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INSTALLED BASE INFORMATION:

Ensuring Customer Value and Profitability after the Sale

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Abstract

This thesis explores the business benefits for capital goods manufacturers in maintaining systematic records for individual products in their installed base. The research results show that such installed base information can be essential for a company interested in improving both the value their customers get from using their products and their after-sales operations' profitability.

Although companies have product-related records on their sales, production, deliveries, service contracts, and service jobs, the data in the often function-specific information systems remain incompatible, and an overview of the installed base is missing. The resulting situation resembles that of manufacturing before ERP systems were introduced to unify function-specific transaction data in the manufacturing process. Whereas the ERP systems for production have been powerful in standardizing transaction data involving product and component *types*, the value for customers after the sale is created through product *individuals*. To implement information systems focusing on individual products, it is necessary to understand which functions are interested in such information and what data should be standardized and gathered.

The research's main objective was to improve understanding of the reasons for maintaining installed base information and understanding of the installed base information's structure. The research's empirical part consists of four in-depth case studies in four capital goods manufacturing companies providing product-related services. In each case study, the focal company developed its installed base information systems.

Consequently, several purposes for installed base information were identified towards providing customer value during the product use, both through ensuring the products' operational reliability and through supporting the customer's goals with the products. Ensuring product reliability for the customer requires that service units be prepared for servicing the individual products in their area and that the company can identify and resolve production and design problems with their products. Supporting the customers' goals requires that sales and product development can adjust the customer offers to differences among customer applications as well as changes in the customers' operations.

At the same time, after-sales operations' profitability can be improved through adjusting investments in service resources and service pricing based on the serviced products. Further, analyses of the installed products and the after-sales service operations support identifying performance problems with products, services, or customer contracts decreasing after-sales service profitability and requiring corrective actions.

The research revealed three main categories of information needed to support the above purposes: information on the individual products, information on the customer site where the product is installed, and information on the service events involving the product installations. These information categories enable analyses involving products, customer applications, and their performance over time.

Keywords: installed base, after-sales service, industrial service, service operations management, Organizational Information Processing Theory, information systems

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Tiivistelmä

Tässä väitöskirjassa tutkitaan asiakkailla käytössä olevaa laitekantaa koskevan tiedon hyötyjä investointihyödykkeitä valmistavien yritysten liiketoiminnassa. Tutkimuksen tulokset viittaavat siihen, että tällainen laitekantatieto voi olla erittäin merkittävässä asemassa yrityksille, jotka pyrkivät parantamaan laitteidensa asiakkaille tuottamaa käytönaikaista arvoa sekä kehittämään myynninjälkeisten toimintojensa kannattavuutta.

Yrityksillä on tyypillisesti asiakkaille toimitettuihin tuotteisiin liittyvää tietoa esimerkiksi tuotesuunnittelun, myynnin, tuotannon, toimitusten, ja huoltopalveluiden osalta, mutta nämä tiedot kerätään ja organisoidaan usein toimintokohtaisesti, jolloin kokonaiskuva asiakkailla olevasta laitekannasta on puutteellinen. Tämä muistuttaa tilannetta tuotantoprosessissa tilaustenkäsittelyn, oston ja kirjanpidon osalta, ennen kuin tuotannonohjausjärjestelmät yhtenäistivät yrityksen transaktioihin liittyvät tiedot. Vaikka tuotannonohjausjärjestelmät ovat olleet tehokas keino yhdistää myös tuotetyyppeihin liittyvää tietoa yritysten toimintojen välillä, asiakkaiden saama hyöty yrityksen tuotteista perustuu kuitenkin tuoteyksilöihin. Tuoteyksilöitä koskevan tiedon järjestelmällisen hallinnan toteuttaminen vaatii ymmärrystä siitä mitkä yrityksen toiminnot tarvitsevat toiminnassaan laitekantaa koskevaa tietoa, ja millaista laitekantaa koskevaa tietoa pitäisi olla saatavilla.

Tämän tutkimuksen keskeisenä tavoitteena on ollut lisätä laitekantatiedon tarpeiden ja laitekantatiedon rakenteen ymmärtämistä. Tutkimuksen empiirinen osuus koostuu neljästä tapaustutkimuksesta investointihyödykkeitä valmistavissa yrityksissä, jotka tarjoavat asiakkailleen myös tuotteisiinsa liittyviä myynninjälkeisiä palveluita. Kussakin tapaustutkimuksessa kohdeyritys oli tutkimuksen aikana kehittämässä laitekantatiedon järjestelmiään.

Tutkimuksessa tunnistettiin useita laitekantatiedon tarpeita laitteiden käytönaikaisen hyödyn parantamiseksi asiakkailla. Nämä liittyvät sekä tuotteiden luotettavuuden kehittämiseen että asiakkaan tavoitteiden tukemiseen. Tuotteiden luotettavuutta voidaan parantaa varmistamalla, että huoltoyksiköt ovat varautuneet huoltamaan alueensa laitekantaa ja että yritys pystyy tehokkaasti tunnistamaan ja korjaamaan laitteidensa tyyppivikoja. Asiakkaan tavoitteiden tukemiseksi sekä myynnin että tuotekehityksen on pystyttävä muokkaamaan yrityksen tarjontaa eri asiakassovellusten ja asiakkaan prosessimuutosten vaatimusten mukaisesti.

Myynninjälkeisten palveluiden kannattavuutta voidaan parantaa varmistamalla, että huoltoresursseihin investoidaan alueellisten erojen mukaisesti, ja että huoltopalveluiden hinnoittelussa huomioidaan huollettavien laitteiden erilaiset vaatimukset. Palveluiden kannattavuuden kehittämistä voidaan tukea myös laitekannan ja palvelutapahtumien analyysien perusteella, jos näistä voidaan tunnistaa laite-, palvelu- tai asiakaskohtaisia suorituskykyongelmia, jotka heikentävät toiminnan kannattavuutta.

Tutkimuksessa tunnistettiin kolme keskeistä tietotyyppiä asennettua laitekantaa koskevien tietotarpeiden tukemiseksi: yksittäisiin laitteisiin liittyvä tieto, asennuskohteisiin liittyvä tieto, ja näihin kohdistuviin palvelutapahtumiin liittyvä tieto. Näiden tietotyyppien avulla voidaan tehdä tuote-, asiakassovellus-, ja suorituskykyanalyysejä tukemaan eri toimintojen päätöksentekoa.

Asiasanat: asennettu laitekanta, myynninjälkeiset palvelut, teolliset palvelut, palveluoperaatioiden hallinta, organizational information processing theory, tietojärjestelmät

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Crafting this doctoral dissertation has been quite a journey. The paths were winding and the crossroads plentiful, and this was during the good times when I was on a path at all. But perhaps this is the very reason that made the journey so enjoyable. It is always enticing to uncover areas and to meet people that you would have missed otherwise. Nevertheless, like on all journeys, it is also good to finally get there. In the following, I express my gratitude to the ones who have supported and accompanied me on this particular journey, and made my walk easier.

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Helsinki, August 2009

Timo Ala-Risku

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DEFINITIONS OF FOCAL CONCEPTS

Installed Base	In this work, "installed base" refers explicitly to the *set of individual pieces of equipment* currently in use. This differs from the typical use where installed base is considered a cumulative equivalent of market share: e.g., 'A product's installed base is the total number of products currently under use' (Oliva and Kallenberg 2003, p. 163).
Installed Base Information	'Installed Base [systems include information on] where the sold products are located, who owns and/or operates them, what they are used for, under which conditions they are applied, their life cycle status, which service actions and technical changes have been performed, which parts serviced or replaced and their current technical state' (Borchers and Karandikar 2006, p. 2).
Installed Base Item	Individual product instance, piece of equipment.
Installed Base Location	The context where an individual product is used: e.g., geographical location, application, and environment.
Installed Base Event	An interaction involving an individual product: e.g., maintenance visit, repair operation, replacement, customer claim.
Product	A configuration comprised of hardware and software components. Further, the terms "product type," "product variant," or "product version" are used to denote an abstract class of products with similar features, whereas "equipment" and "item" are used to refer to physical products with their individual characteristics.
Product-service system	'a market proposition that extends the traditional functionality of a product by incorporating additional services' (Baines et al. 2007, p. 1543).
Product-service (system) supplier	A company providing products and additional services for their customers.
Uncertainty	The difference between the amount of information required for a task and the amount of information possessed by the performer of the task (Galbraith 1973).
Service	An activity performed for others with economic value and done on a commercial basis (Baines et al. 2007, p. 1545).

Service Base	The set of individual pieces of equipment covered by service contracts with customers.
Subunit	A group with specialized tasks in an organization (Tushman and Nadler 1978). In this work, the particular functional subunits of interest are service units, service resource management, sales, product management, and product development.
Subunit task environment	'Those external actors which are attended to by organizational members' (Tushman and Nadler 1978, p. 616).
Subunit task complexity	The predictability of outcomes when selecting among alternatives (Galbraith 1973; Campbell 1988).
Subunit interdependence	'Degree to which a subunit is dependent upon other subunits in order to perform its task effectively' (Tushman and Nadler 1978, p. 616).

1 INTRODUCTION

This thesis explores the business benefits for capital goods manufacturers in maintaining systematic records related to individual products in their installed base. Although companies have product-related records on their sales, production, deliveries, service contracts, and service jobs, the data in the often function-specific information systems remain incompatible, and an overview of the installed base is missing. To implement integrated information systems focusing on individual products, it is necessary to understand which functions are interested in such information and what data should be standardized and gathered.

The main objective of this work is to support developing installed base information systems, both through propositions for information systems design and through theoretical treatment of installed base information impacts on managing operations at capital goods manufacturers with after-sales services. For these purposes, the research aims to improve the understanding of the reasons for maintaining installed base information and the understanding of installed base information's structure.

Whereas many companies are actively developing their installed base information management, apart from a few contributions, the currently available literature does not address installed base information as its own concept. Nevertheless, information on the products in customer use is referred to in literature dealing with after-sales service operations, sales and marketing, and product development, but this fragmented treatment does not constitute an analyzable description of the phenomenon, nor provide practical guidelines on developing the information system in different business contexts. Under these circumstances, it was considered appropriate to initiate an explorative multiple-case study program to gather empirical data systematically on the practical purposes and requirements for installed base information with companies engaged in installed base information system improvement initiatives. The empirical data together with available literature is then used to form propositions to support further development of installed base information management.

1.1 Background and motivation

Many capital goods manufacturing companies have been interested in seeking additional revenues by offering after-sales services to their customers (Wise and Baumgartner 1999). Three reasons have been identified for this shift of enterprise rationale: First, substantial and more stable revenue can be generated from an installed base of products with a long life cycle (Knecht et al. 1993; Goffin 1999; Wise and Baumgartner 1999). Second, the customers for capital goods demand more in services when concentrating on their core competences and seeking cost savings possibilities (Prahalad and Hamel 1994; Oliva and Kallenberg 2003; Komonen 2006). Third, services can be a sustainable source of competitive advantage (Matthyssens and Vandenbemt 1998; Goffin 1999; Parasuraman 1999; Youngdahl and Loomba 2000).

Manufacturing companies have some advantages when competing with other service providers for the customers' service business. In particular, as original equipment manufacturers, they enjoy unique advantages with product-related services (Oliva and Kallenberg 2003):

- Lower customer acquisition costs: because manufacturers are involved in the sales of new products, they have information on new equipment joining the installed base.
- Lower knowledge acquisition cost: many services provided to an installed base require special knowledge about the product and its technology. The product manufacturer has an additional advantage as it has knowledge of the product service requirements over its life cycle.
- Lower capital requirements: manufacturers possess many specialized production technologies required to fabricate spare parts or to upgrade existing equipment.

In addition to the potential for increasing revenues, some contributions emphasize also that after-sales services are valuable in providing better information on product use and product performance to support business. The most often cited purposes are related to improving product quality in product development (e.g. Knecht et al. 1993; Lele 1997; Cohen and Whang 1997; Goffin and New 2001; Cavalieri et al. 2007) and identifying additional sales opportunities (e.g. Wise and Baumgartner 1999; Campbell 2003).

Despite the manufacturer advantages in product-related services and resulting support for product business, an observation from practice shows that manufacturers moving into service business are frustrated with poor visibility to their installed base, lacking information on the products they have delivered to identify service requirements and new opportunities (Auramo and Ala-Risku 2005; Brax 2005; Borchers and Karandikar 2006).

Discussions with the case company representatives during this research also showed the frustration with poor visibility to the installed base and indicated that information on the installed products can provide important input for decisions. The following examples from the cases are given to indicate the motivation for this research from the perspective of the studied case companies:

> *[Q1] We should be able to gather standardized information on all the products we have delivered. (Electrical Engineer, Case A)*

> *[Q2] There are not enough people in data gathering and analysis. […] The information system of [after-sales] services is incomplete. (Sales Manager 1, Case A)*

> *[Q3] It is extremely important to know how our installed base is working, and take that into account in our product development. (Product Director, Case B)*

> *[Q4] It would be best that [we] are always responsible for the maintenance, as we would then have all the information [on the products]. It's a dream, but then it would be very easy for us to operate. (Service Manager, Case B)*

> *[Q5] Basic information on what products we have out there […] this information is nowhere to see as an aggregate. Each [local unit] has their own databases where this information is.[…] we need to ask each unit separately or commence a separate study. (Product Manager 1, Case C)*

> *[Q6] One guy in our team is sorting this mess out. It would definitely be a good thing, if you could retrieve all [equipment] data from the database with a single identifier. (Product Performance Analyst, Case C)*

> *[Q7] We need one big installed base database to contain all the information that's needed by different service lines […] otherwise all departments have their own databases to manage, and record information, so there is not one big picture. (Service Customer Account Manager 1, Case D)*

> *[Q8] What I can tell you about installed base [information], is that it's an absolute necessity that we have that […] Every time you build up a new system you need to put that into the database. (Sales and Marketing Director, Case D)*

This short list of quotations illustrates three important issues with installed base information: 1) the installed base is of interest in various functional subunits in the companies, 2) although information related to the installed base often exists, without specific coordination, it is easily dispersed in various non-uniform and disconnected systems, and 3) the interest is on individual products rather than the number of installed product types.

The first two characteristics resemble the situation with transaction processing before enterprise resource planning systems were introduced—functional subunits (e.g. purchasing, order management, accounting) interested in the transactions of a manufacturing company each had its own separate systems and data sources (Kumar and van Hillegersberg 2000; Akkermans et al. 2003). Whereas transaction-oriented ERP systems provide integration among subunits for product manufacturing and sales, they do not serve the purposes and information needs after the sale (e.g. Agnihothri et al. 2002; Brax 2005; Cohen et al. 2006). One reason for this is uncovered by the last observation above, namely the interest in individual products—a specific product in the customer installation, not the sales transaction, ultimately delivers value for the customer (Woodruff 1997).

Recognizing the importance of understanding the installed base of equipment, there is surprisingly little research on what information is necessary and how to gain desired installed base visibility (Borchers and Karandikar 2006).

The motivation for the research work reported in this thesis arises from the gap between practitioner interest in the topic of installed base information and its unsatisfactory treatment in the body of literature. If the installed base of products is used to generate profitable new revenue and cost savings opportunities for the capital goods manufacturers, what must we know about the "installed base" that is allegedly the basis of those opportunities? And, assuming the information is at hand, how are the opportunities generated with the information?

1.2 Research purpose

The motivation and goal for the research program reported in this thesis can be stated as:

> *This research's principal aim is to support the development of installed base information management to improve the business processes of manufacturing companies providing product-related services for their customers.*

The underlying instrumental goal is to improve managerial decision making with information systems supporting organizational information processing and decision making. The motivation and research interest reflect those typical for *design sciences*: 'to develop scientific knowledge to support the design of interventions or artifacts by professionals and to emphasize its knowledge orientation: […] *knowledge to be used in designing solutions, to be followed by design-based action'* (van Aken 2004, p. 226; italics in original). Hence, the research aims to form design propositions that state how information on individual products in the installed base can be used to support profitable customer value creation in after-sales business.

Although the usefulness of information on the installed products' characteristics, whereabouts, and lifetime performance has been acknowledged, the body of literature discussing such information and its uses has remained unstructured and disconnected, often touching on the information needs from the perspective of a single functional subunit in an organization. To the best of the author's knowledge, there is no comprehensive treatment of the phenomenon of "installed base information," nor of the contexts of use for such information.

As the thesis adopts the viewpoint of design sciences (Bunge 1967; Niiniluoto 1993; van Aken 2004), the main analytical method used is what Simon refers to as a 'means-ends analysis' (Simon 1996, p. 121), that is, the analytical process of finding the 'appropriate means to reach designated ends' (Simon 2000, p. 72). The knowledge resulting from these analyses is used to form design propositions (van Aken 2004; Denyer et al. 2008) that make statements about the relationship of the means and ends.

Following this logic, it is useful to decompose the goal of this research to improve both the understanding of the ends for installed base information (RQ1) and the understanding of the means of establishing a useful overview of the installed base (RQ2):

> *RQ1: Why should a manufacturing organization providing product-related services gather installed base information?*

> *RQ2: What information should a manufacturing organization providing product-related services gather on the installed base?*

The line of thought leading to the above research question is further elaborated in chapter 4 where the research design for this work is described.

1.3 Scope definitions for the thesis

There are several important restrictions to the research scope. Because this research's principal aim is to "support the development of installed base information management in order to improve the business processes of manufacturing companies providing product-related services for their customers," it is necessary to provide some definitions about the information types, the business processes, the products, and the services of interest.

Definition of installed base

To start with, the term "installed base" is often used to denote an aggregate, 'the total number of products currently under use' (Oliva and Kallenberg 2003, p. 163), or 'a measure of the number of units of a particular type of product or system (in case of bundled offerings) actually in use' (Borchers and Karandikar 2006, p. 53). Whereas this is sufficient when evaluating market size or when comparing market shares of competitive products (e.g. Farrell and Saloner 1986; Trott 2001), exploiting business opportunities in the installed base requires a more detailed view of the products.

In discussing installed base systems as opposed to customer relationship management applications, Borchers and Karandikar (2006, p. 54) use the following definition: 'Installed Base (IB) systems, […], attempt to track down exactly where the sold products are located, who owns and/or operates them, what they are used for, under which conditions they are applied, their life cycle status, which service actions and technical changes have been performed, which parts serviced or replaced and their current technical state.' Along their definition of the installed base system, in the context of this thesis, the term *installed base* is used as a collective noun for currently used individual products sold or serviced by the focal company. Thus, the installed base is regarded as formed by the individual products, rather than as a figure indicating the number of installations. *Installed base information* is used to refer to information on these individual products: their location, owner, user, application, operating environment, status, and service history. Consequently, *installed base information management* concerns the systematic gathering and storage of installed base information.

Products and services of interest

The target organizations of the research presented in this thesis are capital equipment manufacturing organizations providing after-sales field services for customers using their equipment in fixed locations. This means that consumer goods manufacturers are not considered within this work, nor are capital equipment manufacturers with mobile products, e.g., transportation equipment or earthwork equipment. The reason for this limitation has been to ensure better comparability across the individual cases, as one strength of multiple-case studies is the clarification through case comparisons of whether emergent findings are idiosyncratic to a single case or more consistently replicated across the cases (Eisenhardt 1991). For the same reason, about the services of interest, the scope of this thesis is restricted to after-sales services concerning the products at customer sites (thus excluding e.g. installation services and consultation services that differ greatly among the studied organizations).

Business processes of interest

In terms of business processes, this research focuses on the needs for and uses of installed base information in after-sales field service processes and in those processes of manufacturing organizations reported to have an interest in the installed base information—sales and product development (e.g. Knecht et al. 1993; Lele 1997; Cohen and Whang 1997; Wise and Baumgartner 1999; Goffin and New 2001; Campbell 2003; Cavalieri et al. 2007).

Information of interest

A further scope definition of this thesis relates to the information of interest: The primary focus is on information that can be systematically stored and analyzed in an information system. As discussed in the literature by proponents of the Organizational Information Processing Theory (e.g. Galbraith, 1973; Tushman and Nadler 1978), different uncertainties in operations drive the requirements for information processing designs in the organization. When rules and procedures, hierarchies, and goal-setting no longer suffice with increasing uncertainty, the organization needs to invest in organization designs that either reduce the information processing needs or increase the information processing capacity (Galbraith 1973). Within this work, the interest is on the latter, and the focus, in particular, on requirements for organizational information systems. Surely, installed base information processing can and should be performed through human relationships also (Galbraith 1973): for example, field engineers are regularly tipping off sales managers with sales opportunities and attending product management meetings for product maintainability improvements. However, such information processing is outside the scope of this work, where systematic and analyzable installed base information is studied.

Organizational information systems are considered a viable alternative for uncertainty reduction when there is a need for common formalization of events occurring in an organization's domain (Galbraith 1973), when the uncertainty is fundamentally about lacking specific information rather than about multiple conflicting interpretations of a situation (Daft and Lengel 1986), and when there is interdependence among the operations of organizational subunits (Goodhue et al. 1992). These contributions underscore that to understand the role of installed base information, an understanding of the commonalities in information requirements across subunits is required.

Utility of interest

A final clarification to the thesis' scope is necessary to the underlying ultimate goal of supporting information systems development: This thesis focuses only on the perceived utility and logical structure of information in the studied organizations. Whereas references to information system implementations are made in both the literature review and the empirical part of the research, a detailed analysis of the costs of obtaining, gathering, and maintaining installed base information is left for further research to address.

1.4 Research approach

This research adopts a design science orientation. The motivation for the research reported here is based on an observation that the concept of installed base information is ambiguous and insufficiently studied (Borchers and Karandikar 2006), despite the assumed utility of such information in managerial decision making (e.g. Wise and Baumgartner 1999; Oliva and Kallenberg 2003; Cohen et al. 2006). Using the concepts of Herbert Simon (1996), the research focuses on a design problem involving an *artifact* and its uses, or more generally, a design problem involving *means* (information management) and *ends* (business decisions). As both the shape of the central artifact and its uses are inadequately understood, the research can be seen to concentrate on an *ill-structured problem* best approached with exploration through design (Simon 1973a). This entails an analysis of both the ends (why create or use an artifact) and the means (what are the required properties of the artifact), which both are considered central to the design science orientation with problem-oriented research goals (Simon 1996; Holmström et al. 2009).

Design science is considered to convey and distill knowledge on 'how to achieve something' instead of 'why something is observed' (Simon 1996; van Aken 2004). Consequently, this research's design goal is to identify requirements influencing and guiding an installed base information system's design in organizations within the study's context. Prescriptive knowledge on means and ends, such as design requirements, can be codified as a *technological rule* seen as 'a chunk of general knowledge, linking an intervention or artifact with a desired outcome or performance in a certain field of application' (van Aken 2004, p. 228). Denyer et al. (2008) further develop the form of technological rules or design propositions to what they call CIMO-logic, 'in this class of problematic Contexts, use this Intervention type to invoke these generative Mechanism(s), to deliver these Outcome(s)' (Denyer et al. 2008, pp. 395–396).

Despite design science's prescriptive and practical orientation, a requirement for theoretical meaningfulness links the technological rules with explanations on why they are claimed effective (Bunge 1967; van Aken 2004; Holmström et al. 2009). Mario Bunge (1967) voiced one of the earliest concerns for such linking: 'Before adopting an empirically effective rule we ought to know *why* it is effective: we ought to take it apart and reach an understanding of its *modus operandi*. This requirement of rule foundation marks the transition between the prescientific arts and crafts and contemporary technology.' (Bunge 1967, p. 133, italics in original) More recently, Holmström et al. (2009) underline the importance of combining both exploration through designs and explanation by theoretically treating the designs' implications as a prerequisite for meaningful design-oriented operations management research. In particular, they see the explorative phase as important for solving managerially relevant new problems, but that the explanatory phase is necessary for examining theoretically relevant contingencies. Without the latter phase, the understanding on why an artifact or intervention should be effective in the studied contexts remains limited and hinders the generalizability of the designed problem solution to other contexts.

Adopting these guidelines for the design science orientation in operations management studies, an explorative multiple-case study was selected as an appropriate research strategy to formulate design propositions inductively for installed base information use. Van Aken (2004) differentiates between two extremes of multiple-case studies in the design science research: the extracting multiple-case study and the developing multiple-case study. The former intends to uncover technological rules as already used in practice, whereas the latter develops and tests technological rules in close collaboration with the people in the field. This research includes aspects of both, in that the studied organizations had some experiences with installed base information management, but in large, the applied practices still required further development. Hence, despite the limited managed information concerning geography or content, some rules of using specific information for specific decisions were identified in the field, whereas other rules were developed with case company personnel.

The research consists of a literature review and an empirical part of four case studies. The research's empirical part used primarily qualitative data-gathering methods—interviews, workshops, case company documentation reviews, and case company information systems analyses. The data were analyzed using inductive reasoning with iterating reflections to extant literature (Eisenhardt 1989; Dubois and Gadde 2002), and the analyses resulted in forming design propositions (Denyer et al. 2008) for using installed base information in managerial decisions.

The results from this exploration through designs (Simon 1973a) were further reflected on the Organizational Information Processing Theory (e.g., Galbraith 1973; Tushman and Nadler 1978) to link the propositions with a relevant theoretical discourse (Holmström et al. 2009). As the findings' theoretical reflection projected contingencies for the propositions' applicability, and as these contingencies could also be identified in the studied cases, the results can be considered to provide first steps towards substantive or mid-range theory on installed base information management (Glaser and Strauss 1967; Bourgeois 1979; Holmström et al. 2009).

1.5 Structure of the thesis

The thesis consists of eight chapters. After this introductory chapter, Chapter 2 gives the managerial and theoretical context of the research. Recent development on structuring after-sales operations is reviewed, and installed base information's increasing role is motivated from the Organizational Information Processing Theory viewpoint. Chapter 3 presents and discusses relevant prior research touching the installed base information phenomenon. Prior contributions addressing information-processing needs in plant maintenance, field-service, sales, and product development are analyzed with the intent to show that there are commonalities among an organization's functional subunits in their information needs relating to the installed base, thus justifying the study of an installed base information concept. The literature review also illustrates that the discussion of the need for such information has been disconnected in several streams of literature.

Chapter 4 gives the details of executing the empirical research reported in this thesis. The study's purpose and the research questions are formulated based on the discussed literature. The research design is described with motivation for selecting a case study approach for the research program and for using interviews as the main enquiry method.

Chapter 5 introduces the individual case studies and gives a comparison of the case companies' service business processes and operating environments. Chapter 6 presents the research effort's findings through a cross-case analysis. The first section discusses installed base information needs and uses in field services—both in service operations and in planning for service resources. The second section details the installed base information needs of the other manufacturer subunits sharing interests with the service subunit. Finally, the third section describes the installed base information types requested in the analyzed subunit tasks.

Chapter 7 elaborates the design propositions formulated during the research by synthesizing the contributions in literature and the case studies' empirical findings. The first section constructs the design propositions by detailing the use mechanisms relating installed base information to customer value creation and to the after-sales business profitability. The second section summarizes the requirements for organizing the installed base information as the last design proposition. The third section discusses the contextual factors affecting the formulated design propositions' applicability and gives theoretical explanation for the effectiveness of the previous sections' design propositions.

Finally, Chapter 8 summarizes the research results, evaluates the value of the research program, and suggests topics for further research.

Further, Appendix A gives a detailed account of each of the four case studies contributing to this research effort's findings.

2 RESEARCH CONTEXT

This chapter gives this research's foundations both from managerial and theoretical perspectives. The managerial context is addressed in section 2.1 where the literature review concentrates on after-sales services and recent development in structuring the service offers to better support customer value creation with industrial products. The key purposes of this review are 1) to describe the product-related services of interest within this study, and 2) to illustrate the different engagement levels in service operations available to a manufacturer. Both these aspects are central to analyzing this research's empirical cases.

The theoretical context is discussed in section 2.2 where the Organizational Information Processing Theory is used to understand the underlying organizational reasons for installed base information processing needs and to understand the increasing interest in maintaining such information by manufacturers focusing on product-related services. This section also gives a theoretical grounding to which the empirical findings reflect in the discussion. The chapter concludes with a brief summary of these two perspectives in section 2.3.

2.1 After-sales service business

2.1.1 Services

The nature of services in contrast to products is a heavily discussed topic, as the formerly accepted definition of services as distinctly Intangible, Heterogeneous, Inseparable, and Perishable (IHIP) are contested (Vargo and Lusch 2004; Lovelock and Gummesson 2004; Araujo and Spring 2006; Sampson and Froehle 2006). There have been plausible arguments that the entire discussion about "what is product and what is service" is meaningless, as both can include tangible and intangible components (Araujo and Spring 2006), both require objectifying and stabilizing what is transacted between the provider and customer (Callon et al. 2002), and both require an understanding of the production process for efficient resource use in the production operations (Sampson and Froehle 2006).

Whereas the exact universal characteristics constituting a service are likely to elude uncontested definition (Araujo and Spring 2006), for this work's purposes, "services" refers to those activities that capital investment goods manufacturers provide to support and improve the products they sell to their customers. In this context, the definition of service process by Sampson and Froehle (2006) is useful: 'With service processes, the customer provides significant inputs into the production process.' The customer inputs they refer to can be of three types (Wemmerlöv 1990): the customer's self, his belongings or other tangible objects, and information. Defining services in this way, even the manufacturer's process resulting in engineer-to-order products should be considered a service. Whereas this is one intriguing consequence of this definition (and much in line with Levitt's (1972, p.42) famous provocation: 'Everybody is in service'), the scope of services of interest is restricted to after-sales field services, i.e., services addressing the installed capital goods base (Agnihothri et al. 2002; Oliva and Kallenberg 2003).

Araujo and Spring (2006) offer an illustration (after Delaunay and Gadrey 1987) capturing the main entities participating in a service context discussed in this work (Figure 1). Customer requests Service provider to perform a service for its Product.

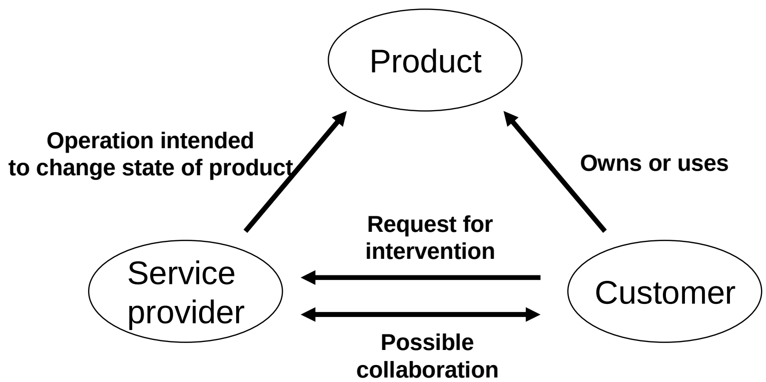

Figure 1: The relationship of participants in a service context (applied from Araujo and Spring 2006; Delaunay and Gadrey 1987)

As for the specific services manufacturers provide to their customers, there have been attempts to provide structure to the various service concepts based on whether they support the customer's pre-sales or after-sales activities (Samli et al. 1992), whether they are transaction- or relationship-oriented (Frambach et al. 1997), whether they support the products' or customer's processes (Mathieu 2001), or what their strategic role is in the manufacturer's business (Cavalieri et al. 2007).

The chronological distinction of services concerning the sales process distinguishes among product services aiding the buyer in identifying the product offer and stimulating adoption (pre-sales services); product services aiding the customer in putting the product into use, such as installation and training (sales services); and product services keeping the customer satisfied with the purchase, such as failure handling and maintenance inspections (after-sales services) (Samli et al. 1992). As noted above, the focus of this research is on the after-sales services where the existing installed base is the service target.

2.1.2 After-sales services

Frambach et al. (1997) analyze industrial services from the suppliers' perspective regarding whether the services should be designed to support the customers' purchase and use of products as add-on service transactions or to strengthen the relationship between the provider and customer. Mathieu (2001) discusses the service categorization from the customer's viewpoint: Does a service provide support for the products for the customer or, more directly, the customer's business process? Oliva and Kallenberg (2003) use a combination of similar dimensions to create a four-field categorization of industrial services (Table 1).

Table 1: The installed base service space (Oliva and Kallenberg 2003)

	Product-oriented services	End-user's process-oriented services
Transaction-based services	*Basic installed base services* Documentation Transport to client Installation/commissioning Product-oriented training Hot line/help desk Inspection/diagnosis Repairs/spare parts Product updates/upgrades Refurbishing Recycling/machine brokering	*Professional services* Process-oriented engineering (tests, optimization, simulation) Process-oriented R&D Spare parts management Process-oriented training Business-oriented training Process-oriented consulting Business-oriented consulting
Relationship-based services	*Maintenance services* Preventive maintenance Condition monitoring Spare parts management Full maintenance contracts	*Operational services* Managing maintenance function Managing operations

To the extent a manufacturer's resources and markets allow, selecting services to provide is a strategic decision (Cavalieri et al. 2007): If the role of services is perceived as unavoidable to handle warranties, the after-sales services are restricted to the lowest level of product support, and the operations are considered a cost center. Or, the manufacturer might see the after-sales services as a source of revenues, for example, through spare-parts sales and consolidate the services as a profit centre. One step further, a relevant business generator can be identified by bundling products and services into bundles, or solutions, that address the customers' needs on a larger scope. In such situations, the services are arranged as a business unit. Finally, Cavalieri et al. (2007) identify that, taking a long time horizon, the after-sales services can be perceived as a brand-fostering investment for excelling in product price, quality, and functionality.

In a similar vein, Baines et al. (2007) consider that products and services form a system where customer value is generated through both product components and service components. In the context of industrial services, their classification of what they call "product-service systems" can be reflected in maintenance outsourcing strategies from the customer viewpoint (Martin 1997) which, in turn, are affected by different levels of asset management decisions (Arts et al. 1998). A comparison of these three is presented in Table 2.

Table 2: Comparison of product-service systems, maintenance outsourcing contract types, and decisions influencing the contract

Product-service systems (Baines et al. 2007)	Maintenance outsourcing contracts (Martin 1997)	Decision levels influencing the maintenance contract (Arts et al. 1998)
Not a product-service system: Products and services considered separately.	*Work-package contracts*: maintenance planning and control performed by customer; service provider only provides staff and tools	*Operational control:* short-term allocations of maintenance capacity to maintenance demand. Decisions concern: maintain now or later, maintain or replace, use contractors or work overtime.
Product-oriented product-service systems: promoting/selling the product in a traditional manner, while including in the original act of sale additional services such as after-sales service to guarantee functionality and durability of the product owned by the customer.	*Performance contracts*: contract stipulates the desired performance on key outputs, such as failure rates, availability, response time, and time for restoring system interruption. Supplier can decide on necessary tasks to achieve those.	*Tactical control:* categorizing maintenance requirements based on equipment criticality and maintenance response urgency.
Use-oriented product-service systems: selling the use or availability of a product that is not owned by the customer (e.g. leasing, sharing).	*Facilitator contracts*: client is only the user of the physical assets owned and maintained by contractors.	*Strategic planning:* requirements for production units, estimating all cost factors including maintenance during the life of the production unit.
Results-oriented product-service systems: selling a result or capability instead of a product	-	*Strategic planning*: company objectives and means to reach those objectives

Traditionally, products and services are considered separately (Baines et al. 2007). Products are the main sales item, and product-related services are provided for those who ask for them. From the customer's viewpoint, such services from the product manufacturer are, by large, only one alternative among others to source maintenance capacity (Arts et al. 1998). Contracts matching such service supply and service demand can be seen as work-package contracts (Martin 1997). With the product-oriented product-service systems of Baines et al. (2007), the supplied products and services have a common goal of uninterrupted operations for the customer. The customer retains the decisions on acceptable availability levels for equipment (Arts et al. 1998), negotiates a suitable performance contract (Martin 1997) with the supplier, and is indifferent about the exact maintenance plans and operations required to achieve the desired availability. With use-oriented product-service systems, the customer abandons equipment ownership and sources production capacity from the supplier if that is considered superior to investments in and maintenance of own production capacity. The agreement takes the form of a facilitator contract (Martin 1997). Finally, with results-oriented product-service systems, the customer is considering a make-or-buy decision within its own production system.

It is noteworthy that the product-service system categories can be seen to expand through the "basic installed base services," "maintenance services," and "operational services" in the classification of Oliva and Kallenberg (2003) above. Thus, both (Cavalieri et al. 2007) and (Baines et al. 2007) can be understood to suggest such a particular development path towards closer supplier-customer relationships with each service offer level including and bundling the prior level's service offers.

Put the other way around, if "basic installed base services" are considered components in providing the "maintenance services" and "operational services," from a service delivery perspective, the different product-service system strategies change the performance measures for the provider and responsibility sharing between customer and product-service system supplier (Cavalieri et al. 2007). However, the field operations performed remain largely the same. Similarly, independent of the services offered, a key challenge for a capital goods manufacturer in the transformation to a product-service system supplier is the need to create a global service organization capable of responding locally to the installed base's requirements (Oliva and Kallenberg 2003).

2.2 Organizational information processing and after-sales services

A useful frame of reference for understanding the challenges related to product-service suppliers' organization design can be found with Organizational Information Processing Theory (Galbraith 1973, 1974; Tushman and Nadler 1978; Goodhue et al. 1992), which views organizations as information processing structures with the task to reduce uncertainty in operations.

Tushman and Nadler (1978) use organizational "subunits" to conceptualize an organization's structure concerning information processing. Subunits are functional groups (or departments) in an organization that are differentiated in their tasks but are interdependent to varying degrees, as their activities must be linked. In this work's context, the main functional subunits of interest are product development, sales, after-sales service operations, and service resource management (see section 1.3).

2.2.1 Organizational Information Processing Theory

Organizational Information Processing Theory is concerned with the design of structures and mechanisms to deal with information processing requirements (e.g. Galbraith 1973; Tushman and Nadler 1978; Daft and Lengel 1986; Goodhue et al. 1992). Because of differentiation in organizational systems, various functional units with specialized tasks and goals exist within an organization (Lawrence and Lorsch 1967). The task-specific information processing requirements differ among the functional units because of differing goals and resources and because of differing degrees of interdependency among the functions (Galbraith 1974).

Goodhue et al. (1992) combine the views of Galbraith (1973) and Tushman and Nadler (1978) and consider information processing to reduce uncertainty at the level of functional subunits (Figure 2): interdependence among subunits, complex or non-routine subunit tasks, and an unstable subunit environment create uncertainty (Tushman and Nadler 1978) that can be addressed by reducing the need for information processing or by increasing information processing capacity (Galbraith 1973).

Regarding uncertainty, Daft and Lengel (1986) distinguish between "uncertainty," as missing some specific information required for the decision at hand, and "equivocality," as not knowing what information could be of value in the decision making. This distinction is in line with Galbraith's (1973) *definition for uncertainty* as the difference between the amount of information required for a task and the amount of information possessed by the task's performer.

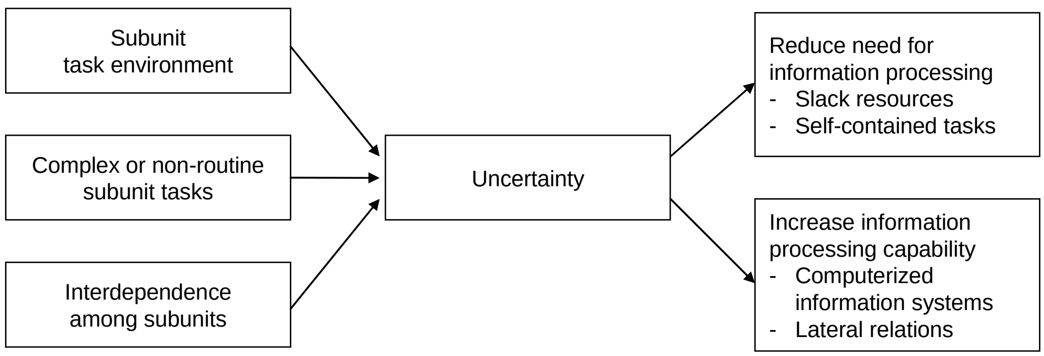

Figure 2: A prescriptive model of Organizational Information Processing (applied from Goodhue et al. 1992; combining (Galbraith 1973) and (Tushman and Nadler 1978))

In the following, the three sources of uncertainty and the means to reduce the uncertainty in decision making are presented in more detail to provide a framework for analyzing the increasing interest on installed base information and for discussing the research's empirical results.

Uncertainty arising from the subunit task environment

Task environment is considered 'those external actors which are attended to by organizational members' (Tushman and Nadler 1978, p. 616). The task environment is a source of uncertainty, because it is outside the organizational boundaries and therefore poorly controllable by the organization or subunit affected by its properties (Thompson 1967; Lawrence and Lorsch 1967).

There have been several attempts to give structure to the different types of environmental uncertainty that might affect the organization and its decision-making processes. Dess and Beard (1984), building on many sources (e.g. Aldrich 1979; Jurkovich 1974; Pfeffer and Salancik 1978; Mintzberg 1979; Scott 1981; Child 1972), arrive at the following classification of task environment dimensions in their study:

- *Environmental munificence*: extent to which environment can support sustained growth
- *Environmental dynamism*: change that is hard to predict that heightens uncertainty for key organizational members
- *Environmental complexity*: homogeneity-heterogeneity, concentration-dispersion, i.e., the similarity or dissimilarity of key elements of interest in the environment

Whereas the construct of task environment is typically considered on the organization level (see above and e.g. Dill 1958; Lawrence and Lorsch 1967), a more modest definition is useful in this research by considering the environmental characteristics for each of the studied subunits. This follows the standpoint taken by Tushman and Nadler (1978), as well as McCann and Ferry (1979), who contend that information processing in organizations should be studied by analyzing structural requirements within and among subunits rather than considering the entire organization.

Considering the installed base of equipment a relevant part of the task environment for the subunits, environmental munificence can be interpreted as opportunities the installed base offers concerning new product or service sales. Similarly, environmental dynamism is reflected in the rate and type of changes in the installed base that complicate decisions or challenge prior decisions made in the subunits. Finally, environmental complexity can result from differing characteristics or locations of the equipment in the installed base.

Uncertainty arising from subunit task complexity

Subunit tasks have different levels of complexity (Tushman and Nadler 1978). The differences in complexity arise from differing amounts of outcome predictability (Galbraith 1973) and from how well the task is understood (Thompson 1967).

Campbell (1988, p. 40) reviews literature on task complexity and identifies three distinct approaches to task complexity: 'Complexity is treated as: (a) primarily a psychological experience, (b) an interaction between task and person characteristics, and (c) a function of objective task characteristics.' Of these, the last one is of interest within this research. Campbell (1988) further synthesizes from publications treating objective complexity four main characteristics that make tasks complex:

- Presence of *multiple potential ways* to arrive at a desired end-state
- Presence of *multiple desired outcomes* to be attained
- Presence of *conflicting interdependence* among paths to multiple outcomes
- Presence of *uncertain or probabilistic links* among paths and outcomes

This list of complexity characteristics can be interpreted as uncertainty in choosing means and ends (Simon 1996, 2000). The first item is related to uncertainty in deciding which means to prioritize and the second, which ends to pursue. The third kind of complexity is present in situations where there are several desired ends, but each identified means has some undesirable effects on some of the desired ends. The fourth kind of complexity refers to situations where the impacts of means on desired ends are not well known.

Uncertainty arising from interdependence among subunit tasks

Task interdependence has been studied among individual jobs (e.g. Mohr 1971), among organizational subunits (e.g. Tushman and Nadler 1978), and among organizations (e.g. Aiken and Hage 1968). For this research's purposes, the focus is at the level of organizational subunits, as suggested by Tushman and Nadler (1978) as well as McCann and Ferry (1979) for situations where information processing is studied within single organizations.

Perhaps the best known task interdependence classification is Thompson's (1967) definition, where he distinguished among pooled, sequential, and reciprocal interdependencies. Several authors have based their own work on these definitions (e.g. van de Ven et al. 1976; Egelhoff 1991; Malone and Crowston 1994; Kumar and van Dissel 1996; Andres and Zmud 2001; Harter and Slaughter 2003).

This classification of Thompson (1967) is used also for discussing this research's results, and in particular, the definitions given by Kumar and van Dissel (1996) are found most useful for the present purposes. Building on Thompson (1967), Mintzberg (1979), and Robey and Sales (1994), they summarize the main characteristics of the interdependence types as (Kumar and van Dissel 1996, pp. 283–284):

- *Pooled interdependence*: 'units share a common resource, but are otherwise independent […] involves the least amount of interdependence because any one participating unit can be plucked out, and as long as there is no significant corresponding withdrawal of resources, the others can continue to work uninterrupted.'
- *Sequential interdependence*: 'units work in series where the output from one unit becomes input to another unit. […] Pulling out a sequentially interdependent unit is like breaking a chain—in extreme cases the whole subsequent set of activities may cease to function.'
- *Reciprocal interdependence*: 'units feed their work back and forth among themselves; in effect each receives input from and provides output to others, often interactively […] Changes or problems in one unit could affect not only those downstream but also those upstream. In fact, the concept of upstream and downstream is no longer meaningful as the participants in the relationship feed work back and forth to each other.'

Information processing means to reduce uncertainty

As discussed in the literature addressing organizational information processing (e.g. Galbraith 1973; Tushman and Nadler 1978), different types of uncertainties in operations require different information processing designs in the organization. The simplest, least costly, and most frequently used means to reduce uncertainty in performing tasks are rules and programs that, in effect, replace single decisions with predefined ways that apply in given circumstances. If there is a decision to be made in a situation where the predefined rules or programs do not apply, one is to resort to hierarchical referral to superiors. They are assumed to have a more high-level view of the company goals and, thus, be better able to make the particular decision so that it is aligned with the overall organizational goals. When rules and procedures, hierarchies, and goal-setting no longer suffice with increasing uncertainty, the organization needs to invest in organization designs that either reduce the information processing needs or increase the information processing capacity (Galbraith 1973).

