd.

Jones, G. (1987). Organization-client Transactions and Organizational Governance Structures. Academy of Management Journal 20:197-218, 1987.

Karlöf, Bengt; Östblom, Svante (1993). Benchmarking, Tuottavuudella ja laadulla mestariksi. Weilin+Göös. ISBN 951-35-5687-5. Finland.

Kawasaki, S.; McMillan, J. (1986). The Design of Contracts: Evidence from Japanese Subcontracting. University of Western Ontario, Canada.

Keil, Thomas (2000). External Corporate Venturing: Cognition, Speed and Capability Development. Helsinki University of Technology Institute of Strategy and International Business. Doctoral Dissertations 2000/2. Espoo, Finland.

Kidder, L.; Judd, C.M. (1986). Research Methods in Social Relations. 5th edition. Holt, Rinehart and Winston, New, York, USA.

Killing, J.P. (1988). Understanding Alliances: The Role of Task and Organizational Complexity. In F.L. Contractor & P. Lorange (Eds.), Cooperative Strategies in International Business: 55-67. Lexington, Mass.: Lexington Books.

Kneeland, Godfrey A. Jr. (1986). Partnering in Design and Construction. McGraw-Hill Inc. ISBN 0-07-024038-8.

Kogut, Bruce (1988). Joint Ventures: Theoretical and Empirical Perspectives. The Wharton School, University of Pennsylvania, Philadelphia, Pennsylvania, USA. Strategic Management Journal, Vol 9, 319-332, 1988.

Kotabe, Masaaki (1992). Global Sourcing Strategy, R&D, Manufacturing and Marketing Interfaces. Quorum Books. USA. ISBN 0-89930-667-5.

Lam, Alice (1997). Embedded Firms, Embedded Knowledge: Problems of Collaboration and Knowledge Transfer in Global Cooperative Ventures. Organization Studies 18:6, 1997. Berlin, Germany. ISBN ISSN 0170-8406.

Lancaster, Geoffrey A.; Lomas, Robert A. (1985). Forecasting for Sales and Materials Management. MacMillan UK. ISBN 0333365828.

LaPedus, Mark (2000). Seeking Riches in 3G Chips. May 15, 2000. Electronic Buyers' News.

Laseter, Timothy M. (1998). Balanced Sourcing, Cooperation and Competition in Supplier Relationships. A Strategy and Business Book. Booz, Allen & Hamilton Inc. USA. ISBN 0-7879-4443-2.

Lee, Hau L. (2002). The Certainty of Supply, Chain Uncertainty. iSource Business, April/May 2002. Vulcan Publications, Birmingham, AL, USA.

Lewis, Jordan D. (1990). Partnerships for Profit: Structuring and Managing Strategic Alliances. Free Press, USA. ISBN 0029190509.

Liotta, Bettyann (2000). Now You See Them…Now You Don't. February 28, 2000. Electronic Buyers' News.

Liotta, Bettyann (2000). Squeeze on Supply. March 13, 2000. Electronic Buyers' News.

Littler, Dale; Leverick, Fiona; Bruce, Margaret (1995). Factors Affecting the Process of Collaborative Product Development: A Study of UK Manufacturers of Information and Communications Technology Products. Product Innovation Management 1995; 12:16-32.

Madhok, Anoop; Tallman, Stephen, B. (1998). Resources, Transactions and Rents: Managing Value Through Interfirm Collaborative Relationships. Organization Science/ Vol 9., No. 3, May-June 1998.

Magretta, Joan (1998). The Power of Virtual Integration: An Interview with Dell Computers' Michael Dell. March-April, 1998. Harward Business Review.

Magretta, Joan (2002). Why Business Models Matter. Harvard Business Review Spotlight: Practical Strategy, May 2002. Harvard Business School Publishing Corporation.

Makridakis, Spyros; Wheelwright, Steven C. (1990). Forecasting Methods for Management. 5th edition. John Wiley & Sons, USA. ASIN 0471600636.

Mayer, John H. (2000). Cost, Power, Supply Still Top OEMs List of Concerns. August 21, 2000. Electronic Buyers' News.

Mayer, Marc H.; Lehnerd, Alvin P. (1997). The Power of Product Platforms. Building Value and Cost Leadership. New York, USA. The Free Press. ISBN 0-684-82580-5.

McKeefrey, Haily Lynne (2000). Supply Chain Domino Effect. March 27, 2000. Electronic Buyers' News.

Mc Keefrey, Haily Lynne (2000). AVL Grows in Importance. May 1, 2000. Electronic Buyers' News.