A reduction in information processing needs follows from adding slack resources or creating self-contained tasks. Slack resources can mean time buffers or resource buffers (Galbraith 1974) that effectively reduce the task complexity because of decreased conflicts among operational means and because of decreased need for prioritizing goals (Campbell 1988). Self-contained tasks can be created by arranging subunits in output based groups and taking care that the subunits have the resources they need to produce the desired output (Galbraith 1974). This, in effect, reduces the uncertainty of the subunits by making the subunits less interdependent in their processes (Thompson 1967). Both of these means to reduce uncertainty require an investment by the organization, as a decision to create slack resources is, by definition, a selection to increase inputs per output, and self-contained units might require replicating resources so that subunits are not interdependent because of shared resources or sequential operations (Kumar and van Dissel 1996).

According to Galbraith (1973, 1974), information-processing capacity can be increased with two general approaches: investments in organizational information systems and creation of lateral relations. Lateral relations, such as teams, task forces, and integrating roles, are more effective in situations where the relevant information to be processed is qualitative and ambiguous (Galbraith 1974). Information systems are considered a viable alternative for uncertainty reduction when there is a need for common formalization of events occurring in an organization's domain (Galbraith 1973), when the uncertainty is fundamentally about absence of specific information rather than about multiple conflicting interpretations of a situation (Daft and Lengel 1986), and when there is interdependence among the operations of different subunits (Goodhue et al. 1992).

Within this work on installed base information, the focus is, in particular, on the requirements for organizational information systems with possibilities for analytical treatment of large masses of structured data.

2.2.2 Organizational information processing and manufacturer after-sales services

The framework described above is useful in viewing the changes of information needs when capital goods manufacturers are moving to centrally controlled service operations and to product-service systems of increasing complexity.

As after-sales services have traditionally been viewed as a necessary evil to keep product customers happy in the hope of future sales opportunities (Lele 1997; Oliva and Kallenberg 2003; Cavalieri et al. 2007), the service units have been considered more a cost center than a source of revenue in themselves. Thus, in the terminology of Galbraith (1974), the capital goods companies' main organizational response to the uncertainties related to the services has been one of 'reducing the need for information processing through self-contained tasks': the local units that best know the local customers have been authorized to take care of the operations by themselves as they see fit (Arnold et al. 2001).

However, with increased customer-orientation, manufacturing companies have realized that their customers value not only the suitability of the product functionalities for their operations, but also the availability of the products to keep their operations untroubled with equipment failures (Lichtental and Long 1998; Tsang, 2002; Markeset and Kumar, 2005). This has led to after-sales services gaining in importance as part of the differentiation strategies and revenue streams of manufacturing companies (Wise and Baumgartner 1999; Oliva and Kallenberg 2003). The emphasis has been increasingly on turning the services into streamlined and cost-effective customer value-adding operations of their own (Voudouris et al. 2006; Cavalieri et al. 2007). As a result, new uncertainties are confronted in the after-sales service operations as the volume of activities increases, and they are integrated in the organization's core businesses.

Increasing *environmental uncertainties* can be seen to result from competition in the after-sales service market increases (Lewis 2001; Pilling 2005; Honeyman 2006): after-sales service contracts are renegotiated with customers, and smaller service companies are acquired. Thus, the equipment serviced by a local unit changes more radically than before, when customers took care of the maintenance, only requesting specific services, and each equipment manufacturer used to concentrate on servicing his own equipment.

More *complex or non-routine tasks* result both from having new kinds of equipment to be serviced because of increased after-sales service market flexibility and from the service units being challenged with new kinds of services devised to compete in the maintenance and repair service markets (e.g. Tsang 2002; Baines et al. 2007; Cavalieri et al. 2007): Instead of its being sufficient to know how to repair or replace a broken item, the service units need to know how to provide preventive and condition-based maintenance to guarantee promised uptime, and in cases of unavoidable breakages, possess the capacity to have the problem fixed within hours.

Increased *interdependence among subunits* results from interest in optimizing investments in the after-sales services. Resources need to be efficiently distributed among the local service units. This leads to a multi-level inventory problem for spare parts, as well as to decisions on centralizing some service personnel to reduce idle capacity of some specialized skills (Cohen et al. 2006). In other words, coordination needs between the local service units are increased (cf. Crowston 1997). And, instead of being left on their own in the local service units, the entire organization has increased interest in after-sales services, as they have the most frequent contact with equipment at the customers, and the service units's activities give clues to evaluate performance of services and products, as well as to learn of new sales opportunities (Ives and Vitale 1988; Markeset and Kumar 2003; Pintelon and Puyvelde 1997; Zackariasson and Wilson 2004).

2.3 Summary of the research context

The above literature review shows that a manufacturer can provide a great variety of specific services to improve customer value after the sale (Frambach et al. 1997; Mathieu 2001; Oliva and Kallenberg 2003)—ranging from technical support and spare-part sales to resource and operations management for the customer. These services can be treated separately or perceived as product-service systems that bundle the sold equipment with product-oriented performance contracts or use-oriented or results-oriented facilitator contracts (Martin 1997; Baines et al. 2007; Cavalieri et al. 2007).

The second section illustrated the relevance of installed base information in the product-service supplier operations. As after-sales service offers become more structured, and the manufacturers increasingly emphasize customer value from their products' use, the service operations are likely to be more centrally controlled. With an increasing share of revenue coming from services, and with performance contracts sanctioning poor product quality in service operations, the decisions in sales and product development subunits become more intertwined with the performance in service subunits.

With this kind of development, it seems no longer feasible to address the uncertainties in the after-sales operations with the means of reducing the information processing needs through slack resources. Instead, investments in increasing information-processing capacity with information management systems look unavoidable, especially because the interdependence among individual service units as well as among service units and other functions is increasing (Galbraith 1974). Indeed, several authors have claimed that the provision of industrial services demands new ways of using information technology (Agnihothri et al. 2002; Brax 2005; Cohen et al. 2006).

3 PRIOR RESEARCH TOUCHING INSTALLED BASE INFORMATION

The previous chapter discussed the increasing importance of unified installed base information across service units and other functional subunits of manufacturers engaged in after-sales services. This chapter is to review presently available literature to uncover the treatment of installed base information needs in the different functional subunits.

The following discussion has three purposes. First, the specific goals and key decisions are portrayed for each subunit of interest. These are important to support the analysis of the empirical cases (chapter 6) and to form the concluding propositions (section 7.1). Second, the equipment data referred to in the literature is used as a basis for understanding installed base information as a concept. Third, the review intends to convey the fragmentation of relevant literature and the marginality of explicit treatment of the installed base information concept.

The reviewed literature can be summarized to concern the following five functional subunits: local service units (section 3.1.3), field engineer resource management (section 3.1.4), spare-part management (section 3.1.5), sales and marketing (section 3.2.1), and product development (section 3.2.2). The contributions have been analyzed to identify subunit specific goals, key decisions of the subunits, and the installed base information that seems related to those decisions. Each subunit can be seen to have goals for creating customer value and goals for cost efficiency. These goals are pursued in part with decisions influenced by some characteristics of the installed base. In the literature analyses, the installed base related information required the most interpretation, as in some contributions, such information is implicitly assumed to exist, and in others, substitute information is suggested for analyses about the installed base (e.g. sales data or warranty data).

The remainder of the chapter contains a detailed analysis of literature related to the installed base information requirements in the functional subunits listed above. The next section describes the installed base information uses in the context of field services, and the following section discusses the sales and product development perspectives on installed base information. Finally, a summary of the review is given in section 3.3.

3.1 Installed base information with field services

Typical after-sales services for a manufacturer range from providing a technical help desk, spare parts, and product upgrades to preventive maintenance, condition monitoring, and full maintenance contracts (Samli et al. 1992; Oliva and Kallenberg 2003). Those requiring a visit by a field engineer to the installed equipment are considered field services (e.g. Bleuel 1975; Hambleton 1982; Blumberg 1994).

Considering that the different service contracts (Martin 1997) or product-service systems (Baines et al. 2007) shift maintenance responsibilities so that the service provider takes up tasks performed and decisions made previously by the customer (Arts et al. 1998), the analysis of installed base information processing is started by briefly reviewing literature on asset information management of the in-house maintenance operations of owners and users of installed equipment. This gives a baseline understanding on the servicing operations' goals and information requirements in maintenance, which is then supplemented by reviewing literature on information requirements with field service specific phenomena such as scheduling and dispatching of field engineers (e.g. Watson et al. 1998) and planning of spare-part distribution inventories (e.g. Cohen et al. 2006).

3.1.1 Customers' in-house maintenance operations

Maintenance and repair operations in an industrial context have the goal of ensuring trouble-free operations in production. Inadequate equipment maintenance leads to failures and unplanned downtime, which result in consequential costs such as loss of committed production, decrease in quality, inefficient use of facilities, equipment, and personnel, as well as penalties and customer dissatisfaction (e.g. Ashayeri et al. 1996; Moore and Starr 2006). Thus, the most often cited key performance indicators for the maintenance operations in the view of its direct customer, production operations, include equipment availability (Arts et al. 1998; Tsang et al. 1999; Löfsten 2000) and overall equipment effectiveness (e.g. de Groote 1995; Ljungberg 1998; Jeong and Phillips 2001; Komonen 2002; Bamber et al. 2003; Smith 2007). The latter originates in the work of Nakajima (1989) and includes equipment availability along with equipment performance and output quality measures.

Overall equipment effectiveness is strived for by decisions on the appropriate maintenance policy for each serviceable part (e.g. de Groote 1995; Tsang et al. 1999). Maintenance policies are generally classified in corrective and preventive maintenance, the latter of which is further divided into scheduled maintenance and predictive (based on usage or condition monitoring) maintenance (e.g. de Groote 1995; Tsang et al. 1999; Yamashina and Otani 2001). Selecting the maintenance policy for a single piece of equipment depends on failure patterns (Sherwin 1999), existence of measurable indicators of impending failure (Tsang et al. 2006), and consequences of failure (Fernandez et al. 2003; Deshpande and Modak 2003). To make rational choices on the maintenance practices, information must be gathered to evaluate failure patterns and identify failure indicators (Sherwin 1999). This is most often done with a computerized maintenance management system (Arts et al. 1998).

Computerized Maintenance Management Systems (CMMS) or Maintenance Management Information Systems (MMIS) appeared in the early 1980s because of maintenance gaining recognition and enabling IT development. Initially, they were used for administration rather than management support, but progressively, the CMMS have been developed to include technical and historical data on equipment and support for work order management, personnel management, inventory control, and reporting (Pintelon et al. 1999). CMMS data has been used, for example, in:

- spares management: support for correct spare-part identification and identification where an individual spare can be used (Pintelon et al. 1999)
- analyzing downtime and problem frequency to determine correct maintenance policy (corrective, scheduled, condition) or other actions (develop skills, design out problems) (Fernandez et al. 2003)
- analyzing condition-monitoring data and comparing to thresholds to trigger maintenance actions (Moore and Starr 2006)
- recording data for performance indicators, such as work hours and work orders per maintenance type (preventive, corrective), both planned and realized (Arts et al. 1998)
- reliability analyses: failure rates and mean-times between failures, failure causes, repair/restoration and prevention times, direct costs, and downtime costs (Marguez and Herguedas 2004)

Although the maintenance function as a source of valuable information for maintenance decision support has been acknowledged, the information has mainly been used for operational control (Tsang et al. 2006). A suggested reason for this is that subsets of valuable information often reside in diverse proprietary systems, and the lack of integration among these systems has prohibited companies from obtaining the analytical benefits hoped for (Ljungberg 1998; Werner and Vetter 2003; Moore and Starr 2006; Smith 2007): In particular, condition-monitoring systems, maintenance workflow systems, and resource management systems are often operated separately, despite their strong connection in supporting both execution and planning of maintenance operations.

However, independent of information systems used, selecting maintenance policy, in general (Gabbar et al. 2003), and defining condition-monitoring thresholds, in particular (Moore and Starr 2006), can be problematic for the user's own maintenance organization: With new installations, initial historical data for thresholds or policy evaluation are missing, and vendor references are often not adapted to operational conditions. Further, end users seldom have feasible access to off-production reliability testing for policy evaluation (Marguez and Herguedas 2004). Finally, despite subsequent information accumulation, the review of prior policy decisions is considered laborious and is often not done (Tsang 1995; Gabbar et al. 2003; Moore and Starr 2006). These observations show the advantages that a manufacturer service organization might have in terms of using cumulative information from both the manufacturing and servicing of their products.

3.1.2 Field service management

Although the field service goals align in principle with goals of the customers' in-house maintenance operations concerning trouble-free production capacity for the customer, there is also an explicit additional productivity goal for the service operations (Agnihothri et al. 2002). The resulting complexity regarding field service operations management has been summarized by Blumberg (1994) as a management challenge: 'A critical, disciplined approach to the management, control and allocation of people, parts and data with specific emphasis on service delivery, on a time-critical basis, can generate significant improvement in service productivity and quality.' He also gives an outline of the process of allocating resources for a single service delivery (Blumberg 1994, p. 268):

1. Fully identify the service call requirement, and ensure that the call is passed to the person or organization most capable of meeting the service need;
2. Evaluate the call to determine whether an on-site service engineer is required;
3. Evaluate, through on-the-line diagnostics using historical information on problem-symptom-cause-corrective action, if the user can be instructed to correct the service problem directly without an on-site dispatch; and
4. Identify the formal requirement to dispatch and optimally assign a specific service engineer for specific skill levels and parts needed, based on the diagnostic process.

This dispatching process illustrates the key difference between the equipment user's own maintenance operations and the service provider's operations: there is a strong focus on evaluating the problem concerning what kind of a field engineer, if at all, is required to visit the customer site. This is a consequence of the greater cost involved with sending a field engineer as opposed to using in-house service engineers to check a problem. Another critical point is the last step where resources of service engineers and parts are drawn on to have the service call optimally completed. To have such resources at hand, they need to be planned for.

Watson et al. (1998) discuss field service personnel planning by applying the hierarchical organizational planning model of Anthony (1965), reproduced in Figure 3. They distinguish three levels of planning: the evaluation of the total number of required field engineers, the allocation of field engineers to service areas, and finally planning the dispatching strategies for eventual customer calls. This is in line with the planning and scheduling framework of Thompson (1995), where four tasks of labor scheduling are (1) forecast customer demand; (2) translate demand forecasts into staffing requirements; and (3&4) schedule staff and control schedule in real time.

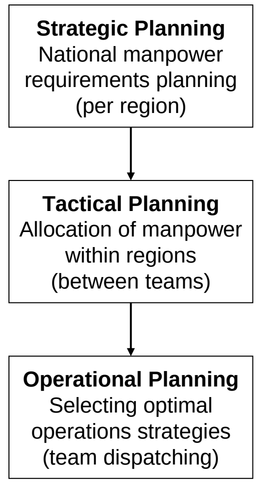

Figure 3: Classical hierarchy of organizational planning (Watson et al. 1998, after Anthony 1965)

In addition to field engineers, the other key resource requiring planning is the spare-part inventories (Cohen et al. 2006). This raises a peculiarity in the field service literature—there are two distinguishingly separate research streams on field service operations management: field engineer management (Hill 1992; Haugen and Hill 1999; Brusco and Johns 1995, 1998; Agnihothri et al. 2003) and spare-parts management (e.g. Fortuin and Martin, 1999; Wong et al. 2005; Cohen et al. 2006). The former implicitly assume unrestricted spare-part availability (e.g. Hill 1992; Collins and Sisley 1994; Haugen and Hill 1999), whereas the latter assume unrestricted field engineer availability and name spare-part fill rate as the main performance criterion of field service effectiveness (e.g. Kilpi and Vepsäläinen 2004; Wong et al. 2005; Cohen et al. 2006).

Whereas it is true that both spare-parts and field engineers can be provided to customers as separate services (e.g. Martin 1997; Cavalieri et al. 2007), the low number of contributions addressing both these aspects is noteworthy, as both elements are critical for successful equipment servicing in an industrial context. Worth mentioning is the exception to this rule by Blumberg (1994), where both elements are discussed as equally important for high service levels.

One reason for this duality might be that these resources require different control mechanisms. Quoting Vollman et al. (1997 p. 335): 'For make-to-stock firms, 100 percent service implies huge inventories. For make-to-order firms, immediate delivery implies substantial idle capacity.' Ironically, these two are combined in field services, particularly with unplanned service calls—to achieve 100 percent immediate service delivery, one needs huge local spare-part inventories to ensure spare-part availability and substantial idle capacity to ensure field engineer availability.

In the following sections, these separate streams of field service literature are reviewed to identify their particular goals, key decisions to attain those goals, and installed base related information needed for the decisions. The scheduling and dispatching operations of local service units are reviewed first, followed by an account on field engineer resource management. Finally, literature on spare-part inventory management is reviewed.

3.1.3 Local service subunits

The general business goals of customer satisfaction and profitability translate to local service subunits as quality and efficiency goals for service operations (Agnihothri et al. 2002). Customers value robust solutions and fast response to their problems (Hill 1992; Agnihothri and Mishra 2004), and profitability of operations is easily lost if single problems require several customer visits and if field engineer time is wasted in traveling (Blumberg 1994).

The key decisions in service subunits relate to allocating service jobs to field engineers. The allocation logic follows the typical categorization of field service jobs into preventive maintenance and emergency jobs (e.g. Bleuel 1975; Watson et al. 1998; Lin et al. 2002; Blakeley et al. 2003). Preventive maintenance jobs create the basic workload and are often allocated to field engineers as routes (e.g. Blakeley et al. 2003; Voudouris et al. 2006), and additional customer calls are then inserted into these engineer job queues (e.g., Haugen and Hill 1999).

Service quality with a single service job is strived for by identifying suitable field engineers (Hill 1992; Lesaint et al. 2000; Lin and Ambler 2005) as well as necessary spare parts (e.g. Blumberg 1994). Service efficiency and desired customer response time, in particular, have been approached with dispatching algorithms to improve field engineer selection based on desired response times (e.g. Hill 1992; Haugen and Hill 1999; Papadopoulos 1996).

Although no comprehensive treatment has been provided on what information on the target equipment is needed for scheduling and dispatching, based on contributions in literature, it can be summarized that at least the location information (Hill 1992; Haugen and Hill 1999), criticality of the equipment (Papadopoulos 1996), access constraints (Blakeley et al. 2003), engineers skilled with the equipment (Blakeley et al. 2003; Voudouris et al. 2006), and equipment service history (Voudouris et al. 2006) might influence the field engineer selection.

Information on equipment might be needed to allocate the base workload of preventive maintenance to field engineers. An iterative tool to assign serviced equipment to engineers and build efficient daily maintenance routes accounting for equipment access restrictions is given by Blakeley et al. (2003). They consider engineer skills by product category in the route definitions. Voudouris et al. (2006) describe a planning tool used at British Telecom. Service demand forecasts are based on historical data and matched with field engineers to create service routes. The route definitions are adjusted, accounting for "skill shortages" and "skill surpluses" among areas, although they give no definitions for skill categories or their relationship with the installed equipment.

Equipment information can be relevant also when adding emergency jobs to the field engineer routes. Revisiting the dispatching process description by Blumberg (1994), the most critical elements are related to identifying the relevant service call characteristics that enable to 'optimally assign a specific service engineer in terms of specific skill levels and parts needed' (p. 268).

Generally, the efficiency considerations of the dispatching problem are discussed in a situation where the customer waits with a failed piece of equipment (Hill 1992; Collins and Sisley 1994; Papadopoulos 1996; Haugen and Hill 1999; Lesaint et al. 2000; Lin and Ambler 2005), which makes the dispatching both time and quality critical (see Figure 4 for a breakdown of the service call time line).

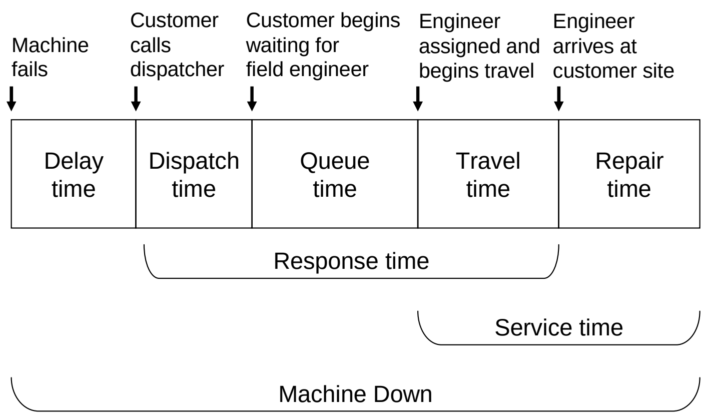

Figure 4: Service call time line (adapted from Watson et al. 1998 and Haugen and Hill 1999)

The success of the dispatching process is evaluated through the field service performance measures—response time average (e.g. Collins and Sisley 1994), percentage of responses on time (e.g. Blumberg 1994), percentage of resolutions within service level agreement (e.g. Hill 1992; Haugen and Hill 1999; Papadopoulos 1996), or first call effectiveness (e.g. Hill 1992). Depending on the performance measure, the dispatching process can be thought to emphasize the location of the nearest engineer (response time), the skills of the engineer (first call effectiveness), or a combination of both (resolutions within service level agreement).

Some works assume all engineers equally capable of handling a call and concentrate only on the time criticality in devising dispatching algorithms. Hill (1992) makes a simulation experiment to compare the performance of six dispatching rules that vary in their prioritization of call arrival, engineer travel time, and call expiration time (promised response time). Haugen and Hill (1999) consider dispatching rules as insertions in service engineer call queues to minimize the induced additional workload.

Other works include additional constraints such as field engineer skills or customer priorities. Collins and Sisley (1994) describe an automated dispatching system using a logic similar to Haugen and Hill (1999), but it considers engineer skill suitability for the call and tries not to dispatch engineers with special primary skills on secondary calls if alternative solutions exist. Papadopoulos (1996) presents a dispatching system based on a network queuing model accounting also for customer calls with different priorities. Lin and Ambler (2005) outline a proposal to extract the implicit knowledge of veteran dispatchers as weights to a decision tree system that could automate the engineer selection based on criteria used by human dispatchers. Decision points to be weighted include call priority and response and expiry times of the call, travel time, and engineer skills.

The general observation on the research on dispatching algorithms is that they give different weights to different decision constraints caused by the serviced equipment. This can be understood in the light of the work by Lesaint et al. (2000, p.23) who give an impressive list of the multiplicity of constraints that a dispatcher might need to consider:

- Engineers must be matched to tasks;
- Each engineer operates primarily within a predefined area;
- Each engineer has off-hours and predefined breaks during the day (for example, lunch, time for personal appointments) that must be inserted into his or her schedule;
- Engineers can perform only one activity at a time;
- The last task of the day might require overtime, if allowed;
- Some tasks must be performed within an agreed-on time window;
- Some tasks must be started or completed by an agreed-on time;
- Access to customer premises may be granted only to certain people at certain times;
- Task execution may be broken according to rules that take into account task and break details;
- Task duration depends on the engineer's experience and skills, and journey duration depends on its start time;
- Some tasks must be sequenced in time, for example, collecting equipment before making a visit; and
- Different engineers in different places must perform some tasks in parallel at the same time.

Again, location information, equipment criticality, access constraints, engineers skilled with the equipment, and equipment service history can be seen as underlying equipment related information in addressing these dispatching constraints.

3.1.4 Field engineer resource management

The underlying organizational goals for field engineer resource management are achieving a balance between minimizing investments in resources and maximizing the quality of service provided by those resources, given a certain demand for services. These are approached with decisions concerning optimizing the headcount of engineers (e.g. Hambleton 1982; Agnihothri and Karmarkar 1992; Klimberg and van Bennekom 1997; Watson et al. 1998; Voudouris et al. 2006; Tang et al. 2007) and the amount of training provided (Brusco and Johns 1998; Homer 1999; Agnihothri and Mishra 2004; Brusco et al. 1998; Campbell 1999; Pinker and Shumsky 2000; Agnihothri et al. 2003).

Because resource planning must be based on a demand forecast for the resources (Mentzer and Moon 2004), of interest in this section is how information on installed base is reflected in forecasting the demand for field engineer resources. For these purposes, the key characteristics of the installed base seem to be equipment locations, service histories, customer contract coverage, and characteristics of the equipment determining the required skills for field engineers (Klimberg and van Bennekom 1997; Watson et al. 1998).

Klimberg and van Bennekom (1997, p. 182) summarize the challenges in field engineer planning: 'The complexities and uncertainties of the operating environment present many challenges for this aggregate planning. The total FE [field engineer] labor hours needed is a function of multiple variables: characteristics of the equipment, characteristics of the FEs, contractually required response, field office locations, and customer locations." As an example of the "characteristics of the equipment,' Watson et al. (1998) considered product type, usage, and product reliability in the service demand forecasts they discuss in their work.

Whereas the number of field engineers and their skill levels affect also jointly the performance of field engineer planning, the research streams addressing those two are somewhat disconnected. One stream concentrates on quantifying service demand to assess the number of engineers needed to achieve (mainly response time-based) performance goals in an area. The other stream concentrates on service capacity by analyzing the effect of field engineer cross training on the service performance. The disconnectedness of these two is visible in that, typically, engineer skills are not considered in the former, and geographical distribution of service targets not in the latter.

The roots of field engineer resource planning are in emergency service resource planning (i.e. ambulance, police, and fire station location and staffing problems; see Larson 1975). Whereas there is a clear similarity with the response time requirements within geographical areas, the context of field services brings additional dimensions to the problem—variable (but to an extent predictable) service frequencies at specific discrete service locations and variable skills of the servers (Bleuel 1975). Some early field service planning articles assessed the size of service territory per service engineer based on equipment density (Smith 1979) and the composition of service teams to balance response time and service quality (Bleuel 1975).

The stream analyzing the number of engineers needed per service area tends to disregard the consideration of skill distribution among the engineers. Engineers are mostly treated either as equally skilled (e.g. Hambleton 1982; Agnihothri and Karmarkar 1992; Tang et al. 2007) or as fully specialized so that the staffing problem can be evaluated within each skill category (e.g. Watson et al. 1998; Voudouris et al. 2006). The characteristics of service areas mostly used in evaluating the need for engineers are equipment density and call rate per equipment group (Hambleton 1982; Agnihothri and Karmarkar 1992). Watson et al. (1998) used the most detailed analysis, as they identified the frequency of service calls to differ per product and that forecasts of demand should be based on various territory-specific characteristics such as 'product mix, the number of machines in service per product type, expected usage of each machine, and machine reliability curves that associate machine usage and failure curves to expected service calls' (Watson et al. 1998, p. 223).

An interesting work considering both staffing requirements per area and skill distribution is that of Klimberg and van Bennekom, 1997. They develop set covering models solved for field office location alternatives and the numbers of field engineers required by variably minimizing cost, minimizing response time, maximizing back up, and accounting for probabilistic demand for a set of customer locations. The field engineer skills are divided into three inclusive levels so that a higher-level engineer performs faster with all kinds of customer equipment. They use two models for forecasting the total engineer demand: the first is a function of product failure frequency, mean time of repair by respective skill level, and travel time; the second model accounts for the probabilistic nature of demand by incorporating a chance constraint for engineer availability.

In contrast to the above literature, the works that concentrate on cross training engineers and its effects on service performance tend to treat the demand as geographically uniformly or indifferently distributed (with some exceptions such as Agnihothri and Mishra, 2004). They focus on analyzing the effect of the number of additional skills (Brusco and Johns 1998; Homer 1999; Agnihothri and Mishra 2004) or the effect of depth of training in the additional skills (Brusco et al. 1998; Campbell 1999; Pinker and Shumsky 2000; Agnihothri et al. 2003).

The key message of research on cross training is that secondary skills are needed, but they need not be perfect to improve capacity use. Brusco and Johns (1998) give the results of an experimental study based on linear programming to evaluate cross training in four skill classes. The mean demand and number of field engineers are treated as given constants in a single factory setting. They contend that cross training enables increased flexibility, especially with chaining skills to maximize backup availability. Later, Brusco et al., (1998) show that already about 50% productivity in cross-trained skills results in 80% of potential workforce savings. They also highlight that cross training is most useful with high variability in demand for at least one skill type. Whereas their treatments of engineer skills are abstract, electricians, mechanics, and pipefitters are used as exemplary skill classes. Campbell (1999) confirms the usefulness of less-than-perfect cross training in equally theoretical skill treatment using a nursing context.

Finally, Agnihothri and Mishra (2004) give the most comprehensive analysis by considering, in addition to the above dimensions, the likelihood of server-mismatch, that is, the likelihood that the dispatcher evaluates the call requirements wrong and sends an engineer with unsuited skills to the customer equipment. Among other things, their simulation results indicate that if the share of travel time is large (i.e. low density of installed base), it is more useful to train several engineers in several skills than to aim for 100% efficiency of a few engineers' secondary skills.

In summary, equipment location and service history can be seen as relevant installed base information for service territory planning, and information on equipment types is needed for assessing field engineer skill requirements.

3.1.5 Spare-part inventory management

Much as with field engineer resource management, the underlying goals of spare-part inventory management are in balancing between service quality and required investments. With spare parts, the goals translate to maximizing end-user spare-part availability and minimizing investments in inventories, given an expected spare-part demand (Fortuin and Martin 1999; Huiskonen 2001; Cohen et al. 2006). The key decisions made relate to spare-part stock keeping unit (SKU) inventory locations and inventory levels. Typical means for the balancing act are demand pooling among inventory locations (e.g. Lee 1987; Axsäter 1990; Alfredsson and Verrijdt 1999; Grahovac and Chakravarty 2001; Wong et al. 2005) and demand pooling through the use of spare-part commonalities and interchangeability of parts (Levitt 1972; Baker et al. 1986; Kranenburg and van Houtum 2007). The spare-part demand forecast seems to require understanding of the points of consumption at least in terms of geographical distribution, their respective criticalities, and service levels agreed on with the customer (Cohen et al. 1997; Kilpi and Vepsäläinen 2004; Wong et al. 2005; Ghodrati and Kumar 2005; Deshpande et al. 2003; Cohen et al. 2006).

Compared with other types of inventory planning problems, the distinguishing characteristics with spare-part inventories are often quoted to be numerous SKUs, low average demand with sporadic demand peaks for many SKUs, high value of spare parts, and the obsolescence risk resulting in inventory markdowns (e.g. Fortuin and Martin 1999; Huiskonen 2001; Cohen et al. 2006). These characteristics make attaining a high service level costly in terms of spare-part inventory investments. Nevertheless, as stock-outs often result in consequential costs greatly exceeding the inventory carrying costs, a deliberately low service level is often not a desirable alternative.

Much spare-part inventory research considers only one inventory echelon, i.e., they concentrate on the inventory management of internal plant maintenance operations (e.g. Huiskonen 2001; Akcali et al. 2001; Dekker et al. 1998; Braglia et al. 2004; Rustenburg et al. 2000; Fortuin and Martin 1999). Consequently, these contributions approach the spare-part problem as a spare-part replenishment problem. A notable feature, however, is the use classifications of spare-parts along different dimensions (such as value, criticality, demand intensity, or demand predictability). This aims to reduce the problem space to fewer control alternatives based on some contextually relevant characteristics of spare-part consumption.

The other research stream concentrates on multi-echelon spare-part systems, where pooling concepts are used to balance investments and availability. This stream is traditionally attributed to being launched by the METRIC-model (Multi-Echelon Technique for Recoverable Item Control) of Sherbrooke (1968). Here, the main tools used are mathematical models aimed at improving the problem of service levels and inventory investments across many inventory locations (e.g. Lee 1987; Axsäter 1990; Alfredsson and Verrijdt 1999; Grahovac and Chakravarty 2001; Wong et al. 2005).

A key feature in these studies is the use of pooling techniques known to reduce the safety stock investments with uncertain demand (Eppen 1979). A manufacturer providing services to the installed base is in a unique position to use the pooling effect (Fortuin and Martin 1999; Kilpi and Vepsäläinen 2004). As the manufacturer extends the spare-part management service to a greater number of product customers in a geographical area, the number of spare-part SKUs remains largely the same, whereas the demand for each item becomes more stable. This lowers the necessary safety stock investment per installed product and reduces the risk of obsolescence with better inventory turns. The manufacturer also has the opportunity to influence part commonality among product types, which further improves the spare-part pooling benefits (Levitt 1972; Baker et al. 1986; Kranenburg and van Houtum 2007).

Whereas the overall flow of spare parts can make inventory investments for the OEM less risky, service levels to the customers remain a challenge because of lead-times and prioritization problems. Inventories need to be positioned to provide requested lead-times for the spare parts, often measured in hours (Cohen et al. 1997; Kilpi and Vepsäläinen 2004; Wong et al. 2005; Cohen et al. 2006). Further, a spare-part item used in several products might have different demand, depending on the application where the product is used (Ghodrati and Kumar 2005) and be more critical for one customer than for others. Customers paying a premium for a higher spare availability should be prioritized over lower value customers (Wang et al. 2002; Deshpande et al. 2003; Cohen et al. 2006). This comes back to the plant level classification discussions and requires detailed information on the contextual criticality differences in the installed base.

Summarizing the above discussion, spare-part planning needs at least equipment type, location, and criticality information on the installed base.

3.2 Installed base information with sales and product development

The field service operations have been identified as a source of installed base information also for purposes outside the service operations themselves. Ives and Vitale (1988) discuss several examples of information technology uses in the context of maintenance services. They contend that in addition to supporting information input for the maintenance operations, information technology can be used to capture data from outputs of the maintenance services used for product design (component reliability), manufacturing (new material effectiveness), sales (competitor performance), purchasing (supplier component performance), and maintenance management (employee performance for training decisions).

Goffin and New (2001) discuss the new product development process and its relationship with after-sales services. Based on five case studies, they arrive at a model of field support and new product development interaction. Input from field services is needed in design to determine quantitative goals for reliability (e.g. mean-time-between-failure, MTBF) or supportability (e.g. installation times, fault diagnosis times, field access times, repair times/costs, user training times, and upgrade times).

There are also more cursory comments on using field data as an input in other functions such as sales and promotion (e.g. Wise and Baumgartner 1999), marketing and customer relationship management (e.g. Campbell 2003), new product and service development (e.g. Lele 1997; Cohen and Whang 1997), product and service quality improvement (e.g. Cavalieri et al. 2007), and consulting services such as asset management and production optimization for the customer (e.g. Borchers and Karandikar 2006).

Based on these comments, the following sections discuss sales and marketing as well as product development as the most frequently cited users of installed base information outside the service processes.

3.2.1 Sales and marketing

Put plainly, the goal of sales and marketing is to generate revenues for a company. Whereas the profitability of each product or service sale depends also on the contributions of other functions in a company, there are better and worse deals to be made with different customers. Sales and marketing literature under the labels of "customer relationship management" and "key account management" emphasize the importance of selective treatment of customers and retaining profitable customer relationships (e.g. Grönroos 1990; Ojasalo 2001; Zablah et al. 2004). These are approached through decisions on customer segmentation to differentiate product offers or pricing for larger customer bases (e.g. Bose 2002; Corner and Hinton 2002; Campbell 2003; Xu and Walton 2005), and through responsiveness to requirements of important single customers (Ojasalo 2001). The installed base information considered relevant for these decisions can be summarized as customers' product and service usage, interaction histories, customer profitability, and geographic factors (Ojasalo 2001; Bose 2002; Crosby 2002; Jackson 2005).

With customer relationship management (CRM), there has for some time already been a strong impetus to consolidate information on customers within an organization to support the sales managers with customer contacts and to provide analytical insights on customer segments for marketing purposes (e.g. Bose 2002; Corner and Hinton 2002; Campbell 2003; Xu and Walton 2005). Zablah et al. (2004) discuss divergent perspectives presented in prior literature on CRM and contend that CRM has been viewed as a process, a strategy, a philosophy, a capability, and a technology. Common goals in all the approaches are customer retention and customer profitability. Hence, they provide a synthesizing definition for CRM: 'CRM is an ongoing process that involves the development and leveraging of market intelligence for building and maintaining a profit-maximizing portfolio of customer relationships.' (Zablah et al. 2004, p.480).

This definition is faithful to the roots of customer relationship marketing. The history of CRM traces back to relationship marketing in the context of services, with Grönroos (1990) as one of the earliest contributors. 'The role of relationship marketing is to identify, establish, maintain and enhance relationships with customers and other stakeholders, at a profit, so that the objectives of all other parties involved are met; and that this is done by a mutual exchange and fulfillment of promises' (Grönroos 1990, p. 7). In the late 1990s, the ideas of customer retention and long-term business opportunities were embraced under the term CRM (Lindgreen et al. 2006), and ever since, they have gained vastly in the interest of researchers (Ngai 2005).

With concurrent development of information systems that enable the analysis of vast amounts of customer data, the thorough business strategy aspects of relationship management have often been forgotten, and the term *CRM* has become, at times, synonymous with information technology or software solutions that analyze customer data (Crosby 2002), even to the extent that packaged off-the-shelf analysis software has emerged as "CRM solutions" (Light 2003; Bull 2003; Campbell 2003; Xu and Walton 2005). Furthermore, such CRM software and software packages, in particular, have been criticized as mere tools for front-line operations such as sales force automation or call center support and abandoning the idea of analytical approach necessary to develop customer relationships (Bull 2003; Crosby 2002; Jackson 2005; Xu and Walton 2005).

Whereas the customer data analysis aspect is the most interesting side of CRM when considering installed base information, much of the literature concentrates on applying CRM to consumer markets and financial services as a prime industry (e.g. Peppard 2000; Bull 2003; Rygielski et al. 2002; Campbell 2003; Jackson 2005). In addition, even though it has been recognized that customer data analyses should be especially useful in the business-to-business environment (e.g. Rygielski et al. 2002), contributions detailing the data requirements for customer analyses are absent. From the consumer market-oriented CRM literature, it is possible to infer the following key items (Bose 2002; Crosby 2002; Jackson 2005):

- Purchase patterns and product/service usage
- Touch points and interaction histories
- Customer satisfaction data
- Customer profile: profitability and customer segment data
- Geographic and demographic factors

Another relevant stream of literature for the present discussion is that related to key account management in business-to-business context (e.g. Arnold et al. 2001; Birkinshaw et al. 2001; Ojasalo 2001). Arnold et al. (2001) discuss global account management and draw the conclusion that in situations where the purchasing functions of the customers are more globally oriented than the sales functions of industrial companies, there is a risk that a supplier with poor visibility to sales activities is played for the lowest local price by a global customer better informed on regional differences.

Ojasalo (2001) draws an interesting synthesis of key account management literature and achieves a four-element model of an account management life cycle:

1. Identifying key accounts,
2. Analyzing key accounts
3. Selecting suitable strategies for key accounts
4. Developing operational level capabilities

He stresses the importance of considering the customer account both as an organization and as people who are the main contacts. He further provides insights to the important questions to be answered at each phase. Selected questions relevant from the installed base information viewpoint are summarized in Table 3. The questions can be interpreted to indicate a need for installed base information as part of the customer analyses. In particular, equipment types in use, service histories, and geographical locations of the installed base are of interest.

Table 3: A framework of KAM practices at company level (abridged from Ojasalo 2001)

Key Account Management Element	Company Level Approach
Identifying key accounts	Which existing or potential accounts fulfill the criteria of strategically important accounts now and in the future?
Analyzing key accounts	What are the account's products/ services, inputs, internal value chain, markets, suppliers, and economic situation? What is the history of the relationship with the account in terms of sales volume, profitability, investments and adaptations made, buying behavior, information exchange, special needs, buying frequency, and complaints? What is the account's portfolio of competing suppliers, and what is the selling company's position in this portfolio?
Selecting suitable strategies for key accounts	Which strategic alternative best fits the present and future business?
Developing operational level capabilities	How could products/services be customized for the key account? How could the organizational structure be improved to meet the key account's requirements better? What factors make the selling company trustworthy in the eyes of the account, and how could these factors be enhanced?

3.2.2 Product development

The goal of product development is to ensure long-term competitiveness by creating profitable products that gain market acceptance (e.g. Wheelwright and Clark 1992; Griffin and Hauser 1996; Cooper and Kleinschmidt 2007). Attaining these goals in product development requires innovative designs, but also decisions on what performance improvements are required (Majeske et al. 1997; Goffin and New, 2001) and a controlled process with decisions on which development projects to pursue (Cooper 1990; Wheelwright and Clark 1992).

As can be inferred from the discussion below, the installed base information of main interest for product development seems to relate to failure frequencies of product versions, servicing times, and information on environmental factors. Further, the strong reliance on sales and marketing to provide market insight for prioritization decisions indicates a shared interest with sales in the current products' spread of use.

Within product development, Product Data Management and, more recently, Product Lifecycle Management systems are considered information systems that gather all relevant product information to be easily accessible through uniform user interface (Batenburg et al. 2005; Rangan et al., 2005). Interestingly, based on the review of PDM literature, product development seems to have scarce interest in the products they have designed after they have been delivered to customers. From the viewpoint of installed base information, the PDM/PLM systems consider "product data" as mainly related to product type (with possible revisions and/or variants), supplemented perhaps with manufacturing data on individual instances of the products (e.g. Philpotts 1996; Peltonen et al. 1996; Kovacs et al. 1998; Batenburg et al. 2005; Rangan et al. 2005). Whereas this engineering and manufacturing data is seen as useful also in after-sales activities such as delivery, maintenance, and disposal (Peltonen et al. 1996; Sackett and Bryan 1998; Hameri and Nihtilä 1998), after-sales services are not discussed as a notable source of information in their own right. The only exceptions are short passing comments that product life cycle management also should cover the operations and maintenance phases (Kovacs et al 1998; Gao et al. 2003; Rangan et al. 2005).

In addition, literature viewing new product development as a process tends to give little weight to services as an information source. Although marketing is seen as an important interface to incorporate market expectations and user needs. Especially in the initial concept development and evaluation phase (e.g. Cooper 1990; Souder and Moenart 1992; Griffin and Hauser 1996; Gomes et al. 2003; Kohn 2006; Sherman et al. 2005), the after-sales functions that could convey experience on the performance of previous product designs are not among valued sources for information (Goffin 2000). Instead, additional support for design decisions from external sources e.g. from customers, suppliers, competitors, professional publications, professional meetings, and professional contacts, has been discussed (see Sherman et al. 2005).

An underlying reason is probably the emphasis on the innovativeness of new products. Majeske et al. (1997) describe three types of product design goals: 1) adding customer features, 2) quality and reliability improvements, and 3) cost reduction opportunities. Although these all influence a new product's success, the last two are seldom addressed as explicit goals requiring attention, but rather, they are seen to reflect constraints that inhibit the incorporation of desired features (e.g. Sherman et al. 2005).

The strongest arguments for using after-sales experience in product development are presented by Goffin (1998, 2000) and Goffin and New (2001) in their demands for design-for-supportability in product development. Their work indicates that the product design determines lifetime costs through designs affecting mean times between failures, servicing durations, and required rate of preventive maintenance, even though these are infrequently quantitatively assessed during the development process (Goffin 1998; Goffin and New 2001). They further argue that field support engineers and managers do have firsthand experience on the product lifetime aspects and should have an opportunity to influence the product designs (Goffin 2000).

Another stream of literature that discusses the role of after-sales services in product development decisions is research on extracting reliability information from warranties (e.g. Majeske et al. 1997; Oh and Bai 2001; Murthy and Djamaludin 2002; Rai and Singh 2003; Petkova et al. 1999; Wu and Meeker 2002). Warranty data can be used to build component reliability models (Murthy and Djamaludin 2002) and can support the product development process in (Majeske et al. 1997; Petkova et al. 1999; Rai and Singh 2003):

- Early warning/detection of wrong design, production process, parts, materials, etc.
- Selection and justification of engineering design improvement projects
- Comparison of performance before and after design fix
- Assessment and refinements of reliability predictions
- Evaluation of performance of design solutions carried over from former products
- Relationship among test data at development stage, inspection results of production and field performance

Compared to laboratory tests of product prototypes, using field data provides information on actual usage profiles and exposure to environmental factors difficult to simulate in the laboratory (Oh and Bai 2001). However, using warranty data for these purposes has two major shortcomings (Rai and Singh 2003): not all relevant problems take place during the warranty period, and not all problems occurring during the warranty are claimed.

Summing up, these contributions indicate that the role of information on the installed equipment seems more prominent in supporting product development, especially when evaluating design decisions aiming to affect reliability or the product's life-cycle cost. Although focusing only on the marketing and R&D integration, Gomes et al. (2003) found in their study that formal interchange of information has a higher effect with less innovative new product development projects, whereas collaboration–oriented integration supports innovative new product development. This supports the above inference that information on the installed product base could be most useful for assessing product development goals related to reliability and cost, rather than innovative new features. This also reflects the distinction of "equivocality" and "uncertainty" presented by Daft and Lengel (1986). Innovative goals of product development suffer more from equivocality than uncertainty. It is not necessarily well understood what information would lead to more innovative products. In contrast, the reliability and cost goals could use well understood, but at times absent, information—failure frequencies, their causes, and their remedies and prevention costs.

3.3 Summary of prior research touching installed base information

The review of reported research on the operations in different functional subunits reveals that several decision-making processes in a manufacturing organization providing after-sales services depend on information on installed equipment.

The first branch of literature of interest consisted of contributions to the field service operations, which are ultimately performed by local service units (Oliva and Kallenberg 2003; Cavalieri et al. 2007). As summarized in Table 4, from the perspective of the organization, the local service units have an organizational purpose of providing effective and efficient services for the local customers (e.g. Blumberg 1994; Agnihothri et al. 2002). Key decisions for this goal involve selecting the most suitable resources for each service job among the available field engineers and spare parts, based on the characteristics of the individual service target.

Table 4: Summary of installed base information needs identified in the literature review

Subunit	Goals of subunit	Key decisions of subunit	Installed base related information used in decisions
Local service unit (3.1.3)	Ensure service quality and service efficiency	Selection of closest and most capable field engineer and suitable spare parts	Equipment location Equipment criticality Equipment characteristics Access restrictions Service history
Field engineer resource management (3.1.4)	Balance investments in resources and quality of service	Headcount of engineers and amount of training	Equipment locations Equipment characteristics Service histories Customer contracts
Spare-part management (3.1.5)	Balance investments in inventories and end-user spare-part availability	Inventory locations and inventory levels per SKU	Equipment locations Equipment criticalities Customer service levels
Sales and marketing (3.2.1)	Ensure customer retention and customer profitability	Customer segmentation and customization of offers for key customers	Products and services of customer Interaction histories Customer value Geographical factors
Product development (3.2.2)	Design profitable products	Prioritization of development projects, features to add, product performance improvements to make	Equipment failure rates Equipment servicing times Environmental factors

Because the service units depend on two key resources—field engineers and spare-parts (Blumberg 1994; Cohen et al. 2006)—literature on the management of those resources was also reviewed. Field engineer resource management is responsible for the recruiting, training, and allocation of field engineers. Their organizational goal is to keep the required investments to a minimum while ensuring sufficient availability of capable field engineers (e.g. Klimberg and van Bennekom 1997; Watson et al. 1998). The service targets in the concerned area influence the required decisions on the headcount and training needs. Spare-parts management is responsible for procurement of spare parts and positioning of inventories (e.g. Fortuin and Martin 1999; Huiskonen 2001; Cohen et al. 2006). In addition, their goals reflect the requirement to get high availability of resources while keeping the necessary investments low. Again, decisions should reflect the particular needs in each planning area.

In addition to the field service information requirements, the context of the original equipment manufacturer as the service provider needs to be considered. The most often cited installed base information users outside service operations are related to product development (e.g. Ives and Vitale 1988; Knecht et al. 1993; Lele 1997; Cohen and Whang 1997; Cavalieri et al. 2007) and sales and marketing (e.g. Wise and Baumgartner 1999; Campbell 2003).

Sales and marketing have the firsthand responsibility to generate revenues for the company, but also doing it in a beneficial way by striving for continuity and profitability in the customer relationships (e.g. Grönroos 1990; Ojasalo 2001; Zablah et al. 2004). This entails the use of customer information, including product and service usage, to identify priority customers for specialized treatment and to segment others for more standardized approaches. Product development aims to develop lucrative new offers thriving on novel features and on improvements of known sources of dissatisfaction (e.g. Wheelwright and Clark 1992; Griffin and Hauser 1996; Cooper and Kleinschmidt 2007). The latter, in particular, have been noted to benefit from reviewing existing products and their performance in the customer applications (Majeske et al. 1997; Petkova et al. 1999; Rai and Singh 2003).

Extant literature on the function-specific information requirements reveals that there indeed can be installed base-related uncertainties in the subunits of the organization. The decisions summarized in Table 4 can be unfavorably affected if information on the installed base is incomplete or misleading (i.e. available information is less than required information; see Galbraith, 1973). Moreover, the information requirements seem uniform enough to warrant a high-level conceptualization of "installed base information" as a phenomenon of its own. In addition, this concept only indirectly addressed this far motivates further inquiries into systematic installed base information management.

4 RESEARCH DESIGN

This chapter describes how the empirical part of the research was conducted. The first section builds up the research questions and explains the motivation for the adopted research approach. The second section establishes the research setup of a multiple-case study, and the third section details the research methods used for gathering empirical data. The fourth section clarifies the selection of a functional subunit as the unit of analysis and explains the subunits studied in the empirical part. The final section describes how the research design has addressed the requirements for rigor in qualitative case studies.

4.1 Research questions

Based on the literature review, the concept of installed base information is relevant, because the increasing interest in well-defined and controlled after-sales operations and sophisticated product-service systems (section 2.1) increases uncertainties in service operations as well as increases the need for subunit integration through common information on the equipment in use (section 2.2).

In addition, the review on goals, decisions, and product information needs in the functional subunits (chapter 3) indicates that various decisions indeed depend on or can benefit from information on the installed equipment (section 3.3). The installed equipment base seems to impact the task uncertainty of several subunits regardless of the after-sales business development highlighting the need for an integrated view on the installed base. However, the summary of subunit specific needs for installed base-related information in the previous chapter resulted from interpreting existing contributions that did not explicitly focus on the information needs, nor on arranging such information at the organizational level. Hence the goal for this work:

> *This research's principal aim is to support the development of installed base information management to improve the business processes of manufacturing companies providing product-related services for their customers.*

Because this research's motivation arises from generating instrumental knowledge on the interaction of information and business processes to be applied in the socio-technical context of business organizations, it belongs to the domain of design sciences (Niiniluoto 1993; van Aken 2004; Holmström et al. 2009). The hallmark of design science is the aim for prescriptive knowledge, codified as means-ends propositions (Simon 2000), technical norms (Niiniluoto 1993), technological rules (Bunge 1967; van Aken 2004), or design propositions (Denyer et al. 2008). A technological rule can be considered 'an instruction to perform a finite number of acts in a given order and with a given aim' (Bunge 1967, p. 132) or as 'a chunk of general knowledge, linking an intervention or artifact with a desired outcome or performance in a certain field of application' (van Aken 2004, p. 228).

More specifically, such rules have a basic form of prescription 'if you want A, and you believe that you are in a situation B, then you ought to do X' (Niiniluoto 1993, p. 12). Van Aken (2004) discusses also a form that he calls a heuristic technological rule: 'if you want to achieve A in a situation B, then something like action X will help.' He considers a heuristic rule a 'design exemplar,'that is, 'a general prescription which has to be translated to the specific problem at hand; in solving that problem, one has to design a specific variant of that design exemplar' (van Aken 2004, p. 227). Echoing the heuristic rule view, Denyer et al. (2008) prefer the term design proposition to technological rule, as the described actions or interventions cannot always be offered as mechanistic and precise instructions. They also add a fourth element of "mechanism" to the prescriptive statement and call this the 'CIMO-logic' of prescription: 'in this class of problematic Contexts, use this Intervention type to invoke these generative Mechanism(s), to deliver these Outcome(s)' (Denyer et al. 2008, pp. 395–396). This logic of design propositions is used throughout the empirical part of the research reported in this thesis.

Adding the generative mechanisms as a part of design propositions is much justified. Whereas in business economics, the generally held goal "A" (or desired 'Outcome') is about maximizing profits (Niiniluoto 1993), the complexity of socio-technical organizations renders the achievement of this goal to a multitude of alternatives (van Aken 2004). For example, the goal of maximizing profits can be pursued through revenue increase or cost savings, which decompose to alternatives of e.g. revenue increase by developing more competitive product designs or by engaging in more aggressive sales efforts or cost savings with more efficient service operations or with more systematic inventory management. These again decompose in sets of alternatives themselves. Simon ([1945] 2000, p. 73) discusses this hierarchy of ends: 'Ends themselves, however, are often merely instrumental to more final objectives. […] Rationality has to do with the construction of means-ends chains of this kind.' Hence, explicit treatment of the generative mechanisms is necessary to communicate how an intervention is supposed to lead to the outcomes.

Then, to support the aim of developing installed base information management, an important first step is to study the intended outcomes and the generative mechanisms to be achieved with such information management (Simon 1973b). Improving the availability of even high quality information to decision makers does not straightforwardly imply improving profits through improved operational efficiency or process effectiveness. The characteristics and choices of the decision makers such as their awareness of available information, their motivation and willingness to use that information, and the decision makers' reliance on their own expertise have a strong influence on the operational effect of all information management efforts (DeLone and

McLean 1992, 2003; Clark et al. 2007). Nevertheless, whereas there does not exist a direct 'more X results in more A' relationship between information and performance, it is necessary to understand their enabling relationship of 'if not X [e.g. information], then not A [e.g. performance]' (Markus and Robey 1988, p. 590, examples added by author). Therefore, the first research question is defined to identify the desired outcomes and generative mechanisms to be achieved with the general intervention of maintaining systematic installed base information (van Aken 2004; Denyer et al., 2008):

> *RQ1: Why should a manufacturing organization providing product-related services gather installed base information?*

Then, to clarify the means to achieve identified ends, the specific information needs on the installed base must be studied. Thus, the second research question follows to ask for more detailed characteristics of the studied intervention:

> *RQ2: What information should a manufacturing organization providing product-related services gather on the installed base?*

Concentrating on these two research questions of means and ends in the collection of empirical data and its analysis creates an understanding of the installed base information phenomenon that can then be codified as design propositions for further practical and theoretical treatment (Denyer et al. 2008; Holmström et al. 2009).

4.2 Research program

As scarce literature addresses the form and complexity of installed base information, and as the available contributions addressing different aspects of installed base information can be found in several disconnected streams of literature, an in-depth analysis of this neglected phenomenon was considered necessary. Because unifying research on information needs is missing (Borchers and Karandikar 2006), the concept of installed base information required further elaboration based on primary data from empirical studies explicitly addressing the development of the concept. Case studies, and multiple-case studies, in particular, with design science research (van Aken 2004), have been considered an appropriate research strategy for exploring unrecognized phenomena in the context of operations management by several authors (Eisenhardt 1989; Ellram 1996; Meredith 1998; Stuart et al. 2002; Voss et al. 2002),. Accordingly, the empirical part of the research comprised four case studies in four different organizations.

Research investigating poorly understood phenomena involves constant iterations among empirical data gathering, data analysis, and identification of enfolding literature (Eisenhardt 1989; Dubois and Gadde 2002). Whereas such iterations were present in the process of this research as well, for the sake of presentation clarity, the relevant prior contributions to the research subject have been discussed in the literature review above, and the results of the empirical part of the research are to follow in subsequent chapters. As suggested for inductive case studies, an *a priori* understanding on the phenomena was formed from the potential commonalities among functions to access specific information on the installed base (Eisenhardt 1989; Strauss and Corbin 1990).

The research approach adopted for the case studies is explorative with descriptive and inductive goals (Voss et al. 2002; Eisenhardt and Graebner 2007): improve understanding of the phenomenon of installed base information and formulate propositions on the role of installed base information in organizational information processing. Adopting the viewpoint of design sciences (Bunge 1967; Niiniluoto 1993; van Aken 2004), the underlying instrumental goal of the research is ultimately linked to improvement of IT systems supporting organizational information processing. However, the intent of the case studies has not been in developing instantiations of IT systems (implementations or prototypes), but in identifying constructs and models to aid in the design of such systems. Such constructs and models themselves can be considered IT artifacts (Simon 1996). Whereas theories have been developed to predict or explain phenomena that occur with respect to the use of IT artifacts (DeLone and McLean 1992, 2003), little research has focused on the evaluation of models and emerging IT artifacts (Hevner et al. 2004; Benbasat and Zmud 1999). This is remarkable, as emerging IT capabilities have been identified as a significant enabler allowing organizations to rearrange their structures and change the way they do business (Drucker 1988, 1991; Orlikowski 2000).

In selecting the cases, theoretical sampling (Eisenhardt 1989; Miles and Huberman 1994; Voss et al. 2002) has been used to attain research data from companies with contextual similarities (capital investment goods, international operations) and interesting differences (different types of products, different service offers, differences in service organizations). As the data needed for addressing the research questions has required substantial access to the case organizations (Yin 1994), a practical consideration has influenced the case selection. The case studies have been performed during research projects with organizations that had ongoing development in installed base information management. This is common for design-oriented research, where the participation of companies interested in the studied problem is often required (van Aken 2004).

4.3 Research methods

Empirical data collection

Whereas the case studies were performed in close co-operation with the representatives of case company development programs, the author was responsible for the design of each case study. The gathered case material is mainly qualitative in nature, interviews having been the primary method of inquiry used in the studies. Interview data have been supplemented with company internal documentation and database reviews, as well as results of concurrent research by fellow researchers related to after-sales services in the studied organizations (Table 5). Qualitative data collection methods have been recommended for research aiming at understanding phenomena (Ellram 1996) and interviews of information users particularly important when striving for improvements with organizational information systems (Simon 1973b; DeLone and McLean 1992, 2003; Watson and Frolick 1993).

Table 5: Company internal material reviewed in the case studies

	Company internal material reviewed in cases
Case A	Sales and Service process flowcharts Warranty claim process flowcharts and claim record database excerpts Information system overviews Survey data from accredited service partners
Case B	Warranty claim process flowcharts and claim record database excerpts After-sales service process flowcharts Installed base audit process flowcharts and record database excerpts Service records Sales records Information system overviews Written material of adjacent research efforts
Case C	Installed base development roadmap and business case analyses Installed base records Service records Company presentations in academic workshops Written material of adjacent research efforts
Case D	Installed base development roadmap Installed base information management process guide Installed base records Company presentations in academic workshops Written material of adjacent research efforts

In the four case studies, 111 people were interviewed. Each interview lasted between one and two hours and was recorded whenever possible, resulting in 72 interview transcripts and 39 handwritten interview memoranda. The interview material is stored as interview notes, recordings, and transcripts in a case study database. The interviewees were selected together with key contacts at the case companies. The selection was based on the researchers' *a priori* understanding of relevant subunits, whereas the key contact suggested knowledgeable interviewees of each subunit. The list of interviews was appended during each study as it became evident that more informants were needed to uncover details on specific issues. In the first two case studies (Case A and Case B), a fellow researcher was present with the author in each interview. In Case C, the interviews were performed by the author and a case company key contact. In Case D, the author was the sole interviewer (refer to Appendix A for more details). The interviews were mostly performed in person by visiting the case company sites, with the notable exception of Case D, where a large share of interviews was performed by phone.

The interview data was gathered using semi-structured, open-ended interview guides and asking the interviewees questions in the following generic themes, but going into detail with each respondent's specific tasks (Stuart et al. 2002):

- What kind of information do you currently have on the installed base?
- How do you use that information in your work tasks?
- How do you have access to that information?
- What additional information would you need on the installed base?
- How would you use that information in your work tasks?

- How could this information be accessible?
- What challenges are there in obtaining reliable information on the installed base?

Whereas the themes might seem naïve on face value, they convey the important enabling relationship of 'if one does not have this information (X) available, then one cannot perform this task accurately/efficiently (Y)' (following Markus and Robey, 1988, p. 590). A more detailed account of case-specific interview protocols and interviewed personnel is given in Appendix A where the individual case studies are described.

In addition to the interviews, in each case other research material on the case was also available (Table 5). In Case A, a concurrent survey study on product information requirements of authorized service partners was used to improve understanding of the service process and the particular context of independent service companies. The case company interviewees also provided process flowcharts to describe the operations they were involved with formally. Further, the interviewees introduced the information systems used with sales and delivery processes as well as with after-sales services and provided excerpts of system data to illustrate the structure and quality of data on the installed base currently available.

In Case B, in addition to the operative personnel, the interviews also included systems specialists responsible for the internal information systems who provided snapshots of product-related data in various information systems and data warehouses. The operative interviewees presented flowcharts of the operations and information systems they were involved with in their tasks. In particular, product information in after-sales service systems, warranty claims systems, installed base auditing systems, and sales systems were reviewed. Working meetings where the research material and tentative results were reviewed with case company representatives provided additional insight into the processes and practices used at the organization. There was also a concurrent research effort by fellow researchers on the service processes of the case company, and discussions with them improved the understanding of the case company service business.

In Case C, data in the installed base information system and data from service records were reviewed. The interviewees presented formalized use cases they had identified for the installed base information development initiative. Intensive working meetings with the key contact at the case company were elemental in strengthening the company process understanding and contextual relevance of initial analyses. Supplementary material for understanding the case company service business was available in academic workshops arranged by fellow researchers, as well as write-ups of research reports detailing the service delivery processes of the case company.

In Case D, data in the case company's installed base information system and data from service records were reviewed. Working meetings with the steering group where the research material and tentative results were reviewed provided additional insight into the processes and practices used at the organization. As with the previous case, supplementary material for understanding the case company service business was gathered by attending academic workshops arranged by fellow researchers and using write-ups of research reports detailing the service delivery processes.

Data analysis

Each case study analysis started with transcriptions of the interview records. The transcripts were then codified to differentiate passages referring to the above-described grand themes of the interviews. In particular, the information types, analyses based on the information, and affected decisions were recognized. Specific attention was paid to the level of detail required on the installed base information, as well as additional data required for making relevant analyses to support the decision- making process. This method of analysis aligns with the 'means-ends analysis' suggested by Simon (1996, p. 121) and follows the CIMO-logic (Context, Intervention, Mechanism, Outcome) described by Denyer et al. (2008, pp. 395–396). The identified interview-based information needs and uses were contrasted with the supplementary material to verify correct interpretations of the informant data needs and decision types. Conflicts between these were clarified with the case company representatives during each case study.

For the purposes of within-case analyses, two kinds of tabulations were used for the codified data: one to discern data requirements by functional subunit and by purpose within each subunit (role-ordered matrix of Miles and Huberman 1994), and one to identify linkages between installed base information sources and users by subunit. Based on these analyses, case reports were prepared for each case study organization. Several iterations with the steering group of each case organization were performed to improve the report and to clarify the relevant specifics for each case. The reports were presented in case company specific dissemination sessions of 10–20 people per organization, including managers responsible for installed base information development initiatives and involved personnel. Comments and elaboration in each case were appended to the case-specific material and noted in further analyses.

The cross-case analysis was performed with meta-matrices (Miles and Huberman 1994) where the case data was organized by functional subunits to identify common themes in installed base information needs and to recognize contextual differences in the information needs or perception of the installed base. The case studies' supplementary material was used in the cross-case analyses to identify concrete context-dependent similarities and differences in the installed base information types and the processes using the information. In particular, the cross-case analyses focused on differences related to products (e.g. systems vs. non-systems products, remote connectivity, software components), services (e.g. service contract types, share of 3rd party equipment, service organization structure), and customers (e.g. local vs. global customers, end users vs. OEM customers).

4.4 Unit of analysis

This research follows the standpoint taken by Tushman and Nadler (1978) and McCann and Ferry (1979) who contend that information processing in organizations should be studied by analyzing structural requirements within and between subunits rather than considering the entire organization. Therefore, the analyses were performed by comparing information uses and requirements grouped by functional subunits across the cases, rather than analyzing the companies' organizational structure. Note that the functional subunits used in the analyses are not meant to suggest any specific organizational structure, nor do they reflect any single case's structure. They are generalized functions needing installed base information to support their specialized tasks, independent of their arrangement in an organizational structure.

In the literature review, it was identified that, in addition to the field service operations and service planning functions, the functional subunits most often quoted to benefit from information related to the installed base are the sales function and the product development operations (e.g. Ives and Vitale 1988; Knecht et al. 1993; Lele 1997; Cohen and Whang 1997; Wise and Baumgartner 1999; Campbell 2003; Cavalieri et al. 2007).

This guided interviewee selection, and the results of the research concentrate on these subunits. However, in each of the case companies, a business function titled product management interfaced with sales and product development, Product managers' responsibilities varied somewhat among the organizations but generally included product quality management, product market monitoring, product support coordination for local units. In each case organization, there were several product managers who each had a responsibility over a few product families.

Consequently, the case data analyses were performed within the following functional subunits: service units, sales units, spare-part planning, field engineer resource planning, product management, and product development.

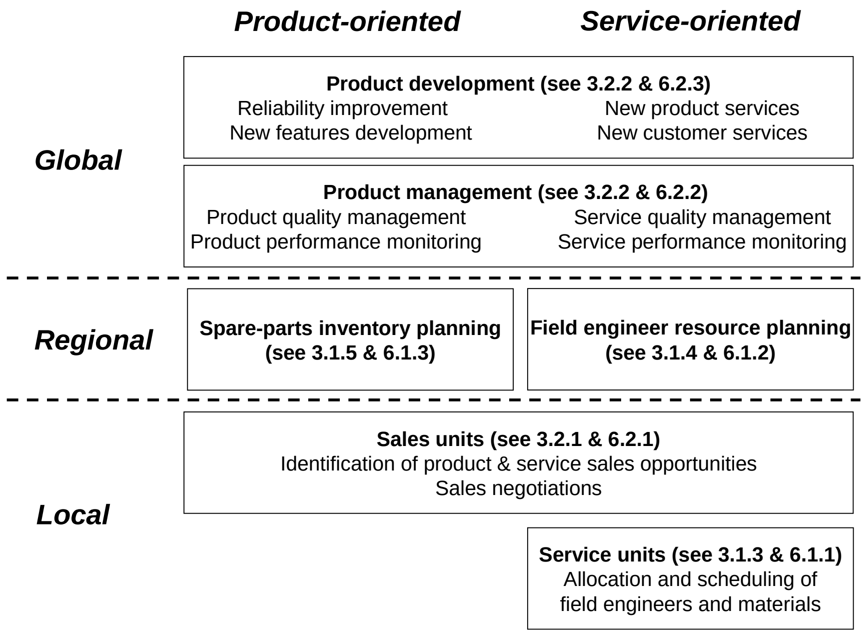

Figure 5: Functional subunits analyzed

In Figure 5, the analyzed subunits are shown with their main scope of interest for installed base information (left-hand side labels). Further, the figure illustrates that some subunits in the companies considered both product and service aspects (labels on top). Finally, the sections of this thesis dealing with literature and empirical results are indicated for each analyzed subunit.

4.5 Validity and reliability

The quality of research methods used in qualitative case studies is often evaluated along four dimensions: construct validity, internal validity, external validity, and reliability (Yin 1994; Stuart et al. 2002; Voss et al. 2002).

Construct validity refers to the correctness of operational measures used for the concepts under study. Multiple sources of evidence, establishing a chain of evidence, and having key informants review case drafts have been suggested to enforce constructs to reflect the concepts of interest (Yin 1994; Voss et al. 2002; Stuart et al. 2002). In this research, multiple sources have been used, both in forms of crosschecking interview data between informants and by contrasting informants' views with company documentation, where possible. Care has been taken to portray the chain of evidence in this thesis as accurately as possible without sacrificing conciseness. As described above, case-specific steering groups with representatives from the case organizations have participated in reviewing the case drafts. In addition, interviewees have participated in the reporting sessions, which provided an additional loop of feedback on the constructs developed in the studies.

Internal validity relates to the credibility of the causal relationships claimed to exist within the case data. Internal validity has been pursued in this research with pattern matching across informants within cases and across subunits among cases. Efforts to control researcher bias has been made by having two researchers conduct the initial two case studies, involvement of a case company representative in Case C, and strong participation of the steering group in Case D. Thus, complementary insights and convergence of observations through iterative analyses (Eisenhardt 1989) have been used to reduce the risk of considering erroneous indications of relationships as factual causalities (Yin 1994).

External validity is intended to evaluate the extent the findings of the case studies can be applied to contexts outside the studied cases. Collecting data from multiple cases and selecting the cases by using replication logic rather than random sampling has been suggested to improve the external validity of case-based research (Yin 1994; Meredith 1998; Eisenhardt and Graebner 2007). The cases have been selected with purposive efforts to gather research material from organizations in different industries and with different types of service offers. Nevertheless, results of explorative case studies might well be considered preliminary propositions with imperfect generalizability because of the recent emergence of the proposed patterns observed only in a limited number of situations. Thus, the findings reported in this thesis warrant further elaboration in subsequent research efforts, as discussed in the last chapter of this thesis.

Reliability evaluation is concerned with whether another researcher provided with the same tools and same research material would make similar interpretations and conclusions. The use of a case study protocol and gathering the research material in a case database have been considered proper means to ensure the study's repeatability (Yin 1994; Stuart et al. 2002). The case study protocol, along with interview guidelines used in the cases, have been described above and discussed in more detail in Appendix A. All case material (i.e. interview recordings, interview transcripts, company documentation, case data reductions, and case reports with version control of iterations) has been stored in a case database for easy retrieval later.

5 INTRODUCTION TO THE CASE STUDIES

This chapter's first section gives short introductions to the studied case companies and each study's main case-specific findings. More details on each of the case studies can be found in Appendix A. The second section compares the case characteristics to the extent relevant for discussing the cross-case analyses in the following chapter.

5.1 Case studies

Case A

The case company A is a manufacturer providing cooling systems for commercial use. The goal of the research effort with the case company was to investigate and describe the development needs in product-related information exchange between the manufacturing organization and its accredited service partner network. The rationale and motivation of the case company was twofold: 1) improve its installed base information availability for new service development and product management and 2) improve the service effectiveness and efficiency of its service partners for higher customer satisfaction.

During the study, it was recognized that service efficiency and effectiveness were the key benefits to be expected from more systematic installed base information management. As the customers operated their equipment mainly in a run-to-failure mode, most service visits were unplanned. If the local service partner was not involved in the equipment's initial installation, the service partner might not have any knowledge about the failed piece of equipment before visiting the customer site. Moreover, because customers were often incapable of describing the product and problem accurately enough, the service partners had difficulties in estimating the spare parts needed for the visit. Information on the items in the installed base maintained by the case company was seen beneficial for the service partners to improve the identification of service targets and new equipment entering the installed base.

For the case company, understanding product performance (energy consumption, in particular) in customer applications and identification of "epidemics" of failing components were seen as the most important uses for installed base information. Improving the product reliability based on installed base information was identified as requiring more comprehensive access to the service events performed by the service partners and improved remote connectivity to the products.

The most important pieces of information were seen as the locations of each item, their service bills-of-material, and component changes performed during the service events. Additionally, more widespread access to remote monitoring data and use environments were seen to support the identified purposes for installed base information.

Whereas the installed base information needs were identified, obtaining the data after the warranty period proved challenging in the service business organization at the time of the study. Accredited but independent service partners were also supporting other manufacturers' equipment and found it too laborious and unprofitable to provide service records or updates on installed items for each equipment manufacturer separately. It was recognized that changes were required in the service delivery process to improve information gathering.

Case B

The case company B is an industrial process flow control component manufacturer. The research effort's goal with the case company was to investigate and describe the development needs in product-related information exchange among subunits of the product and service organizations, as well as identify current installed base-related data in diverse information systems of the case company. The motivation for the case company was to improve its installed base information availability to support the operations at the customer interfaces and the order-delivery process of engineer-to-order products.

The main reasons for gathering installed base information were linked to service efficiency and effectiveness. All maintenance contracts were started with a detailed product audit including for each process location the items, accessibility, and relevant installation interfaces. These records were used to suggest critical upgrades for the customer, to plan for correct field engineer training and spare-part inventories in the area, and to ensure appropriate tools and spare parts were available for each service job.

Whereas the installed base records were sufficient for each maintenance contract, on the global level, the spare-part management hoped it would have a better picture of the installed equipment of all important customers so that a share of spare parts could be stocked or prefabricated for the most critical demand. Similarly, on the global level, both sales and product management were interested in how well the different configurations suit particular customer needs to identify update opportunities and reliability and performance problems.

Because a notable part of the company's products were engineer-to-order products, the various possible product configurations were extensive. Thus, it was seen that all installed base items should be recorded by their serial numbers. Although product type codes would suffice for sales lead identification purposes, they would not disclose the exact product variant. Using only product type codes would reduce the information's utility for spare-part identification, reliability analyses, and replacement unit fabrication. There was also interest in the location characteristics concerning product interfaces, accessibility, corrosive agents, and operating temperature for the various analyses.

Case C

Case company C is a machinery and solutions manufacturer. The research effort's goal with the case company was to investigate and describe the development needs in installed base information management to improve global support for after-sales service operations and product performance analyses

For the case company, the major reason for maintaining installed base records at local service units was that the service operation effectiveness and efficiency depended on the information. Although the practices of assigning service jobs and customer sites varied among local service units, each unit made dispatching decisions for urgent repairs based on the location, accessibility, and the product type serviced. Further, the local service resources, such as field engineer operating areas and spare-part inventories, were managed based on the installed base with service contracts.

Unifying local information systems was seen important to manage these resources also on the global level. Other key uses for globally uniform data were seen in product development, replacement sales, service contract sales, and reliability analyses benefiting from the ability to analyze commonalities and differences across operating regions.

In the case study, it was seen important to record the installed base item data with globally unique product identifiers. This was necessary, as some components and subassemblies of the products could be updated and, thus, invalidate the original product type code. Hence, it was also necessary to record each product's main components. Service event records concerning the changed components were of most interest for analytical purposes. This data would be useful for planning spare-part inventories for third party equipment and for analyzing reliability issues among products and geographical regions.

Case D

Case company D is an electronics equipment manufacturer. The company had an on-going development project to improve uniform installed base information's global availability. The research effort's goal with the case company was to investigate and describe the development needs in installed base information management to improve global support for after-sales service operations and product and service performance analyses, as well as new service development.

In general, local service units had acceptable records of the installed base in their area. The service events were required to be started with reference to the target products. Repair and replacement services concerning the physical equipment used product serial numbers in their operations, and software-related services used version numbers with the service jobs. These records were necessary, especially for the technical support services, as they needed to solve customer problems often related to the combination of hardware and software, rather than either separately. Some customers also allowed remote access to help in problem analysis. Additionally, installed base information was used to prioritize customer service tasks. The target service response times could depend on the item's criticality even within a single service contract. Being able to tend to urgent requests faster helped in complying with service-level agreements of service contracts and, thus, service profitability.

The planning of support engineers and spare parts in each service unit also used the available information on installed equipment, as well as service event histories, to forecast service workload and spares consumption. The item-specific service levels were valuable also in positioning spare-parts inventories to enable investment in short delivery times only when needed.

With frequent new product introductions, identifying upgrade sales opportunities was an important use for the installed base information. Service sales used the installed base information to agree on specific service levels for the items and, hence, to balance the profitability and customer pricing of the service contracts. For some software products, the service contract pricing was based on numbers of installations.

The installed base information was also used for product reliability analyses, such as identifying problematic production batches and calculating mean-time-between-failure figures to support service resource planning. Service process performance was analyzed based on service event records by event type, products involved, and participating personnel. These were used to identify development needs to improve the service quality and profitability.

For each installed base location, the item data of interest was, for most purposes, on the product type level, although the hardware repairs and warranty processing also needed serial numbers to operate. Location characteristics of main interest related to operating temperature, humidity, and corrosive agents that might damage the products. Service events were already well-recorded, but more details on service reason, component changes, and reasons for change were desired for reliability analyses and warranty processing.

5.2 Comparison of case characteristics

Whereas all the four studied case organizations were providers of industrial investment products and services, the types of products and services varied among the companies. Concerning the cross-case analyses, the most relevant characteristics of the products, services, and organization of the case companies are summarized in Table 6 and discussed below.

The products of case companies A and C are best described as "stand-alone products" for the purposes of this research. This means they, by large, do not require other products to provide the value they are designed to deliver for the customer. In contrast, the products supplied by case companies B and D are "system components" in the sense that their utility to a customer depends on how they are integrated together and with other components of the customer's production system.

All the case companies had products with remote connectivity in their product offering, although this functionality was available only on newer product generations. And, the service organizations' coverage of remote access to the equipment was further restricted, as some service customers hesitated to allow a remote connection to be activated in all cases except Case C. Whereas all case companies had products using embedded software to control their operations, only case company D had software products as distinct sales items providing additional functionality for the customer.

The service contracts offered by the case companies varied. At one extreme was Case A's mainly transaction-oriented approach, where services were provided on request to maintain and repair the products, with only a few performance contracts with key customers. At the other extreme was Case D with its mainly performance-oriented contracts and a strong tendency towards facilitator-oriented customer relationships, where customers would be charged based on their capacity usage. Likewise, the extent of after-sales service business varied among the companies: case company A attained less than a tenth of total revenue from services; case company B, about a fourth of revenue; case company C, more than half of revenue; and case company D, a third of revenue. In addition, whereas case companies A and B targeted their service offer mainly on their own products, more than half of the serviced equipment of case company C was originally manufactured by other companies in their industry. Case company D also targeted their service offer mainly on their product business customers, but as a systems integrator, the service agreements more often than not included a notable share of third party products. The after-sales service markets for case company D also showed signs of a maintenance outsourcing trend among the customers, thus making it an interesting scenario to start scaling up the service offer to cover also other OEMs' equipment.

Table 6: Comparison of case characteristics

	Case A	Case B	Case C	Case D
Product	"industrial cooling devices"	"process machinery"	"machinery/solutions"	"electronics systems"
Product role at customer	Stand-alone product	Production system component	Stand-alone product	Production system
Product failure at customer	Revenue loss, goods & labor loss	Revenue loss, safety hazard	Revenue loss, safety hazard	Revenue loss
Remote data connectivity to equipment	Yes, depending on product and customer	Yes, depending on product and customer	Yes, depending on product	Yes, depending on product and customer
Software a notable part of product offering	No	No	No	Yes
Service contracts	Mainly work-package contracts	Work-package, some performance contracts	Mainly performance contracts, but also work-package contracts	Performance contracts, towards facilitator contracts
Service organization	Mainly a network of credited service partners	Own service operations, partly outsourced service engineers	Own service operations	Own service operations, partly outsourced service engineers
Competitor equipment in service	N/A (service partners do have)	Not extensively	Yes	Not extensively, but third party systems components
Spare-part sourcing	Locally, also third party spares used	Own spare-part channel	Own spare-part channel + third party-specific local arrangements	Own spare-part channel + local sourcing for maintained third party equipment
Service engineer skill categorization	Fully skilled	Specialization by customer + specialization by product	Differences between local units—formal or informal specialization by OEM, service task type, equipment age	Local field engineers multiskilled + problem type specialized global engineers
Installed base information availability	Based on sales and warranty data. Incomplete data because of sales through middlemen	Customer locations and applications well known during sales process. Varying service histories in service units.	Customer locations and applications well known because of installations. Varying service histories in service units.	Incomplete initial installation data because of sales with and without installation. Varying service histories in service units. Customer support jobs centrally tracked. Possibility for online installed base identification.

In the companies' installed base information management initiatives, the issue of third party products in service resulted in a distinction between the installed base of company's own products and the service base of all products covered with service contracts. Simultaneously, the case companies' products are also serviced by other organizations, resulting in the categories illustrated in Figure 6. Despite identifying this conceptual difference, for the lack of a better word, the term "installed base information" is used to denote all information concerning items of either class. The reason for uniform handling of the information is that, for the purposes of both service operations and other decision support, it was considered useful to have similar access to information concerning own products whether in own or third party service and third party products in own service. Further, the categorization of an item is not necessarily permanent, as occasionally items outside service contracts might be serviced (e.g. repairs), and items might be installed as replacements or upgrades in third party equipment.

Concerning providing the field service to their customers, the case companies had some notable differences in the service organization. Case company C had made a decision to use only own field engineers to perform the service operations to retain maximum control of operations efficiency and customer service levels. Case companies B and D also used, in addition to their own field engineers, outsourced local engineer resources, whereas case company A had only a set of highly skilled problem solvers within their own service organization and relied mainly on a network of accredited service partners.

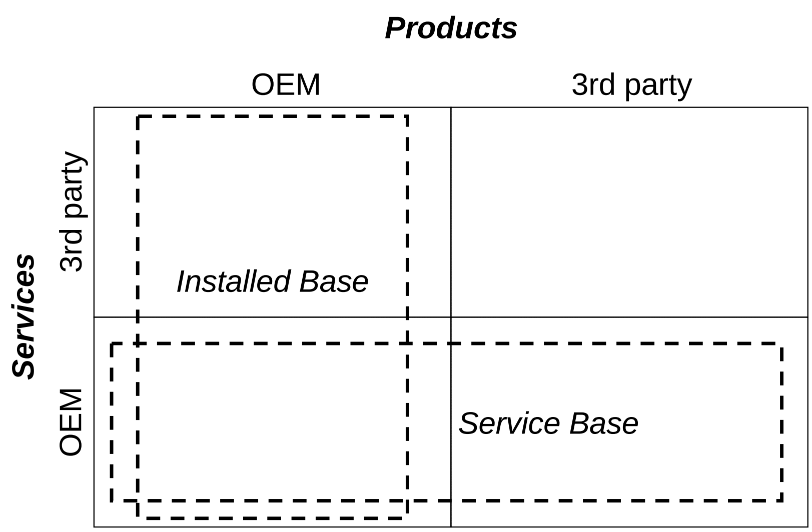

Figure 6: Installed Base vs. Service Base

All case companies had a centralized structure for providing the service units with spare parts, but local practices differed, and especially, spare parts for third party equipment were sourced locally. The field engineers skill categorizations varied greatly in the cases. In Case A, the field engineers in the partner network were fully skilled so that, generally, any field engineer could handle all service tasks. In Case B, there were customer-specific field engineers familiar with all the equipment in service for their customers, but also some globally used product-specific experts dispatched to solve demanding customer problems. Case company C had several practices in the local service units—some arranged the field engineers by their abilities with distinct service operations and some by their abilities with specific equipment types. In Case D, the service personnel were categorized by service task and equipment type.

Finally, the status of installed base information available at the time of study within the case companies varied both among and within the companies. Case A provides two kinds of products: fixed installations and freestanding products. On the former kind, the case company had comprehensive records based on the installation projects, but the latter kind was also taken into use through middlemen and, hence, the end user was not always known. In addition, because of the structure of their after-sales service network of preferred partners, for both product types, the service history information was restricted to warranty claims.

Case B had the possibility to maintain good records on the end-user applications and location characteristics, as most products were ordered, either as engineered products or through a product configurator, where details of the application were input. At the time of the study, this opportunity was not systematically used outside the engineering department. A complication for the use of sales records to create initial installed base data was that some of the case company's direct customers were systems integrators. Hence, the end-user location was not known for all sold items, and several systems integrators could deliver to the same end-user location. Therefore, installed base audits were performed with each new service contract to update item status. Service histories were recorded for all customer sites in the service units, although system incompatibilities reduced the usefulness of the records outside service operations.

Case C had good installation records on all their products, as they always sold their products with installation service. Regarding the service history records, there were globally great differences between local service units. Whereas each unit had decent records for their own operations, the systems and data structures used were incompatible. This made a centralized analysis of equipment data cumbersome. At the time of the study, the company had a harmonization project going on to produce standard definitions for the key installed base data items and to make those data centrally available.

In Case D, products were sold both with and without installation services, and thus, the final destinations and applications of the items were not always known. As to the field service records, local differences in data structures disabled easy data consolidation. Moreover, some customers also had internal service engineers that they used for part of the service jobs, thus making comprehensive recording of all changes taking place in the installed base impossible for the case company. However, for technical and software support, they had a centralized system, where all customer cases were tracked. As a distinctive technical characteristic, their newer product components were capable of reporting themselves to a central database at the customer, and with the leave of the customer, this on-line installed base data was also available to the case company.

6 CROSS-CASE SUBUNIT ANALYSES

This chapter presents the cross-case subunit analyses by detailing the commonalities among and differences between the studied cases regarding installed base information uses and the installed base information types requested. The first section discusses in detail the installed base information needs for service operations and resource management; and the second section, the information needs in the other studied subunits. The last section describes the types of installed base information identified for an idealized installed base information system.

6.1 Field service operations and resource management

The first part of this section gives detailed descriptions on the use mechanisms for the installed base information and the information types needed in different after-sales service operations. The local service units of the case companies perform these services. The information uses are related to daily operations, and although different service tasks have commonalities in the information needs, the relative importance of information types and their effect on operations vary.

The latter two parts discuss management of the service resources: skilled field engineers and spare parts and materials that must be at hand to take care of the various confronted service tasks. Resource management defines the production capacity of the service units. Analogous to the production capacity in the manufacturing context, the service capacity requires up-front investments in the pool of resources in such a way that services agreed with or anticipated by the customers can be delivered cost-efficiently within expected lead-times. The specific qualities of capabilities needed in an area are largely defined by the installed base in service in that area. Only parts and materials that can be consumed in the area are rational candidates for stocking in the area, and only skills that are relevant for the items in the area are considered when evaluating training or recruiting needs for field engineers.

As evident in the studied cases, another important factor in planning the service capability is the pool of service contracts and included service level agreements. Skills and materials related to services agreed with local customers require specific attention in planning. More importantly, the service level agreements influence the quantities of resources required in an area. Assuming a fixed failure rate of items in a service area, the shorter the response times, the higher the uptime, or the higher the percentage of first-visit resolution promised to the customer, the greater are the investments in field engineers and spare-part inventory needed to deliver the services within the service level agreement.

6.1.1 Operations in service units

As an addition to the literature on scheduling and dispatching of field engineers (section 3.1.3), it can be claimed that the division of field service job types to only preventive maintenance and emergency jobs is somewhat of a simplification, as in practice, the same engineer resources are used also for planned repairs, change deliveries, upgrades, and occasionally for technical support (Cases B, C, and D). Whereas the simplification might be adequate for distinct scheduling purposes, from an information requirements viewpoint, the variety of jobs is greater than that.

Compared to prior literature, another notable feature in how the service tasks are assigned in the case organizations is the finer granularity of skill requirements. Whereas most contributions assume only a few types of skills to be matched, in practice, there can be a delicate consideration on probable task contents, target equipment, and site access restrictions to assess the most capable engineer for the task.

In the literature review, the following installed base information seemed of main interest for scheduling and dispatching in the local service units (see section 3.1.3): equipment location, equipment criticality, customer importance, equipment characteristics, and service history. Based on the case studies, this list can be both extended and classified in more detail by service task type (Table 7). In particular, it is emphasized that having equipment bills-of-materials for spare-part identification is critical in ensuring high levels of first-visit-resolution of field service tasks. Another information type concerns environmental characteristics of the equipment location, as they can be critical in customer problem analysis.

The following sections discuss the role of installed base information needs in preparing for after-sales service tasks. The tasks covered are planned maintenance operations, planned repair and change operations, unplanned repair operations, upgrade and extension operations, technical support, and remote maintenance operations.

In general, the cases were in notable agreement on the key information necessary for each service task type. The following generalized descriptions are thus applicable to all cases, with explicit discussion of issues prominent in case-specific contexts.

Table 7: Summary of installed base information needs by service task type

	Main role of installed base information	Other information required	Effect on service efficiency	Effect on service quality	Cases where observed
Planned maintenance operations	Item types and locations to optimize engineer routing	Maintenance plans for items, engineer skills by item type	[primary] Optimization of engineer use rate	Ensuring correct operations and item status analysis	A, B, C, D
Planned repair and change operations	Item bill-of-materials for material orders, item type to select engineer	Engineer skills by item and task type, prior service events for the item	Maximization of first-visit-resolution to minimize number of visits	Maximization of first-visit-resolution for customer satisfaction	B, C, D
Unplanned repair operations	Item status information and prior events to estimate tasks, Item BOM for spare-part assessment, item type and location for engineer selection	Service level agreement for the target item, engineer skills by item and task type, engineer locations	Minimizing number of visits, minimizing disruptions to other tasks.	[primary] Ensuring first-visit-resolution for immediate problems within promised lead-time	A, B, C, D
Upgrade and extension service operations	Item identities, location environment details	Original sales or delivery project documents	[primary] Reducing costs in preparative site inspections	Ensuring correct deliveries	B, C, D
Technical support operations	Item identities and locations, location environment details, prior service events	Product documents and manuals	Minimizing time for correct resolution	[primary] Minimizing time for correct resolution	A, B, C, D
Remote maintenance operations	Item location environment details, item bill-of-materials, prior service events		Minimizing remote measurement interpretation failures: minimizing unnecessary site visits	Minimizing remote measurement interpretation failures: minimizing unnoticed problem symptoms	A, B, C, D

Planned maintenance operations

Description

Planned maintenance tasks are service tasks scheduled in advance with the customer, either implicitly (e.g. maintenance performed twice a year, Case C) or explicitly (e.g. maintenance scheduled according to periodic service breaks in customer's operations, Case B). Typical actions in planned maintenance tasks in the studied cases include equipment cleaning, refilling of liquids, changes of wearing parts, and visual inspection. The main challenge is to maximize the efficiency of engineer resource use by maximizing the number of visits an engineer can cover during a shift.

Role of Installed Base Information

Planned maintenance services are straightforward to deliver, as the target of the service delivery and actions performed are known well in advance per customer contract. Hence, the materials required on a service visit can be reliably identified and secured for the service delivery. Information needed for material allocation consists of the maintenance plan (either as planned for the item type or as agreed explicitly with customer).

Typically, the routine activities performed during planned maintenance visits do not require item-specific skills to deliver high quality maintenance, and thus, the problem in engineer selection is mainly that of minimizing the cost of the resource use—a routing problem characterized by the locations of the items and number of available engineers to designate for specific areas. Information needed for engineer allocation consists of the maintenance plans and item locations. The maintenance plans, however, can be adjusted according to item usage:

> *[Q9] [maintenance plans] are more influenced by the use environment [than just product type], whether the product in heavy use or in a quieter [application]. It has a greater impact on the frequency of maintenance visits and repairs. (Service Development Manager 2, Case C)*

Effect on service delivery cost and quality

Allocating resources for planned maintenance focuses on minimizing delivery cost. Optimizing the routes of the service engineers based on item locations can have a considerable impact on the effective working time of the engineers. Poor routes waste engineers' time between customer visits. Ensuring delivery quality is less problematic, as the service operations consist of routine actions that can be well prepared for.

Case specifics

In Case C, some local service units had dedicated personnel to perform the routine planned maintenance operations, whereas other field engineer resources were used for more demanding planned and unplanned operations. This was seen to ease the scheduling work, as the planned maintenance personnel would not need high product-specific skills and, dedicated to only planned tasks, their scheduling would not need to account for unplanned events.

Planned repair and change delivery operations

Description

Planned repair operations are repair tasks that have been identified by the customer, during previous inspections or through remote monitoring, but that did not require immediate action. They can thus be scheduled, taking into account the constraints of customer convenience (e.g. maintenance shutdown), engineer resource availability, spare-part lead-time, and estimate of time to subsequent failure.

Change deliveries are planned repair tasks performed to prevent identified quality problems from impacting customer operations. The main difference with other planned repair operations is origin of the task. From the viewpoint of the organization, it is necessary to identify centrally all products still in operation affected by the quality problem.

The original equipment manufacturer might have an advantage over other service providers in spare-part identification and in spares availability and procurement costs, as they manage, or at least they have managed, the sourcing channel for the original parts used in production. Similarly, they might have a quality advantage because of the best access to product training for the field engineers and original product documentation, as well as the best access to the original product designers and engineers most skilled with demanding problem situations.

Role of installed base information

With planned repair and change deliveries, the target of the service operations and the actions performed are known in advance with satisfactory accuracy. The materials needed during the visit can be ordered in advance, perhaps preparing with potentially needed additional spare parts as well. Installed base information needed is the bill-of-materials of the item to identify relevant spare parts for the planned task. In addition, analysis of similar prior service events to the item type can provide information on potentially needed additional spare parts.

> *[Q10] The more experienced guys check first the equipment service history to see what the equipment has eaten; there you can start reasoning [what spare parts might be needed]. (Field Operations Development Manager, Case C)*

The field engineer selection for planned repairs and change deliveries is based on the target item and the planned task contents. Depending on the skills of the engineers in a service unit, the emphasis varies between these two factors: whether there is more engineer specialization for specific item types or for specific repair tasks. As the deliveries are planned, the availability of the most suitable engineer can be ensured with engineer schedules. Installed base information for the engineer selection consists of target item classification by engineer skills. Analysis of similar prior service events with the item type might provide information on potential problems encountered during the service delivery and affect the selection of the engineer.