Miller, Matt (2001). What's the Marketplace Forecast? iSource Business, August 2001. Vulcan Publications.

Miller, Sarah (2002). Collaboration by Design. iSource Business. June/July 2002. Vulcan Publications.

Millson, Murray R.; Raj, S.P.; Wilemon, David (1996). Strategic Partnering for Developing New Products. A four-stage process can help management answer the question it must answer when forming partnerships to develop new products. Industrial Research Institute, Inc. May-June, 1996.

Monczka, Robert M; Handfield, Robert B.; Scannel, Thomas V.; Ragatz, Gary L.; Frayer, David J. (2000). New Product Development. Strategies For Supplier Integration. Milwaykee, Wisconsin, USA. ASQ Quality Press. ISBN 0-87389-468-5.

Murphree, Julie (2002). Demand Management. iSource Map Series, iSource Business. December 2002/January 2003. Cygnus Business Media.

Murphy, Erika (2001). E-Verify, The Kathie Lee Factor. iSource Business, July 2001. Vulcan Publications.

New Technology Introduction Process. Leading Science 3 Training Group Work. Spring 2001.

Nishiguchi, Toshihiro (1994). Strategic Industrial Sourcing, The Japanese Advantage. Oxford University Press. UK. ISBN 0-19-507109-3.

Nokia Press Release: For the first quarter, Nokia currently expects to report growth and good profitability – despite a more challenging business environment. March 15, 2001.

Nokia Press Release: Nokia's second quarter margins above 15% with pro forma pre-tax profit of nearly EUR 1.2 billion. Press Release. July 19th, 2001.

Nokia Press Release Q3/2001. Nokia Achieves third-quarter profitability targets with pro forma operating margin of 15,2% and EPS or EUR 0,16. October 19th, 2001.

Nokia Press Release Q4/2001. Nokia continues strong performance in challenging year 2001. January 24, 2002.

Nokia Press Release 1Q/2002. Nokia exceeds 1Q profit targets on slightly lower sales. Press Release, April 18, 2002.

Nurmi, Ilari (1998). Strategic Alliance Partner Selection in an Emerging Industry. Helsinki University of Technology. Department of Engineering Physics and Mathematics. Institute of Strategy and International Business.

OEM Collaboration Guidelines, September 2001.

Industry satisfaction survey, September 2000. I.R.O. Research Oy.

Industry satisfaction survey, June 2001. I.R.O. Research Oy.

Ojo, Bolaji (2000). A Tough Juggling Act in a Tight Component Market. March 27, 2000. Electronic Buyers' News.

Ojo, Bolaji (2000). Forecast Inaccuracies Twist the Supply Chain. August 14, 2000. Electronic Buyers' News.

Olkkonen, Tauno (1993). Johdatus teollisuustalouden tutkimustyöhön. Helsinki University of Technology, Industrial Economics and Industrial Psychology. Finland. ISBN 951-22-1774-0.

Osborn, R.N.; Baughn, C.C. (1990). Forms of Interorganizational Governance for Multinational Alliances. Academy of Management Journal, 33 (3), 503-519, 1990.

Orr, Sandy (2001). I Can See Miles and Miles. iSource Business, September 2001. Vulcan Publishing.

Pearson, John N.; Gritzmacher, Karen J. (1990). Integrating Purchasing into Strategic Management. Long Range Planning, Vol. 23, No. 3, pp. 91 to 99, 1990. USA.

Picot, A. (1991). Ein Neuer Ansatz zur Gestaltung der Leistungsteife. Zeitschrift fur Betriebswirtschaftliche Forschung 41(4), 336-357.

Poirier, Charles C. (1999). Advanced Supply Chain Management. How to Build a Sustained Competitive Advantage. Berrett-Koehler Publishers, Inc. San Fransisco, USA. ISNB 1-57675-052-3.

Poirier, Charles C.; Reiter, Stephen E. (1996). Supply Chain Optimization, Building the Strongest Total Business Network. Berrett-Koehler Publishers, Inc. USA. ISBN 1-881052-93-1.

Prahalad, C.K.; Hamel, Gary. (1990). The Core Competence of the Corporation. Harward Business Review, May-June 1990.

Polanyi, M.E. (1958). Personal Knowledge: Towards a Post-Critical Philosophy. Chicago, University of Chicago Press.

Reese, Andrew K. (2001). Leap of Faith. iSource Business, Online Supply Chain. April 2001. Vulcan Publications.

Reese, Andrew K. (2001). Stop. Collaborate and Listen. iSource Business, Online Supply Chain Solutions, September 2001. Vulcan Publications.