Effect on service delivery cost and quality

Installed base information on item types and bills-of-materials were seen to support the scheduling of planned repair operations. The emphasis with planned repair operations is on delivery quality, although it strongly affects the delivery cost: poor delivery quality (unsuccessful service visit or inadequate repair resulting in subsequent failures) means further visits to the customer site and results in increasing delivery costs. Moreover, even worse, if the result from poor service quality is additional downtime for the customer equipment, the costs for the customer can far exceed the costs of any engineer resource. The result is reduced customer satisfaction and penalties for the product-service provider with customer contracts including availability as a performance measure.

> *[Q11] The service providers should prepare properly […] [At times we need to use] other service providers that only smell the money and send some fiddlers over. Sometimes the bunch enters the door like they own the place, and after a short conversation you know that this will result in nothing good. And once the job is done, out of the door they are. […] not so long ago, one of those teams had installed a bearing wrong. Luckily we noticed this before the start-up. (Customer, Case B)*

Unplanned repair operations

Description

Unplanned repair tasks are such tasks that result from a breakdown or malfunctioning of equipment or from identification of an impending failure and that require fast response to minimize the harmful impact on the customer's process. They are scheduled for the earliest possible point in time, and scheduling restrictions arise from skilled field engineer and spare-part availabilities. The unplanned repairs are the most complex of service tasks to allocate for the field engineers, as the constraints for the decision are the most demanding. Rightly, these tasks have received the most attention in the literature addressing field engineer dispatching problems (see 3.1.3).

As with planned repairs, the original equipment manufacturer might have advantages with spare-part availability and cost, as well as with quality because of in-house product expertise.

Role of installed base information

Because unplanned repairs are often performed with strong time-pressure to minimize customer operations downtime, it is essential to provide a first-visit-resolution with short response time. The job details required to resolve the problem are approximated with item and problem description, prior problems with the particular failed item or known problems in general for the item type, and possibly remote monitoring of the failed item. In some cases, installed base information can support the correct identification of the item in question, as person-to-person communication of a problem might not always provide enough detail for unambiguous identification:

> *[Q12] Mostly customers have a hard time describing the equipment and problem accurately. The result is often two visits: one to identify problem and the other to repair it with correct tools and materials. (Service Manager, Case A)*
>
> *[Q13] Some customers can tell meaningful details of their problem. Some only tell that the device does not work. Also the customer's capability to describe the equipment varies greatly. If we get a service call redirected through [case company A], then we get good information on the equipment type and everything. They have these recorded in their installation folders. (Service Partner 1, Case A)*
>
> *[Q14] If we get the service call from the customer, they describe the problem as 'does not work'. Also the equipment type is left for us to guess. […] If the service call is redirected through [case company A] we get somewhat better information. They have at least analyzed the equipment type concerned. […] If you know what kind of equipment there is before leaving to the site, you can ask advice for problem identification from other experienced fellows. It shortens the visit duration. (Service Partner 2, Case A)*
>
> *[Q15] With service contracts with service levels of, say, two hour response times […] you need to identify as quickly as possible the equipment concerned, based on the address and whatever information the caller can provide. (Service Development Manager 1, Case C)*

Based on the item and problem assumption, likely needed spare parts are identified and located. Necessary installed base information is the service bill-of-materials for the item to identify compatible spare parts for the service tasks.

> *[Q16] If the service call comes [from a very remote customer site], the guys come first to the office to ensure that every potentially needed component for the visit is in the van. You'd need to have a truck to have all components with you all the time. […] The equipment type would be important to know in advance. I don't know how well [the case company A] can identify what parts they have used in each production batch, but that kind of information would be very relevant for us to know. (Service Partner 3, Case A)*

> *[Q17] If the field engineers serve a rather small amount of [products] and visit them regularly, they'll know [what spare parts are potentially needed]. On the other hand, if they have large amount [of products] that they visit perhaps just once or twice a year, then they will have problems on remembering which [product] there is at the customer site. In these situations [installed base] information could prove useful. (Service Development Manager 2, Case C)*

The engineer selection emphasizes closest available engineer with enough skills to handle the assumed actions needed to fulfill the service tasks. Necessary installed base information is the location of the item, item type to evaluate needed item-specific skills, and prior events and current operational status, if available, to assess the problem and likely task-specific skills needed.

> *[Q18] [In all local units,] we should be able to [use information] on our field engineers capabilities, as some are better skilled with one manufacturer's products or some product type than others […] Then knowing what equipment we have [we could] match these. We could use this to determine how to arrange service areas and to define how service jobs are allocated. (Service Development Manager 1, Case C)*

There might also be customer site-related access criteria that affect the field engineer selection:

> *[Q19] There are industrial plants, where the access is a bit more difficult, one may need protective clothing, […] or have attended specific training to get access [to the plant], […] or have a certification to be eligible for [specific applications]. (Service Development Manager 2, Case C)*

The service level agreed for the target location in the service contract is needed in prioritizing an incoming unplanned service task. If all capable engineers are currently reserved, the criticality of the newly reported failure must be compared with other on-going service tasks to make relocation decisions, if necessary. The same applies to spare parts. It might be justified to reallocate already reserved spare parts for an urgent unplanned task if it is deemed more valuable than the original reservation. Alternatively, when resources are tight, it might be necessary to prioritize the call based on the product type:

> *[Q20] One [use for installed base data] is just to understand, what [product versions] the [customers] are on, and are there [customers] that are really behind, […] So if we could see customers that are seriously behind in [product versions], […] then that would be one thing, sort of flag that, so that we need to do something because that customer is no longer supported, and we should stop service, I mean should stop answering calls because we are not on a supported [product] anymore. (Service Product Manager 2, Case D)*

Effect on service delivery cost and quality

Because faulty equipment typically incurs heavy consequential costs for the customer, speed is of the essence with unplanned repair tasks. Concerning service output quality, in most cases, there is a primary concern of restoring the faulty equipment back to a working state or at least minimizing the problems or hazards it is causing in the faulty state. A secondary concern is to take care of the root cause of the problem, which might be performed with a subsequent, planned repair operation. Service delivery cost is often the least critical component with unplanned service operations.

Installed base information on item types, bill-of-material, and locations is most critically needed to provide quick reference for decision making with these urgent service operations. More accuracy to task-specific skill and spare-part requirements assessment can be obtained by analyzing item status information and prior service events.

Case specifics

In Cases B and D, where the maintained items are components in a larger system, location-specific information (system interfaces, behavior of other items in the system) were deemed as especially useful in determining the problem type and likely solution requirements.

In Case C, if there is a safety hazard with the malfunctioning product, the first visit is allocated to the closest available field engineer, independent of whether he is particularly skilled with the product or problem. The immediate hazard is solved quickly, and if the engineer cannot solve the problem, the repair might then be scheduled for a suitable engineer at a later time.

Upgrade and extension service operations

Description

Upgrade and extension operations are service tasks that originate from item sales, and where items are replaced with newer versions that provide more capacity, added functionality or improved efficiency for the customer. Extension operations are new installation tasks differing from initial installations in that they extend the already existing installed base at the customer, and therefore, might require some understanding of the extended installed base.

The deliveries are scheduled as planned repair operations, but they might require prior inspections at the customer locations to audit the current equipment and their status for further planning of the delivery.

The original equipment manufacturer has the advantage of original delivery and manufacturing documents to support both the inspection activities as well as the design of the upgrade solution. This requires that the original documentation be connected with the customer equipment.

Role of installed base information

Depending on how thorough a change or upgrade is, the requirements for understanding the target equipment vary. For minor changes, the delivery could be performed based on equipment information available from sales records and prior service visits:

> *[Q21] As installed –data such as product configuration, test records, and layout at customer site is for us especially relevant when making upgrade or extension deliveries. (Delivery Project Manager, Case A)*

> *[Q22] The upgrade deliveries would be significantly easier, if we knew what to expect at the customer site. For example, do we need to update other components such as the power supply as well. (Product Delivery Project Manager 2, Case D)*

In cases of extensive upgrades and extensions, the delivery planning requires preparatory visits to the customer site(s) to assess the locations occupied by the new items.

> *[Q23] When auditing the installed base at a customer, we record the equipment serial numbers, [process location identifiers], physical location within a plant. We perform a visual analysis of each device, based on specified criteria, and record the observations and comments. […] We also record the alignment of the device, electrification, and related pipework so that we can manufacture a suitable replacement unit and prepare with correct fittings. […] Further we also record the accessibility to the [process location], tools needed to access, and*

> *estimated access duration to plan for the installation work. (Service Manager, Case B)*

These visits are most often performed after the customer has made the decision for new installations, both because of the cost associated with the visits and as customer systems of high complexity might have item interdependencies hard to analyze before a detailed upgrade/extension configuration is known.

Installed base information was seen to ease the inspection, as having initial data on the items reduces the visit workload by enabling confirmation of valid data. In particular, if the identity of an installed item is unchanged, information available in prior documents (e.g. design specifications) can be used with no further examination. With modifications of competitor equipment, a more comprehensive analysis is needed.

Effect on service delivery cost and quality

Inadequate information on the product or system to be modified or extended can result in delivery delays because of incompatible items. Gathering the required information from scratch, however, was considered costly, and it was seen that by having basic data on equipment on the customer location, these costs of delivery preparation are reduced.

Case specifics

In Cases B and C, the customers were offered specific auditing services, where the current performance and improvement potential with upgrades were evaluated. Whereas these auditing services were designed to provide the necessary information for potential subsequent upgrade, extension, or service offers, also the auditing services would benefit from existing installed base records that could be updated during the visit.

In some local service units of Case D, they could remotely access the systems at customer locations to identify changes in the installed base. Such updated data could then be also used for partly automated upgrade analyses:

> *[Q24] Our modules that we call intelligent, have a chip on board that holds the part number and serial number. We can remotely log in to all our [customer sites] and extract this data. If the customer changes a module, we get an update on a monthly basis and we update that data in [the installed base] database, so we can administer the modules on the sites. […] This is why it's also important to have the accurate installed base data, because [the installed base system] will then tell us what needs to be done to upgrade from version A to version B, and where something needs to be done, and this falls in to the [upgrade] services. (Service Customer Account Manager 3, Case D)*

Technical support operations

Description

Technical support refers to services that help the customer to use, maintain, repair, or solve problems related to items in her operations. Technical support is typically provided remotely. Scheduling the support tasks depends on the concerns of the customer and can vary from critical requests requiring immediate attention to additional information requests with no clear expectations for delivery time. At these extremes, they are allocated like unplanned repairs, or like planned repairs, except the engineer location is not critical. Although there is literature on call-center staffing and routing with consumer services, the situation with business-to-business technical services has been scarcely studied (Chevalier and Van den Schriek 2008). The particular feature making business-to-business technical support different from consumer call centers is that the technical support and field operations can share resources, i.e. a competent field engineer might be the most knowledgeable person for some particular problems.

Role of installed base information

Being able to identify the items the customer is requesting support for quickly and correctly is fundamental to effective technical support. In some situations, the item the customer refers to is evident or can be perfectly described by the customer. However, in cases of identification problems, having records of items at the customer might be a valuable shortcut to speed up the delivery of correct support or the redirecting to a support engineer with correct expertise. Analysis of prior service events might also provide information on experienced engineers who can be consulted to solve customer queries.

> *[Q25] In practice, we have a single call-in number and from there the caller gets manually directed to a guy who knows [about the concerned issues] better […] we have lists of people, where you can identify who to direct to with what kinds of issues. (Field Operations Development Manager, Case C)*

If the customer question relates to context-specific properties or behavior of equipment, then information on service events, operating environment, or other items in the customer system can provide valuable clues for the technical support about how to guide the customer to proceed. In particular, this additional information can exclude many potential resolution paths and, thus, speed up the delivery of correct support.

> *[Q26] We have some repair jobs that actually improve the product features, but you cannot determine whether or not this job has been performed on a product based on the bar code on its side, only some external differences give clues if you know what to look for […] of course, we have a repair database, where we can identify based on the serial number what products have been serviced […] but if there's a case*

that the repair is not recorded in the database, then it's pretty difficult to find out. (Product Manager 1, Case D)

[Q27] Of course it [installed base data] is helpful for the engineers. When a customer raises the case, they can use it, if we have this kind of information in some systems, then the engineer does not need to ask customers, we can always check the installation dates for software, it's easier for the engineer to locate the root cause of the problem. (Service Customer Account Manager 1, Case D)

[Q28] And if you think about the installed base system, then of course it's relevant information what's the customer's software version and what patches have been updated. Of course it's very relevant. And in practice, one function needing this information is our software support. If there's a support request, it's essential to find out the software status at the customer, so that we can start dealing with the issue and supporting the customer. It's very fundamental to know the software status. (Software Product Manager 1, Case D)

Effect on service delivery cost and quality

The delivery speed (and thus efficiency) and quality of advice depend on how well the support engineer can identify the customer situation and knowledgeable other engineers in problems exceeding his experience. Depending on the support case, installed base information can vary between being a crucial component in the customer support case and being completely redundant for the case. However, in all cases studied, being quickly able to understand the customer situation was valued as a sign of professional support and, thus, a part of a positive customer experience.

[Q29] We have been very pushing the last two years for our customer teams to make sure that [service] data is up-to-date, especially the installed base data. Because without that, we are wasting time answering wrong questions for the customer. (Product Manager 1, Case D)

Case specifics

With queries related to items that are parts of a production system (Cases B and D), the correct identification of the individual item is important, as the capabilities and troubleshooting of an item also depend on the encompassing system (software configuration issues, item interfaces, other items in the system).

[Q30] The problems are seldom purely [our] hardware and software problems, there are often parameterization issues, for example compatibility issues with […] other commercial software that may have

> *a different upgrade cycle at the customer. (Technical Support Development Manager, Case D)*

Especially with queries related to competitor/third party items (Cases C and D), it might be necessary to identify capable support engineers among the field engineers familiar with such equipment.

Remote maintenance operations

Description

Remote maintenance operations are service operations performed to ensure the correct operation of the equipment, but do not require a visit to the customer site, as they are performed over remote connectivity to the equipment. The basic remote maintenance operation is remote monitoring as a support service used to give information on predefined measures on installed items. Typically, this information includes operational characteristics describing the condition and usage of the item. An example description from Case B:

> *[Q31] We perform remote monitoring services with [larger customers]. The services include a monthly health check, assessment of repair needs, and maintenance planning. […] The diagnostics are based on comparing monitored readings with test records from manufacturing. (Service Manager, Case B)*

The original equipment manufacturer has the advantage of the best product expertise to interpret remote monitoring data, but the more remotely the services are provided (i.e. the less familiar the engineer is with the customer application), the better installed base records on the context and service history might be needed to support the remote maintenance operations.

Role of installed base information

With remote maintenance operations, the equipment identity is always known, as the remote connection explicitly defines the equipment connected to. However, to interpret measurement data with remote monitoring correctly, it might be necessary to have additional information concerning the item under surveillance. Operating environment characteristics of the location, configuration of the item, or past service events can change the meaning of measurements from acceptable to alarming.

Effect on service delivery cost and quality

Having relevant contextual information available for more accurate interpretation of remote monitoring data of an item reduces the number of both unnecessary field personnel site visits as well as unnoticed indicators of pending equipment failure.

> *[Q32] With the [remote control system] you can work remotely on the equipment. Changing [some control parameters] and reading the diagnostics can give an idea of the problem. In best situations, the customer can solve the problem and it reduces our visits to the customer site. (Service Partner 1, Case A)*

> *[Q33] Every now and then they [the field engineers] check the remote diagnostics of the customers. Basically a continuous monitoring is started only after a customer contacts us. […] After the initial installation, and during the warranty period, they check that the equipment seems to operate as it should. With the remote monitoring you can see the problems before the customer. Many times we have gone to the customer and told of potential impending problems. This happens quite a lot. Especially during the warranty period. (Service Partner 3, Case A)*

> *[Q34] The customers, they see the advantages from an [operating cost] point-of-view, they haven't got to have technicians to take care of these activities, or if their availability is higher because [we are] logging in [remotely] once a week to make some maintenance tasks, then it's saving them money, and it's providing better service to their end-customers. (Service Director 1, Case D)*

Hence, installed base information can be used to reduce costs and to improve service quality. This is especially relevant for updates of software in equipment, as the immaterial nature of the updates does not necessarily require a service visit in person.

Case specifics

More proactive examples of remote maintenance are remote melting of ice forming in the cooling elements of their products (A) and remote updates of software used in products (D). The scheduling of such remote operations varies, depending on whether there is an urgent problem at the customer or it is about a planned maintenance operation.

> *[Q35] Quite a many of the customer problems can be resolved with an additional melting operation performed remotely. (Electrical Engineer, Case A)*

> *[Q36] With the [remote control system] we can check the likely problem at the customer site. With remote melting operations we may be able to postpone a prospective night job to the next working day. Even though we may not be able to solve the problem, at least we can do something for the customer. (Service Partner 3, Case A)*

6.1.2 Field engineer resource management

Description

As can be expected, based on the literature review in subchapter 3.1.4, field engineer resource planning was considered a multidimensional problem in the studied cases. The demand for engineer resources was seen to depend on the installed base and the service contracts. The types of skill needs depend on the types of items in the installed base and the particular services offered to each customer. The number of skilled engineers needed depends on the number of items in the installed base with service contracts. In addition, the locations of the engineer resources depend on the geographical distribution of the demand for the specific skills, as well as the service levels (e.g. response times) agreed with the customers.

In planning the supply of engineer resources, the case organizations identified that the efficiency and effectiveness of an engineer to perform a specific task depend both on his general experience with the equipment type concerned and on his experience with the specific contents of the task performed. Thus, whereas there are discussions in the literature that the equipment types in the field impact the numbers of different engineer skills needed (e.g. Agnihothri and Mishra 2004), and that the resource demand is forecast by evaluating service task types (preventive maintenance and emergency repairs) separately (e.g. Watson et al. 1998), the studied cases indicate that resource planning might need to consider engineer skills by equipment type and task type simultaneously or select the most appropriate dimension to use for planning.

Role of installed base information

An accurate account of item types and geographical locations is important to forecast the service demand. The distances between service sites affect the number of service visits a single engineer is able to perform during a work shift (Smith 1979).

> *[Q37] Basically you can identify three phases in the capacity planning: first, product related [analyses], how often to visit, how long visits […] that basically determines the work load for the field engineers. This influences [the second analysis], number and location of service resources. […] And third, the day-to-day operations, as unplanned repairs need to be fitted to the plan. (Service Development Manager 2, Case C)*

To reduce the complexity in demand forecasting and securing relevant engineer skills, several alternatives were used in the studied cases:

- Dedicated engineers for specific pieces of equipment or customer sites (Cases B, C)

> *[Q38] The skills of the field engineers depend on the installed base in the area. We train our engineers accordingly. (Service Manager, Case B)*

> *[Q39] The service manager, in addition to defining maintenance programs for the equipment and other tasks, he needs to decide how to organize the services with the men [he has]. [In most cases] the arrangement is that each man gets a number of equipment as his responsibility. (Service Development Manager 1, Case C)*

> *[Q40] Of course, the skills of the guys need to be managed, but it is done [in our service unit] so that we check what capabilities a guy needs and send him to attend a course. (Field Operations Development Manager, Case C)*

- Dedicated engineers for equipment types (Cases B, C, D) to maximize utility of experience with similar pieces of equipment, for example:

> *[Q41] You need to be somewhat of a specialist to correctly associate the problem with our device or the customer's [control system]. An expert can tell the difference immediately, others may never find out. (Sales Director, Case B)*

> *[Q42] In this area, there are [products] based on certain technologies […] There they have done so that engineers are specialist within [the product type], they only maintain [the product type] and solve their problems. They are only assigned [products of this type], as they exist there with such density that this is feasible. (Service Development Manager 1, Case C)*

> *[Q43] [generally the field engineer selection is done based on] product manufacturer, product type for own products, product age, electrification system. If we go to a more detailed level, we have special experts for single components, but that becomes quite challenging [to be managed with information systems rather than reliance on service manager experience]. (Service Development Manager 2, Case C)*

> *[Q44] We are training experts to the regions during market introduction efforts. […] Important to know, how many customer projects we had for a new product. And how many old versions are out there […] to assess support effort needs, to decide on the workload estimates for different capabilities. (Service Resource Manager, Case D)*

- Dedicated engineers for task types (Cases C, D) to maximize utility of experience with tasks to be performed. This kind of dedication was used both to maximize efficiency (routine maintenance tasks performed by less experienced staff, i.e. with lower cost resources) and to maximize effectiveness (highly demanding and time-critical operations performed by most experienced engineers):

> *[Q45] [in another area] there's a skill group 1 that takes care of […] very basic maintenance, […] then there is the skill group 2 that performs preventive maintenance and technical service modules and maybe some problem solving […] then [in the area] there are also many very old [products] that have difficult problems and require special expertise […] the skill group 3 then drives around these and takes care of the most problematic ones. This is how the jobs are also allocated. (Service Development Manager 1, Case C)*

> *[Q46] We call it spare-part installation, more or less a board swapping work. I don't want to have the complete first line maintenance, I only want to have this board swapping, nothing more. It is a different function, we don't need high knowledge, we only need to know where electricity is and how to ramp-down and reboot the system, if it's needed, depending on module changed. (Service Product Manager 3, Case D)*

Within a case organization, a mixture of these approaches often co-existed. Depending on the installed base serviced by a local service unit, the service unit might favor field engineer dedication by equipment types (if installed base includes enough similar equipment within a small geographical area) or field engineer dedication by task type (if installed base includes a great variety of equipment within a small geographical area).

To forecast demand, historical service records were seen useful as analyzable by equipment type and by task type. This not only enables the demand forecasts by contextually relevant dimension, but also the critical evaluation of which planning dimension would be most appropriate for a given region. In essence, whether a better density is achieved by equipment type or by service task type:

> *[Q47] [With the number of different allocation models used in local units], we have not enough data to verify whether one model is better than the other. We would be highly interested to analyze, is this [specialization, by product or task type] more efficient than the use of plain service areas. (Service Development Manager 1, Case C)*

Another skill-based analysis of interest was whether there is a case for centrally controlling some specific skills to cover more demand by highly skilled engineers (Cases B and D). Whereas most tasks are assigned by some rule, a subset of demanding tasks had to be assigned to a dedicated pool of skilled manufacturing engineers:

> *[Q48] Less than 10% of installed equipment serviced directly by us. But at times we send engineers in difficult cases to customer sites. (Service Manager, Case A)*

> *[Q49] Our [centralized expert] people are available for the service organizations, but they [the service organizations] are generally capable of handling all kinds of cases, as long as the problem doesn't involve the [control systems]. (Sales Director, Case B)*

> *[Q50] Within this model, actually within all models […] there are additionally experts that come into your area to help with special problems. (Service Development Manager 1, Case C)*

> *[Q51] We have built up a competence resource pool. The main focus of this resource pool is knowledge transfer to the support structure worldwide, […] to enable global experts to export inside this support structure. (Service Resource Manager, Case D)*

Further, the service unit specific demand forecasts are periodically reviewed on a regional level to identify potential balancing needs among the service units. The capacity and demand of service units is balanced by shifting customer site responsibilities among service units or by acquiring skilled personnel through training, recruiting, or transfers among units.

> *[Q52] There are different practices […] It can be for example so that in a region all [local] service managers are called in to a meeting, and plans are made to organize the service areas for the following year, what is the situation with local service capacities, are there any training needs, and […] the service area boundaries, they are not carved in stone either. […] This is done by the regional service manager and the local service managers. The local service manager makes the local planning, and currently he needs to raise a hand, if he thinks he needs [more field engineers]. (Service Development Manager, Case C)*

> *[Q53] On the management side, [one of the benefits] is how to reduce costs per customer call. […] Here we think about centralizing versus decentralizing [the resources] in several countries […] this is where it would be very useful to have [global] installed base data available. We could understand the expected number of customer cases and where what kind of installed base exists. (Service Business Development Manager 1, Case D)*

Effect on service delivery cost and quality

Installed base information is used to approximate the need of engineer resources for agreed work and an acceptable amount of unplanned work. Hence, the aim is to secure service delivery quality by ensuring enough suitable personnel and simultaneously avoid excess costs because of overestimates for the resource need.

> *[Q54] For example, quite basic data on [product types] has been used for maintenance scheduling, defining maintenance needs. [This] enables more detailed planning of how often to visit and what to do during the visits. […] Of course if we had even more detailed component data, there are always some products that require more servicing due to some special features […] It would be great if these could be accounted for in planning the work load. (Service Development Manager 2, Case C)*

> *[Q55] If you have a new product in a country where you did not have this product before, then you have to have in this country a service technician who knows the basics of this product. If you have one product or a hundred, you still need at least one person, also for only one product. So not everything is linear in our calculations. (Product Performance Analyst 4, Case D)*

Information on the installed base was considered most helpful in analyzing how the service delivery capability is affected by changes in numbers and types of equipment in service, changes in service contracts, or changes in field engineer availability. This could be done as "what-if"-scenario analyses or as sensitivity analyses on current resource sufficiency or after the fact to adjust resources appropriately for a change in the situation.

Case specifics

When providing services through an accredited service partner network (Case A, some units in Case D), field service load planning cannot be performed centrally, as each partner has its own pool of items in service likely to include third party items as well.

If engineers are equally skilled regarding equipment (i.e. serviced equipment uniform or engineer competences do not vary significantly, as is the case with some local service units in Case A), resource planning can be performed with the aggregate of all items, considering only equipment locations and total number of service events.

When remote monitoring (Cases A, B, and C) or software with remote connectivity (Case D) is a major component in the installed equipment, a greater share of services can be provided remotely. This gives more freedom in the geographical distribution of service engineers and load balancing among service units:

> *[Q56] Remote monitoring enables the centralization of skills, since there is always a competent engineer in our control room. (Service Manager, Case B)*

> *[Q57] One thing that happens through evolution if you like, is that with advanced technologies we are able to connect from remote locations, which means that some of the services we offer are from remote locations, which means that we are not talking about local engineers*

> *who sit with the customer, and have a personal contact with the customer and a personal understanding of the customer's [product]. So if a remote engineer is able to access a [product] configuration [remotely] to provide services, it would put him in a more advantageous position. (Service Director 1, Case D)*

However, this makes it all the more important to be able to analyze likely service demand in greater service areas and highlights the need for a wide coverage of installed base information on which to base the analyses. The importance of installed base information for centralized services was particularly evident at the beginning and end of product life cycles (Case D):

> *[Q58] We also make forecasts for the next version: if in the old version we had hundred [service events], then in the next version, we suppose we can better see how many we will have in the future. (Product Performance Analyst 4, Case D)*

> *[Q59] I think [inadequate software status in installed base information system] makes a lot of problems. There are challenges in technical help centres, because they would want to know the customer status. For old software ramp-down, we would need a clear picture on where old software is located, so that we don't stop support too soon. (Product Performance Analyst 3, Case D)*

> *[Q60] It would be interesting to analyze if there are situations, where it would be more efficient to upgrade products for free for the customer than to maintain the support structures needed for servicing. (Technical Support Development Manager, Case D)*

6.1.3 Spare-parts inventory management

Description

Spare-parts inventory planning aims to ensure that all required materials and spares are available within requested lead-times while minimizing investments in inventory (e.g. Cohen et al. 2006). In the field service context, the lead-times in the most challenging situations are measured in hours. This makes the spare-part management necessarily a multi-echelon problem, as central inventory locations are incapable of providing that kind of service level (illustration in Figure 7).

> *[Q61] Our [customer-specific inventories] are handled separately […][As for the others] here we have a list of spare-parts and their availabilities based on inventory locations: distribution warehouse, factory warehouse, supplier warehouse, and make-to-order products. (Spare Parts Logistics Manager, Case B)*

[Q62] Sometimes we deliver to stock, sometimes to a customer stock, sometimes to our own stock, to a car, or directly to the site. Sometimes the location is more or less, in some countries we have a forward location that the technicians visit. (Service Product Manager 3, Case D)

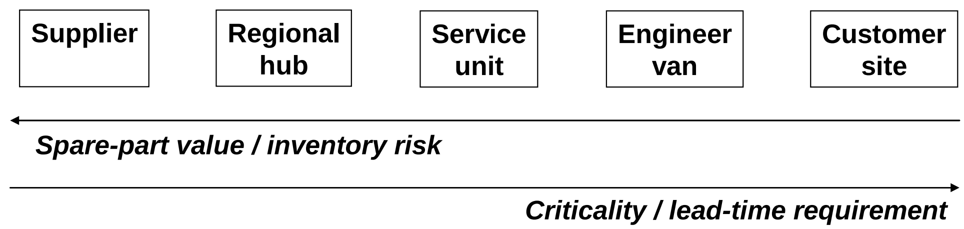

Figure 7: Balancing between inventory investment and lead-time requirement in spare-part stocking decisions (applied from Cohen et al. 2006)

The significance of spare-part availability in the downstream inventories was obvious, as expected:

[Q63] Depends on the case where to set the inventory, but the service van is our most important inventory. (Spare Part Logistics Manager 1, Case C)

[Q64] Based on experience we have a set of commonly needed parts in the service vans. They are replenished daily based on consumption. [One critical component] has many variations and is so heavy that they cannot all be carried in the van stock. (Service Partner 2, Case A)

In the upstream operations of spare-part deliveries, identifying correct spare parts was seen as a key issue for efficient service operations:

[Q65] I suppose the most important data item [of installed base information] for us is the serial number of each device so that we know what is in a customer location. Many spare parts requests contain only the device type [which cannot be reliably converted to individual spare-parts for engineer-to-order products]. (Spare Parts Logistics Manager, Case B)

[Q66] If we can't deliver the spare parts, then servicing [the products] is very difficult, at least profitably. It all comes down to identifying the correct parts. (Spare Parts Business Manager, Case C)

From the perspective of an OEM supplier with maintenance and repair services, a key feature of spare-parts inventory planning is that for each inventory location, there can be several types of demand that need to be satisfied:

1) unplanned service operations within service contracts
2) scheduled service operations within service contracts
3) unplanned service operations without service contracts
4) customer or third party spare-part requests for breakdown repairs
5) customer or third party spare-part inventory replenishment orders

These demand types differ in their priorities and predictability with installed base information. The first two demand types depend on the own or third party equipment under service contracts (i.e. service base, Figure 6), and are the most critical ones to fulfill in terms of customer satisfaction within the service business. The last three demand types depend on the installed base of own equipment outside service contracts (i.e. top-left quarter in Figure 6). In addition, the first three types of demand are channeled through the field engineers, whereas the latter two are delivered through spare-part sales. These are summarized in Table 8.

Table 8: Comparison of different spare-part demand types

Demand type	Criticality based on	Spare-part distribution channel	Role of IBIM in demand forecasts
1) Unplanned in-service	Agreed response time	Field engineers	Mtbf's for items in local contracts, location criticality
2) Scheduled in-service	Service contract	Field engineers	Changes in installed base to adjust SKU locations
3) Unplanned no contract	Customer importance	Field engineers	Items in geographical area
4) Emergency request from customer/third party	Customer importance	Spare-part distribution	Changes in installed base to adjust SKU locations
5) Replenishment order from customer/third party	Customer importance	Spare-part distribution	-

The interviewees saw the need to handle the differing demand types separately. Most time-critical and costly was securing availability for the demand type 1 (unplanned with service contract), and hence, detailed installed base information was seen important in planning the inventories:

> *[Q67] Because when we are signing contracts with 4-hour turnaround time, we have to locate exactly our stocks, that we can fulfill our requirements. For this we need the site location, and what is in it. (Service Product Manager 3, Case D)*

Demand type 2 (planned with service contract) was more relaxed with service lead-times:

> *[Q68] Our customer teams know which machines are due for periodical maintenance and our [installed base audit records] give support, as the front line can ensure spare-part availability prior to the operations. We*

> *have listed spare-part types that need to be checked for availability and those that don't have to. (Spare Parts Logistics Manager, Case B)*

It was also seen that these two demand types 1 and 2 (planned and unplanned) behave differently and should be handled separately for accurate inventory control:

> *[Q69] There are no problems [in spares availability], if there is a controlled system shutdown that we can plan for. There are more problems when something breaks and needs to be replaced immediately. Or if something else [in the system] breaks, and while the system is down, other checks are of course also performed and repaired if considered necessary. (Spare Parts Logistics Manager, Case B)*

> *[Q70] In many front lines we monitor the spare-part consumption to optimize the service van inventory for planned maintenance and unplanned repairs separately. (Spare Part Logistics Manager 1, Case C)*

> *[Q71] It's a very relevant issue, shutdown repairs and other emergency repairs need to be handled swiftly […] While the one placing the order knows [the type of demand], at times emergency orders may still get lost in the masses of other orders [in the spare-part supply chain]. (Spare Parts Logistics Manager, Case B)*

Demand type 5 relating to replenishment orders might require further explanation. Installed base information was considered irrelevant for forecasting customers' inventory replenishment orders, as the timing and quantity of the orders are more dependent on customers' inventory management processes than consumption of parts (Cases B and D). In particular, analyses of local spare-part consumption frequencies can be misleading if this type of demand is not noted in the analyses. This is problematic with both demand types 4 and 5:

> *[Q72] For equipment that is not considered within our repair service, that is supported through spare-part sales, only in exceptional cases we get information on which specific item it replaces. […] Or, it might as well end up as an extension in the customer system. (Product Manager 1, Case D)*

Role of installed base information

In general, it was understood in the cases that if there were no changes in the installed base, past consumption of spare parts in inventory locations would be accurate for spare-part replenishment forecasts, with scarce additional value from understanding the installed base. But, as the Spare Parts Manager interviewed in Case D summarized, 'there are always changes in the installed base':

New product introductions where new spare-part SKUs might need to be planned for each inventory location based on the volume of installations in the area the locations serve (Cases B, D)

> *[Q73] It would be interesting to see what products have we delivered along the years, For example, if there was a new product introduction five years ago, how rapidly would the installed base grow, and when does the demand for spare-parts increase. Currently [such an analysis] would be tedious to perform. (Spare Parts Logistics Manager, Case B)*

Equipment entering and leaving service contracts changes the spare-part demand type (Cases C, D).

> *[Q74] If we change the contract from repair to a higher level, then there is normally 2-3 weeks of analysis on where are the [spare-part] modules, and how many modules does [the customer] have, because he normally does not get this information out of his system. It's really a physical check. Sometimes the modules are faulty or broken. It's a big problem, when we have to take over such equipment. What we do normally, we make a due diligence for this equipment, it's more or less a visual check: if it's an original module or not. Otherwise we need to send it back to our technical centre and it costs a lot of money. (Service Product Manager 3, Case D)*

Product life-cycle phases also create changes in the spare-part business—end-of-manufacturing and end-of-use require special attention to balance between availability, investments, and workload.

As the product is no longer manufactured, an estimate for the final lot size to order from component suppliers is needed to ensure spare-part availability (Cases B, C, D).

> *[Q75] When the manufacturing of a product ends, we need to buy components and modules for our spare-part inventory. At that point, we would need to know what's the [mean-time-between-failure and installed base] to determine how many pieces we need in our inventories. […] Currently, this end-of-life calculation involves quite a many people in the organization. Let's say so that partly because of insufficient data it involves a bunch of crowd [in our organization] and the end result is still a bit uncertain. (Product Manager 1, Case D)*

Fully functional equipment and parts upgraded at one customer can be used as spare parts at another customer if an analysis of global installed base records shows customers still using prior equipment types (Case D).

> *[Q76] One use is for asset recovery. The global installed base is needed for after-market identification for removed components. (Product Manager 2, Case D)*

Having the ability to identify old equipment was also considered an important sales lead that would support the service business with the customer by reducing the variety in serviced items (Cases B, D).

> *[Q77] There are some old products in the field that have not been manufactured in the last ten years. But they are considered to be so good, that customers are still requesting those instead of the more recent substitute products. This situation adds to the demands for our spare part capabilities. It should be analyzed from the marketing perspective how to replace these older products in the field. […] And if we saw [based on installed base data] who are running such older products, we could direct our marketing effort and even use pricing to influence the demand. (Spare Parts Logistics Manager, Case B)*

Finally, spare parts within the service area of an inventory location might no longer be needed, and thus, the ability to deliver those can be removed (Cases C, D). The most fruitful situation would be to analyze the entire installed base for equipment completely out of use. These decisions, however, need to be carefully evaluated:

> *[Q78] Now this is one gem for the [installed base information]. […] For example the pricing [of spare-parts] needs to be done twice a year. It's clear that if we could cut the number of spare-part items to half, or even two-thirds, it would be visible even in the quality of our work […][However] it is quite an effort to add a new spare-part item, we need around hundred different parameters, including customs tariff codes and refurbishing locations. If we remove an item, but after a while need to reintroduce it… well it's a tough decision. (Product Manager 1, Case D)*

For spare parts not manufactured at own production plants, the sourcing decisions can be made based on the geographical distribution of demand. Parts with only local demand can be left to be procured and stocked by respective service units, but spare parts with wider demand are candidates for more centralized control. This was seen extremely relevant in planning inventory investments when providing services to other OEMs' equipment (Cases C, D). To understand the geographical distribution of third party spare-part demand, the centralized availability of information on installed base items and spare-part consumption in service events were considered highly important.

> *[Q79] By collecting component failure rates also from competitor equipment we can also plan our spare part inventories better. (Assistant VP of Service Quality, Case C)*

> *[Q80] We should be able to analyze commonalities in spare part needs globally across service units to determine best sourcing strategies and distribution structures for them. This is particularly relevant for the non-[Case C] equipment. (Vice President of Service Delivery Process, Case C)*

> *[Q81] [Installed base] quantities for our OEM partners are also very important, because we have negotiations with our OEM partners, and we have to know how much equipment was sold in our countries. And we as headquarter, did not know how many pieces of equipment was bought by our local company from [an OEM partner] for example, because we make that locally. We as headquarter have no effort with this equipment, that's why we are not interested to know. But afterwards, when we are making a new contract with [the OEM partner], then we have to know that we already have installed a million products, because then we have a better condition. (Product Performance Analyst 4, Case D)*

Long-term optimization of spare-part inventory investments was considered one application of installed base data. Analysis of local installed base items for commonalities in spare-part compatibility could be used for inventory risk pooling by selecting to stock commonly usable spare parts instead of product-specific ones (Case A) or using "too good" spare parts (Case B). Use of higher value spare parts might be justified if the result is lower total investment in spares inventories.

> *[Q82] You can use them [spare-parts] interchangeably. A good service technician doesn't get stuck with the equipment type, as he understands how the equipment operates. He'll get them [the spare-parts] to work in any brand. (Service Partner 2, Case A)*

> *[Q83] Most spare-parts can be fitted in all manufacturers' equipment, also [Case Company A] uses normal components which makes the service operations easier in the field. (Service Partner 3, Case A)*

Effect on service delivery cost and quality

Spare-part availability is a critical component for reliable service delivery. Because the required amounts and points of consumption for spare parts are in practice defined by the equipment they are used for, installed base information on the items and their geographical locations, together with pursued service levels, is valuable in determining necessary inventory locations and levels. Installed base information can be used in assessing both minimum and maximum consumption for balancing the contradictory goals of availability and inventory investment.

> *[Q84] There are many repairable units within a site, and sometimes one unit is more important than another. […] It could be on one site that this*

> *code number is needed in 4 hours and on another site in 8 hours. [Detailed customer site items and service levels] will be very helpful also to optimize our costs, if we only have lead times of 4 hours we need a lot of assets. So we can optimize our business case and the business case of the customer. (Service Product Manager 3, Case D)*

Case specifics

Not only the specific pieces of equipment at each site, but also knowing the equipment interfaces with other items in a customer system can be relevant for spare-part inventory planning:

> *[Q85] One issue that is an outright obstacle for spare-part sales is that for [some spare-parts] you need correct fittings to install them. […] Already this single product family has close to a hundred variations in the fittings, and this only concerns the new interface type.[…] The guys out there say that if they had [relevant fittings] available, it would surely increase spare-part sales. (Spare Parts Logistics Manager, Case B)*

Replacement of engineer-to-order products might require information on the exact product replaced to ensure compliant configurations and reduce work in redesigning the product:

> *[Q86] In those cases where product engineers can identify the drawings used for the original part, our work is easy. We can then use the old NC-tooling programs and such. But if they cannot identify [the original drawings], we have to go through the whole engineering cycle anew. One more item to maintain, likely new NC-programs to create, […] and new layout planning that may result in differing layout of the product, although functionally equivalent [with the original product]. (Production Manager 2, Case B)*

6.2 Decision support for sales, product management, and development

This section discusses business processes only indirectly involved with the installed base, but that can support their operations with visibility to the installed base and actions performed in the after-sales service units. In particular, sales, product management, and product development are discussed in detail (see Figure 5 in subchapter 4.4).

6.2.1 Sales

Description

As discussed in the literature review on sales support (3.2.1), both customer relationship management and key account management contributions consider customers' product and service usage, geographic factors, interaction histories, and customer profitability of interest for the sales function (e.g. Ojasalo 2001; Bose 2002; Crosby 2002; Jackson 2005). The case studies provided a detailed view on how these information needs are related to installed base items and service events and how they support different kinds of decisions made in sales operations.

The decisions affected by installed base information can be broadly categorized in three categories (Figure 8): identifying potential opportunities with customers (sales leads), preparing quotations and negotiating terms of contracts (tendering), and monitoring the compliance with customer contracts. Each category has its specific uses for information on customer product usage (items), geographic factors (locations), and interaction histories (events). These are discussed separately for product sales and service sales below in more detail.

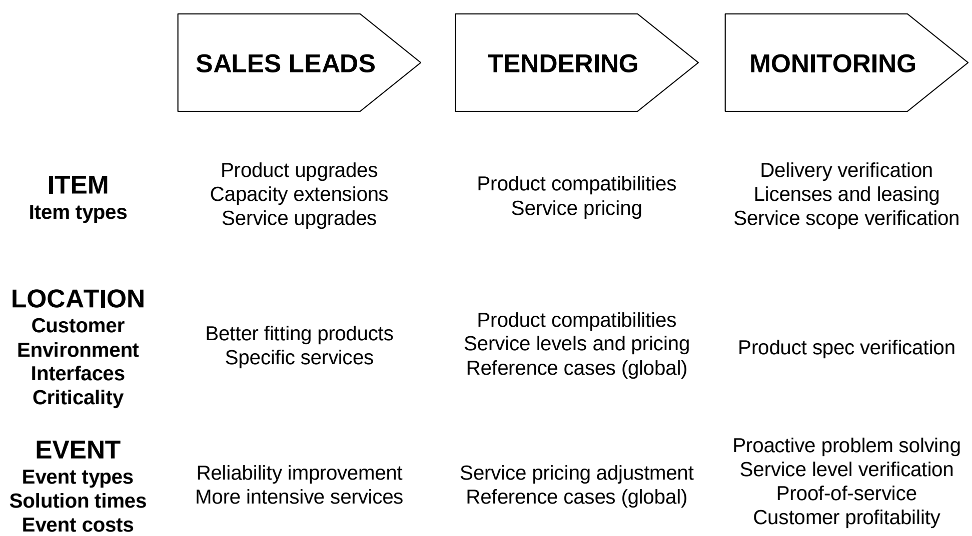

Figure 8: Installed base information use in sales operations

Support for sales leads for item sales

The sales managers in the cases were understandably strongly of the opinion that no information system can replace direct contacts with customers and discussions with field engineers for identifying sales opportunities. Nevertheless, they saw the value of installed base information in analyzing the status and potential prospects of a customer before making direct contact. As a sales director in Case B stated:

> *[Q87] It is always a good thing, if the sales manager gets talking points. […] Of course, you can show your expertise to the customer: co-operation with us is straightforward and adds value, as we know your situation. (Sales Director, Case B)*

Analyses of the installed equipment were seen to support identifying functionality, maintainability, and capacity upgrade potential at customers. As for the functionality upgrades, the relevant analyses were related to old equipment types that could be replaced by newer versions with improved features.

> *[Q88] With this kind of information [comprehensive records of installed items], we could check where the most significant installed bases are. That would have great potential for retrofit sales, and of course service sales […] We could also plan for upgrades in quite a different way. We could proactively identify and suggest upgrades that would provide enough improvements that it would pay off for the customer. (Sales Director, Case B)*

> *[Q89] [another use we would have for installed base information is] knowing which customers are on which [product versions], and seeing the roadmap for new releases, we would start to see which customers to target with a push for installation. (Service Product Manager 2, Case D)*

> *[Q90] Another thing is the power supply. It's all about energy consumption, and if you know what your power supplies feed in […] you can offer on the operating expenses side that you put in something that reduces it from 20kW to 10 kW, you can immediately make calculation on savings on energy costs. (Sales and Marketing Director, Case D)*

At the time of the studies, in Case B, specific audits were made to identify such equipment at single customer sites; in Case C, field engineers regularly visiting equipment identified replacement potential; and in Case D, equipment installation records were used.

> *[Q91] The field engineer will go through the equipment audits with the salesperson, and they analyze what they should offer for each upgradeable process location. It also includes visual checks on the conditions of the equipment. […] Oftentimes even the customer does not know exactly what exact equipment is in each location, all replacements are not necessarily recorded. (Manager, Installed Base Audit Systems, Case B)*

Maintainability upgrades are identified by reviewing old equipment types that could be replaced to reduce maintenance costs at the customers. Currently, the data supporting such identification is the same as above for Cases B, C, and D.

> *[Q92] It is also essential to narrow the product assortment in terms of service production. It is a viable sales argument that product replacements lead to reduced spare-part inventories and maintenance costs. (Sales Director, Case B)*

> *[Q93] One of the goals with [our installed base auditing system] is to be able to make concrete the point for a customer that 90% of your*

> *equipment has no spare-part available anymore, would it perhaps make sense to start with upgrading those. (Manager, Installed Base Audit Systems, Case B)*

> *[Q94] From the service perspective we'd need the update versions, so we'd know if the systems are properly working. A matrix of old and new systems, some are incompatible. And if you don't know in detail, what's working and what not, we may have a problem with our […] maintenance support. (Sales and Marketing Director, Case D)*

Capacity upgrade potential requires information on current capacities of the items in the customer's process and understanding the customer's business situation to identify a case for capacity extension. Both system component suppliers (Cases B, D) saw that installed base items must be recorded in such detail that the throughput capacity they provide for the customer can be identified. This way, sales managers can proactively suggest upgrades as the customer's business grows.

> *[Q95] From the hardware point-of-view we need to know what's the hardware there, how many of each item are there […] and if you want to have [capacity] planning over that, you might be able to increase capacity without adding sites [for the customer]. (Sales and Marketing Director, Case D)*

In addition, details concerning the locations where the items are installed were considered of interest for sales lead identification. In particular, arising conflicts with environmental compliance or compatibility issues were seen as a source of sales opportunities. If changes in the installed base environmental conditions have made existing equipment unreliable, they are potential candidates for replacement. In some situations, environmental conditions (e.g. temperature and humidity in Case A, or corrosion agents in Case B) might change to such a degree that the existing products' performance is compromised. These were seen as potential situations to make replacement suggestions for customers.

> *[Q96] I have the impression that many plants plan for lower [process medium concentration] values. Then they ramp up to increase throughput. As the process medium gets more aggressive, there'll be problems with material durability [of the products]. (Engineering Manager, Case B)*

A similar situation arises when items have been partly replaced or modified by the customer or a third party, and the compatibility of changed items has not been assessed because of urgency or unawareness. In Case D, it was seen useful to identify all items, both software and hardware, installed in each location to be able to suggest upgrades to customers proactively in situations where the current configuration of items might not perform optimally.

> *[Q97] If sales can identify a version update potential in the installed base, we start our selling efforts. If we get the [customer interested], we need more details on the installed base status to see what other upgrades are needed to maintain stability […]. So, a high level overview and in-depth data, both are needed. (Service Business Development Manager 1, Case D)*

> *[Q98] Sales can use [the installed base data] to identify conflicts between software and hardware, or identify wrong […] or older versions, that's how you can target marketing actions to try to persuade the customer to upgrade. (Service Marketing Manager, Case D)*

Regarding the interaction histories with the installed base, the analysis of service events was used to identify sales leads. Here, the main analyses of interest were to find out what specific problems there have been or if there has been a recent increase in service operations at the customer that could be removed with new equipment investments. Cases B, C, and D used such analyses on their service histories in those service units where this information was adequately available at the time of the studies.

Support for tendering with item sales

The tender preparation for customers was another task where the case companies used their installed base records or saw prospects for using data if it was readily available. In particular, installed base data was seen to support compatibility assessment and reference case identification.

> *[Q99] Also internally [records of installed items and applications] would be helpful. If there is a young sales guy who doesn't have long experience, it could be useful to check what we have delivered to similar locations. (Project Delivery Manager, Case B)*

In cases of upgrade or extension sales, compatibility analysis with the application location characteristics and existing items was seen important for two reasons. First, as the necessary sales items can be well defined during the tender preparations, the price negotiations can be conducted with lower risks of subsequent surprises in the implementation phase. Second, it gives a professional impression if technical feasibility and location characteristics (e.g. required dimensions, power availability, and resistance to the elements) are noted from the beginning.

> *[Q100] It would be fantastic, if a customer would approach us with 'I have this process location…' And our salesperson could immediately reply that 'Ok, the conditions there should be like this, and according to our knowledge you currently have this and this installed. What's the problem, have there been some changes lately? (Sales Director, Case B)*

> *[Q101] For complete upgrades we only need information on power availability and required dimensions […] For partial upgrades we need more information on the interfaces [between distinct components]. (R&D Director, Case C)*

> *[Q102] [Installed base system] could be used for the customer quotations. So the [software] sales price is based on volume of [operational equipment]. (Service Customer Account Manager 1, Case D)*

In Case D, some local units had the capability to use an upgrade configurator based on their installed base records. The configurator analyzed the required item replacements, once the desired upgrade level was determined in the system. In case of inadequate existing records, as in Cases B and C, specific audits were performed to ensure correct initial data:

> *[Q103] If we rely on customer delivery records 15 years back, it may well be that the entire process no longer exists, or [our products] have been transferred to other applications. In that sense the audits are the only correct option to find out […] but if we would audit only the product details, we couldn't tell if the products are in a suitable application. (Sales Director, Case B)*

In cases of challenging customer applications, the sales managers hoped there was an easy tool to search for reference cases with similar conditions of corrosion, exceptional dimensions, or performance requirements. Being able to refer to existing implementations was seen as a potential order winner. In Cases B, C, and D, there were known reference cases, but they were pre-selected based on their apparent exceptional features:

> *[Q104] When making tenders for customer projects, at times the customers request reference deliveries for similar sites. Or, if there is even a single process location with extreme conditions, they want to have references of similar implementations, as failures may have dangerous consequences, and also, if there is critical process location where failure leads to shutdown of the entire plant. […] our current reference database is manually updated […] they can't always know in advance whether or not a delivery is a valuable reference in the future and should it perhaps be recorded. […] we should be able to identify more broadly installed items with application details. (Delivery Project Manager, Case B)*

> *[Q105] Very often as we make tenders, we check for references of deliveries to similar processes of different customers. If we would additionally have the capability to say that a certain product performed very well in the application, or that it didn't and we have opted for*

> *another solution that is more expensive but works. (Product Director, Case B)*

A special case was that of new product introductions, where customers often wanted to know how many and where installations had already been commenced with the new product. The sales personnel were also keen to learn about the initial service histories of new product installations to be able to determine whether to offer the new product to their own accounts:

> *[Q106] If there would be a report [based on global installed base data] that I could call up to compare or know how many [customers] have already upgraded to [a certain product version] for example. A customer normally is always asking…If I propose a new upgrade, they would ask me how many customers did it already. (Service Customer Account Manager 2, Case D)*

Support for monitoring of item sales

There were also comments on installed base information supporting monitoring of the sales contracts. In particular, in Case D, as the delivered systems cover several sites, the sales managers appreciated the firsthand information in the installation tool to monitor the progress of implementation to verify promised delivery times and to support the invoicing process. Further, in Case D, license-based software products needed to be monitored, in terms of both installed quantities and use periods, to ensure compliance with the sold license restrictions. In addition, having the product identifiers updated regularly from customer applications could enable global fraud prevention:

> *[Q107] We now have on the hardware side the trend, where you have companies taking four faulty modules and combining them as a new module and selling that back to our customer. Some kind of grey market for repair and replacement, which is obviously not in our interest. We […] need to able to black list serial numbers: that item has already been destroyed, so it's impossible that the serial number is still in use. (Product Manager, Case D)*

Details on the location environment of new installations were hoped for in Cases A, B, and D to verify that the products were used in the environment that the customer had informed in the request for quotation. Each company had experience with cases where the customer had downplayed the environmental characteristics to reduce the investment costs, only to later complain about poor performance or reliability of the products. Having the ability to check such inconsistencies systematically was welcomed.

Case companies A and D had identified a growing potential for equipment leases to customers and, therefore, saw the item-specific location information to increase in importance as lease agreements would need to be monitored.

Finally, case companies A and C, who had wide coverage in connectivity to the remote monitoring facilities of new equipment installations, used the status monitoring regularly to follow up on sales contracts. Proactive measures could be taken to ensure customer satisfaction with the new product if complications were found. Also in Case B, the idea of follow-up was welcomed for specific deliveries:

> *[Q108] Customer processes are developing towards higher [requirements for our products]. There are borderline cases where we have no experience on how the products will do, so we take some risks. We should be following up even closer those cases where we debate over whether or not to make a tender. If we get the deal, then we should monitor the products whose reliability we have questioned, how they are doing in the application, to learn more. (Product Director, Case B)*

Support for sales leads for service sales

The sales managers saw installed base information to support also sales of after-sales services, in particular maintenance and availability services. Similar to item sales, the phases of sales lead identification, contract negotiation, and contract monitoring each had their own uses for installed base information.

Installed base item analyses to support identification of service sales leads were related to spotting items with insufficient service coverage. In Cases B, C, and D, information on the installed base was used to identify equipment not covered by a service contract and equipment that would be better served with a different service agreement:

> *[Q109] [Instead of flat rate contracts], as the [customers] are starting to have tight budgets we are starting to think what technologies are supported with what service levels, and then go for on the top sales. […] It leads to narrowing the scope as much as we can to get the right price, and then we go for [specific targeted service offers]. (Service Marketing Manager, Case D)*

Information on the applications where the equipment is used, or environmental conditions, were seen as a useful addition to installed base data in Cases A and B to reveal needs for specialized service propositions. For example, the processes at the customers of Case B influence the service requirements for the products:

> *[Q110] [At some plants,] the risk level is high. For example, a paper machine is in the end only a machine that contains hot water, not a very demanding process. [Accidents] with hydrocarbons are much more dangerous, as [at worst] it's about the lives of hundreds of people. (Sales Director, Case B)*

In addition, service history analyses for specific problems at the customer sites were considered useful in Cases C and D to identify repeating issues that could perhaps be avoided by agreeing with the customer on more intensive servicing of the equipment.

Support for tendering with service sales

During the service contract negotiations, information on the types and numbers of items in the installed base is essential to determine correct pricing for service contracts and to ensure eligibility for service. There were both product lifecycle-based and condition-based rules to ensure service profitability. Items must be of versions still supported by the service organization (as in Case D), or items must be in such a condition that they can be supported without prior repair or upgrade (as in Cases B and C):

> *[Q111] We approach the service business so that if we are to accept full responsibility of all the devices at a customer site, we need to check that the [devices] are such that we trust. Or if we don't trust them, we propose a replacement. Of course this needs to be also in the customer's interest. You can't just cheat, or you are thrown out. (Sales Director, Case B)*

> *[Q112] We need to identify such customers [using older equipment] globally so that we can prepare for servicing them when otherwise shutting down product support. We also need to identify them locally so that we do not offer them services that are costly for us to provide […] We need to ensure that the service contract covers only products and software that we currently support, and not every bit and piece that we have delivered to the customer ages ago. (Service Business Development Manager 2, Case D)*

In Cases B and C, this information was most often collected with an audit of the service targets before agreeing on the service. The audits are also used to gather accessibility information on the locations to support service planning. In Case D, the installed base information was mostly available in the customers' information systems. In Case D it was also considered relevant to have information on the criticalities of individual items in the customer system to be able to determine service level requirements for specific targets. This enables competitive bidding by reducing the service levels of non-critical products, while ensuring that the availability of the complete system is not compromised:

> *[Q113] We also need installed base information for our contract database […] because we have lead times depending on the code numbers. We don't say just that this customer has this service level, we are more detailed. Sometimes there are redundant modules in the system, so it is not mandatory to deliver a redundant module in 4 hours. Instead, we send it in 10 or 12 hours. […] we can have a more flexible offer if this is needed. Normally, we want to have only one lead time, but then the customer says the price is too high, so we have to reduce the service*

> *level, and this could be a way to handle this. (Service Product Manager 3, Case D)*

Using the installed item types for service pricing also requires information on the reliabilities of item types. These can be based on either average mean times between failures or more specific service history analyses. In situations where service contracts are being renewed, the customer-specific service history is analyzed for pricing decisions and service product upgrades (Cases B, C, and D):

> *[Q114] When we renew our [service] agreements […] in terms of installed base knowledge, we are curious about the detail what we get. We would be very interested in the installed base knowledge. Actually […] during normal tendering, it's more sort of benchmark of our prices against some sort of benchmark. Our price per some element in the installed base. (Service Product Manager 2, Case D)*

In negotiations with service customers, it was seen useful by the sales managers of Case D to have the ability to analyze service histories of comparable customers to help with service level and pricing decisions. Service performance analyses based on service event records of local units servicing the prospective customers were also seen useful by the sales force in Case D to understand the capability of the service units and potential requirements for additional staffing when negotiating with the customer:

> *[Q115] Today we use to define our service calculation algorithm based on the installed base we have worldwide and the number of [service events] we have for each product, and forecast for the products how many products will be sold in next years, and other information we receive from R&D colleagues. Based on this information, we define our algorithm to calculate the service effort, and so we have a tool to make quickly a service offer to our customer. (Product Performance Analyst 4, Case D)*

Support for monitoring of service sales

Once the service agreements are in effect, the sales managers welcomed updates on the installed base items to identify needs for updating service contract coverage or pricing, should notable changes occur in the installations at the customer (Cases B and D):

> *[Q116] We have a commercial need to maintain the installed base records for software, as the pricing of some support services are based on the type of software and number of installations at the customer […] The pricing needs to be updated when there are changes in the software installed base at the customer, these dynamics require continuous installed base monitoring. (Software Product Director, Case D)*

Correspondingly, in situations where the service bundle offered to the customer also contains services sourced from third parties (e.g. maintenance for other OEM components in systems deliveries), the number of installations is needed to ensure correct maintenance fees for these service partners:

> *[Q117] If it is about third party [services], where you have billing for maintenance services […] based on the installed base, you need to have the information what is still in commercial use, what is still there, and not just what assets we have based on what has been delivered to the customer. That can be different, and if you take the wrong one, what has been delivered, then we pay more fees to [the 3rd party service provider] than we should. (Product Manager 3, Case D)*

If during the contract period, there are service level problems attributable to the customer (e.g. accessibility restrictions, Case D), or service calls for items not covered by the contract (Cases C and D), the sales managers should be able to identify and resolve such issues with the customer before they deteriorate the profitability of the service contract:

> *[Q118] Our managers want to know for example, which [equipment] has a service contract. Because, if it does not have a service contract, we don't want to make the service for it. And to be able to decide on the help desk level for questions coming from our customer, if the customer has a service contract for this equipment or not. (Product Performance Analyst 4, Case D)*

Accurate service histories were considered valuable as a proof-of-service to motivate the customer to renew service contracts. It is an interesting complication resulting from successful preventive maintenance and proactive repairs that the customer might feel the service contract is overpriced. This is because of the reduced number of direct contacts with field engineers as fewer problems propagate to impact customer operations (Cases B, C, and D). Accurate service event records during the contract period provide the sales managers proof-of-service for customers questioning the value they derive from the contract:

> *[Q119] To support preventive maintenance […] we would report that in the next month saying: look, we avoided a big problem because detected it via that mechanism. […] You have your contracts not based on hourly rates, but flat rate, and you have to perform at 99,999. Well, you need to prove that somehow. We need to have measures to show that in a database. (Product Manager 3, Case D)*

Analyzing customer specific records of service events is also interesting for the sales managers to monitor the service level agreement compliance by the service organization. If the number of delivery lead-time problems becomes alarming, or if reaching promised uptime is questionable, service capacity adjustments must be made to avoid contract penalties (Cases C and D):

> *[Q120] We want to have within the [customer system], a kind of light recorder, what's going on […], what are the major alarms, where are inconsistencies, in order to support preventive maintenance […] The idea would be to operate on a joint basis [with the customer], and give me an insight [to the agreed key performance indicators] already in an early phase, because it would be to our both disadvantage if we could not make it. (Product Manager 3, Case D)*

Finally, having access to analyze global installed base items and service event records is necessary when negotiating with global customers requesting globally uniform pricing for products or services. In addition to regional differences in personnel and logistics costs, the regional differences of the customer's installed base might influence the differential pricing (e.g. equipment age or version) and having visibility to these supports the argument that a flat rate cannot be applied across regions (Cases B and D):

> *[Q121] [one of our customers] has now a global unit to harmonize service agreements, and we try to block them the best we can. It is not our advantage to globalize local prices. The customer will do cherry picking, if something is somewhere cheaper that becomes a de facto standard. We try to [inform] the customer what it is that he actually is buying locally. (Service Marketing Manager, Case D)*

6.2.2 Product management

Description

Because of the organizational characteristics of the case companies (described in subchapter 4.4, illustration in Figure 5), the tasks that have been discussed in the literature under the common title of product development have been split into product management (of existing products) and product development (of new products and product versions). Hence, product management refers here to tasks needed to monitor and improve product quality and performance and assess and improve the market attractiveness of the product portfolio. These were identified in the literature review (in section 3.2.2) as:

- Early warning/detection of wrong design, production process, parts, materials, etc.
- Comparison of performance before and after design fix
- Assessment and refinements of reliability predictions

Considering the results of the literature review, the installed base information of interest for product management can be narrowed to failure frequencies of product versions, servicing times, and information on environmental factors. Based on the case studies, the information requirements must be extended to also include bills-of-materials, customer identities, and rich service history data. These are discussed in the following under the headings of warranty claims handling, defect handling, and performance management (illustrated in Figure 9).

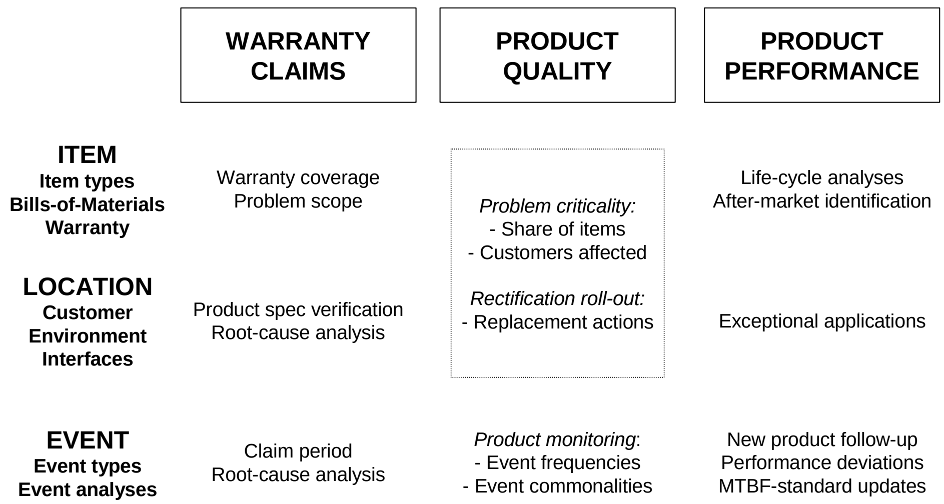

Figure 9: Installed base information uses for product management

Support for warranty claims handling

Product claims handling consists of two distinct processes: solving the immediate problem that the customer has and identifying and rectifying the root cause of the problem. The former process is motivated by retaining customer satisfaction and is critical to perform in a timely manner. The latter is motivated by proper allocation of costs and improvement of practices to avoid recurrence of the problem in the future. In the context of this study, the first process is identical to the situation of unplanned repair operations discussed in section 6.1.1, and consequently, only the latter process will be discussed here in more detail.

When analyzing the eligibility of the warranty claim compensation, the first piece of information of interest is whether the warranty of the claimed item was in effect at the time of the malfunction. This requires identifying the item's serial number and the capability to connect the number with warranty agreement with the customer, as conditions can differ depending, for example, on whether the warranty starts from the delivery date, installation date, or commissioning date (Cases A, B, and D):

> *[Q122] It [the warranty period] is often difficult to determine, as our products can be ordered much before the actual commissioning [of the plant]. (Quality Manager, Case B)*

> *[Q123] And this information is very important when we are talking about upgraded equipment, because inside equipment, inside a system*

some modules have warranty and some not. On the software side it's a bit easier, but on the hardware side we need always go down to the [serial] number. (Service Product Manager, Case D)

Another dimension of claim eligibility might be that the item was not used according to specifications. Controlling for this requires identifying the location where the item was installed and ensuring that the environmental characteristics of that location are according to customer specifications available during the original sales negotiations, e.g. the level of corrosion agents (Cases A, B, and D):

[Q124] It occurs often with warranty cases, that the customer reports the process location characteristics as quite different from those in the initial order. And it is not about someone trying to cheat, but rather about changes in the plant spec since the original order. […] The problem is that it is easily the responsibility of the supplier, if the supplier cannot prove that it is not. […] Considering the number of middlemen and contractors in some projects, how can our sales organization in, say, South Africa, find out the original spec that was used in designing the product. (Sales Director, Case B)

Records of environmental characteristics also support the problem root-cause analyses (Cases A, B, and D). For example:

[Q125] Typically we investigate issues such as operating and environmental conditions to find out why [a product] does not endure in the location. (Quality Manager, Case B)

[Q126] For example in Peru we had corrosion problems, and we have directives saying for example that [some products] may not be installed closer than 5 km to the sea. And when we ask about the sites they may be 10m from the sea. (Technical Support Manager, Case D)

Further, service event records or remote monitoring might provide clues to analyze problem simultaneity. If many items are claimed together, service records or monitoring data might disclose whether they have been replaced all at once or during a longer time frame and only claimed as one batch (Cases A and D):

[Q127] [For each customer claim] we'd need time, service reason, which module changed, why changed. Often we get what we call "no-trouble-found" modules, that were replaced just-in-case as the technician was on the site fixing a related problem. For example all four modules were replaced, although only one was reported faulty, then all replaced modules are claimed. That's why we would need information on why [they were] changed. (Technical Support Manager, Case D)

Service event records can also support assessment of the scale of the problem. There might be similar claims or repair events with other pieces of the same equipment type that have not reached product management, as they have been handled locally (Cases A, C, D):

> *[Q128] This [corporate warranty claim] system is somewhat biased to be used for product reliability improvement, as the local units [report mainly] electronics and components that are difficult to repair by themselves. If you cannot fix it locally, then you need to give feedback to the factory. (Assistant VP of Service Quality, Case C)*

The installed base also plays a role with financial estimates concerning the overall warranty costs for the organization:

> *[Q129] It's a legal issue, it's mandatory to have for our business report […] We need to know our figures and how much money we need for the next three months to deal with the warranty issues, and we do this based on installed base. […] If we say 300 million [certain units] are installed, and 20 million are under warranty, we have to dimension the costs for the warranty for the next 3 months. (Service Product Manager, Case D)*

Support for product quality and performance management

Product performance, as referred to by the interviewees, has two distinct measures: operational quality within acceptable limits (i.e. delivering the intended function for the customer process) and failure rate within acceptable limits (i.e. delivering the intended availability for the customer process). Concerning installed base information, these refer to different data. The first relates to operational condition (e.g. temperature in Case A, operating accuracy in Cases B and C, or data throughput in Case D). The second relates to number of disruptive events having taken place (e.g. number of breakages, amount of downtime). The product management teams saw the possibility to analyze these attributes by product type as valuable input for quality control of both design and production.

One purpose for having installed base data with high coverage was that systematic defects could then be identified and rectified with a controlled process (Cases A, C, and D). If a periodic analysis of numbers of unplanned operations with specific equipment types indicated a recent increase in problem frequency, service records would be analyzed in more detail to check for commonalities of problems (e.g. same component changed, same problem cause, or symptoms reported). If similarities existed, the installation dates of the involved equipment could be checked to identify a potentially problematic production period:

> *[Q130] Records of installed equipment should include the bill-of-materials, what upgrades and component replacements have been made, and where the replacement components were sourced from. The records*

would help in analyzing systematic problems in products or specific components, and in proactive replacement of problematic units. (R&D Engineer, Case A)

[Q131] In terms of installed base information needs […] it's the bill-of-materials, as then we would know what is out there. Especially with a BOM with […] component serial numbers. That would always get us forward. (Product Manager 2, Case C)

[Q132] I receive information, that for this product, we had last year ten [service events], for instance, of them five major ones and two emergencies. And this information is then mapped to the installed base to see how good this product is. Had we too many [events] with it? That's also a quality question for the product. If we sold a thousand worldwide, and have already 100 [service events], then something is not working. (Product Performance Analyst 4, Case D)

Once a quality problem has been identified (either with the installed base data analyses or with direct field engineer or customer contacts), the decision on prioritization of corrective actions among other development tasks could also be supported by installed base data. Whereas severe problem consequences (e.g. health risks) are a key priority factor, less critical problems could be prioritized by an analysis of share of items affected with the problem in the equipment type or an analysis of the number and importance of customers having problematic equipment in their installed base (Cases C and D):

[Q133] One need [for installed base information] is to be able to check the scope of the problem, to focus improvement efforts properly. If someone somewhere is forcefully requesting a product change, we cannot currently easily check, whether it is a relevant request or not. Also regional differences in the change requests influence [the prioritization]: the price for labor varies regionally, and [we need to analyze] whether to invest in materials or field operations for a single change request. (Product Manager 1, Case C)

[Q134] [customer warranty claims] and [service records on equipment level] is where we measure the scope of the problem. In the field it can be very difficult to see where we use this data. With this we try to figure out how widespread the problem is and what items are concerned, and then we start with more detailed analyses on what is the real cause for the problem. (Product Performance Analyst, Case C)

[Q135] Product [managers] are requesting installation information on specific sets of serial numbers to assess scopes of identified problems, or if they see irregular service peaks for distinct serial number series. […] For example, they use [our analyses] as an input for decisions on

> *whether to make a callback or sort the issue during next service cycle. (Product Performance Analyst 1, Case D)*
>
> *[Q136] Another example: the customer was complaining last year that there was a high failure rate on a particular module. And as the customer saw 4-5 failures, he shouted that this is a high failure rate, what's going on? He only saw the number of those suddenly broken. But with installed base data we could say that look, you have five faulty units […] but you have 2000 of them installed […] and they are working. The failure rate is that low. Then we can say that there is no immediate need to do anything at the customer network. We internally of course look into those issues, but we don't need to call back from the customer. (Service Customer Account Manager, Case D)*

Finally, once the necessary rectification measures have been devised (e.g. callback, replacement, or change order), installed base data could be used to notify the involved service units on the exact customer sites that have affected equipment installed and monitor the actions, instead of the prevalent practice of broadcasting change needs to all units to check their local installed bases for specific items:

> *[Q137] If there is a problem, we check which [products] it involves. Then we pick out the delivery addresses, sort them by country, and send [service units] a note that you have this kind of [products] and here are their delivery addresses: there's a potential problem. This is how it works, for those we know the delivery address […] We don't find any systematic data on [older products and with those] we send photographs around and fill the inboxes of each other […] Here it [installed base data] would be valuable. Now it goes like, please estimate how many [such products] there are approximately, then we make a note to [service units] with a few photographs and tell them to pay attention the next time they visit one of such. (Product Manager 2, Case C)*
>
> *[Q138] You have a code number in 2005, and then in 2006, there is different hardware behind. […] Normally this [changes within a product type] is behind the serial number. […] And of course we need the information, if we have a real problem with a module and it needs to be replaced in all customer systems then we need this information directly to know and inform the customer that there is an issue, and replace the module. (Service Product Manager 3, Case D)*

Another use for high coverage installed base data was seen in the analysis of product performance. Systematic updates of operational condition data (be it visual checks during maintenance visits or remotely measured performance indicators) could be compared against set targets for product types or specific components, as well as the frequency and cause of service visits. This was seen of interest in all the cases:

> *[Q139] The energy consumption of the equipment could be improved by having remote access to a wider pool of equipment and by monitoring and optimizing their control parameters. (Electrical Engineer, Case A)*

> *[Q140] We would like to be able to make lifecycle cost analyses. In particular it would be useful to demonstrate a difference in maintenance costs between our products and competitor products. […]Data on reclamations is collected in our quality system. We analyze the costs induced, and the root cause for the problem. But that is the only data we get, service histories are not available as systematically. (Product Manager, Case B)*

> *[Q141] Component level performance analyses would be valuable as we develop our subcontractor relationships. We'd like our suppliers to think of the end-user as their customer rather than just us. We are increasingly transferring product development and manufacturing process development responsibilities to selected suppliers. This kind of analysis at the end-user level would motivate the subcontractors. (Procurement Manager, Case B)*

> *[Q142] We have been doing [reliability] studies, where we monitor with [some local units] per product type, […] divided the product by component category and analyzed how much we get [failure reports] by component category. (Product Manager 1, Case C)*

In addition, if location and application characteristics would also be included in the data, it would enable the evaluation of context-specific performance issues and provide valuable information for further product generations. In particular, exceptionally demanding environments would be of interest for close follow-up of product performance.

> *[Q143] In terms of product diagnostics data, we'd like to make analyses by customer application: how our products are used and how they are performing. For example, have they been correctly configured? […]We need to improve our installed base records: what was the product, who was the customer, to what kind of an application is it installed, how was the test data. […] Even though we know the [customer process location] where each product is going to, we'd need information on updates made on that location. (Product Manager, Case B)*

> *[Q144] What we actually can't see in this data set, which is local data, is some descriptions on the environmental conditions where [the product] operates. For example, general climate conditions [describing] that with a 99% likelihood there is a prevailing humidity percentage of x % (Product Performance Analyst, Case C)*

> *[Q145] If we know of a [problematic] piece of equipment, it would be good to have information on the use environment. The operating country tells something, but […] has it been operated at all, or has it been operating without end. The usage information helps to understand the sizing problem [for the application] (Product Manager 1, Case C)*

> *[Q146] Another issue related to quality. It could be that a particular module has a higher failure rate in one region than in another region. It could be a temperature issue for example, if some [customer sites] are in the desert and others in areas with four seasons, you could track down causes for quality issues. (Service Customer Account Manager 3, Case D)*

At the time of the studies, in Cases B, C and D, product management used available service reports to evaluate the performance of the products. A key performance indicator for reliability was the mean time between failures (MTBF), which is initially based on an estimate for new product introductions but was updated during the product life cycle based on observations:

> *[Q147] The more we have that [installed base and service] information, the better we can estimate reliability figures, such as MTBF's. (Product Director, Case B)*

> *[Q148] Already for a longer period we have been monitoring the reliability of our volume product [in one area]. The reason for selecting this area is that [they] have the most detailed [service records]. And in particular, they have all the time had very good databases on the configurations of products in the field. We have been able to distinguish [a volume product] and even its different versions. (Product Performance Analyst, Case C)*

> *[Q149] [one important use for global installed base information] is MTBF analysis. Currently, failures can be analyzed accurately, but the reference number for analyzing the mean-times in the population is not available, e.g. a new version of products replaces an undefined number of old versions in the [customer applications]: how to know how many old products are still in use to calculate MTBFs in light of seen failures of old equipment (Product Manager 2, Case D)*

These product type-related reliability figures were used in the design of standard maintenance plans for each product type to support service resource planning (see 6.1.2) and to support sales operations (see 6.2.1):

> *[Q150] We should have an idea of how much equipment we have, or how much equipment each region has to support. That means man power*

in the local company but also here in the headquarters […] in the global service department. (Product Performance Analyst 4, Case D)

[Q151] [key installed base information is] per customer just the number of [products] installed, […] and as I said, maybe the [product version] history. I'm mostly looking at it, because we are also right now starting developing a new costing tool, so basically our people in the areas when they get a request for tender, can easily go and calculate […] the cost of the service. (Service Product Manager 1, Case D)

Further, the updates of MTBF figures could be used to evaluate the impact of the actions of product management and product development to improve product reliability:

[Q152] [one interesting area of analysis] is the reliability follow-up after product upgrades […] how upgrading a product has impacted the service frequency, has it been worthwhile. (Assistant VP of Service Quality, Case C)

In Cases C and D, operational condition data and performed service events were closely monitored, in particular, for new product installations to capture quickly potential quality issues with new product versions. This capability was also sought in Case A:

[Q153] With pilot tracking […] in those countries where we have the [remote monitoring] system in use, we can catch the data of an individual [product] monthly to identify any problems. Typically if see some actions, we can identify the service guy and call him. (Product Performance Analyst, Case C)

[Q154] Although we test each piece of equipment at the factory with running them in much harsher conditions than what the products encounter in actual use, new product launches often involve problems that are revealed only after a period of use. We would like to have such products under specific test surveillance in actual use. (R&D Engineer, Case A)

Support for service quality and performance management

In Cases C and D, the performance of productized services (i.e. service agreement types) were also seen as important to measure on a global scale, in addition to service units being financially responsible for the performance of their local service operations:

[Q155] So that's one thing [use for installed base data], other than that, we also monitor and try to influence the financial performance of our services. Obviously the responsibility to manage that is in the [local units], but we can keep an eye on that and support their questions about

> *how to deal with certain things from a financial point of view. (Service Product Manager 2, Case D)*

In particular, both case organizations saw that offering the same service concept for various products likely leads to differences in service value for the customer and profitability for the provider. Having wide coverage of service event data detailing the pieces of equipment serviced would enable an evaluation of product type-specific differences in service performance. This way, local or product-specific adjustments in the service offer could be substantiated, and it could be ensured that the service products are not underperforming or underpriced:

> *[Q156] The hardware services report pretty much on unit level, MTBF's and the repair times compared to targets. Then from a [service job] handling point in software services, we'd have even more reports based on case types, severity, how quickly we've been dealing with them, what technologies have been involved, who's fixing them, then the product lines and defects, how long we let the customer wait. There are lots of metrics that we can establish […]. (Service Director 1, Case D)*

> *[Q157] Some cases you'd need to do [comparison of service performance] technology specific, for other cases customer specific, as you need to understand whether you deliver what you promised, and how to improve on things. (Software Service Development Manager, Case D)*

In addition, general problems in product maintainability can be identified when analyzing the service performance if there are products experiencing exceptionally long service times for particular service tasks. Consequently, maintenance programs or product designs can be corrected accordingly:

> *[Q158] [another interesting area for analysis is also] maintainability and installability. Different service modules have standard performance times, [and it's interesting to analyze] how they vary: how does a service module perform with a specific product, is there an issue within a module that could be easily fixed and that has a great effect [on efficiency]. For example, the replacement of [some components of a product] were designed so that it took two engineers to replace them, and another issue was that the lifetime of [some components in a product] was too short in relation to the maintenance cycle. (Assistant VP of Service Quality, Case C)*

6.2.3 Product development

Description

Product development decisions considered here include the prioritization of development projects and choices in development paths within a single development project and, thus, refer to the following tasks identified in the product development literature (in section 3.2.2):

- Selection and justification of engineering design improvement projects
- Evaluation of performance of design solutions carried over from former products
- Relationship among test data at development stage, inspection results of production and field performance

These decisions are discussed separately for new product development and new service development. A summary of product development uses for installed base information types is given in Figure 10.

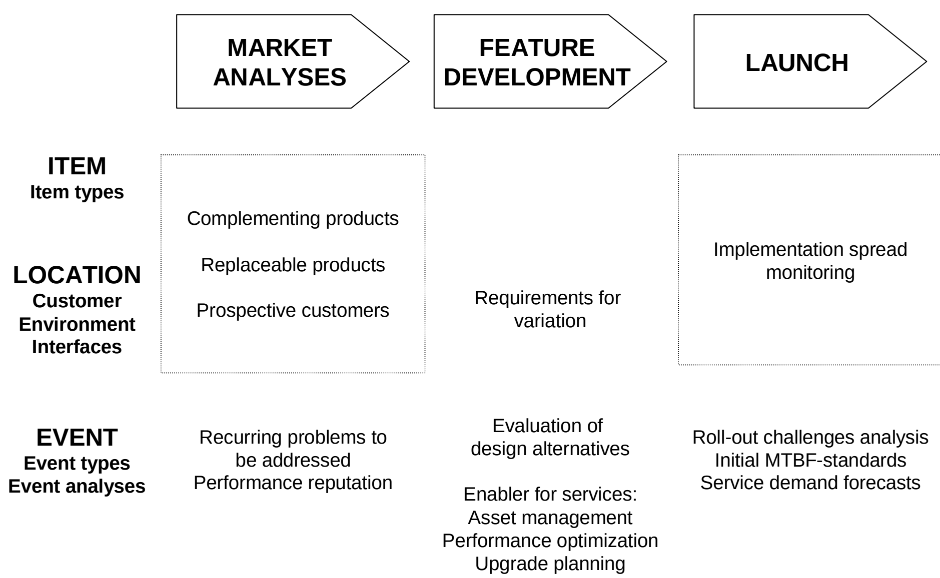

Figure 10: Installed base information uses in product development

Support for new product development

New product development's main goal is to improve the company's product offering with attractive additions that either complement or replace current products in the portfolio. In general, development project prioritization decisions are based on the resulting products' market value. In assessing the market value of the proposals, several useful analyses of information on current installed base were identified.

The existing number of complementing products or products to be replaced in the installed base gives an indication of market potential for the development suggestion:

> *[Q159] [based on current installed base data] I have made some volume estimates for upgrade potential. The extent of installed base, where this kind of a product would fit to […] and the other way around, I check that we have such and such numbers of certain product types, so that we would need specific upgrades for those. (R&D Director, Case C)*

> *[Q160] Of course it is meaningful [when developing a new product version] what is the, sort of penetration and usage rate, and of course the customer comments on the useful, they are inputs that affect the product development. And of course the comments and improvement suggestions received through different channels […] The penetration is one of these [inputs], not a critical one, but it may turn out to be the decisive piece of information, if other issues point in that direction. (Software Product Manager 1, Case D)*

Currently, the studied organizations used sales volumes to approximate the installed base of related products and extrapolations of known local installed bases but saw that it would be useful to be able to analyze also related service histories, especially to identify replacement potential. In Case D, service histories were thought useful, in particular, for analyzing initial problems with earlier versions to give indications of expected early challenges that might be detrimental to product launch and of potential market acceptance problems that must be addressed with the new product.

In assessing the goals for the development project, customer application-specific analyses were seen of high interest in Cases B, C, and D. It was suggested that analyses of the various interfaces (installation dimensions, control circuits, software) older versions of products are used with and the various environmental conditions that the older versions endure would be useful for supporting the decisions on technology selections. These both indicate the potential in new product replacements and improve understanding of the possible variants needed in production:

> *[Q161] Typically with more demanding applications, around the world similar products are used with varying parameters. In some applications they work fine, in some others not so well. It would be interesting to find out common and divergent factors, where they have worked and where for example […] another kind of product has been employed. […] With warranty reclamations we have a direct contact, we can find out about the process the product is used in, are [different requirements more strict] than was known during the process planning phase. (Engineering Manager, Case B)*

> *[Q162] The process medium and operating temperature are the first things of interest, […] how the product is operated in the customer*

> *process, […]Is the location near the shore, as also the external environment may impact the requirements, such as protection for sand or fire or maritime climate. For example, in Norway some bolts won't work at all. (Engineering Manager, Case B)*
>
> *[Q163] We'd need to be able to analyze […] as processes change, how do our products do in new processes, how does product development need to address that. (Product Director, Case B)*
>
> *[Q164] [Global installed base data would be interesting] regarding the product portfolio. It's kind of, if we had a better understanding of all the [complete and running] systems, on what kinds of [products and software] components should we package. (Software Product Manager 1, Case D)*
>
> *[Q165] Of course we are interested in what products each customer has. The needs of the most important customers are in particular monitored. (Product Performance Analyst 2, Case D)*

In addition, interviewees in all cases identified that being able to analyze service events for related products would provide information on poor performance issues that must be addressed in the development project. Such findings would support decisions on materials, suppliers, and design for new products:

> *[Q166] Information on unreliable components is essential. For example, if a specific [component type] has experienced a number of failures, we may change not only that one [component type], but also the supplier. (R&D Engineer, Case A)*
>
> *[Q167] If we'd be able to analyze that a certain material isn't suitable for, say, applications in contact with seawater, that would definitely be noted in new designs (Procurement Manager, Case B)*
>
> *[Q168] If the same problem or service request repeats with a product, this should give an impulse to develop the robustness [of the product]. Of course, everything wears out, but if somewhere something wears out faster, one should think about the causes for this. (Engineering Manager, Case B)*
>
> *[Q169] With a comparison of spare-parts consumption and the installed base, we could identify weak spots in the products, that need to be made better or developed in another direction. (R&D Manager, Case B)*

This was particularly emphasized, as it was seen that reliability and maintainability issues would impact the service profitability because of the performance-oriented contracts used with customers. With the availability or uptime promises of such contracts, the service provider carries all costs of poor design:

> *[Q170] It is essential to be aware of the benefits [of installed base information] in product development, although they are indirect. It is also in the interest of the [local sales and service units] to improve the product quality, as it is their customer relationships that are at stake. We need to understand the needs for product lifetime information in the whole chain, as it impacts the service business for several decades. (Assistant VP of Service Quality, Case C)*

Product reliability and maintainability were also seen as important brand issues without extensive service business as Case A demonstrates:

> *[Q171] Although the supportability and maintainability of equipment is not directly affecting us, as we do not have extensive after-sales services, many customers are relying on recommendations of their service providers. Thus, a reputation of poor serviceability may hurt our new product sales. (After-Sales Manager, Case A)*

> *[Q172] Maintenance is a key question for the customers, and maintainability a prerequisite for extensive sales. It is a guarantee of trouble-free operations. […] Currently only the biggest problems reach us through the service partner network. We should be able to make comprehensive analyses of our products. […] The service partner network is troublesome in the sense that if they perform poorly in [preventive] maintenance, we get blamed for bad products. After all, it is our name that stands on the faulty equipment. (Sales Manager 1, Case A)*

Finally, by improving the performance data for installed equipment, data for related products of a new design could be used to estimate initial new product MTBF's better. These, in turn, are required to plan maintenance and to forecast the number of service resources required for pilot implementations:

> *[Q173] If we had the [global] installed base to provide us scale, we could […] compare different product releases and the workloads they create [in services]. This would help us plan our resources better, as we'd know what kind of challenges different kinds of releases have previously produced. (Service Business Development Manager 2, Case D)*

> *[Q174] One of the problems we've had is the time delay from installation to the installed base. […] especially in the early phase of deploying a new product, the installed base was poorly supporting mtbf*

calculation and that was really a problem, because in the early phase the mtbf's are most interesting. (Product Performance Analyst 3, Case D)

Support for new service development

The main goal of new service development is to improve the service offering of the company with attractive additions that complement and support current products and services in the portfolio. As for new products, development project prioritization decisions are based on the market value of the resulting services.

Using the distinction of Mathieu (2001) and Oliva and Kallenberg (2003), services can be roughly divided into services supporting the product and services supporting the customer.

As with designing new products, in devising new services supporting the products, it is useful to identify the number of equipment that a new service concept might target to assess market potential (Cases C and D). Whereas this can be done based on sales volumes of products, if the installed base information also includes information on the customer applications (e.g. environments), more specific service concepts can be designed for valuable niche customers. In addition, there is always the question of how many delivered products are still in use:

> *[Q175] It's really what technology the customer has. So we can look what kind of market potential there is. If we know there's this kind of equipment and we cannot offer a service to that kind of equipment, then we can say there is a gap and we cannot offer this service today. But if we have the accurate information about the installed base it would be easier to say, why don't you buy this service from us. But I think it all boils down to the same: we need to know the technologies installed. (Product Manager 1, Case D)*

> *[Q176] Once support for ramped-down products expires, the customer can buy an extended service period […] we need installed base analyses for market potential analyses with all [products'] life-cycle phase changes. (Product Manager 2, Case D)*

Comprehensive service event records would provide a valuable source of design support for new services (Cases B, C, and D), for example, identifying frequent service events that could be served with a productized service concept (e.g. an increase of product failures at a certain product age—proactive replacement services):

> *[Q177] For the purposes of developing the service business it would be good to analyze what kinds of service needs there are, so that you can sell those kinds of services also to others. Somebody performs the service*

> *jobs anyhow; one just needs to be able to identify what kinds of jobs are frequently done. (Quality Manager, Case B)*

> *[Q178] If we'd know better how our products behave by product type or even by production version in different operating environments […] [Reliability analyses] would improve with data on usage […], numbers of unplanned service visits, customer segments […], applications with regional differences. It would surely support the development of maintenance service processes and designing customer or application specific service modules. (Assistant VP of Service Quality, Case C)*

With newly developed services, service events could also be analyzed for the resource needs of similar services to assess cost of delivery for the proposed service (Case D):

> *[Q179] When we start the service development, […] of course to build the business case, you would need this kind of business information to see the potential, say if we have x percent penetration, then the volumes would be like this. That's kind of along the line, and of course for the business case you would need to know how much resources are needed. On that kind of level you would need that [capacity planning based on service records], but that would be a more global point-of-view than just us in the region. (Service Product Manager 2, Case D)*

Development of services supporting the customer (Mathieu 2001) also benefits from having visibility to the installed base of the customer. For some service developments, installed base information is a requirement for the service concept. Asset management services require a varying level of detail in installed base item information ranging from number of items for financial purposes (Case D) to performance records required by legislation (Cases A and C). In addition, spare-part management as a stand-alone service supports the customer by ensuring materials availability for the in-house maintenance process (Cases B and D). Customer process optimization and process bottleneck identification services require detailed information on the operational performance of different items in the customer process (Cases B and D). Extension or upgrade planning services require detailed information on compatibilities and interactions of current installed base items and their replacements or additions (Case D). Performance optimization and extension planning are currently performed by gathering relevant data as separate projects in the case organizations. Having up-to-date records on the installed base were seen to ease both the identification of such service opportunities as well as the execution of the audits required for the services.

Information on using the installed items is relevant for new service pricing scenarios that align the customer and service provider interests similar to "power-by-the-hour" or results-oriented service contracts (Baines et al. 2007):

> *[Q180] The future model would be that we have insurance based service contracts […]. The pricing model for that will be in close*

> *relation to the basic software licensing models […] you have a piece of basic support fee you have to pay, then you have in addition a fee according to the number of [products], and you have a third block which is related to the [capacity usage] that may be implied by […] the pieces of software functionality you have there. Based on that you would fix that in [service] contract and your revenues would go automatically with the success of the customer, meaning the success of the use of the features and [capacity]. So, of course you can ask the customer [about the capacity use], but better would be that the system would tell. Or, what is the actual status. That would make the agreement and relationship with customer also easier. (Product Manager 3, Case D)*

6.3 Description of installed base information

This subchapter summarizes the installed base information types that have been requested for the various tasks in the studied cases. Hence, whereas the previous chapter focused on individual tasks and their needs for installed base information, the current interest is in distinct pieces of information, their associations, and their main uses as portrayed in the studied cases. The aim is to provide a succinct overview of the installed base information as requested by the interviewees, and hence, tables are the prime presentational tool used in this section.

The analysis of the case studies revealed three major categories for installed base information:

- information related to products of interest (installed or serviced by the company)
- information related to the service actions of the company
- information related to the customer site or process phase that is the target of product deliveries and service operations

For the purposes of discussion in this thesis, in the following sections, these categories are called installed base Item Data, Event Data, and Location Data, respectively.