Reichheld, Frederick F. (2001). Lead for Loyalty. Harward Business Review, July-August 2001. Volume 79, number 7. Harward Business School Publishing.

Research Program of the Partnership for a New Generation of Vehicles. Fourth Report. (1998). National Research Council. National Academy Press, Washington D.C. USA. ISBN 0-309-06087-7.

Rivette, Kevin G.; Kline, David (2000). Discovering New Value in Intellectual Property. January-February, 2000. Harvard Business Review.

Robertson, Jack (2000). Component Shortage Fanning Out. March 13, 2000-1202. Electronic Buyers’ News.

Robertson, Jack; MacLellan, Andrew (2000). OEM’s Get Patent Wake-up Call. September 4, 2000 – 1227. Electronic Buyers’ News.

Rodin, Rob (2001). Lessons in Supply Chain Survival. iSource Business, Online Supply China Solutions. November, 2001. Vulcan Publications.

Roos, Gina (2000). Serious Case Of The Shorts, Lead Times are Stretching Out. February 7, 2000. Electronic Buyers' News.

Roos, Gina (2000). As Demand Soars, OEM's Face a Long Wait. February 21, 2000. Electronic Buyers' News.

Sahlin, Michael (2001). Supply Requirements. An Interactive View on Concurrent Engineering with an Information Prespective. Global Supply Chain Forum: Reasearch Roundtable, Concurrent Product Development across Supply Chain.

Schillaci, Carmela Elita (1987). Designing Successful Joint Ventures. The Journal of Business Strategy, vol. 8, no. 2.

Schorr, John E. (1998). Purchasing in the 21st century. A Guide to State-of-the-Art Techniques and Strategies. John Wiley & Sons. USA. ISBN 0-471-24094-X.

Shah-Baljko, Jennifer (2000). Racing for the Checkered Flag. February 14, 2000. Electronics Buyers' News.

Simchi-Levi, David; Kaminsky Philip; Simchi-Levi, Edith. (2000). Designing and Managing the Supply Chain. Concepts, Strategies and Case Studies. McGraw-Hill International Edition. ISBN 0-07-118870-3.

Spekman, R.E.; Forbes, T.M.; Isabella, L.A.; MacAvoy, T.C. (1998). Alliance Management: a View from the Past and a Look to the Future. Journal of Management Studies. Vol. 35:6, November 1998. Oxford, Blackwell. ISBN ISSN: 0022-2380.

Steensma, H.K. (1997). Internalizing External Technology: A Model of Governance Mode Choice (Working paper). Blooomington, Indiana, USA. Indiana University.

Sullivan, Laurie (2000). Allocation Anxiety. Smaller OEMs Especially Hard Hit by Shortages. August 21, 2000 – 1225. Electronic Buyers' News.

Thomas, Robert J. (1993). New Product Development. Managing and Forecasting for Strategic Success. The Portable MBA Series. John Wiley & Sons Inc. USA. ISBN 0-471-57226-8.

Thomke, Stefan; von Hippel, Eric (2002). Customers as Innovators, A New Way to Create Value. Harvard Business Review, April 2002. Harvard Business School Publishing Corporation, Boston, MA, USA.

Tushman, M.; Andersson, P. (1997). Managing Through Cycles of Technological Change. Managing Strategic Innovation and Change: a Collection of Readings. New York, Oxford University Press. ISBN ISSN: 0-19-510010-7/0-19-510011-5.

United Nations, New York and Geneva (1996). Exchanging Experiences of Technology Partnership; Papers prepared for the Meeting of Experts on Technology Partnership for Capacity-building and Competitiveness, and recommendations. 10-12 April 1996, Helsinki, Finland.

Van Mieghem, Timothy (1995). Implementing Supplier Partnerships. How to lower costs and improve service. Prentice Hall, USA. ISBN 0-13-180365-4.

Verghese, Matt (2001). In your opinion, what are the most important value propositions in the supply chain? iSource Business, Online Supply Chain. April 2001. Vulcan Publications.

Vilkamo, Tiina (2000). Aspects of Partnering in Fast Technology Environment. Helsinki University of Technology, Finland.

Virolainen, Veli-Matti (1992). An Analytical Framework for Raw Materials Inventory Control in Industrial Firms. Lappeenranta University of Technology, Finland.

Wallace, Thomas F. (1999). Sales & Operations Planning. The How to Handbook. T.F. Wallace & Company, USA. ISBN 0-9674884-0-0.

Whyte, Cherish (2001). Front-end Alignment. iSource Business, July 2001. Vulcan Publications.

Whyte, Cherish (2001). Collaboration Equals Domination. iSource Business, October 2001. Vulcan Publications.