From the customer's viewpoint, the installed base locations are, in a sense, the key interest—uninterrupted operation and output of expected quality at each location is the main concern (e.g. de Groote 1995; Ljungberg 1998; Jeong and Phillips 2001; Bamber *et al.* 2003; Smith 2007). The exact products in operation and details of services performed at the locations are indifferent to the customer, as long as the expected output of the location is secured, and expected costs are not exceeded. Depending on their mutual contract, the product-service provider might have great freedom in deciding which products and services to use for each customer location (Martin 1997; Baines et al. 2007). To optimize its service delivery processes, the product-service supplier must have particular information about each of the locations, which is independent of current items and services in use there. Such location-specific information is also important when comparing the performance of products across customer applications to improve the competitiveness of new product and service offers.

Although less significant for the customers' primary interests, the product-service provider also wants to measure the products and services it has delivered, both to understand its cost structure and to maintain and improve its delivery performance and competitiveness. This motivates the recording of Item details at the customer locations and Events that have involved those items and locations. The relationships among the three data categories are illustrated in Figure 11 below.

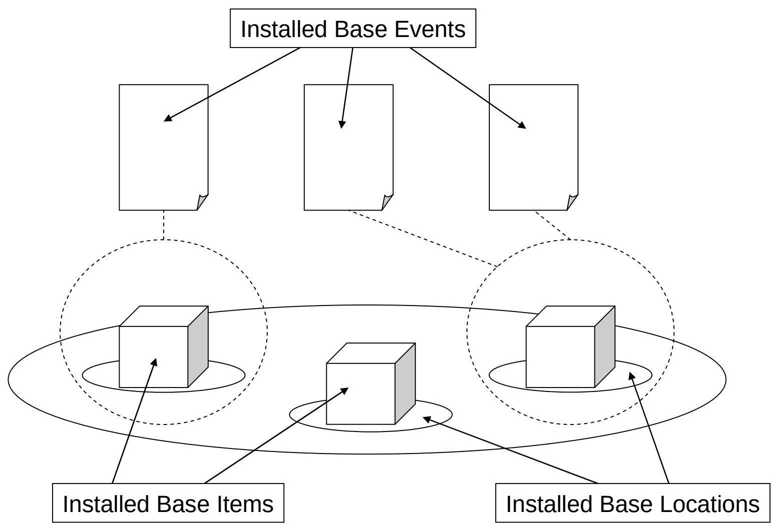

Figure 11: Illustration of Installed Base Items, Locations, and Events

In practice, the installed base item data and installed base location data might be handled as one record, depending on the utility of being later able to discern among different items occupying a location. The one of these two of more interest varied among the studied cases.

- In Cases A and C, the item was clearly of primary interest, with the location data only telling the whereabouts of the item. At the time of the respective studies, the way of conceptualizing installed base data in these companies was based on items that had location data as their attributes.
- In Cases B and D, the opposite was true. The customer process location was of primary interest, with the item(s) only providing requested functionality and capacity for the customer business process. The items were considered readily changeable in cases of problems or changed customer needs. At the time of the respective studies, the way of conceptualizing installed base data in these companies was based on locations having items listed as their attributes:

> *[Q181] The [process location identifier] does in general not change. If there is a need for a new device, a new [identifier] is created. This way, we don't mess up with all the old information with the old [identifiers].*

> *At each [location identifier], there is a device or a device combination, which is identified by its serial number. […] Service operations are always connected with a [location identifier] and not with a product serial number. Service histories and customer services are all built on the [process location identifiers]. (Service Manager, Case B)*

This reflects the differing role of the case company products in their customers' operations. The two suppliers of system components were understandably more interested in the functions their products provide to the encompassing customer process, whereas the stand-alone product suppliers would not need to do so.

Another consideration for information management arises from the fact that information on the installed base might be incomplete, not necessarily because of inadequate recording practices, but because of the business context of the company: 1) If products are also sold without installation services (Cases A, B and D), there might be numbers of items whose location data is not known. 2) If products are also serviced by customers or competitors (all cases), no event data can be obtained. 3) If after-sales services are provided for third party products (Cases C and D), there might be numbers of items whose detailed item data (e.g. manufacturer, BOM, age) are not known unless specifically audited for the purpose (Figure 12).

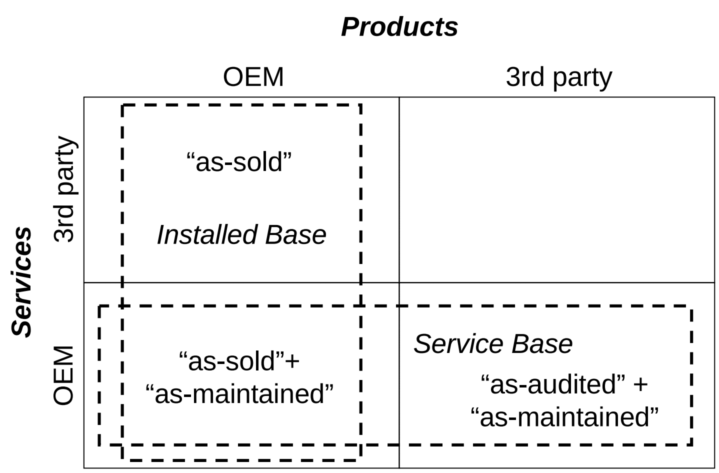

Figure 12: Availability of information for different product-service configurations

As described earlier, there are good reasons for uniform handling of the different types of information—for both service operations and decision support, it is useful to have similar access to information concerning own products whether in own or third party service and concerning third party products in own service. Moreover, with time, items and locations might shift from one category to another, which should not mean any complications for information management. For example, products sold through middlemen without installation services might show up later in maintenance contracts. However, such high incompleteness of data can be problematic for information systems. Parsons and Wand (2000) discuss this issue in detail and provide tentative solutions for handling data structures and analyses of data classes in such circumstances.

The aim of the discussion to follow is to elaborate on the conceptual differences between these data categories and present the observed information types related to each category in a concise format. The implementation of systems for gathering, storing, and processing data in each category depends on contextual issues not elaborated in detail within the scope of this study. Hence, the following tables resemble the *design exemplars* discussed by van Aken (2004) because they need to be adapted for particular purposes. In addition, to be sure, the following is not intended to suggest a need for using a single information system for the operations in all subunits. Rather, the message of this categorization and data type summary is that the different data types should be uniformly accessible through standardized and unambiguous identifiers for Items, Locations, and Events, independent of the system where individual pieces of information related to each of these categories are stored. Further, a level of standardization within each data type is required (e.g. how the bill-of-materials is represented for the Items, how the operating environment is coded for the Locations, or how root causes for Events are described). In practice, for a specific business context, each of these requires a purposeful balancing between the level of detail needed for the relevant analyses and the feasibility of gathering detailed data.

6.3.1 Installed base item data

Installed Base Item Data describes an item in the installed base. If an item is replaced, this information is no longer relevant for the customer process location. If the item is transferred to another process location, this information should still be available for that item, despite its new location.

The data concerning the installed base items can be subdivided into two subcategories:

- Item Properties: data that describes the item as an artifact
- Item Status: data describing the item’s capability to perform its intended function

The Item Data elements identified in the cases are listed in Table 9. The recorded Item Properties might get changed through interventions by the owner or a service provider. The changes can be captured by recording the Events in a consistent manner or by monitoring activities (remote or local checks). The Item Status is changed because of tear and wear, and the changes must be captured through remote monitoring or in-person inspection activities.

Table 9: Installed Base Item Data

Item Data	**Key: Unique Item ID**	
Item Properties (current)	**Description**	**Main purposes**
Original equipment manufacturer	Indicates the manufacturer of the item (i.e. competitor or other third party):	Service resource management: spare-part sourcing (e.g. [Q79]) Service resource management: maintenance outsourcing ([Q117])
Manufacturing date	Indicates age of the item/production batch of the item	Service operations management: spare-part compatibility ([Q77]) Service resource management: field engineer skill requirements ([Q43])
Item classifications	Item classes indicating - product family and version	Sales: leads for new product versions ([Q89]) Sales: service level adjustment based on product versions ([Q112]) Sales: service cost analyses for tendering ([Q113]) Product management: product analyses, e.g. MTBF calculations ([Q149]) Product development: product market analyses ([Q159])
	- technologies used	Service operations management: field engineer skill requirements ([Q43])
	- sales item	Service resource management: substitute for BOM with spare-part compatibility analysis ([Q73])
	- capacity for customer process	Sales: additional sales potential ([Q95])
Bill-of-materials	Hierarchical item composition indicating last known configuration; each part or compound can be identified with: - sales item code - serial number (sales item + serial no.) - a reference to another Installed Base Item - compatible spare parts or replaceable units (spare-part SKU)	Service operations management: ensuring necessary component for a service visit ([Q16]) Service resource management: spare-parts inventory planning ([Q67]) Product management: Callback or defect rectification analyses—which items exactly involved ([Q135])
Warranty	The coverage and period of manufacturer warranty for the item	Product management: claim handling ([Q122]) Service operations management: eligibility of customer requests ([Q28])
Maintenance plan	Reference to preventive maintenance tasks - item class specific plan - explicitly agreed with customer based on the item location criticality	Service operations management: planned maintenance scheduling ([Q9]) Service operations management: planned maintenance materials ([Q68]) Service resource management: basic load estimates ([Q39])

Item Data cont.		
Item Status (cumulative)	**Description**	**Main purposes**
Time stamp	Indicates when the recorded status data has been confirmed	Status history aggregation Assessment of status data currency
Cumulative usage	Indicates the mileage of the item, e.g. hours in operation, distance traveled	Service operations management: planned maintenance scheduling ([Q9]) Product management: product quality analyses ([Q145])
Operational condition	Conformance to performance norms	Product management: Follow-up of new product installations ([Q153]) Service operations management: Follow-up of repairs and changes ([Q152]) Service operations management: Trend analyses for impending failure detection ([Q31]) Product management: product quality analyses ([Q143])
Physical condition	Conformance to visual norms	Sales leads for upgrade sales ([Q91])
Reference data (current)	**Description**	**Main purposes**
Customer process id	Reference to the data entry for the customer location that the item occupies	Connect item and location data

The data type "item classifications" deserves additional attention. When recording data on individual items, their membership in different classes becomes a key issue in making aggregate analyses on the items. Whereas each produced item typically belongs to a product class characterized by its product code or sales code, this does not always lead to desired results when used for aggregate analyses:

- Service units and service resource planning: For assessing the field engineer's ability to handle a specific case, the product code needs to be converted to specify what specific technologies are used with that code (Case C).
- Product management: For analyses of prior design decisions, aggregation of data by the product codes is not necessarily helpful, as there might have been minor design changes that did not require updates in the product code. Hence, using the product code to aggregate performance data, it cannot be determined whether such changes have made a difference in product performance or suitability for various environments (Case B).
- Product development: Customized one-of-a-kind items might have no direct parent product design that they would be instances of, but rather, they share features of several products. In such a case, the classification becomes problematic, as the relevant product code differs depending on the feature analyzed (Case B).

In Case D, the products involve a strong software component that determines much of the equipment performance and features for the customer. Whereas the software items can be remotely "repaired" and replaced, their treatment as part of installed base information was not seen to differ from other bill-of-material items in item data.

6.3.2 Installed base location data

Installed base location data describes the context of an installed base item. If an item is replaced, this information does not change, but should be associated with the new item. Alternatively, if an item is transferred to another location, this information no longer applies to that item. Instead, the information related to the new location should be associated with the item.

The Location Data elements are listed in Table 10. The product-service provider has no direct influence on the installed base location data, as the customer changes it only through major rearrangements. Field personnel capture such changes through communication with the customer or observations.

Table 10: Installed Base Location Data

Location Data	**Key: Unique Customer Process ID**	
Location Property Data	**Description**	**Main purposes**
Owner	Customer reference for item sales	Identification of all locations and items owned by a customer
User	Customer reference for service sales (might differ from above)	Identification of the user of the products
Application	A description of the purpose of use at the customer	Analysis of product performance in different customer contexts ([Q143]) Product management: follow-up on performance of exceptional installations ([Q108])
Physical location	Information on the location's whereabouts - Site street address - Site GPS coordinates - Position at the customer site	Service operations management: routing of field engineers ([Q39]) Service resource management: inventory location optimization ([Q67])
Accessibility	Information for field service access: - when access (office hours/weekends), - how access (persons needed to contact, keys needed, specific tools/lifting equipment needed, certificates needed)	Service operations management: scheduling of visits and preparing necessary tools ([Q23]) Service operations management: identifying certification needs ([Q19])

Location Data continued…		
Location Property Data	**Description**	**Main purposes**
Environment	Environmental characteristics with potential impact on items, e.g. - temperature - corrosion factors	Technical support: evaluating potential problems because of operating environment ([Q126]) Product management: attributing product failures to environmental conditions ([Q146]) Product development: environmental challenges for new products ([Q162]) Sales: Upgrade sales leads based on changed conditions ([Q96]) Sales: identification of reference cases for exceptional environments ([Q104]) Sales: evaluation of environment for service offers ([Q110])
Interfaces	Compatibility information that cannot be derived from item characteristics: e.g. - power supply available - available physical dimensions - software platforms to connect to	Technical support: evaluating potential problems because of incompatibility issues ([Q30]) Sales: upgrade and extension compatibility analyses by reviewing interfaces in the customer system ([Q101]) Product development: interfaces to comply with for new products ([Q161])
Criticality	Classification of consequences of item failure at location	Service operations management: service level requirements ([Q84])
Reference data		
Unique Item ID(s)	The item(s) occupying the customer site or process phase	Connect location and item data
Installation date(s)	The date of installation for each item	Assessment of data currency Enable comparative analyses with prior items in the location ([Q152])
Service contract(s)	Contracts to refer to for getting details on agreed services and criticality	Link locations to service contracts

6.3.3 Installed base event data

The logical structure given here for installed base event data aims to describe the common contents of service events of interest for subsequent analyses in different business functions. The main point of this representation is that all types of events should be accessible with the same search keys (e.g. by item concerned, performer, period, etc.) to enable comprehensive and efficient performance analyses.

The key elements of Event Data are provided in Table 11. The specific event types need not be processed in a single system. That is, the transactions related to new installations, customer claims, and field service events can each be handled in their own workflow systems, but these characteristics should be available through a single interface for easy analysis.

Table 11: Installed Base Event Data

Event Data	***Key: Unique Event ID***	
Event Property Data	**Description and Examples**	**Main Purposes**
Event classification	Indicates what the event is about - A new installation - A customer claim - A scheduled maintenance operation - A scheduled repair or replacement - An unplanned problem - An upgrade or extension - A customer support request - A remotely monitored intervention	Categorization of event types for problem solving support ([Q132]) Product management: Cost analyses by service type ([Q156]) Product development: analysis of frequencies of event types to identify new service product needs ([Q178]) Sales: service contract cost analyses, proof of service delivery ([Q115]) Technical support: overview of problem item history ([Q26])
Time Stamps	Identifies the time of the event - initiation time - processing phase times - completion time	Service resource management: Field engineer planning ([Q158]) Product management: quality cost analyses ([Q157])
Event performer(s)	Identifies people responsible for handling the event	Field Engineers and Technical support: Requests for assistance with similar prior cases ([Q25]) Product management: Requests for details on remotely identified problems ([Q153]) Service resource management: Field engineer skill and improvement analysis ([Q156])
Event Costing Data	**Description**	
Personnel time usage	Indication of man-hours allocated for the event	Service operations management: Costing
Mileage	Indication of travel expenses to be compensated for the event	Service operations management: Costing Service resource management: Routing of field engineers ([Q37])
Material usage	Indication of spare parts and materials consumed by the event	Service operations management: Costing Service resource management: spare-part consumption based inventory decisions ([Q70]) Service resource management: monitoring of spare-part consumption of third party items ([Q79])

Event Data continued…		
Event Analysis Data	**Description**	
Installed base item changes	Identifies changes made in installed base item data during this event and updates Installed Base Item data	Product management: Replacement analyses for claim and quality management ([Q123])
Event reason	Root cause for the event's occurrence informing how to potentially avoid event in the future, e.g. - schedule - product defect (detail) - installation defect (detail) - operational maltreatment (detail)	Sales: Product and service upgrade sales leads based on improvement of specific problems ([Q156]) Product management: Quality problem analyses ([Q127])
Reference Data	**Description**	
Customer process reference id	Identifies the installed base location involved with the event	Connects location details and involved customers with each event
Unique item id(s) involved	Identifies the item(s) occupying the installed base location at the time of the event	Connects the involved items with each event
Service contract	Identifies the customer contract (if any) according to which the event was performed	Connects the relevant service contract with each event Service performance analyses ([Q155]) Customer / contract profitability analyses ([Q157])

As a summary of the induced installed base information classes, a comparison with similar categorizations in prior literature is in place.

Borchers and Karandikar (2006) list product attributes of interest for a manufacturer interested in its installed base—owner company information, technical configuration with serial numbers of main parts, site and location, application with environment and importance, associated service contracts, and service actions performed. Their list includes important information types recognized during this research as well, but they do not provide structure for the data categories or any analysis for the uses of individual pieces of information.

Tsang et al. (2006) suggest a data model that incorporates Installation data, Condition data, Failure/replacement data, and Maintenance action data. Their model of the maintenance data is aimed to support and optimize condition-based monitoring, whereas the data model presented in this thesis covers a larger variety of data uses. Nevertheless, requirements for the same data were identified during this research also, and the first two items of (Tsang et al. 2006) are included in Item Data and the last two in Event Data in the model presented here.

There is also a relevant international standard (SFS-EN 13460:2002 Maintenance. Documents for maintenance) that details comprehensively various document types that might be of use during the maintenance phase of equipment. Interestingly, however, although the list of documents also contains documents of “equipment basic data” (A.2) and “item history record of maintenance operations” (A.3) similar to the identified Item data and Event data in this study, no purposive uses for these two documents are given. As such, the standard serves as an informative checklist of documentation that a maintenance organization should consider relevant for its operations, but the standard does not make prescriptions about how to use the above documentation to support operations’ efficiency or effectiveness.

Using the terminology of the design propositions with CIMO-logic (Denyer et al. 2008), the standards describe to some extent how the “Intervention type” of installed base information should be formed, but they do not consider the desired outcomes, nor the use mechanisms that lead to such outcomes. Further, there is no discussion on the effect of the use context on the usefulness of the information.

7 RESULTS AND DISCUSSION

This chapter summarizes and elaborates the cross-case analyses and formulates design propositions for further validation and field testing (Denyer et al. 2008; Holmström et al., 2009). The notation of the CIMO-logic (cf. section 4.1) is used to present the knowledge generated during the research: 'in this class of problematic Contexts, use this Intervention type to invoke these generative Mechanism(s), to deliver these Outcome(s)' (Denyer et al. 2008, pp. 395–396). Hence, the formulated design propositions specify the 'Context' of use, and inform how systematic installed base information (the 'Intervention type') can be used in analyses and decisions (the 'generative Mechanisms') to achieve desired operational performance (the 'Outcomes').

The first section concentrates on building the core design propositions based on both available literature and the empirical findings of the case studies. Although each of the CIMO aspects is covered in forming the propositions, the focus is on the 'Mechanisms' and 'Outcomes.' The second section discusses the 'Intervention type' of systematic installed base information in more detail and summarizes the general types of mechanisms that rely on the information. The third section elaborates the characteristics of different contexts influencing the effectiveness of the design propositions, with Organizational Information Processing Theory as the analytical framework.

As such, the two first sections describe the resulting propositions from the exploration through designs (Simon 1973a), whereas the third section discusses the theoretical explanation for the effectiveness of these propositions (Bunge 1967) and suggests limitations to their effects in different contexts (Holmström et al. 2009).

7.1 Installed base information uses

In the following, grounding on the case analyses, general design propositions are formulated on the mechanisms through which the intervention of using *systematic installed base information management* is proposed to lead to desired outcomes. The term "systematic installed base information management" refers to organizing the installed base data in such a way that it is accessible and analyzable for the person performing the decision. In particular, the underlying logic to achieve systematic installed base information management concerns having unique identifiers for items, locations, and events to access and combine data from different sources (see descriptions in section 6.3). It is important to note that the design propositions refer to enablers for the desired outcomes, because outcomes cannot be suggested to result causally from information availability (Markus and Robey 1988). One also needs to use the information in decisions to get any true effect on performance, and with information systems, other factors such as system architecture and usability also influence the usefulness of the information (DeLone and McLean 1992, 2003). Further, as this study has been exploring the range of information uses through qualitative research, the evaluation of the propositions is left for further research, as will be discussed in the final chapter of this work. With these cautions in mind, the propositions give structured statements on how installed base information is linked to different types of business benefits.

To reconstruct the underlying inductive logic leading to the general propositions as carefully and transparently as possible (Eisenhardt 1989), stepwise aggregations of particular research findings leading to the eight design propositions are presented. First, supported by the literature review, an *assumption* of the key decision impacting the performance of operations is formulated for each proposition. Second, individual observations from the cross-case analyses are summarized in *induced technological rules* (Bunge 1967; Niiniluoto 1993; van Aken 2004). Here, the definition of technological rule by van Aken (2004) is particularly purposeful: 'a chunk of general knowledge, linking an intervention or artifact with a desired outcome or performance in a certain field of application.' Each technological rule is justified by references to interview quotations. The references are given to highlight case evidence used to induce the rules and to indicate the section in cross-case analysis where relevant discussion for the rules can be found.

The induced rules, or "chunks of knowledge," are then synthesized as more general *design propositions*, which follow the CIMO-logic detailing the context, where an intervention is proposed to enable specific generative mechanisms leading to desired outcomes (Denyer et al. 2008). This logic is reconstructed explicitly with the first design proposition, but the remaining design propositions are constructed identically.

Based on the case studies, the main uses of installed base information fall into three categories: support for service deliveries, support for service resource planning, and support for decision making based on aggregate installed base information.

Support for service deliveries

The main uses of installed base information with service deliveries relate to the general goals of ensuring service quality and service delivery efficiency.

Whereas field service quality can be analyzed along several dimensions, one main quality expectation is that the field engineer solves the customer problem he was allocated to address (e.g. Hill 1992; Haugen and Hill 1999; Papadopoulos 1996). Some reasons for service failure can be reduced by carefully considering the prerequisites for a successful job completion in the particular customer context—the spare parts and tools likely to be needed if a site visit is necessary (Kilpi and Vepsäläinen 2004; Wong et al. 2005; Cohen et al. 2006) and the skills the field engineer should possess with the expected problem and involved equipment (Blumberg 1994; Blakeley et al. 2003; Voudouris et al. 2006).

Based on the previous contributions (e.g. above and Collins and Sisley 1994; Lesaint et al. 2000; Agnihothri and Mishra 2004; Lin and Ambler 2005) and the case studies, an assumption is made that matching service jobs and service resources is critical for the service quality concerning first visit resolution:

Assumption 1: If you want to achieve a high first-visit-resolution percentage with service jobs, ensure the identification of the likely service job contents and a match between the expected job and allocated engineer and materials.

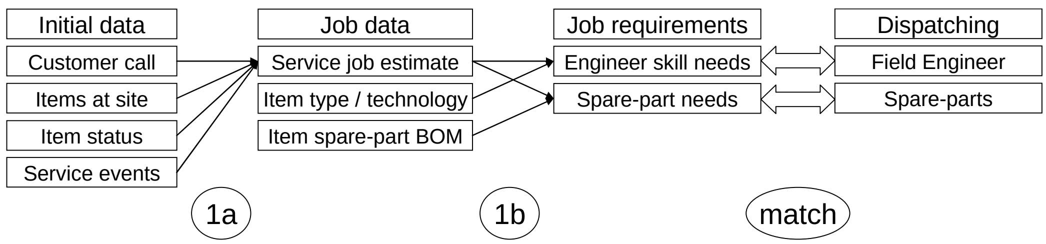

Figure 13: Propositions of installed base information impact on dispatching quality

Both the analysis of service job contents and the analysis of potentially suitable field engineers and materials can be supported by installed base information management (e.g. [Q10] … [Q12], [Q14] … [Q19]), illustration in Figure 13:

Induced rule 1a: If you want to identify likely service job contents effectively, maintain records of items per customer site, item status information, and item service histories to narrow down probable causes for the job request.

Induced rule 1b: If you want to ensure a match between service job requirements and allocated engineers and materials, maintain records of installed items per customer sites and engineer skill and spare-part related information on each installed item to assess skill and spare-part needs.

The above induced rules can be broken down to explicitly demonstrate the connection with the idea of the CIMO-logic (Denyer et al. 2008). Taking rule 1a as an example, in the 'Context' of field service operations, the effective identification of likely job contents is one desired 'Outcome.' Maintaining records of items per customer site, item status information, and item service histories are the 'Intervention' required to enable the generative 'Mechanism' of narrowing down the probable causes for the job request.

The induced rules are particularly meaningful in contexts where there is such a variety in installed base items that skill specialization is needed, and the possibility to use only a preferred engineer for each site is limited. Additionally, the rule 1b is significant in situations where the variety, size, or value of spare parts prohibits a complete spare-part set in a field engineer's inventory. As an example illustrating these situational factors, in Case A, the variability in the installed base items serviced by a service partner could be so low that all the field engineers were practically equally capable of handling a service call, rendering rule 1a indifferent for such service units. However, even such service units were told they needed job-specific information on the spare parts (e.g. [Q64]), indicating that rule 1b would apply.

These technical rules can be further summarized as a general proposition:

Design Proposition 1: In field service operations, maintain systematic installed base information to support the identification of prerequisites for successful service deliveries to achieve high field service quality.

Again, the CIMO-logic of design propositions (Denyer et al. 2008) can be identified in formulating the above proposition. In the 'Context' of field service operations, one desired 'Outcome' is high field service quality, as described in Assumption 1 derived from the empirical cases and the reviewed literature. To achieve this outcome, it is proposed that maintaining systematic installed base information is an 'Intervention type' that supports the 'Mechanism' of identifying prerequisites for successful service deliveries.

In addition to service quality, service efficiency improves if the service organization is capable of completing successfully more service visits per time unit (e.g. Smith 1979; Klimberg and van Bennekom 1997). Thus, the efficiency improves as unsuccessful visits are reduced (see above) and as the service throughput time is reduced (e.g. Haugen and Hill 1999; Papadopoulos 1996; Lesaint et al. 2000). Process performance improvement with streamlining the subsequent phases of the process is considered one main thesis of operations management (e.g. Goldratt and Cox 1984; Schmenner and Swink 1998). Thus, the following assumption on the goal of service efficiency is made:

Assumption 2: If you want to minimize service task processing times, ensure unproblematic workflow of the service tasks.

Installed base information can be seen to have an impact on the processing times of several service process phases (Figure 14). Installed base information can be used to reduce the service throughput time by speeding up the identification of customer importance (e.g. [Q20]), customer equipment (e.g. [Q13], [Q15]) by helping to form an initial hypothesis of necessary operations (e.g. [Q12], [Q14], [Q22], [Q24], [Q26] … [Q28], [Q31]), by optimizing the traveling routes of the field engineers based on equipment locations (e.g. [Q18]), by informing the engineers on accessing the equipment (e.g. [Q19], [Q23]), and by giving technical information or references to other experienced field engineers to make the solving of encountered problems faster (e.g. [Q25], [Q29], [Q32] … [Q34]). These identified performance and data linkages can be summarized as the following rules:

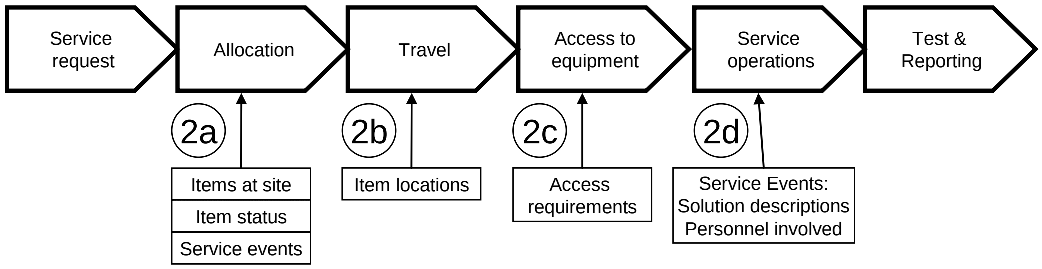

Figure 14: Installed base information impact on service delivery process

Induced rule 2a: If you want to minimize the time of service target and probable job cause identification, maintain records of items per customer site and item service histories, invest in remote monitoring technologies, and use them to analyze the customer situation.

Induced rule 2b: If you want to minimize engineer time spent in traveling, maintain records of items per customer site and site locations and use them to optimize field engineer routes.

Induced rule 2c: If you want to minimize engineer time spent with reaching the service target, maintain information on site access requirements and use that to ensure the dispatched engineer is able to access the equipment.

Induced rule 2d: If you want to minimize the time spent with finding support for challenging service jobs, maintain service records with information on job contents and involved engineers and use them to identify likely experts on the job.

The first three induced rules (2a–2c) are meaningful in contexts where the possibility to use only a dedicated engineer for each site is limited, and therefore, there exists a dispatching process that can be made more efficient. As a counterexample, in Cases B and C, some customer sites had field engineers that only serviced that single location. Rule 2d, concerning support identification, can be considered consequential in situations where several engineers are involved with similar service jobs or equipment. These rules can be further summarized as a general proposition:

Design Proposition 2: In field service operations, maintain systematic installed base information to improve and expedite decisions in the service delivery process to achieve high service efficiency.

Hence, installed base information can be seen to have a relevant role in ensuring both high effectiveness and efficiency of service operations by enabling timely and successful decisions in field engineer dispatching.

Support for service resource planning

In the case studies, there was evidence that installed base information can be used in service capacity planning to optimize the investments in field engineers and spare-parts inventory.

As can be summarized from the literature concerning field engineer aggregate planning, there is a dual aim of minimizing costs of field service engineers (e.g. Klimberg and van Bennekom 1997), while avoiding poor service quality because of insufficient training (e.g. Pinker and Shumsky 2000) or over-use and exhaustion of the engineers (e.g. Homer 1999). Hence, the following goal assumption on productivity is formulated:

Assumption 3: If you want to maximize field personnel productivity, maintain a match between available engineers and expected service demand in each area by skill type.

Installed base information can be used to make estimates on the service demand by analyzing the frequency of occurrence and duration of events for each product type (e.g. [Q37], [Q38], [Q53], [Q54], [Q58]):

Induced rule 3a: If you want to forecast service demand accurately, maintain records of item types at customer sites, site locations, service events, and service contracts for the items and use them as raw data for estimating expected service tasks during the forecast period.

If the service loads per engineer vary greatly in geographical areas (e.g. because of changes in engineer numbers or items in service), or there are infrequent occurrences of specialized resource needs, installed base information can be used to analyze different scenarios of new service area definitions or service resource centralization (e.g. [Q48] … [Q57]).

Induced rule 3b: If you want to balance service load among service areas, maintain equipment type and location data, and use it to make shifts of serviced item or service task responsibilities among areas at the same or different levels in the hierarchy and reassess service demand for involved areas.

In making field engineer training need estimates, the local installed base that the engineers are supporting was seen as a central decision criteria (e.g. [Q38], [Q40], [Q44], [Q52]).

Induced rule 3c: If you want to analyze training needs, maintain records of item types at customer sites, and use them to identify shortages of product knowledge in each area.

In situations where specialized service capabilities (e.g. skills or diagnostics tools) are maintained for equipment types, a global installed base analysis can support decisions on reallocating service resources (e.g. [Q59], [Q60]).

Induced rule 3d: If you want to reduce variety in service capabilities, maintain records of item types at customer sites, and use the data to identify capabilities with low demand and to pursue the customers to upgrade.

Finally, because field engineer productivity improves with the service target density (e.g. Smith 1979; Hambleton 1982; Agnihothri and Karmarkar 1992), it might prove useful to analyze whether a better density per engineer results from skill specialization for product types or with specialization for task types (e.g. [Q39] … [Q47]):

Induced rule 3e: If you want to determine efficient skill categorizations, maintain service records that can be associated with service task types, items and locations, and use the data for service job density analyses by product and by service task.

These induced rules are meaningful in contexts where the variety of equipment requires specialization of field engineers for efficient and effective service operations. Again, the Case A service partners with their equally competent field engineers provide an example of contexts where the rules are of limited applicability (see discussion in section 6.1.2).

The following general proposition is given as a result:

Design Proposition 3: In field service resource planning, maintain systematic installed base information to support the forecasting of field engineer skill needs in an area to achieve high field personnel productivity.

Regarding spare-parts inventory planning, the literature review indicated that the key decisions are in balancing the availability with investments in inventories (e.g. Lee 1987; Axsäter 1990; Wong et al. 2005; Kranenburg and van Houtum 2007). Cohen et al. (2006) suggest that spare-part inventories of service organizations should be analyzed as hierarchical multi-echelon structures, where decisions of the inventories in each location depend on the service level requirements and the installed base below the location. This can be encapsulated as a goal assumption of the form:

Assumption 4: If you want to ensure spare-part availability cost-efficiently in an inventory location, maintain a match between the spare parts in the inventory and the spare-part consumption forecast for the area it serves.

The installed base information needed to support various analyses in the spare-part hierarchy was evident in the case studies ([Q61] … [Q71], [Q73], [Q74], and [Q84]). In particular, new equipment entering and old equipment leaving the installed base that inventory location serves were deemed important to identify as they might change the portfolio of SKUs at the area.

Induced rule 4a: If you want to identify the needed spare-part SKUs accurately in an inventory location, maintain records on items (with their spare-part BOMs) and their locations, and use them to identify the spare part SKUs with potential consumption in the area.

Further, product-specific spare-part consumption analyses (e.g. [Q73], [Q79]) were seen interesting to support inventory level decisions:

Induced rule 4b: If you want to forecast spare-part consumption accurately in an inventory location, maintain spare-part usage in global service event records as well as item and location details, use them to build average spare-part consumption for product types, and use updated averages for the installed base items in the area.

In situations where spare-parts production is discontinued, it might be necessary to place a final order for all future needs. Whereas there are means to influence the spare part demand later (e.g. through pricing), the most reliable estimate for the needs can be achieved with installed base information (e.g. [Q75]):

Induced rule 4c: If you want to forecast product end-of-life spare-part consumption, maintain records on spare-part consumption for each product type and records on items in the global installed base, and use them to make volume and trend analyses for the discontinued spare-part SKU.

In situations where specialized spare-part SKU's are maintained for equipment types, a global installed base analysis can support decisions on the ramp-down of spare-part delivery capability (e.g. [Q60], [Q77], and [Q78]):

Induced rule 4d: If you want to reduce the number of spare-part SKU's, maintain records of item types at customer sites, and use them to identify SKU's with no or low demand and to pursue the involved customers to upgrade.

In situations where spare-part needs differ across regions and spare-part procurement is controlled centrally, installed base data can be used to identify the lowest common echelon in the distribution chain for untypical spare parts. These can then be sourced or stored only locally (e.g. [Q76], [Q79] … [Q83]).

Induced rule 4e: If you want to identify effective spare-part locations, maintain records of installed items and locations, and use it to identify regional commonalities in required spare-part SKU's.

Summarizing again the induced rules identified in the cases, the following proposition can be provided:

Design Proposition 4: In field service resource planning, maintain systematic installed base information to support forecasts of spare-part needs in an area to achieve high spare-part availability and high inventory turns.

Both service resource planning processes, the one related to field engineers and the one related to spare-part inventories, can be seen to have similar benefits from installed base information. This is because of the two key characteristics of field services: the distributed nature of field service production and the installed equipment as the factual source of service demand (to the extent stipulated by service contracts and included service-level agreements).

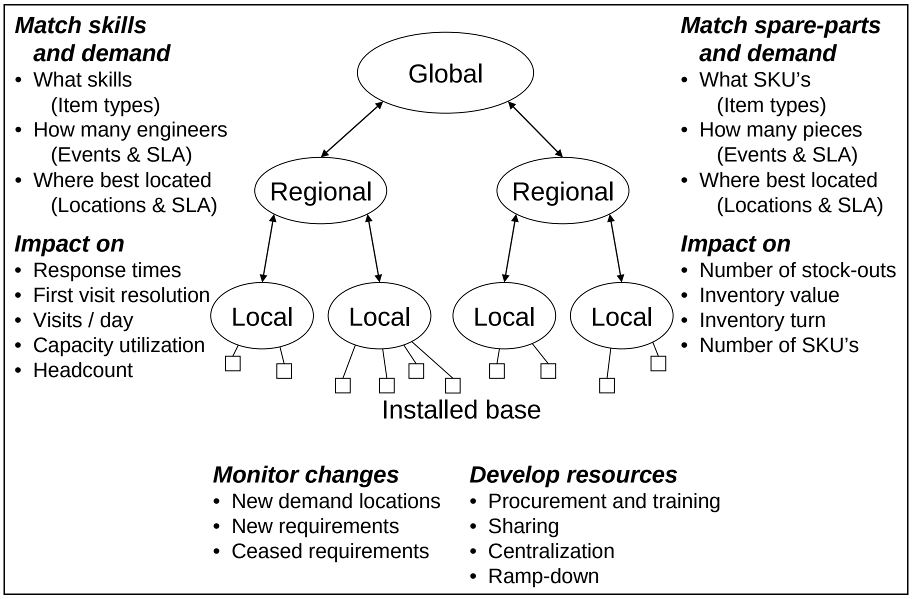

Figure 15: Field service resource management and the installed base

For both kinds of resource planning, the generic uses for installed base information are matching the resource types with the items, matching the resource quantities with the event frequencies, and matching the resource locations with the item locations (Figure 15). These matching analyses can then be used to react to changes in the installed base or resource availability or to manage the resources and their locations, as these analyses can be considered at several levels of hierarchy—resources found at customer sites, at the local service unit, within a region, or globally.

Support for decision making in sales and product development

As discussed in the literature review of sales- and marketing-related installed base information needs (section 3.2.1), the general goals with customer relationship management and key account management are customer retention and customer profitability maximization (e.g. Grönroos 1990; Ojasalo 2001; Zablah et al. 2004). One common feature with these goals is up selling, i.e. the persuasion of customers to make additional purchases and upgrades. Such sales opportunity identification was also a common purpose for installed base information within the studied cases.

Within new product development literature (section 3.2.2), the relationship with marketing was seen as fundamental for designing successful products with market acceptance (Souder and Moenart 1992; Griffin and Hauser 1996; Sherman et al. 2005; Kohn 2006). Whereas innovative features of new product or service designs are more likely to result from interactions with customers and field engineers (Gomes et al. 2003), in the studied cases, the installed base information was seen relevant for market acceptance in analyzing the potential market size for new product and service designs. This was especially the case if the new designs were obvious complements or replacements for existing products.

The reviewed literature on sales and marketing, as well as product development, leads to the following assumption on business goals:

Assumption 5: If you want to identify business opportunities, gather information that helps to understand your customers' needs.

Analyses of products currently in use in customer applications (installed base items and locations) and their performance (items status and events) provide one type of information for understanding the customers' needs. Sales managers can use such analyses to identify operating cost saving or process performance improvement potential with newer technologies (e.g. [Q90], [Q92] … [Q95], [Q100]) or customer process changes that render installed products unsuitable ([Q96]). In addition, customer needs can be stimulated by targeting marketing efforts to customers with older products in use (e.g. [Q87] … [Q89], [Q91], [Q98]).

Induced rule 5a: If you want to identify upgrade sales potential, maintain records of items in customer applications, item statuses, and service histories to recognize performance improvement opportunities for the customer.

The identification of customer needs for product development can be supported in two ways with the installed base information. One is the evaluation of market size for new designs, and the other is the evaluation of differences in customer needs for a design.

The market opportunity of a new product or service concept can be evaluated by identifying the number of customers with potential needs for the new design—customers currently using products that can be replaced by the new design (e.g. [Q159], [Q160]) or customers using complementary products needed for the new product or service concept ([Q175] … [Q179]).

Induced rule 5b: If you want to quantify prospective markets for new products or services, maintain records of items at customer locations to identify complementary or substitutable products in use.

Installed base information is also valuable for product development in situations where there are differences in applications and environments among the customers. There might be specific reliability needs in some applications that must be accounted for in product design to make it suitable for a larger market (e.g. [Q143] … [Q146], [Q161], [Q162]) or some applications might need to be regarded as a market of their own (e.g. [Q163] … [Q165]).

Induced rule 5c: If you want to understand market segments for new products, maintain records of items, customer applications, item statuses, and service histories to identify performance or reliability requirements in specific contexts.

The previous syntheses of the case study findings suggest that installed base information can be used to analyze customer and market needs for the products and services of a company. The identified sales opportunities and product or service market segments can then be used in directing the company resources to prioritize the most promising opportunities. This is summarized in the proposition below.

Design Proposition 5: As a product-service supplier, maintain systematic installed base information to support the analysis of customer needs per product, service, or application to identify business opportunities with existing customers.

In accordance with the business goal of customer retention (Grönroos 1990; Zablah et al. 2004), customer satisfaction is a key element (Bose 2002; Crosby 2002; Jackson 2005). High customer satisfaction can be attained by developing operational capabilities to customize products and services for the key accounts (Ojasalo 2001), as well as ensuring product reliability in customer applications (Majeske et al. 1997; Petkova et al. 1999). These can be summarized as the following assumption:

Assumption 6: If you want to maximize customer satisfaction, customize your offers to match the customer needs for operational features and reliability.

Understanding the customer's needs is again of importance. As above, sales managers can use analyses of customer equipment and application to customize upgrade offers to reduce the customer's operating costs or improve process performance (e.g. [Q90], [Q92] … [Q95], [Q100], [Q139]). Additionally, installed base information was seen relevant for convincing customers that the offered products are suitable for the customer needs with reference cases of prior implementations in similar contexts (e.g. [Q99], [Q104] … [Q106]). When selling services, installed base information supports sales managers in tailoring service-level agreements based on the criticality of the application or environmental factors (e.g. [Q109], [Q110], [Q113]). Hence, the following rule seems to apply in the studied cases:

Induced rule 6a: If you want to customize sales offers proactively, maintain records on items, customer locations, and service events to identify relevant environmental and performance factors that can be mapped to product or service configuration characteristics.

The dimension of customer satisfaction related to product and service reliability can benefit from installed base information. Identification and resolution of quality problems based on item and service event data (e.g. [Q130] … [Q135], [Q139] … [Q142]) and, in particular, proactive implementation of corrections at customers (e.g. [Q137], [Q138]) reduce the amount of disruptions to the customer application. Likewise, analyses of service quality by service type or product type might trigger actions that improve the reliability of services (e.g. [Q157], [Q158]). Also in more acute situations where the customer expresses his doubts on the reliability and performance of the supplier's products or services, installed base data on numbers of items operating perfectly (e.g. [Q139]) and service frequencies and results (e.g. [Q119], [Q120]) can be referred to in an attempt to regain customer satisfaction.

Induced rule 6b: If you want to ensure trouble-free operations for the customer, maintain records of items at customer locations and service events to search and correct quality problems proactively.

Hence, it is proposed that the installed base information has a purpose in securing customer satisfaction:

Design Proposition 6: As a product-service supplier, maintain systematic installed base information to support proactive customization of product and service offers and to support performance monitoring for quality control to achieve high customer satisfaction with existing customers.

In addition to customer retention, both the customer relationship management and the product development literature stress the importance of profitability of operations—the first, the profitability of customers (e.g. Grönroos 1990; Ojasalo 2001; Zablah et al. 2004) and the latter, the profitability of products and related services (e.g. Majeske et al. 1997; Petkova et al. 1999; Goffin and New 2001). Some discussed means to ensure profitable operations include segmentation and pricing of customer offers (e.g. Bose 2002; Corner and Hinton 2002; Campbell 2003; Xu and Walton 2005), reduction of warranty costs through design for reliability (Majeske et al. 1997), and reduction of maintenance costs through design for maintainability (Goffin 1998; Goffin 2000). This gives the following assumption on means to improve profitability:

Assumption 7: If you want to improve the profitability of product-service systems, adjust pricing through segmentation or redesign products and services to lower the after-sales costs.

The studied cases indicated that installed base information could support the profitability of operations in a multitude of ways. Profitability of service operations has been already extensively discussed above, as Proposition 2 suggests means to use installed base information to improve the profitability of individual service deliveries through efficient operations, and Propositions 3 and 4 discuss means to improve service resource use to make investments in service resources more profitable.

One means to ensure profitability of customer relationships was seen to have a rigorous approach in service sales. With installed base information (often gathered for this specific purpose), sales managers wanted to be sure that only items profitable to support are included in service contracts and receive support (e.g. [Q111], [Q112], [Q114], [Q118]). In addition, the pricing models for services require thoroughness to ensure profitability. The cost of services might differ between items (e.g. [Q115], [Q151]), and local differences in installed equipment for global customers must be accounted for in pricing (e.g. [Q121]). Consequently, changes in serviced items also must be reflected in the service prices (e.g. [Q116], [Q117]).

Induced rule 7a: If you want to ensure profitable service offers, maintain records on items at customers and service events per product type to evaluate service cost standards for products, and adjust customer prices accordingly.

The management of warranty costs was also seen as an application for installed base information. In this context, the key purpose for installed base data was seen in the verification of eligibility of the customer warranty claims (e.g. [Q122] … [Q126]) and analysis of the problem scope (e.g. [Q127], [Q128]). In addition, the financial preparations for quality problems, as required when budgeting for the warranty costs, could be quantified with installed base information (e.g. [Q129]). Hence, the following rule is proposed to hold in the studied business contexts:

Induced rule 7b: If you want to ensure the justification of warranty costs, maintain records of installed items as well as their applications and environments to evaluate the appropriateness of the use of the product and correspondence to the use indicated in the customer order.

Analysis of service events by product types was seen useful to evaluate product type standards for maintenance requirements and support costs (e.g. [Q147] … [Q154]). Similarly, analysis of service events by service type were made to maintain operational servicing standards (e.g. [Q155] … [Q158], [Q173], [Q174]). These standards were used to support local units in service resource planning and in the pricing of service offers. But further use was identified in analyses of local or product specific deviations from these standards to recognize improvement needs threatening the profitability of products or services ([Q168]…[Q169], [Q171]…[Q172]).

Induced rule 7c: If you want to ensure the profitability of product types and service concepts in after-sales operations, maintain records on items at customers and service events per product type to identify inadequate performance in own operations.

To summarize the above induced rules, the following general proposition is given:

Design Proposition 7: As a product-service supplier, maintain systematic installed base information to support the evaluation of customer contracts and product and service performance to improve the profitability of product-service systems

The three propositions on decision support generated by installed base information for sales and product development are summarized in Figure 16.

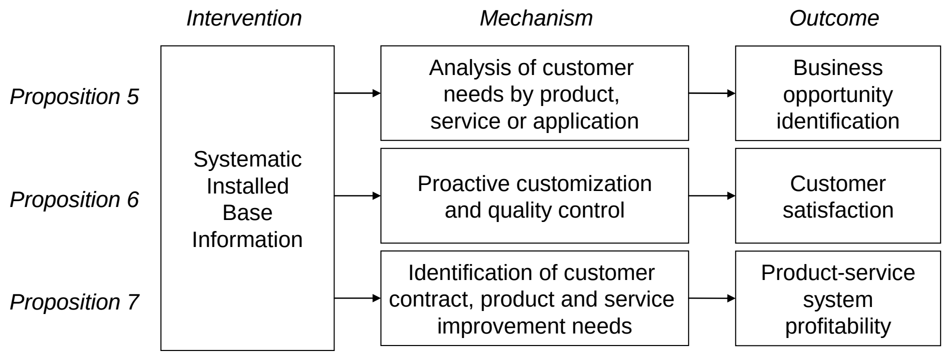

Figure 16: Summary of installed base information uses for sales and product development

7.2 Installed base information requirements

This section provides a closer examination on the logical structure of the general Intervention of systematic installed base information management used in the design propositions above. Whereas the specific data items that must be gathered depend on the goals of the installed base initiative (e.g. desired Outcomes and available Mechanisms above) as well as the case-specific Context, the logic of organizing the data is more general. A detailed description of the specific data types identified during this research can be found in section 6.3 and will not be revisited in this section.

In short, it can be concluded that there are three distinct types of installed base information that is sought in the examined business contexts:

- **Installed base item data** that relates to the installed items—their properties and their condition
- **Installed base location data** that relates to the position in the customer process that an item can occupy
- **Installed base event data** that relates to incidents involving the items and locations as well as describes interventions performed

The nature of these information types is very different. The first type is concerned with the current state of affairs and should be updated whenever there is a change in any of the recorded items. The second type is connected to the customer process and generally remains unaffected by all service actions (except new installations which themselves do not change the data, but rather add data elements). The last type is concerned with past transactions that must be recorded as they took place for future reference. Each of these information types can be further broken down into more detailed subcategories and individual data items, which have been described in the previous chapter above (6.3).

The reason for handling these information types separately, but with a capability to combine them, can be seen in the kinds of installed base analyses the interviewees were interested in:

1) Check: verification of single installation status
2) Follow-up: monitoring of changes in performance of a single installation
3) Classification: identification of installations with specific characteristics
4) Comparison: analysis of performance of installations with specific characteristics

These four generalized Mechanisms (Denyer et al. 2008) were noted in many situations. Checking the status of a single installation was especially important when dealing directly with customers—service units preparing for a site visit (e.g. skills and spare parts needed for a visit [Q12]), sales units contacting a customer (e.g. identification of replaceable items [Q93] or changes in customer application[Q96]), or product management handling a warranty claim (e.g. verification of warranty coverage [Q123] and appropriateness of use [Q124]).

Follow-up of a single installation requires access to service events involving the items and location of interest. Again, the main purposes for these analyses come from customer facing units—service units monitoring the success of a repair (e.g. [Q152]) and sales units monitoring compliance to the service-level agreement of service contracts (e.g. [Q119]). Nevertheless, there was also interest for single installation follow-up in product development to monitor first installations of new products or exceptional applications (e.g. [Q153]).

Classification analyses within the installed base involved identifying items or locations with similar properties. Service resource planning required analyses of items of certain manufacturers or technologies to resolve skills needed in an area (e.g. [Q42]). Sales units were interested in focusing marketing efforts on customers with specific types of applications (e.g. [Q89]). In addition, product management was interested in identifying customer sites with items in a certain range of serial numbers to track down known quality problems (e.g. [Q133]).

Comparison analyses require extensive access to service events to analyze similarities and differences in reliability among different classifications of installations. Such analyses were seen useful for identifying problematic product types in terms of reliability or maintainability (e.g. [Q135]), for creating standards for product maintenance plans and servicing times (e.g. [Q54]), or for materials and supplier evaluation (e.g. [Q141]).

Based on the required structural differences in the installed base data, the following design proposition is given:

***Design Proposition 8*:** As a product-service supplier, organize the installed base data as records on items, customer locations, and service events so that you can access these separately and through cross-referencing to enable classifications and comparisons of the dimensions of interest to support decision making in the organization.

7.3 Installed base information and contextual sources of uncertainty

This section takes a contingency view on the design propositions to elaborate further the contextual factors described when formulating the design propositions above. This section also completes the discussion based on the CIMO-logic of design propositions (Denyer et al. 2008) by elaborating contexts where the propositions are most meaningful.

Further, Holmström et al. (2009) suggest that to create a substantial academic contribution with exploration through designs, explanation through theoretical statements that can be studied in other contexts must be provided by showing the links to existing theories and by examining relevant contingencies for the studied means and ends (Holmström et al. 2009). The Organizational Information Processing Theory (Galbraith 1973; Tushman and Nadler 1978) is used both to explain the theoretical rationale behind the propositions and to formulate initial hypotheses on contingent factors on the meaningfulness of the propositions.

Organizational information systems can be used to reduce subunit task uncertainty (Galbraith 1973) arising from the task environment, task complexity, and subunit task interdependence (Tushman and Nadler 1978; Goodhue et al. 1992), as elaborated in the literature review (section 2.2.1). Information processing focusing on individual pieces of equipment, as suggested with the identified installed base information management practices, seems to have a distinct role in reducing uncertainty in decisions:

1) The installed base of products forms a part of the task environment for many subunits. Installed base information describes the task environment and particularly changes therein.
2) The installed base of products and installed base events determine in part the desirability of choices among alternative decisions in subunits and present possibilities for reducing task complexity by simplifying the problem space.
3) Installed base information management is a vehicle for handling various interdependencies of service units and other subunits, in particular, interdependencies involving several service units and long periods.

These roles of installed base information in reducing uncertainties are elaborated further below.

7.3.1 Subunit task environment originated uncertainties

Reflecting the results on the breakdown of task environment dimensions into environmental munificence, dynamism, and complexity (Dess and Beard 1984), each of these can be identified among the studied subunits.

Environmental munificence

Uncertainty arising from environmental munificence, i.e. the capacity of the environment to sustain growth, was most notably present with the sales and product development subunits (see sections 3.2 and 6.2). Both types of subunits were interested in having installed base item data to support the evaluation of opportunities for additional sales or design configurations, mainly by identifying numbers and owners of complementary or replaceable items.

Hence, it can be hypothesized that installed base information is more important in contexts where business growth is sought with replacements and supplements to existing installations, as exemplified with the extensive upgrade business in Case C (e.g. [Q159]). In contrast, if growth is sought in new markets or applications, installed base information cannot be used to describe the environmental capacity to accept new offers. In the latter context, *Design Proposition 5* would be less meaningful.

Environmental dynamism

Uncertainty arising from environmental dynamism related to the installed base was considered alleviated by information on changes of items in the installed base and installed base events. Whereas the sales subunits were interested in identifying changes of performance and functionality of items at single customer sites to support the customer account management (sections 3.2.1 and 6.2.1), service resource planning was interested in changes of items in its region and performance by product type to update service demand forecasts (sections 3.1.4 and 3.1.5 as well as 6.1.2 and 6.1.3).

Again, a hypothesis can be provided on the influence of environmental dynamism on installed base information utility. Taking service resource management as an example, installed base information likely has a greater impact on planning performance in situations with greater changes in the installed base. Therefore, service resource management should benefit greatly from installed base information in Case C where service markets are intensely competitive, and there are frequent changes in the equipment in service at a local unit. The same would apply in Case D where there are continuous installations of new product generations. In contrast, the impact of installed base information on resource planning should be lower in contexts exemplified by Case B. At the time of the study, the service markets for Case Company B were not yet fully established, as many customers were conservative in outsourcing their maintenance operations. Hence, there were infrequent changes in the task environment for Case B service resource management. In this latter context, *Design Proposition 3* would be less meaningful.

Environmental complexity

Installed base information also supports the understanding of complexities of task environments. Understanding the homogeneity or heterogeneity, as well as the geographical dispersion of the installed base items, is valuable in field engineer allocation (sections 3.1.3 and 6.1.1) as well as service resource planning (spare-part inventory locations: sections 3.1.5 and 6.1.3; engineer skill requirements: sections 3.1.4 and 6.1.2). In addition, product management and product development analyze the extent of their decisions' impacts regarding item commonalities and differences, as well as geographical dispersion or customer groups involved (sections 3.2 and 6.2).

Hence, the degree of environmental complexity is likely to affect installed base information utility. Continuing with the example of service resource planning, it can be hypothesized that installed base information has a greater impact on resource accuracy in situations with heterogeneous equipment in service in local units than in situations with homogenous installed bases. An example comes from the context of Case C, where some areas have dense populations with different manufacturers' equipment (e.g. [Q45]), whereas other areas are dominated with a high share of equipment of a single manufacturer (e.g. [Q42]). It can be expected that field engineer resource planning benefits more from installed base data at the former types of service areas, thus making *Design Proposition 3* more meaningful.

Based on the above discussion, it can be claimed that the design propositions are theoretically justified if installed base information reduces task uncertainty through providing information on the task environment. Consequently, the importance and usefulness of installed base information can be hypothesized to differ depending on the extent of installed base-related environmental munificence, dynamism, and heterogeneity that create uncertainty for the task concerned.

7.3.2 Subunit task complexity originated uncertainties

As for the subunit task complexity as a source for uncertainty (Tushman and Nadler 1978), Campbell (1988) described objective task complexity as resulting from several different mechanisms and their combinations. Three of the key mechanisms he identified are discussed below: multiple paths to attain a desired goal, conflicting interdependence among paths and outcomes, and uncertain or probabilistic linkages between paths and outcomes.

Multiple paths to attain a desired goal

Installed base information can be used to provide decision support in situations where task complexity arises from multiple paths to attain a desired general goal. Within the studied subunits, this kind of complexity can be seen to be present with sales, product management, and product development, where the available resources impose selections to be made among several possible actions to increase sales, improve quality of company offering, or design attractive new offers (see sections 3.2 and 6.2). Having data on the installed base of products can provide substantiation to the prioritization of actions to take. The prioritization can be supported through assessing the expected impact of actions by analyzing the items, customers, or geographical areas involved with alternative actions.

It can be assumed that installed base information is more important in supporting decision making in the presence of multiple alternatives. Taking the example of sales subunits, installed base information has a greater impact on decision quality when there are numerous alternatives (product types/configurations) that must be processed to find a match for a customer need. Contrasting examples are the contexts of Case A where the sales deals with a few stand-alone products and systems and Case B where sales has to select among myriad configuration possibilities to find a suitable match to the specific application of the customer (e.g. [Q99]). In the latter context, *Design Proposition 6* is more meaningful.

Conflicting interdependence among paths and outcomes

Task complexity resulting from conflicting interdependence among paths and desired outcomes can be identified with the resource planning tasks. They often include contradictory goals of maximizing resource availability and minimizing investments in the resources (see sections 3.1.4 and 3.1.5 as well as 6.1.2 and 6.1.3). The studied cases suggest that understanding the installed base structure (i.e. differences and similarities of item composition and criticality and their geographical distribution), the planning tasks can be split in parts with different properties. For field engineer resource planning, the characteristics of the installed base can be used to identify potential ways of reducing the number of skills required of individual engineers— whether there is a sufficient density of single product types to allow engineer specialization by product characteristics or whether there is a sufficient density of like technologies used in the products to enable specialization by technology or service task type.

It can be hypothesized that installed base information is more important for an organization in the presence of conflicting goals than without conflicting goals. An example from spare-part resource planning illustrates this, as with a global spare-part distribution structure, there is always the decision on where to position a spare-part SKU—close to each frontline to ensure availability or further upstream to reduce the capital tied up in the inventory. In Case A, some spare parts are equipment-specific and, thus, can have sporadic demand, whereas other components are commonly used in all equipment (e.g. [Q64]). In the latter case, the demand is more stable and, thus, rational inventory decisions can be made based on consumption, with no need to evaluate the existence or reliability of distinct pieces of equipment in the service area. There is no real conflict in the goals, as common components are a required investment because of frequent and uncontested availability requirement. For more equipment-specific parts, installed base information is likely to be more relevant in balancing the conflicting goals of investments and availability, for example, by customer criticality (e.g. [Q113]), making *Design Proposition 4* more meaningful.

Uncertain or probabilistic linkages between paths and outcomes

Task complexity because of uncertain or probabilistic linkages between paths and outcomes is most notably present with the dispatching task of service units, in particular with allocating field engineers to unplanned repair operations (see sections 3.1.3 and 6.1.1). The probability of selecting the most competent available engineer for the task improves if the equipment and likely problem type can be identified before the dispatching decision. Here, any information on the item composition, status, environment, and service history might prove valuable.

Again, it is hypothesized that the importance of installed base information depends on the presence of probabilistic linkages between paths and outcomes. In particular, it is suggested that installed base information has a greater impact on dispatch decision quality (i.e. first-visit-resolution percentage) in situations where there is greater variety in field engineer skills. Contrasting examples from the studied cases come from Case A, where most field engineers are equally able to handle any service job, and from Case C, where some field engineers are more skilled with some types of equipment than other engineers are (e.g. [Q43]). It seems credible to suggest that, in the latter case, installed base information has a greater impact on the success of dispatching decisions than in the former, where the probabilistic linkages are absent. Consequently, *Design Proposition 1* is more meaningful in the presence of probabilistic linkages.

Based on this discussion, it seems realistic to claim that the design propositions are theoretically justified, as installed base information management might relieve uncertainty arising from task complexity. The uncertainty is reduced by providing information to improve the probability of successful selection among alternatives and by indicating a possibility to reduce the problem space to achieve satisfactory, if not optimal, solutions.

7.3.3 Subunit task interdependency originated uncertainties

The topic of subunit task interdependency as a source of uncertainty requires a different treatment than the two other sources above, as the tasks of different subunits cannot be treated in isolation and as the interdependency has perhaps the greatest implications of the three sources of uncertainty on information processing requirements (Tushman and Nadler 1978). Whereas there certainly are interdependencies among all the studied units to various degrees, the discussion focuses on interdependencies where local service units are involved. This selective treatment is justified with two reasons. The first is the context of this research. As the study has focused on organizations increasingly structuring their after-sales service offers and service operations, the linkages between the subunits producing those services and other subunits are of most interest. The second reason is that, in practice, the service units, and field engineers as key actors within the service units, are the main sources for up-to-date installed base information.

The task interdependence classification into pooled, sequential, and reciprocal interdependencies (Thompson 1967; van de Ven et al. 1976; Egelhoff 1991; Kumar and van Dissel 1996) is used as the basis for the discussions. Based on the findings of this research, a major contributor to the strength of the interdependency between the tasks of different subunit tasks comes from the service contracts with customers.

Task interdependence between a service unit and other subunits

Different after-sales service relationships fundamentally shift the responsibilities in ensuring equipment performance between the customer and supplier (see Martin 1997; Baines et al. 2007; and the discussion in 2.1). It can therefore be expected that the usefulness of installed base information in supporting supplier decisions depends on the responsibilities of the supplier.

Based on the studied cases, the after-sales service tasks (see 6.1.1) included in different depths of service contracts (Martin 1997; Baines et al. 2007; Cavalieri et al. 2007) differed. A summary of the service tasks and contract types is given in Table 12. The table indicates that, as the service provider takes a greater responsibility for the customer's assets, more of the after-sales service tasks move from separate transactions to included contractual operations. This also implies greater requirements for installed base information management as the customer expectations on service responsiveness increase.

Table 12: After-sales service components available with different depths of customer contracts

After-sales service tasks	No contract	Maintenance contracts	Performance contracts	Facilitator contracts
Planned maintenance	-	Included	Included	Included
Planned repair and change delivery	Charged separately	Included / Charged separately	Included	Included
Unplanned repair	Charged separately	Charged separately	Included	Included
Upgrade and extension	Charged separately	Charged separately	Charged separately	Included
Technical support	Charged separately	Included / Charged separately	Included	Included
Remote maintenance	Charged separately	Included / Charged separately	Included	Included

As the customer outsources a greater share of responsibilities to the service supplier with a performance or facilitator contract, the balancing decisions between preventive maintenance (planned maintenance, remote maintenance, and planned repair) and corrective maintenance (unplanned repair tasks) are shifted to the supplier. With contracts that have equipment availability and/or output quality as performance measures (de Groote 1995; Ljungberg 1998; Jeong and Phillips 2001; Komonen 2006), the incentives of the supplier and customer regarding equipment reliability are aligned. If repairs or other visits are charged per transaction, less-than-perfect equipment reliability is a source of revenue for the product-service provider. With contracts that place sanctions on failures and that let the product-service provider carry all preventive maintenance costs, the improvement of product reliability and maintainability becomes a competitive advantage in both product and service businesses—both the product and the service component have an impact on the same performance measure.

Reflecting on the Organizational Information Processing Theory, common and measureable goals mean that the tasks of the product-service provider's functional subunits become interdependent. In particular, the interdependencies are increased between local service units and each of the other subunits of sales, product management, and product development. Sales units can sell items that do not have competent field service engineers in the area, product management might not correct quality problems for increasingly failing products, and product development might create designs difficult to service. Simultaneously, the service units are responsible for recording service events and updating installed base item data to support the alignment of decisions in other subunits. Consequently, there is a reciprocal interdependency but in a more asynchronous and asymmetric form than usually intended with 'feeding work back and forth among themselves' (see Kumar and van Dissel 1996, p.284, and similar definitions of e.g. Thompson 1967; van de Ven et al. 1976).

Hence, it is hypothesized that, as the share of performance-oriented contracts with customers increases, the task interdependence between the supplier's subunits increases, and this is likely to increase the importance of installed base information for product development to enable more detailed reliability analyses with product performance data (e.g. [Q170]), thus making *Design Proposition 7* more meaningful for the organization.

Task interdependence between service unit and customer

Another interdependence of interest is that between a service unit and a customer. Although the customer is external to the company, during a service delivery (in particular with repairs and problem solving) there is a common interest of finding a timely and lasting solution to the task at hand, and the effectiveness of the service process is often dependent on customer input during the service process (Sampson and Froehle 2006). Thus, using the interdependence classifications, there is either a sequential relationship, if the representative of the customer is able to provide all information before the service operation is commenced, or a reciprocal relationship, if additional information has to be processed during the service. Unfortunately, the representative of the customer involved with the service job is not always capable of providing all relevant detail regarding the equipment concerned (e.g. [Q12],…,[Q15]). To reduce the impact of such situations for the overall effectiveness of the service unit, it is valuable to have systematically gathered information on the equipment that can be used without relying on the customer to provide critical input to the service process.

The importance of installed base information in the context of service unit—customer interdependence can be hypothesized to depend on the type of the interdependence. This is, by large, defined by the service contract, which details the responsibility sharing between the customer and the service unit. If the supplier is responsible for only providing workforce when requested (Martin 1997), installed base information can provide efficiency and quality benefits in terms of faster and more accurate dispatching decisions. However, there is no direct requirement to maintain such data. However, if the supplier is responsible for ensuring capacity availability for the customer with performance contracts (Martin 1997; Baines et al. 2007), the service units cannot depend on the customer to inform on maintenance requirements. In such situations, the reciprocal interdependence between the service unit and the customer in service operations has contractually been reduced. This reduction imposes a need for the service provider to maintain relevant details on the service targets, i.e. the items and locations. Hence, installed base information can be hypothesized to be of greater relevance with more extensive service contracts that disable the reliance on customer input and, thus, make *Design Proposition 1* and *Design Proposition 2* more meaningful.

Task interdependencies among service units

Finally, considering the interdependencies among service units themselves, it can be identified that a pooled interdependency exists among the service units to the extent that they proceed independently with their tasks, but they draw on the same resources of skilled engineers and spare parts (Kumar and van Dissel 1996). The field engineer resource management and spare-part inventory management functions coordinate this interdependence. The case studies indicated that installed base information could be used to balance the resources among the service units with rational decision criteria from the viewpoint of the company (e.g. service area redefinitions [Q52], spare-part allocation to most valuable customers [Q84]).

It can be hypothesized that installed base information becomes more relevant to organizations as the degree of the pooled interdependence increases among the service units. Pooled interdependence among the service units can increase because of more centralized engineer resources (e.g. [Q49] … [Q51]), more centrally controlled spare parts (e.g. [Q79] … [Q81]), or because of increasing harmonization of service concepts across service units (e.g. [Q177], [Q178]). If service units are left to operate much on their own (like the service partners in Case A), installed base information is less useful in the organization, and *Design Proposition 3* and *Design Proposition 4* are less meaningful.

Based on the above discussion, it can be argued that the design propositions are theoretically justified, if installed base information reduces task uncertainty by enabling decision makers to assess the impact of their decisions on other subunits, i.e. to assess the interdependence of their current task with other subunits' tasks. Consequently, the meaningfulness of installed base information can be hypothesized to differ, depending also on the level of subunit task interdependence.

8 CONCLUSIONS AND FURTHER RESEARCH

This chapter concludes the research work and first addresses the aim and research questions set for the research program by summarizing the research results. The second section gives an evaluation of the research program. The discussion here concentrates on the value of the results. The used research methods, their purposefulness for the research problem, and the meticulousness of using the methods to study the problem were discussed in Chapter 4. As the research interest for this work has been in understanding means and ends in a practical managerial context (Simon 1996; Holmström et al. 2009), the resulting new knowledge can be evaluated through its utility value. Such an evaluation can be conducted through five dimensions of Thomas and Tyson (1983) as suggested by van Aken (2004): descriptive relevance, goal relevance, operational validity, non-obviousness, and timeliness of the results. Finally, the last section lists further research suggestions for both corroborating and extending the results of this work.

8.1 Conclusions

The motivation and goal for the research program reported in this thesis was stated as:

> *This research's principal aim is to support the development of installed base information management to improve the business processes of manufacturing companies providing product-related services for their customers.*

The research contributes to the development of installed base information management in three ways. First, the research resulted in statements of the relationship between installed base information and the management of operations in manufacturing companies offering product-related services (section 7.1). Second, the logical structure (section 7.2) and key data elements (section 6.3) of installed base information were described. Third, initial suggestions on the contextual differences that have an impact on the relevance of installed base information and the formed propositions were presented (section 7.3).

In the following, the two research questions guiding the study are addressed.

> *RQ1: Why should a manufacturing organization providing product-related services gather installed base information?*

The goal with addressing the question was to find out distinct purposes for the installed base visibility at a product-service supplier—what kinds of ends and use mechanisms are there for the systematic installed base information (Simon 1996; Denyer et al. 2008; Holmström et al. 2009). The ultimate reasons for all the identified purposes for installed base information were related to increasing the value of use for the customer or improving the profitability of own operations, or both.

Woodruff (1997, p. 142) discusses customer value as a competitive advantage and gives the following definition: 'Customer value is a customer's perceived preference for and evaluation of those product attributes, attribute performances, and consequences arising from use that facilitate (or block) achieving the customer's goals and purposes in use situations.' Hence, installed base information should be of interest for all capital goods manufacturing companies concerned with the value that their products deliver to their customers during the use.

Further, the definition for customer value above can be used to consider the uses for installed base information identified in this work. Whereas the product attributes are of interest during the initial sales, in-use value can be achieved through operational reliability of the products and through support for customer's purposes for using the product (Woodruff 1997). Operational reliability is realized with a combination of product characteristics and service actions ensuring satisfying levels of product's availability, performance, and output quality. Customer's purposes can be supported by considering the role of the product in the customer's process and offering improved products, performance optimization, or other product-related services to help the customer attain its goals. Both ensuring operational reliability and generating new offers are easier if the status and performance of the currently installed products can be analyzed.

> *RQ2: What information should a manufacturing organization providing product-related services gather on the installed base?*

The research question was motivated by a desire to understand what kind of data it is that people in product-service supplier organizations need and use when they refer to visibility to the installed base. Reflecting on the first research question and its main intent to understand what purposes are interesting for systematic installed base information management, this second research question aimed to understand the intervention, i.e. opening the black box of "systematic installed base information."

In short, it can be concluded that there are three general, but distinct, types of installed base information sought in the examined business contexts:

- **Installed base item data** that relates to the installed items—their properties and their condition
- **Installed base location data** that relates to the position in the customer process that an item can occupy
- **Installed base event data** that relates to incidents involving the items and locations as well as describes interventions performed

The research results can be summarized with the CIMO-logic for design propositions as a framework, as illustrated in Figure 17. The CIMO-logic for design propositions is defined as 'in this class of problematic Contexts, use this Intervention type to invoke these generative Mechanism(s), to deliver these Outcome(s)' (Denyer et al. 2008, pp. 395–396). Key goals for maintaining systematic installed base information (the intervention) are related to outcomes improving the value customers get from using the company products and services (*Design Propositions 1, 2, 5, and 6*) or that improve the profitability of operations and offering designs (*Propositions 1–4, and 7*).

The mechanisms linking the intervention with the outcomes consist of analyses of service resource needs (*Propositions 1–4*), customer applications (*Propositions 5 and 6*), and operations performance (*Proposition 7*). These were synthesized in section 7.1. The intervention of systematic installed base information management needs to include components related to Items, Locations, and Events to enable the use of the identified mechanisms (*Proposition 8*), as summarized in section 7.2.

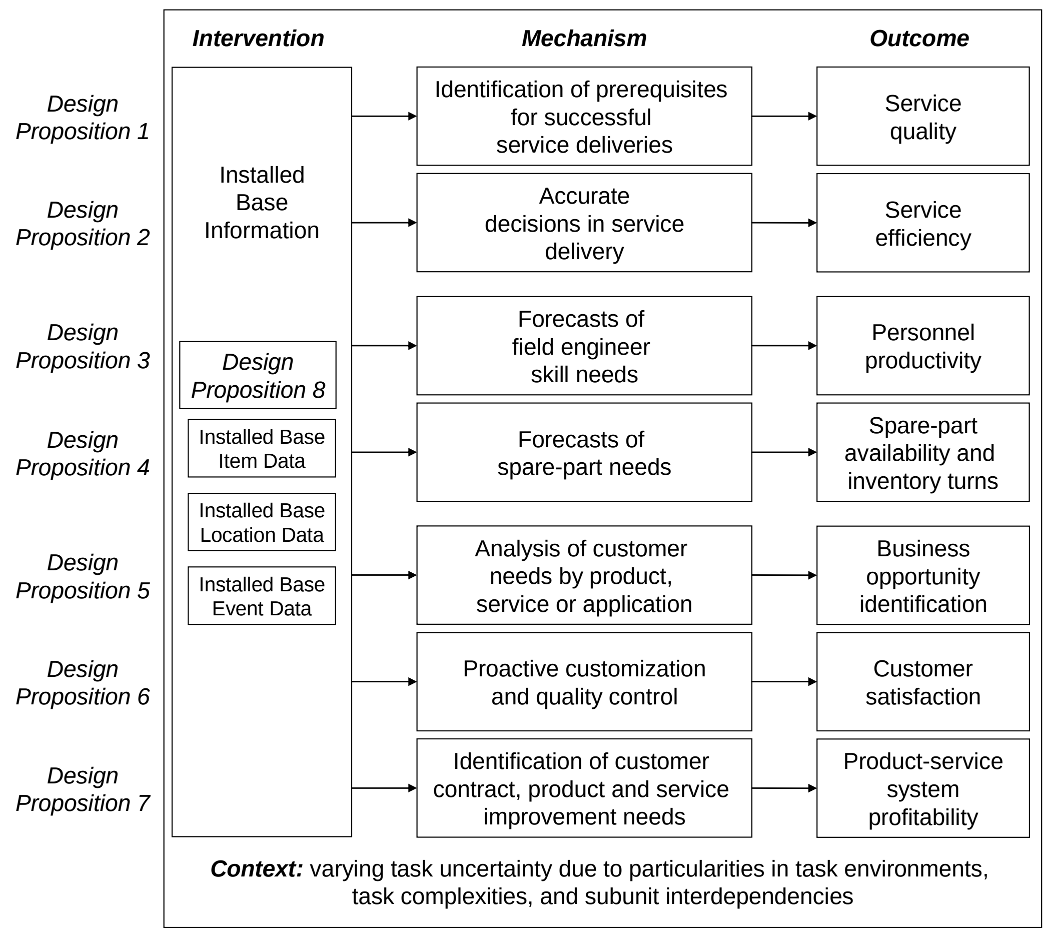

Figure 17: Summary of design propositions

The general business context of suggested applicability for these design propositions is that of investment goods manufacturers engaged in after-sales services. However, the reflection of the case studies on the Organizational Information Processing Theory (Galbraith 1973; Tushman and Nadler 1978; Goodhue *et al.* 1992) in section 7.3 suggests that there might also be differences in the task environments (section 7.3.1) and task complexities (section 7.3.2) that increase or reduce the meaningfulness of the propositions among companies, or even among subunits within a company. In particular, whereas product quality monitoring and analyzing operations performance were of similar interest in all studied business environments (*Design Propositions 6 and 7*), it is suggested that the mechanisms based on matching the installed base information with service resources (*Propositions 1–4*) or with customer offers (*Proposition 5*) have two contingent factors that impact the utility of the installed base information:

1) the greater the heterogeneity and/or dynamism of the installed base, the greater the impact of systematic installed base information on the matching decisions
2) the greater the complexity of matching a resource or offer, the greater the impact of systematic installed base information on the matching decisions

High variety and rate of change in either part increase the complexity of the matching decisions and, thus, increase the information processing needs (Galbraith 1973). Put the other way around, if the installed base is fully homogeneous with respect to the matching decision—for example, all pieces of equipment have a common component (e.g. the same power supply unit)—having accurate records on this does not make any difference to the spare-part selection or inventory decisions. Similarly, if there is no complexity in matching a counterpart, the installed base information does not add anything to the decision. If all field engineers of a local unit are equally effective with servicing any manufacturer's equipment, records on original manufacturers are meaningless for the dispatching decision. Nevertheless, with increasing heterogeneity/dynamism in the installed base or differing probabilities in resource performance, systematic information to support decision making becomes more valuable.

Another contextual factor that seems to impact the relevance of installed base information, and Design Proposition 7, in particular, results from the service offering of the case company (section 7.3.3). With an increasing number of service contracts and increasing supplier responsibilities in the service contracts (Martin 1997; Cavalieri et al. 2007), the product and service processes of the manufacturing companies become more intertwined (Baines et al. 2007). Product quality and maintainability affect service performance, and service quality affects customer satisfaction with the products and, hence, new product sales. As a result, the interdependence within the organization increases and requires improved information processing capabilities on the customer's products to align the goals of the functional subunits.

8.2 Evaluation of the research program

Being design science-oriented research, the aim has been to generate instrumental knowledge (e.g. Denyer et al. 2008; Holmström et al. 2009). Such application-oriented knowledge can be evaluated through its utility value in five dimensions of Thomas and

Tyson (1983) as suggested by van Aken (2004): descriptive relevance, goal relevance, operational validity, non-obviousness, and timeliness. Of these, the descriptive relevance and operational validity will be discussed below in more detail. Goal relevance, i.e. 'the extent to which the results refer to matters the practitioner wishes to influence' (van Aken 2004, p. 237) has been extensively discussed in sections 6.1, 6.2, and 7.1, as the explicit first goal in the research has been to identify such relevant matters for installed base information. Whereas the research topic can be considered timely considering the contemporary interest of manufacturers to engage more intensively in service operations (Wise and Baumgartner 1999; Oliva and Kallenberg 2003; Araujo and Spring 2006; Cavalieri et al. 2007) and the internal development projects of the companies during the case studies, the timeliness of the research results is more difficult to evaluate. The current results are propositions stemming from explorative research and, as such, are subject to further refinement with subsequent empirical evidence (van Aken 2004; Holmström et al. 2009). As for the non-obviousness of the results, whereas some of the resulting propositions are deductible from earlier literature and can be considered somewhat obvious (at least in hindsight), the general conclusion of the item-level installed base information as an important interconnecting device among the interdependent subunits in an organization is non-obvious.

Descriptive relevance relates to the generalizability of the resulting propositions related to installed base information. The raison d'être of technological rules is their applicability outside a unique context (van Aken 2004). Multiple cases have been studied to uncover similarities in installed base information processing needs across different industry and business contexts, as suggested for both inductive description-driven theory building (Eisenhardt 1989; Meredith 1998) and prescription-driven design research (van Aken 2004; Holmström et al. 2009).

There are, however, always limitations resulting from the selection of cases, both because of accessibility and because of constraints in research resources. The design-oriented research problems require participation from organizations interested in the problem in question (van Aken 2004), and the time and other resources available determine the possibility for additional cases (Eisenhardt 1989). Thus, it can be considered certain that the resulting propositions and theoretical hypotheses founded on the studied four cases are not exhaustive in terms of accounting for all contextual factors impacting their application in diverse operational context, nor exhaustive concerning portraying all the uses of installed base information at capital equipment manufacturers engaged in service business. Both of these limitations were identified already within the studied cases, as the need for information was clearly more evident in more complex operating environments. The case companies with more experiences with "higher level" product-service systems could give much more detailed descriptions on how they do or do not use installed base information. This is to say that new needs and restrictions for installed base information will likely be uncovered with further research on implementations of installed base information systems. In addition, new uses are likely to be identified, as new products, services, and processes are designed in organizations.

Nevertheless, the overlap of similar information uses and information requests in the four cases, as reported in the cross-case analysis chapter (along with the author's confirming discussions with a few companies outside the four case studies reported here), encourages the idea that at least a few fundamental building blocks for installed base information management have indeed been identified in this research.

Operational validity, i.e. the extent to which the practitioner is able to control the suggested means (van Aken 2004) deserves a broader treatment, as the operational feasibility of systematic installed base information management was a main concern of several interviewees. There are two major issues with operational feasibility: implementation feasibility of an installed base information system and feasibility of maintaining reliable information on the installed base.

The first issue with operational feasibility is related to implementation of an installed base information system. During the research efforts, it was identified that, because of gradual development of function-specific information processing applications, organizations might end up having several systems containing information on the products. For example, manufacturing units might have their own systems for the purposes of producing and shipping the products; sales units have their systems for handling orders, customer accounts, and service contracts;, and field services have their workflow systems. This is analogous to the situation with information on transactions before enterprise resource planning systems (Kumar and van Hillegersberg 2000; Akkermans et al. 2003).

However, it is not suggested that a single system must replace the current information systems of all subunits; rather, the present aim has been to identify different product-related data types that should be connectable for relevant analyses of the installed base. The management of each kind of data can be handled in a distributed manner in their respective applications, but in light of the resulting propositions, a set of standardized data should made available, either by updating a data warehouse or providing means for retrieval on an as-needed basis, as described for federated database systems (e.g. Sheth and Larson 1990). It is further suggested that uniform recording of the identities of product individuals provides a key to ensure the interconnectivity of distinct systems and, thus, organizational subunits:

- PDM data can be related to a product individual, either explicitly (e.g. design data valid for only a single engineer-to-order individual) or through inheritance (variant- or revision-related information that the individual is an instance of, e.g. general design drawings, maintenance plans).
- Manufacturing data can also be related, either explicitly (e.g. test records, manufacturing BOM with traceability information for component batches) or implicitly (e.g. production batch that the individual is an instance of).
- Sales orders can record the individual products delivered to fulfill the order (i.e. what were the individuals corresponding to the ordered sales items, what were the customer's functional requirements).

- Customer data can be related to individual products within the installation locations, instead of recording only numbers of sales items sold in the CRM systems.
- Maintenance records of service events can be recorded for individual products rather than product types or customer, the primary source of information being the work orders issued for field engineers.
- Remote monitoring is by definition focused on individual products, and monitoring data records can be related to the global product identifiers to enable combinatory analyses with other data.

The second issue with operational feasibility is related to costs of installed base information management. This is as much related to the above discussion of the information system structure and its implementation as to ensuring up-to-date information in such a system. However, as the goal of this research has been to identify the logical structure of installed base information and its role in business processes to reduce uncertainty and improve decision making, the costs of obtaining such information have been deliberately left out of scope of the research. The intent has been to identify desirable and relevant installed base information having value for the decision makers. Whether such information (currently or later) can be feasibly collected and maintained depends on a particular business context and technological development of information gathering means.

At the time of the case studies, the installed base item, location, and event information updates relied prevalently on manual updates by field engineers. Hence, the information quality depended heavily both on careful inspections of the equipment and the environment during site visits and on faithful reporting of these observations along with detailed records of actions on site. Indeed, a most frequent critique of the interviewed practitioners relating to the installed base information management initiatives was the reliability of the data. Because the quality of information is so dependent on the quality of a manual process performed by a vast number of differentially motivated engineers, the data quality in the systems will unavoidably deteriorate after initial enthusiastic efforts to consolidate the base data.

Whereas this might or might not be a valid concern considering the operations of the local units of the case companies, this is not necessarily an inescapable state of affairs. If the propositions above are considered effective within a case, high quality service reports are prioritized, and ways to motivate engineers and their supervisors will be devised. As an example of appreciation for data quality, in Case D, distinct data administrator roles had the responsibility and empowerment for maintaining installed base data accuracy and coverage in local databases.

Another impact on the feasibility of systematic installed base information management results from the improving field data-gathering technologies. At the time of the research, several service units of the case organizations used laptop or handheld computers and other portable devices to receive work orders and to report their work back. The improvement with input efficiency and data quality and timeliness has been remarkable since paper-based reporting systems. Additionally, investments in more capable remote monitoring might become justified both with understanding the value of installed base information and with development of more cost-effective monitoring technologies. Hence, the development of cheap and remotely communicating status measurement devices to be included in each product can render a currently desirable, but infeasible, situation in a business context to a feasible one. This is particularly the case if a major obstacle for information gathering has been the cost of manual information input relative to attainable benefits or the suspected error rate in manual input relative to the precision required for decision making.

In Case D, the remote monitoring possibilities extend further than just status monitoring of the equipment. Through a dedicated communications network, it is possible to interrogate the physical and software configuration of the systems present at each customer location. This made it possible to update installed base Item bill-of-materials to a certain extent to enforce field engineer reporting and even get notifications on situations where there are third party interventions at the customer sites. Installed base Location Data can also be gathered with automated means, such as GPS for physical location. Alternatively, as Case A demonstrated, it is possible to integrate measurement devices that remotely monitor the temperature of the environment to help with remote maintenance operations and problem solving.

Consequently, it is claimed that whereas the operational validity of the design propositions might currently be low in some business contexts, the situation might well improve with technological development and increase the applicability and value of these research results for a wider audience.

8.3 Further research

As stated by Eisenhardt and Graebner (2007, pp. 26–27): 'theory-building research using cases typically answers research questions that address 'how' and 'why' in unexplored research areas particularly well […] By contrast, the research strategy is ill-equipped to address the questions 'how often,' and 'how many,' and questions about the relative empirical importance of constructs.' Because of the explorative stance of this research, the resulting propositions are currently more of the type of 'heuristic rules of indeterminate nature' in contrast to 'algorithmic technological rules' that can be applied as recipes and proven in deterministic or stochastic terms (van Aken 2004). Further research is suggested to validate the propositions in specific contexts to extract more determinate rules or refute their applicability in defined contexts.

In particular, the propositions of the impact of installed base data availability on service delivery efficiency and effectiveness could be measured with quantitative data, either as a cross-sectional study among service units with variable installed base information support or as a longitudinal study with installed base information system development. Such research settings would enable the study of the effects of variable information processing capacity on the operations and decisions. A longitudinal study would also provide more insight on the installed base information impacts on subunit tasks using cumulative information. A viable research framework could be derived from the information systems success model of DeLone and McLean (1992, 2003).

The identified contingencies discussed in Section 7.3 suggest that the meaningfulness of installed base information in a subunit depends on the sources of task uncertainty. Corroboration of these situational factors requires further studies with a larger sample of subunits or organizations. On the organizational level, the most interesting topics for subsequent studies relate to the increases of subunit interdependence with more extensive product-service systems and the resulting increase of performance impacts with installed base information across the subunits. The most interesting impacts on the field services include the impact of heterogeneity of the installed base (task environment) and heterogeneity of resources (task complexity) on the proposed relationship between installed base information and service quality and productivity. The former would perhaps be best studied with longitudinal samples from a set of organizations in the process of changing their product-service system offerings. The latter could be studied within a few organizations by collecting data on their individual service units—performance indicators, installed base information management practices, installed base characteristics, and resource categorizations.

Another research line of both practical and theoretical relevance could be in evaluating heuristic rules for the skill categorization in service units. As the case studies indicated, a multitude of approaches was used to allocate the service load to the field engineers (see section 6.1.2). Because the effects of customer site density on service efficiency have been identified in prior research (originating in the works of Bleuel 1975; Smith 1979), it would be interesting to analyze the boundary conditions for commonalities of equipment and commonalities in service tasks that determine whether it is more efficient to categorize field engineer skills along equipment types or along service task types. This problem domain could be studied with analytical models or simulation models to identify situations where there is a clear preference for one or the other approach.

An interesting research direction is also the use of remote data gathering systems to support installed base information management. While remote monitoring is increasingly used for condition-based maintenance to provide early warning of impending problems (Moore and Starr 2006; Tsang et al. 2006), remote connectivity could be used also for identification of component changes (Case D), usage recording (Case C), or measuring of the operating environment (Case A). There are, however, several tradeoffs of interest with the remote technologies and manual data gathering with site visits. One tradeoff can be identified in upfront investments with integrated remote technology versus manual information gathering costs. Diagnostics sensors and remote connectivity might require costly components, but it is likewise costly to use field engineers' time for information gathering, especially if specific visits are needed to gather data. Another tradeoff relates to the potential maximum coverage of information gathering—newly integrated remote technologies penetrate only slowly the existing installed base and do not provide help with third party equipment in the installed base. In contrast, site visits enable the gathering of data, independent of the age and manufacturer of the equipment, albeit they might require considerable expertise for correct data input. This leads to the third major tradeoff—remote technologies can provide accurate data that can be updated any time, whereas site visit-based data collection might result in manual input errors in the data, and the update frequency is necessarily lower than with automated technical solutions. Elaboration of contexts where the investment in remote technologies pays off and contexts where manual data gathering is more effective are encouraged.

The above trade-offs aside, remote technologies can also have independent business value if the real-time information on the equipment behavior or use in the customer's application can be used for new services for the customer. Research on service innovations going deeper into the customers' processes to provide added value during the use of the supplier's products could help identify additional applications and motivation for systematic installed base information management.

Because the research scope only included fixed installations, another interesting direction for further research involves product-service providers of mobile equipment in an industrial context. Lifting, transport, or construction equipment manufacturers providing support and add-on services to the customers using their equipment are likely to benefit from the Location Data in specific ways. For example, in planning field engineer routes and spare-part locations, the local service units are likely to experience much faster changes in the equipment in service than do the manufacturers of fixed capital goods.

As this concluding section indicates, there are several appealing avenues for further investigation into the use of installed base information in the business processes of product-service suppliers. These are also relevant issues that must be addressed if the product-related services continue to grow their share of manufacturers' profits, and competition in the service markets intensifies.

REFERENCES

Agnihothri, SR and Karmarkar, US 1992, "Performance evaluation of service territories," *Operations Research*, vol. 40, pp. 355–366.

Agnihothri, S, Sivasubramaniam, N, and Simmons, D 2002, "Leveraging technology to improve field service," *International Journal of Service Industry Management*, vol. 13, no. 1, pp. 47–68.

Agnihothri, SR, Mishra, AK, and Simmons, DE 2003, "Workforce cross-training decisions in field service systems with two job types," *The Journal of the Operational Research Society*, vol. 54, no. 4, pp. 410–418.

Agnihothri, SR and Mishra, AK 2004, "Cross-training decisions in field services with three job types and server-job mismatch," *Decision Sciences*, vol. 35, no. 2, pp. 239–257.

Aiken, M and Hage, J 1968, "Organizational interdependence and intra-organizational structure," *American Sociological Review*, vol. 33, no. 6, pp. 912–930.

Akçali, E, Davis, M, Hamlin, RD, McCullough, T, Teyner, T, and Uzsoy, R 2001, "A decision support system for spare parts management in a wafer fabrication facility," *IEEE Transactions on Semiconductor Manufacturing*, vol. 14, no. 1, 76–78.

Akkermans, HA, Bogerd, P, Yücesan, E, and van Wassenhove, LK 2003, "The impact of ERP on supply chain management: Exploratory findings from a European Delphi study," *European Journal of Operational Research*, vol. 146, pp. 284–301.

Aldrich, HE 1979, *Organizations and environments*, Prentice-Hall, Englewood Cliffs, NJ.

Alfredsson, P and Verrijdt, J 1999, "Modeling emergency supply flexibility in a two-echelon inventory system," *Management Science*, vol. 45, no. 10, pp. 1416–1431.

Andres, HP and Zmud, RW 2001, "A contingency approach to software project coordination," *Journal of Management Information Systems*, vol. 18, no. 3, pp. 41–70.

Anthony, RN 1965, *Planning and control systems: A framework for analysis*. Harvard University Press, Cambridge, MA.

Araujo, L and Spring, M 2006, "Services, products, and the institutional structure of production," *Industrial Marketing Management*, vol. 35, pp. 797–805.

Arnold, D, Birkinshaw, J, and Toulan, O 2001, "Can selling be globalized? The pitfalls of global account management," *California Management Review*, vol. 44, no. 1, pp. 8–20.

Arts, RHPM, Knapp, GM, and Mann Jr, L 1998, "Some aspects of measuring maintenance performance in the process industry," *Journal of Quality in Maintenance Engineering*, vol. 4, no. 1, pp. 6–11.

Ashayeri, J, Teelen, A and Selen, W 1996, "A production and maintenance model for the process industry," *International Journal of Production Research*, vol. 34, no. 12, pp. 3311–3326.

Auramo, J and Ala-Risku, T 2005, "Challenges for going downstream," *International Journal of Logistics: Research and Applications*, vol. 8, no. 4, pp. 333–345.