Williamson, O.E. (1985). Markets and Hierarchies: Analysis and Antitrust Implications. New York: Free Press.

Yin, R.K. (1981a). The Case Study as a Serious Research Strategy. Knowlegde, Creation, Diffusion, Utilization, Vol. 3.

Yin, R.K. (1981b). The Case Study Crisis: Some Answers. Administrative Science Quarterly, Vol. 26.

Yin, Robert K. (1994). Case Study Research, Design and Methods. Second Edition. Applied Social Research Method Series, Volume 5. Sage Publications, Inc. USA.

Yin, R. K.; Bateman, P. G.; Moore, G. B. (1983). Case Studies and Organizational Innovation: Strengthening the Connection. Washington DC, USA: Cosmos Corporation.

Websites:

www.abbre.com

www.loyaltyrules.com

www.nokia.com

www.webster.com

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Appendix 1

FORMULAS FOR PROPOSED METRICS

Lost sales =	Unfulfilled sales demands, for example customers who are not willing to wait for delivery and choose competitor's product.
Sales, sales from new products =	Amount of sales in a given time period per product category.
On time delivery to customers =	The percentage of products delivered on a customer requested date compared to all deliveries.
Market share =	Company's share of the overall business globally/regionally/per product.
Forecasting accuracy =	Forecasted sales compared to actual sales in a given time period.
Number of collaborating companies =	Number of companies participating in demand and/or design collaboration among all supply chain companies.
Overall supply chain lead-time =	Time it takes to build a product from scratch and deliver it to the customer.
Supply chain inventory investment =	The cumulative inventories in the whole supply chain, either in terms of units or money.
Customer order lead-time =	The time it takes for the customer to get the product once ordered.
Transaction cost reduction =	Activity based costing, the money saved per transaction.
Gross profit =	Sales minus the cost of goods sold.
End product cost reduction =	Reduction in cost of goods sold or in overhead costs reducing the overall unit price of a product.
Obsolescence =	Excess inventory of end products, work-in-process or parts that cannot be sold or consumed.
Level of excess capacity =	The amount of idle capacity across the supply chain compared to active capacity.

Quality of products/customer returns =	The number of customer returns or repair requests compared to sales.
Discounts and allowances =	The total amount of products sold at a discount compared to overall sales.
Ramp up speed =	The speed at which a new product is taken into production, how fast manufacturing of a new product could start on a certain quality level.
Partnership satisfaction index =	Survey of how the different parties in a partnership see the benefits of a partnership.
Reducing total cost of end product =	End product cost reduction from the original manufacturing cost.
Reducing total cost of product development =	R&D expenditure per product divided by sales is the expenditure per product sold. Cost reductions are calculated from the original product development expenditure per product.
Number of new technology introductions =	The number of new technologies introduced per new product/annually compared to competition.
Timely new product introductions =	Actual time schedule of a launch compared to the planned time schedule.
Product development time =	The overall time spend to develop a new product in man-hours and in calendar months.
Size of a project team =	The overall man-hours required for the product development of a given product.
Customer/supplier loyalty =	The amount of replacement sales in overall sales.
Customer satisfaction =	Customer satisfaction measured through a survey.
Satisfaction survey =	Satisfaction to current practices measured through a survey.
Demand planning accuracy =	Forecasted demand compared to actual demand in a given time period.
Level of excess or missing capacity =	Level of either excess or missing capacity across the supply chain compared to overall capacity.

Appendix 2

QUESTIONNAIRE FOR CELLULAR TERMINAL BUSINESS COMPANIES

BACKGROUND
- What is the type of business you are in?
- What is the size of your company?
- Turnover 1999, 2000 and estimate 2001
- Number of personnel
- Key customers, what type of business are they in?
- Locations of operations, what type of operations per location?
- What are the biggest challenges in electronic manufacturing business today?
- How do you see the future of electronics manufacturing business?
- How do you plan for this future scenario?
- Short term? Long-term?

NEW TECHNOLOGIES
- How do you scan for new technologies to be added to your product portfolio?
- How do you ensure access to new technologies?
- What is the system for meeting customers' technology requirements?
- What kind of help are you looking for from your customer to be able to offer the requested technologies?
- How should technology plan sharing, if any, happen between customers and suppliers?
- How would you use this customers' technology information?
- How do you prepare for quantum leap technology requests from customers instead of evolutionary technology development?
- How do you manage new technology transitions with your suppliers?
- How do you see the best way to access to new technologies should be done in theory?

DEMAND PLANNING
- How do you prepare to future sales volumes?
- What kind of system do you use for demand-supply planning?
- How do you ensure that you meet customer expectations concerning volumes and lead-times?
- How would you like your customers to communicate their demand plans?
- What kind of benefit is there for having this information, i.e. how is it used?
- How do you prepare for big up-and downward changes in demand?
- How you manage your own supplier base concerning demand planning?
- What do you see would be the best way of managing demand in theory?

CUSTOMER-SUPPLIER RELATIONSHIP
- How should a customer- supplier relationship be organized in your opinion?
- To which level of supplier chain should the cooperation be extended?
- What kind of tools do you believe would help in the cooperation?
- Preferred information sharing channels?
- What is partnership?
- What is the value-added of partnerships in your opinion?
- Do you feel that supplier management practices should vary depending on the demand-supply situation?
- What kind of pricing strategies do you prefer?
- Flat price based on forecast, Pricing matrix, Provisional pricing, other
    - How do you manage your own suppliers?
    -

Appendix 3

Case study questionnaire for company C technology cooperation project

Background

- Role of the interviewee? What has been your role in this project?

Business environment and problematic

- What were the key drivers to start investigating the area the particular technology?
- How and why was the technology in question chosen?
- Was there a clear need for a new technology? Or scanning for bookshelf technologies?
- What were the different alternatives for technology access?
- What was the targeted time schedule for the technology implementation?
- How did you define whether to develop the technology internally, jointly or externally? Criteria?
- Was design subcontracting considered, i.e. not having internal resources in the project?
- How was the external party selected? What were the selection criteria?
- How did you decide the form of cooperation to perform? What were the criteria?
- What did the cooperation model selection mean in practice?
- How were future requirements concerning the material defined and taken into account in the project?
- What was the plan for ensuring availability?
- Was the project one-time cooperation or a part of joint long-term relationship?
- How were the required resources determined? Project team set-up?
- What was the cooperation process?
- What was the process to agree the targets, budget and timeschedule of the project?
- How were existing supply strategies and technology roadmaps taken into account in this project?

Solutions

- Was the access to the new technology developed through the project ensured officially? If not, how then?
- What was the way to ensure future availability of the material? What was this availability estimate based on?
- What was the process of agreeing possible intellectual property rights?
- How were the necessary interfaces in and outside the project determined?
- What were the main information sharing and documentation tools and channels? How were they determined?
- How was reporting structure designed within the project and to all participating companies?
- Were the cooperation activities between the two companies only, or were there any third parties involved?
- How was product quality and product cost taken into account in the project solution?
- What was the process of defining the metrics of the cooperation?
- Would there have been alternative means of reaching the same conclusions as the project did?
- Was there a contingency plan in case the project failed?
- Was there a method to determine possible risks?

- Was there an implementation plan in place for the technology into an end product?
- How was technology learning curve and ramp up taken into account in the implementation plan?

Results
- What were the main achievements of the cooperation? Compared to original targets?
- How did the cooperation affect customer's/seller's product portfolio?
- What were the effects on technology roadmaps and supply strategies?
- How was the successfulness of the project assessed in terms of
    - Time schedule
    - Resources
    - Costs
    - Results

  Follow-up on metrics? What were the largest gaps?
- Was there a competitive element in the cooperation?
- Were the effects of the collaboration to the supply chain considered? What would the main effects be?
- Were the possible effects on technology roadmaps and supply strategies followed-up? What were the main effects?
- What tools or processes would have been required in order to cooperate more effectively?
- Was there enough trust between companies to share new ideas and confidential information?
- What kind of processes or supplier management practices would have helped in cooperation?
- Were third parties affected by the cooperation? How was this taken into account?

Theoretical issues concerning technology cooperation
- Why do companies collaborate in the area of new technologies and R&D?
- What contributes to successful technology cooperation?
- What do you see as the biggest limitations/risks for cooperation?
- What makes technology cooperation successful in general?
- How do you define technology cooperation?
- Do you see differences between different forms of technology cooperation? Joint venture? Technology Partnership? Licensing? Joint R&D? Strategic alliance?
- What would be the ideal business model for the type of cooperation that was performed in this project?
- How many and what kind of resources would companies typically be willing to commit to cooperation activities, i.e. projects and coordination?
- What would be an ideal process for technology cooperation? Should company internal development processes be modified to facilitate third party integration?
- With whom is the cooperation typically most value adding? Why?
- What do you see as risks in technology cooperation?
- Can the benefits of cooperation be measured money-wise?
- How can technology and future materials availability be ensured theoretically? In practice?
- What do you see as main tools for technology cooperation and technology access in the future? What will be the biggest changes based on today's situation within the industry?