Axsäter, S 1990, "Modelling emergency lateral transshipments in inventory systems," *Management Science*, vol. 36, no. 11, pp. 1329–1338.

Baines, TS, Lightfoot, HW, Evans, S, Neely, A, Greenough, R, Peppard, J, Roy, R, Shehab, E, Braganza, A, Tiwari, A, Alcock, JR, Angus, JP, Bastl, M, Cousens, A, Irving, P, Johnson, M, Kingston, J, Lockett, H, Martinez, V, Michele, P, Tranfield, D, Walton, IM, and Wilson, H 2007, "State-of-the-art in product-service systems," Proceedings of the Institution of Mechanical Engineers, Part B: *Journal of Engineering Manufacture*, vol. 221, no. 10, pp. 1543–1552.

Baker, KR, Magazine, MJ, Nuttle, HLW 1986, "The effect of commonality on safety stock in a simple inventory model," *Management Science*, vol. 32, no. 8, pp. 982–988.

Bamber, CJ, Castka, P, Sharp, JM, Motara, Y 2003, "Cross-functional team working for overall equipment effectiveness (OEE)," *Journal of Quality in Maintenance Engineering*, vol. 9, no. 3, pp. 223–238.

Batenburg, R, Helms, R, Versendaal, J 2005, "The maturity of product lifecycle management in Dutch organizations—A strategic alignment perspective," Institute of Information and Computing Sciences, Utrecht University, Technical report UU-CS-2005-009.

Benbasat, I and Zmud, RW 1999, "Empirical research in information systems: The practice of relevance," *MIS Quarterly*, vol. 23, no. 1, pp. 3–16.

Birkinshaw, J, Toulan, O, and Arnold, D 2001, "Global account management in multinational corporations: Theory and evidence," *Journal of International Business Studies*, vol. 32, no. 2, pp. 231–248.

Blakeley, F, Bozkaya, B, Cao, B, Hall, W, and Knolmajer, J 2003, "Optimizing periodic maintenance operations for Schindler Elevator Corporation," *Interfaces*, vol. 33, no. 1, pp. 67–79.

Bleuel, WH 1975, "Management science's impact on service strategy," *Interfaces*, vol. 6, no. 1, pp. 4–12.

Blumberg, DF 1994, "Strategies for improving field service operations productivity and quality," *The Service Industries Journal*, vol. 14, no. 2, pp. 262–277.

Borchers, HW and Karandikar, H 2006, "A data warehouse approach for estimating and characterizing the installed base of industrial products," proceedings of International Conference on Service Systems and Service Management, pp. 53–59.

Bose, R 2002, "Customer relationship Management: Key components for IT success," *Industrial Management & Data Systems*, vol. 102, no. 2, pp. 89–97.

Bourgeois III, LJ 1979, "Toward a method of middle-range theorizing," *Academy of Management Review*, vol. 4, no. 3, pp. 443–447.

Braglia, M, Grassi A, and Montanari, R 2004, "Multi-attribute classification method for spare parts inventory management," *Journal of Quality in Maintenance Engineering*, vol. 10, no. 1, pp. 55–65.

Brax, S 2005, "A manufacturer becoming service provider—Challenges and a paradox," *Managing Service Quality*, vol. 15, no. 2, pp. 142–155.

Brusco, MJ, and Johns, TR 1995, "The effect of demand characteristics on labour scheduling methods," *International Journal of Operations Production Management*, vol. 15, no. 1, pp. 74–88.

Brusco, MJ and Johns, TR 1998, "Staffing a multi-skilled workforce with varying levels of productivity: An analysis of cross-training policies," *Decision Sciences*, vol. 29, pp. 499–515.

Brusco, MJ, Johns, TR, and Reed, JH 1998, "Cross-utilization of a two-skilled workforce," *International Journal of Operations & Production Management*, vol. 18, no. 6, pp. 555–564.

Bull, C 2003, "Strategic issues in customer relationship management (CRM) implementation," *Business Process Management Journal,* vol. 9, no. 5, pp. 592–602.

Bunge, M 1967, *Scientific research II: The search for truth*, Springer, Berlin.

Callon, M, Méadel, C, and Rabeharisoa, V 2002, "The economy of qualities," *Economy and Society*, vol. 31, no. 2, pp. 194–217.

Campbell, DJ 1988, "Task Complexity: A Review and Analysis," *The Academy of Management Review*, vol. 13, no. 1, pp. 40-52.

Campbell, GM 1999, "Cross-utilization of workers whose capabilities differ," *Management Science*, vol. 45, no. 5, pp. 722–732.

Campbell, AJ 2003, "Creating customer knowledge competence: Managing customer relationship management programs strategically," *Industrial Marketing Management*, vol. 32, pp. 375–383.

Cavalieri, S, Gaiardelli, P, and Ierace S 2007, "Aligning strategic profiles with operational metrics in after-sales service," *International Journal of Productivity and Performance Management*, vol. 56, no. 5/6, pp. 436–455.

Chevalier, P and van den Schrieck, JC 2008, "Optimizing the staffing and routing of small-size hierarchical call centers," *Production and Operations Management*, vol. 17, no. 3, pp. 306–319.

Child, J 1972, "Organization structure, environment and performance: The role of strategic choice," *Sociology*, vol. 6, no. 1–22.

Clark, Jr., TD, Jones, MC, and Armstrong, CP 2007, "The dynamic structure of management support systems: Theory development, research focus, and direction," *MIS Quarterly*, vol. 31, no. 3, pp. 579–615.

Cohen, MA and Whang, S 1997, "Competing in product and service: A product life-cycle model," *Management Science*, vol. 43, no. 4, pp. 535–545.

Cohen, MA, Zheng, YS, and Agrawal, V 1997, "Service parts logistics: A benchmark analysis," *IIE Transactions*, vol. 29, pp. 627–639.

Cohen, MA, Agrawal, N, and Agrawal, V 2006, "Achieving breakthrough service delivery through dynamic asset deployment strategies," *Interfaces*, vol. 36, no. 3, pp. 259–271.

Collins, JE and Sisley, EM 1994, "Automated assignment and scheduling of service personnel," *IEEE Expert*, vol. 9, no. 2, pp. 33–39.

Cooper, RG 1990, "Stage-gate systems: A new tool for managing new products," *Business Horizons*, vol. 33, no. 3, pp. 44–54.

Cooper RG and Kleinschmidt, EJ 2007, "Winning businesses in product development: The critical success factors," *Research Technology Management*, vol. 50, no. 3, pp. 52–66.

Corner, I and Hinton, M 2002, "Customer relationship management systems: Implementation risks and relationship dynamics," *Qualitative Market Research*, vol. 5, no. 4, pp. 239–251.

Crosby, LA 2002, "Exploding some myths about customer relationship management," *Managing Service Quality*, vol. 12, no. 5, pp. 271–277.

Crowston, K 1997, "A coordination theory approach to organizational process design," *Organization Science*, vol. 8, no. 2, pp. 157–175.

Daft, RL and Lengel, RH 1986, "Organizational information requirements, media richness, and structural design," *Management Science*, vol. 32, no. 5, pp. 554–571.

Dekker, R, Kleijn, MJ, and de Rooij, PJ 1998, "A spare parts stocking policy based on equipment criticality," *International Journal of Production Economics*, vol. 56–57, pp. 69–77.

Delaunay, JC and Gadrey, J 1987, *Les enjeux de la société de service*, Presses de la Fondation Nationale des Sciences Politiques, Paris.

DeLone, WH and McLean, ER 1992, "Information systems success: The quest for the dependent variable," *Information Systems Research*, vol. 3, no. 1, pp. 60–95.

DeLone, WH and McLean, ER 2003, "The DeLone and McLean model of information systems success: A ten-year update," *Journal of Management Information Systems*, vol. 19, no. 4, pp. 9–30.

Denyer D, Tranfield, D, van Aken, JE 2008, "Developing design propositions through research synthesis," *Organization Studies*, vol. 29, no. 3, pp. 393–413.

Deshpande, V, Cohen, MA, and Donohue, K 2003, "A threshold inventory rationing policy for service-differentiated demand classes," *Management Science*, vol. 49, no. 6, pp. 683–703.

Deshpande, VS andModak, JP 2003, "Maintenance strategy for tilting table of rolling mill based on reliability considerations," *Reliability Engineering and System Safety*, vol. 80, pp. 1–18.

Dess, GG and Beard DW 1984, "Dimensions of organizational task environments," *Administrative Science Quarterly*, vol. 29, no. 1, pp. 52–73.

Dill, WR 1958, "Environment as an influence on managerial autonomy," *Administrative Science Quarterly*, vol. 2, no. 4, pp. 409–443.

Drucker, PF 1988, "The coming of the new organization," *Harvard Business Review*, vol. 66, no.1, pp. 45–53.

Drucker, PF 1991, "The new productivity challenge," *Harvard Business Review*, vol. 69, no.6, pp. 69–79.

Dubois, A and Gadde, LE 2002, "Systematic combining: An abductive approach to case research," *Journal of Business Research*, vol. 55, pp. 553–560.

Egelhoff, WG 1991, "Information-processing theory and the multinational enterprise," *Journal of International Business Studies*, vol. 22, no. 3, pp. 341–368.

Eisenhardt, KM 1989, "Building theories from case study research," *Academy of Management Review*, vol. 14, no. 4, pp. 532–550.

Eisenhardt, KM 1991, "Better stories and better constructs: The case for rigor and comparative logic," *Academy of Management Review*, vol. 16, pp. 620–627.

Eisenhardt, KM and Graebner, ME 2007, "Theory building from cases: Opportunities and challenges," *Academy of Management Journal*, vol. 50, no. 1, pp. 25–32.

Ellram, LM 1996, "The use of the case study method in logistics research," *Journal of Business Logistics*, vol. 17, no. 2, pp. 93–138.

Eppen, GD 1979, "Effects of centralization on expected costs in a multi-location newsboy problem," *Management Science*, vol. 25, no. 5, pp. 498–501.

Farrell, J and Saloner, G 1986, "Installed base and compatibility: Innovation, product preannouncements, and predation," *The American Economic Review*, vol. 76, no. 5, pp. 940–955.

Fernandez, O, Labib, AW, Walmsley, R, and Petty, DJ 2003, "A decision support maintenance management system—Development and implementation," *International Journal of Quality & Reliability Management,* vol. 20, no. 8, pp. 965–979.

Fortuin, L and Martin, H 1999, "Control of service parts," *International Journal of Operations & Production Management*, vol. 19, no. 9, pp. 950–971.

Frambach, RT, Wels-Lips, I, and Gtindlach, A 1997, "Proactive product service strategies–An application in the European health market," *Industrial Marketing Management*, vol. 26, pp. 341–352 .

Gabbar, HA, Yamashita, H, Suzuki, K, and Shimada,Y 2003, "Computer-aided RCM-based plant maintenance management system," *Robotics and Computer Integrated Manufacturing*, vol. 19, pp. 449–458.

Galbraith, JR 1973, *Designing complex organizations*, Addison-Wesley, Reading, MA.

Galbraith, JR 1974, "Organization design: An information processing view," *Interfaces*, vol. 4, no. 3, pp. 28–36.

Galbraith, JR 1977, *Organization design*, Addison-Wesley, Reading, MA.

Gao, JX, Aziz, H, Maropoulos, PG, and Cheung, WM 2003, "Application of product data management technologies for enterprise integration," *International Journal of Computer Integrated Manufacturing*, vol. 16, no. 7–8, pp. 491–500.

Ghodrati, B and Kumar U 2005, "Operating environment-based spare parts forecasting and logistics: A case study," *International Journal of Logistics: Research and Applications*, vol. 8, no. 2, pp. 95–105.

Glaser, BG and Strauss, AL 1967, The discovery of grounded theory: Strategies for qualitative research, Hawthorne, New York.

Goffin, K 1998, "Evaluating customer support during new product development–An exploratory study," *Journal of Product Innovation Management*, vol. 15, pp. 42–56.

Goffin, K 1999, "Customer support: A cross industry study of distribution channels and strategies," *International Journal of Physical Distribution and Logistics Management*, vol. 29, no. 6, p. 374.

Goffin, K 2000, "Design for supportability: Essential component of new product development," *Research Technology Management*, vol. 43, no. 2, pp. 40–47.

Goffin, K and New, C 2001, "Customer support and new product development: An exploratory study," *International Journal of Operations & Production Management*, vol. 21, no. 3, pp. 275–301.

Goldratt, EM and Cox, J 1984, *The goal: A process of ongoing improvement*, North River Press, Great Barrington, MA.

Gomes, JFS, de Weerd-Nederhof, PC, Pearson, AW, and Cunha, MP 2003, "Is more always better? An exploration of the differential effects of functional integration on performance in new product development," *Technovation*, vol. 23, pp. 185–191.

Goodhue, DL, Wybo, MD, and Kirsch, LJ 1992, "The impact of data integration on the costs and benefits of information systems," *MIS Quarterly*, vol. 16, no. 3, pp. 293–311.

Grahovac J and Chakravarty, A 2001, "Sharing and lateral transshipment of inventory in a supply chain with expensive low-demand items," *Management Science*, vol. 47, no. 4, pp. 579–594.

Griffin A and Hauser, JR 1996, "Integrating R&D and marketing: A review and analysis of the literature," *Journal of Product Innovation Management*, vol. 13, pp. 191–215.

de Groote, P 1995, "Maintenance performance analysis: a practical approach," *Journal of Quality in Maintenance Engineering*, vol. 1, no. 2, pp. 4–24.

Grönroos, C 1990, "Relationship approach to marketing in service contexts: The marketing and organizational behavior interface," *Journal of Business Research*, vol. 20, no. 1, pp. 3–11.

Hambleton, RS 1982, "A manpower planning model for mobile repairmen," *The Journal of the Operational Research Society*, vol. 33, no. 7, pp. 621–627.

Hameri, AP and Nihtilä, J 1998, "Product data management—Exploratory study on state-of-the-art in one-of-a-kind industry," *Computers in Industry*, vol. 35, pp. 195–206.

Harter, DE and Slaughter, SA 2003, "Quality improvement and infrastructure activity costs in software development: A longitudinal analysis," *Management Science*, vol. 49, no. 6, pp. 784–800.

Haugen, DL and Hill, AV 1999, "Scheduling to improve field service quality," *Decision Sciences*, vol. 30, no. 3, pp. 783–804.

Hevner, AR, March, ST, Park, J, and Ram, S 2004, "Design science in information systems research," *MIS Quarterly*, vol. 28, no. 1, pp. 75–105.

Hill, AV 1992, "An experimental comparison of dispatching rules for field service support," *Decision Sciences*, vol. 23, no. 1, pp. 235–249.

Holmström, J, Ketokivi, M, and Hameri AP 2009, "Bridging practice and theory: A design science perspective," *Decision Sciences*, vol. 40, no. 1, pp. 65–87.

Homer, JB 1999, "Macro- and micro-modeling of field service dynamics," *System Dynamics Review*, vol. 15, no. 2, pp. 139–162.

Honeyman 2006, "Is the fourth party over?" *Service Management*, January 1, pp. 19–22.

Huiskonen, J 2001, "Maintenance spare parts logistics: Special characteristics and strategic choices," *Int. J. Production Economics*, vol. 71, pp. 125–133.

Ives, B and Vitale, MR 1988, "After the sale: Leveraging maintenance with information technology," *MIS Quarterly*, vol. 12, no. 1, pp. 7–21.

Jackson, TW 2005, "CRM: From 'art to science'," *Database Marketing & Customer Strategy Management*, vol. 13, no. 1, pp. 76–92.

Jeong, KY and Phillips, DT 2001, "Operational efficiency and effectiveness measurement," *International Journal of Operations & Production Management*, vol. 21, no. 11, pp. 1404–1416.

Jurkovich, R 1974, "A core typology of organizational environments," *Administrative Science Quarterly*, vol. 19, no. 380–394.

Kilpi, J, and Vepsäläinen, APJ 2004, "Pooling of spare components between airlines," *Journal of Air Transport Management*, vol. 10, pp. 137–146.

Klimberg, RK and van Bennekom, FC 1997, "Aggregate planning models for field service delivery," *Location Science*, vol., 5, no. 3, pp. 181–195.

Knecht, T, Leszinski, R, and Weber, F 1993, "Memo to a CEO," *The McKinsey Quarterly*, vol. 4. pp. 79–86.

Kohn, K 2006, "Managing the balance of perspectives in the early phase of NPD—A case study from the automotive industry," *European Journal of Innovation Management*, vol. 9, no. 1, pp. 44–60.

Komonen, K 2002, "A cost model of industrial maintenance for profitability analysis and benchmarking," *International Journal of Production Economics*, vol. 79, pp. 15–31.

Komonen, K 2006, "Availability guarantees and physical assets management: Empirical evidence of the impact of some underlying factors," Proceedings of the Reliability and Maintainability Symposium, 2006, RAMS '06, pp. 152–158.

Kovacs, Z, Le Goff, JM, and McClatchey, R 1998, "Support for product data from design to production," *Computer Integrated Manufacturing Systems*, vol. 11, no. 4, pp. 285–290.

Kranenburg, AA and van Houtum, GJ 2007, "Effect of commonality on spare parts provisioning costs for capital goods," *International Journal of Production Economics*, vol. 108, no. 1–2, pp. 221–227.

Kumar, K, and van Dissel, HG 1996, "Sustainable collaboration: Managing conflict and cooperation in interorganizational systems," *MIS Quarterly*, vol. 20, no. 3, pp. 279–300.

Kumar, K and van Hillgersberg, J 2000, "ERP experiences and evolution," *Communications of the ACM*, vol. 43, no. 4, pp. 23–26.

Larson, RC 1975, "Approximating the performance of urban emergency service systems," *Operations Research*, vol. 23, no. 5, pp. 845–868.

Lawrence, PR and Lorsch, JW 1967, *Organization and environment*, Harvard Business School Press, Boston.

Lee, H 1987, "A multi-echelon inventory model for repairable items with emergency lateral shipments," *Management Science*, vol. 33, no. 10, pp. 1302–1316.

Lele, MM 1997, "After-sales service—necessary evil or strategic opportunity?", *Managing Service Quality*, vol. 7, no. 3, pp. 141–145.

Lesaint, D, Voudouris C, and Azarmi, N 2000, "Dynamic workforce scheduling for British telecommunications plc," *Interfaces*, vol. 30, no. 1, pp. 45–56.

Levitt, T, 1972, "Production-line approach to service," *Harvard Business Review*, vol. 50, no. 5, pp. 41–52.

Lewis, C 2001, "Competition tough in ship repair and service sector," *The Business Journal*, vol. 21, no. 33, p. 8.

Lichtenthal, JD and Long, MM 1998, "Case study: Service support and capital goods—Dissolving the resistance to obtaining product acceptance in new business markets," *Journal of Business & Industrial Marketing*, vol. 13, no. 4/5, pp. 356–369.

Light, B 2003, "CRM packaged software: A study of organizational experiences," *Business Process Management Journal*, vol. 9, no. 5, pp. 603–616.

Lin, Y, Hsu, A, and Rajamani, R 2002, "A simulation model for field service with condition-based maintenance," Proceedings of the 2002 Winter Simulation Conference, San Diego, California, pp. 1885–1890.

Lin, YT and Ambler, T 2005, "A knowledge-based dispatching model for field service," *IEEE International Conference on Systems, Man and Cybernetics*, vol. 4, pp. 3717–3722.

Lindgreen, A, Palmer, R, Vanhamme, J, and Wouters, J 2006, "A relationship-management assessment tool: Questioning, identifying, and prioritizing critical aspects of customer relationships," *Industrial Marketing Management*, vol. 35, pp. 57–71.

Ljungberg, Õ 1998, "Measurement of overall equipment effectiveness as a basis for TPM activities," *International Journal of Operations & Production Management*, vol. 18, no. 5, pp. 495–507.

Lovelock, C and Gummesson, E 2004, "Whither services marketing?" *Journal of Service Research*, vol. 7, no. 1, pp. 20–41.

Löfsten, H 2000, "Measuring maintenance performance–In search for a maintenance productivity index," *Int. J. Production Economics*, vol. 63, pp. 47–58.

Majeske, KD, Lynch-Caris, T, and Herrin, G 1997, "Evaluating product and process design changes with warranty data," *Int. J. Production Economics*, vol. 50, no. 79–89.

Malone, TW and Crowston, K 1994, "The interdisciplinary study of coordination," *ACM Computing Surveys*, vol. 26, no. 1, pp. 87–119.

Markeset, T and Kumar, U 2003, "Design and development of product support and maintenance concepts for industrial systems," *Journal of Quality in Maintenance Engineering*, vol. 9, no. 4, pp. 376–392.

Markeset, T and Kumar, U 2005, "Product support strategy: Conventional versus functional products," *Journal of Quality in Maintenance Engineering*, vol. 11, no. 1, pp. 53–67.

Markus, ML and Robey, D 1988, "Information technology and organizational change: Causal structure in theory and research," *Management Science*, vol. 34, no. 5, pp. 583–598.

Márquez, AC and Herguedas, AS 2004, "Learning about failure root causes through maintenance records analysis," *Journal of Quality in Maintenance Engineering*, vol. 10, no. 4, pp. 254–262.

Martin, HH 1997, "Contracting out maintenance and a plan for future research," *Journal of Quality in Maintenance Engineering*, vol. 3, no. 2, pp. 81–90.

Mathieu, V 2001, "Product services: From a service supporting the product to a service supporting the client," *Journal of Business and Industrial Marketing*, vol. 16, no. 1, pp. 39–58.

Matthyssens, P and Vandenbemt, K 1998, "Creating competitive advantage in industrial services," *The Journal of Business & Industrial Marketing*, vol. 13, iss. 4/5, pp. 339–355.

McCann, JE and Ferry, DL 1979, "An approach for assessing and managing inter-unit interdependence," *The Academy of Management Review*, vol. 4, no. 1, pp. 113–119.

Mentzer, JT and Moon, MA 2004, "Understanding demand," *Supply Chain Management Review*, May/June 2004, pp. 38–45.

Meredith, J 1998, "Building operations management theory through case and field research," *Journal of Operations Management*, vol. 16, pp. 441–454.

Miles, M and Huberman, M 1994, *Qualitative data*, Sage, Thousand Oaks.

Mintzberg, H 1979, *The structuring of organizations*, Prentice-Hall, Englewood Cliffs, NJ.

Mohr, LB 1971, "Organizational technology and organizational structure," *Administrative Science Quarterly*, vol. 16, no. 4, pp. 444–459.

Moore, WJ and Starr, AG 2006, "An intelligent maintenance system for continuous cost-based prioritisation of maintenance activities," *Computers in Industry*, vol. 57, pp. 595–606.

Murthy, DNP and Djamaludin, I 2002, "New product warranty: A literature review," *International Journal of Production Economics*, vol. 79, pp. 231–260.

Nakajima, S (Ed.) 1989, *TPM development program*, Productivity Press, Cambridge, MA.

Ngai, EWT 2005, "Customer relationship management research (1992–2002)—An academic literature review and classification," *Marketing Intelligence & Planning*, vol. 23, no. 6, pp. 582–605.

Niiniluoto, I 1993, "The aim and structure of applied research," *Erkenntnis*, vol. 38, pp. 1–21.

Oh, YS and Bai, DS 2001, "Field data analyses with additional after-warranty failure data," *Reliability Engineering and System Safety*, vol. 72, pp. 1–8.

Ojasalo, J 2001, "Key account management at company and individual levels in business-to-business relationships," *Journal of Business & Industrial Marketing*, vol. 16, no. 3, pp. 199–218.

Oliva, R and Kallenberg, R 2003, "Managing the transition from products to services," *International Journal of Service Industry Management*, vol. 14, no. 2, pp. 160–172.

Orlikowski, WJ 2000, "Using technology and constituting structures: A practice lens for studying technology in 0rganizations," *Organization Science*, vol. 11, no. 4, pp. 404–428.

Papadopoulos, HT 1996, "A field service support system using a queueing network model and the priority MVA algorithm," *Omega, Int. J. Mgmt Sci.*, vol. 24, no. 2, pp. 195–203.

Parasuraman, A 1999, "Customer service in business-to-business markets: An agenda for research," *Journal of Business & Industrial Marketing*, vol. 13, iss. 4/5, pp. 309–321.

Parsons, J and Wand, Y 2000, "Emancipating instances from the tyranny of classes in information modeling," *ACM Transactions on Database Systems*, vol. 25, no. 2, pp. 228–268.

Peltonen, H, Pitkänen, O, and Sulonen, R 1996, "Process-based view of product data management," *Computers in Industry*, vol. 31, pp. 195–203.

Peppard, J 2000, "Customer relationship management (CRM) in financial services," *European Management Journal*, vol. 18, no.3, pp. 312–327.

Petkova, VT, Sander, PC, and Brombacher, AC 1999, "The role of the service centre in improvement processes," *Quality And Reliability Engineering International*, vol. 15, pp. 431–437.

Pfeffer, J and Salancik, G 1978, *The external control of organizations: A resource dependence perspective*, Harper & Row, New York.

Philpotts, M 1996, "An introduction to the concepts, benefits and terminology of product data management," *Industrial Management & Data Systems*, vol. 96, no. 4, pp. 11–17.

Pilling, M 2005, "Capacity crossroads," *Airline Business*, vol. 21, no. 10, pp. 50–52.

Pinker, EJ and Shumsky, RA 2000, "The efficiency-quality trade-off of cross-trained workers," *Manufacturing & Service Operations Management*, vol. 2, no. 1, pp. 32–48.

Pintelon, L and van Puyvelde, F 1997, "Maintenance performance reporting systems: Some experiences," *Journal of Quality in Maintenance Engineering*, vol. 3 no. 1, pp. 4–15.

Pintelon, L, Du Preez, N, and van Puyvelde, F 1999, "Information technology: Opportunities for maintenance management," *Journal of Quality in Maintenance Engineering*, vol. 5, no. 1, pp. 9–24.

Prahalad, CK and Hamel, G 1994, *Competing for the future*, Harvard Business School Press, Boston.

Rai, B and Singh, N 2003, "Hazard rate estimation from incomplete and unclean warranty data," *Reliability Engineering and System Safety*, vol. 81, pp. 79–92.

Rangan, RM, Rohde, SM, Peak, R, Chadha, B, and Bliznakov, P 2005, "Streamlining product lifecycle processes: A survey of product lifecycle management implementations, directions, and challenges," *Journal of Computing and Information Science in Engineering*, vol. 5, pp. 227–237.

Robey, D and Sales, CA 1994, *Designing organizations* (4th ed.), Richard Irwin, Homewood, IL.

Rustenburg, WD, van Houtum, GJ, and Zijm, WHM 2000, "Spare parts management for technical systems: Resupply of spare parts under limited budgets," *IIE Transactions*, vol. 32, pp. 1013–1026.

Rygielski, C, Wang JC, and Yen, DC 2002, "Data mining techniques for customer relationship management," *Technology in Society*, vol. 24, pp. 483–502.

Sackett, PJ and Bryan, MG 1998, "Framework for the development of a product data management strategy," *International Journal of Operations & Production Management*, vol. 18, no. 2, pp. 168–179.

Samli, A, Jacobs, C, and Wills, J 1992, "What presale and postsale services do you need to be competitive," *Industrial Marketing Management*, vol. 21, pp. 33–41.

Sampson, SE and Froehle, CM 2006, "Foundations and implications of a proposed unified services theory," *Production and Operations Management*, vol. 15, no. 2, pp. 329–343.

Schmenner, RW and Swink, ML 1998, "On theory in operations management," *Journal of Operations Management*, vol. 17, pp. 97–113.

Scott, WR 1981, *Organizations: Rational, natural, and open systems*, Prentice-Hall, Englewood Cliffs, NJ.

Sherbrooke, CG 1967, "METRIC: A multi-echelon technique for recoverable item control," *Operations Research*, vol. 16, pp. 122–141.

Sherman, JD, Berkowitz, D, and Souder, WE 2005, "New product development performance and the interaction of cross-functional integration and knowledge management," *Journal of Product Innovation Management*, vol. 22, pp. 399–411.

Sherwin, DJ 1999, "A constructive critique of reliability-centered maintenance," Proceedings of annual reliability and maintainability symposium.

Sheth, AP and Larson, JA 1990, "Federated database systems for managing distributed, heterogeneous, and autonomous databases," *ACM Computing Surveys*, vol. 22, no. 3, pp. 183–236.

Simon, HA 1973a, "Does scientific discovery have a logic?", *Philosophy of Science*, vol. 40, pp. 471–480.

Simon, HA 1973b, "Applying information technology to organizational design," *Public Administration Review*, vol. 33, no. 3, pp. 268–278.

Simon, HA 1996 [1969], *Sciences of the artificial*, (3rd ed.), MIT Press, Cambridge, MA.

Simon, HA 2000 [1945], *Administrative behaviour*, (4th ed.), The Free Press, New York.

Smith, SA 1979, "Estimating service territory size," *Management Science*, vol. 25, no. 4, pp. 301–311.

Smith, FO 2007, "Asset performance management is the backbone to culture of reliability," *Manufacturing Business Technology*, December 2000.

Souder, WE and Moenaert, RK 1992, "Integrating marketing and R&D project personnel within innovation projects: An information uncertainty model," *Journal of Management Studies*, vol. 29, no. 4, pp. 485–512.

Strauss, A and Corbin, J 1990, *Basics of qualitative research: Grounded theory procedures and techniques*, Sage, Newbury Park.

Stuart, I, McCutcheon, D, Handfield, R, McLachlin, R, and Samson, D 2002, "Effective case research in operations management: a process perspective," Journal of Operations Management, vol. 20, pp. 419–433.

Tang, Q, Wilson, GR, and Perevalov, E 2007, "An approximation manpower planning model for after-sales field service support," forthcoming in *Computers & Operations Research*.

Thomas, KW and Tymon Jr, WG 1982, "Necessary properties of relevant research: Lessons from recent criticisms of the organizational sciences," *The Academy of Management Review*, vol. 7, no. 3, pp. 345–352.

Thompson, GM 1995, "Labor scheduling using NPV estimates of the marginal benefit of additional labor capacity," *Journal of Operations Management*, vol. 13, pp. 67–86.

Thompson, JD 1967, *Organizations in action*, McGraw-Hill, New York.

Trott, P 2001, "The role of market research in the development of discontinuous new products," *European Journal of Innovation Management*, vol. 4, no. 3, pp. 117–125.

Tsang, AHC 1995, "Condition-based maintenance: Tools and decision making," *Journal of Quality in Maintenance Engineering*, vol. 1, no. 3, pp 3–17.

Tsang, AHC 2002, "Strategic dimensions of maintenance management," *Journal of Quality in Maintenance Engineering*, vol. 8, no. 1, pp. 7–39.

Tsang, AHC, Jardine, AKS, and Kolodny, H 1999, "Measuring maintenance performance: A holistic approach," *International Journal of Operations & Production Management*, vol. 19, no. 7, pp. 691–715.

Tsang, AHC, Yeung, WK, Jardine, AKS, and Leung, BPK 2006, "Data management for CBM optimization," *Journal of Quality in Maintenance Engineering*, vol. 12, no. 1, pp. 37–51.

Tushman, M and Nadler, D 1978, "Information processing as an integrating concept in organizational design," *Academy of Management Review*, vol. 3, no. 3, pp. 613–624.

Youngdahl, W and Loomba, P 2000, "Service-driven global supply chains," *International Journal of Service Industry Management*, vol. 11, no. 4, pp. 329–338.

van Aken, JE 2004, "Management research based on the paradigm of the design sciences: The quest for field-tested and grounded technological rules," *Journal of Management Studies*, vol. 41, no. 2, pp. 219–246.

van de Ven, AH, Delbecq, AL, and Koenig, Jr, R 1976, "Determinants of coordination modes within organizations," *American Sociological Review*, vol. 41, no. 2, pp. 322–338.

Vargo, S L and Lusch, RF 2004, "The four service marketing myths: Remnants of a goods-based, manufacturing model," *Journal of Service Research*, vol. 6, no. 4, p. 324.

Vollman, TE, Berry, WL, and Whybark, DC 1997, *Manufacturing planning and control systems*, McGraw-Hill, New York.

Voss, C, Tsikriktsis, N, and Frohlich, M 2002, "Case research in operations management," *International Journal of Operations & Production Management*, vol. 22, no. 2, pp. 195–219.

Voudouris, C, Owusu, G, Dorne, R, Ladde, C, and Virginas, B 2006, "ARMS: An automated resource management system for British Telecommunications plc," *European Journal of Operational Research*, vol. 171, pp. 951–961.

Wang, Y, Cohen, MA, and Zheng, YS 2002, "Differentiating customer service on the basis of delivery lead-times," *IIE Transactions*, vol. 34, pp. 979–989.

Watson, EF, Chawda, PP, McCathy, B Drevna, MJ, and Sadowski, RP 1998, "A simulation metamodel for response-time planning," *Decision Sciences*, vol. 29, no. 1, pp. 217–241.

Watson, HJ and Frolick, MN 1993, "Determining information requirements for an EIS," *MIS Quarterly*, vol. 17, no. 3, pp. 255–269.

Wemmerlöv, U 1990. "A taxonomy for service processes and its implications for system design," *International Journal of Service Industry Management*, vol. 1, no. 3, pp. 13–27.

Werner, T and Vetter, C, 2003, "Optimizing asset usage through integrated maintenance software systems," Proceedings of IEEE Power Engineering Society General Meeting, vol. 1, pp. 430–435.

Wheelwright, SC and Clark, KB 1992, "Creating project plans to focus product development," *Harvard Business Review*, vol. 70, no. 2, pp. 67–83.

Wise R, and Baumgartner P 1999, "Go downstream, the new profit imperative in manufacturing," *Harvard Business Review*, vol. 77, no. 5, pp. 133–141.

Wong, H, Cattrysse, D, and Van Oudheusden, D 2005, "Stocking decisions for repairable spare parts pooling in a multi-hub system," *International Journal of Production Economics*, vol. 93–94, pp. 309–317.

Woodruff, RB 1997, "Customer value: The next source for competitive advantage." *Journal of the Academy of Marketing Science*, vol. 25, no. 2, pp. 139–153.

Wu, H and Meeker, WQ 2002, "Early detection of reliability problems using information from warranty database," *Technometrics*, vol. 44, no. 2, pp. 120–133.

Xu M and Walton, J 2005, "Gaining customer knowledge through analytical CRM," *Industrial Management & Data Systems*, vol. 105, no. 7, pp. 955–971.

Yamashina, H and Otani, S 2001, "Cost-optimized maintenance of the elevator–single unit case," *Journal of Quality in Maintenance Engineering,* vol. 7, no. 1, pp. 49–70.

Yin, RK 1994, *Case study research: Design and methods*, Sage, Newbury Park, CA.

Zablah, AR, Bellenger, DN, and Johnston, WJ 2004, "An evaluation of divergent perspectives on customer relationship management: Towards a common understanding of an emerging phenomenon," *Industrial Marketing Management*, vol. 33, pp. 475–489.

Zackariasson, P and Wilson, TL 2004, "Internetworked after-sales service," *Industrial Marketing Management*, vol. 33, no. 2, p. 75.

APPENDIX A: CASE STUDY DESCRIPTIONS

Case A

Case Study A was performed by the author and M.Sc. Olli Lehtonen. The author was responsible for the design of the case study, but data gathering and analysis was performed together by both involved researchers.

The case company A is a manufacturer providing cooling systems for commercial use. The goal of the research effort with the case company was to investigate and describe the development needs in product-related information exchange between the manufacturing organization and its accredited service partner network. The rationale and motivation of the case company was twofold: 1) improve its installed base information availability for new service development and product management, and 2) improve the service effectiveness and efficiency of its service partners for higher customer satisfaction. There were two phases in the research, where the first phase emphasized the information availability from service operations, and the second phase focused on the warranty-related information availability.

Two publications have reported findings of the case study:

- Olli Lehtonen, 2005, Taking Advantage of After-Sales Product Information in a Multi-company Environment, Master's Thesis, Department of Industrial Engineering and Management, Helsinki University of Technology. (The author acted as the instructor of this master's thesis.)
- Olli Lehtonen, Timo Ala-Risku, 2005, "Enhancing On-Site Maintenance Execution with ICT – A Case Study," Fifth International Conference on Electronic Business, Hong Kong, December 5–9.

Research material from the case

The case study was performed between 2004 and 2005 and consisted of three main types of research material:

1) Interviews of the case company representatives concerning the needs for installed base information, gathered in two phases
2) A concurrent research effort: survey of product information requirements of authorized service companies that provide services to the installed base of the focal company
3) Invoicing records to verify service efficiency measures of the survey

Additionally, company internal documentation, such as process flowcharts and information system overviews, were provided to the researchers.

The researchers and the key contact of the case company selected the interviewees. The selection was based on the researchers' *a priori* understanding of relevant subunits, whereas the key contact suggested knowledgeable interviewees of each subunit. During the study, the list of interviews was appended based on suggestions of the interviewees. Typically, they knew of other knowledgeable people in their subunit or of information management development efforts of relevance for the study. The interview material is stored as interview notes, recordings, and transcripts in a case study database. The part of the interview protocol relevant for this thesis and the interviewees are listed below.

Survey responses were gathered from 31 accredited service partners, and although the survey results are not analyzed further within this cross-case analysis, they nevertheless have influenced the research in the subsequent cases in terms of gaining an understanding of installed base information requirements in the service process. In particular, they have provided insights on the practical challenges with an accredited network of independent service partners.

The interviewees also provided the researchers with process flowcharts to describe formally the operations with which they were involved. Further, the researchers were familiarized with the information systems used with the sales and delivery process, as well as after-sales services, and given excerpts of system data to illustrate the structure and quality of data on the installed base currently available. Working meetings, where the research material and tentative results were reviewed with case company representatives, provided additional insight into the processes and practices used at the organization.

Main conclusions within the case study

Because the motivation for the case study arose from a practical need to understand development needs in improving the product-related information exchange between a manufacturer and its network of service providers, the main focus of the case was in understanding the interdependence of the service operations and manufacturer operations—what information would the service providers need from the manufacturer, and what information could be attained from the service providers for the manufacturer's processes.

Initial service partners' product-related information needs were identified in service partner interviews, and survey data from all accredited service partners was collected to find out the relevance of the data items. The survey among the service partners indicated that about two of every five failures of first-visit-resolution in the service operations could be attributed to lack of installed base information. A key problem was that the customer was mostly incapable of providing information on what product type was concerned with the service request and what the problem was in more detail than "broken product." This resulted in not knowing what spare parts, tools, and product documentation (electrical diagrams, assembly drawings, etc.) were needed for the service visit.

Reasons for gathering installed base information in the case study

During the study, it was recognized that service efficiency and effectiveness were the key benefits to be expected from more systematic installed base information management. As the customers operated their equipment mainly in a run-to-failure mode, most service visits were unplanned. If the local service partner was not involved in the initial installation of the equipment, the service partner might not have any knowledge about the failed piece of equipment before visiting the customer site. In addition, because customers were often incapable of describing the product and problem accurately enough, the service partners had difficulties in estimating the spare parts needed for the visit. Information on the items in the installed base maintained by the case company was seen as beneficial for the service partners to improve the identification of service targets and new equipment entering the installed base.

For the case company, understanding product performance (energy consumption, in particular) in customer applications and identification of "epidemics" of failing components were seen as the most important uses for installed base information. It was identified that improving the product reliability based on installed base information would require more comprehensive access to the service events performed by the service partners and improved remote connectivity to the products.

Information needs on the installed base in the case study

The most important pieces of information were seen as the locations of each item, their service bills-of-material, and component changes performed during the service events. Additionally, more widespread access to remote monitoring data and use environments were seen to support the identified purposes for installed base information.

Whereas the installed base information needs were identified, obtaining the data after the warranty period proved challenging in the service business organization at the time of the study. Accredited but independent service partners were also supporting other manufacturers' equipment and found it too laborious and unprofitable to provide service records or updates on installed items for each equipment manufacturer separately. It was recognized that changes were required in the service delivery process to improve information gathering.

Outline of the semi-structured open-ended interview protocol in Case A

This interview guide was used as a baseline to construct individual interview questionnaires. The interview questionnaire used in each interview accounted for the a priori information that the researchers had on the interviewees' task. For example, when interviewing product development personnel, the questions were directed towards the new product development process. Further, during the interview, sidesteps from the protocol were made to probe for interesting themes emerging during the interview (Eisenhardt 1989; Stuart et al. 2002), such as an interviewee being knowledgeable of other positions' installed base information requirements because of prior work experience or when there were some function-specific information management practices.

1. Responsibilities of interviewee organizational position
    a. Please describe [the operations of the function/process you are involved with].
    b. What are the tasks you are responsible for in your position?
    c. What are the main decisions you are making in your position?
    d. What kinds of reports are you responsible for?
2. Current installed base information availability
    a. What is the main information you currently use in [performing your task, decision making]?
    b. What are the sources for this information?
    c. What kind of information do you use on the installed equipment?
    d. What kind of information do you use on the customers of your company?
    e. What kind of information do you get from the accredited service partners?
3. Additional information requirements on the installed base
    a. What information would be needed on the installed equipment?
    b. How would [your actions, your decisions, the operations in the function/process you are involved with] change if you had this information available?
    c. What additional information would be needed regarding the customers of your company?
    d. What additional information would be needed from the accredited service partners?
    e. How should this information be available?
4. Development needs
    a. What are the most challenging aspects of [your task, the function/process you are involved with]?
    b. What are currently the most pressing development needs for [the function/process you are involved with]?
    c. What are the most challenging aspects in improving installed base information availability [for your function/process]?

Interviewed personnel in Case A

Role (in alphabetical order)	Date of interviews
After-Sales Manager	7.6.2004
After-sales Support 1	23.9.2005
After-sales Support 2	26.10.2005
Business Development Manager	7.9.2005
Customer 1	29.6.2004
Customer 2	7.7.2004
Delivery Project Manager	19.5.2004
Electrical Engineer	9.6.2004
IT Specialist 1	4.6.2004
IT Specialist 2	24.6.2004
IT Specialist 3, 1, and 4	23.11.2005
Materials Manager	11.5.2004
Product Manager 1	7.9.2005
Product Manager 2	6.9.2005
Production Director	6.9.2005
Production Manager 1	9.11.2005
Production Manager 2	9.11.2005
Purchasing Director	12.10.2005
Purchasing Manager	12.10.2005
R&D Director	2.11.2005
R&D Engineer	10.6.2004
R&D Project Manager	23.11.2005
Sales Manager 1	4.6.2004
Sales Manager 2	26.10.2005
Sales Manager 3	2.11.2005
Service Manager	20.5.2004
Service Partner 1	15.6.2004
Service Partner 2	18.6.2004
Service Partner 3	21.6.2004
Technology Manager 1	2.11.2005
Technology Manager 2	2.11.2005
Vice President of Operations	7.9.2005

Workshops and other meetings in Case A

Working meeting at case company	14.6.2004
Working meeting at case company	1.7.2004
Working meeting at case company	3.11.2004
Phase 1 results dissemination workshop	21.12.2004
Working meeting at case company	1.6.2005
Working meeting at case company	22.8.2005
Working meeting at case company	7.9.2005
Working meeting at case company	23.11.2005
Working meeting at case company	20.12.2005
Phase 2 results dissemination workshop	10.1.2006

Case B

The author and M.Sc. Olli Lehtonen performed Case Study B. The author was responsible for the case study design, but the research material was both gathered and analyzed together by the researchers.

Case company B is an industrial process flow control component manufacturer. The goal of the research effort with the case company was to investigate and describe the development needs in product-related information exchange among subunits of the product and service organizations, as well as identify current installed base-related data in diverse information systems of the case company. The motivation of the case company was to improve its installed base information availability to support the operations at the customer interfaces and the order-delivery process of engineer-to-order products.

Findings of the case study have been reported in Timo Ala-Risku, Olli Lehtonen, 2006, "Improving manufacturer operations with installed base information," 17th Annual Conference of Production and Operations Management Society (POMS), Boston, MA, USA, April 28–May 1, 2006.

Research material from the case

The case study material was gathered during 2005, and it consisted of two main types of material:

1) interviews of subunit representatives
2) samples of installed base–related data in different systems

The interviewee selection was performed very similarly to Case A by the researchers and the key contact of the case company. The selection was based on the researchers' *a priori* understanding of relevant subunits, and the key contact selected knowledgeable interviewees of each subunit. In addition to the subunits in need of installed base information, systems specialists responsible for the internal information systems were also interviewed. The systems specialists were interviewed to identify the possibilities of combining product-related data residing in different internal systems. As in the previous case, additional knowledgeable interviewees were identified based on suggestions of the interviewees. The interview material is stored as interview notes, recordings, and transcripts in a case study database. The interview protocols and interviewees are listed below.

The interviewees also provided the researchers with snapshots of product-related data in various information systems as well as data warehouse reports. Further, the interviewees presented flowcharts to describe formally the operations with which they were involved and information systems they used in their tasks. In particular, product information in the after-sales service system, warranty claims system, installed base auditing system, and sales systems were reviewed. Working meetings where the research material and tentative results were reviewed with case company representatives provided additional insight into the processes and practices used at the organization.

As supplementary material, results from a concurrent research effort by fellow researchers on the service processes of the case company were used to understand the case company service business.

Main findings within the case study

As the motivation for the case study was based on improving product-related information management within the case company, the focus of the research was on interdependencies among the organization subunits dealing with the ordering process and the after-sales operations.

There were three notable characteristics in the business of the case company that influenced their installed base information management. First, the installed base of the case company includes heterogeneous products. This resulted from engineer-to-order products forming a significant share of the company's sales. In addition, whereas the more standard products were configured by selecting predesigned modules based on attributes related to the customer application, the vast number of possible combinations makes many produced configurations unique in the installed base.

Second, some direct customers of the company were systems integrators. The end user and the final location for the sold products were thus not recorded at the time of sales. This made the approximation of the current installed base based on sales records difficult. One consequence was that a single customer site could host a number of case company products delivered through different middlemen.

Finally, the after-sales service markets were not well established at the time of the case study. Most end users took care of maintenance themselves and requested only specialist support for occasional more demanding servicing tasks. This resulted in infrequent contact with a great share of the installed base, thus reducing the ability to have good coverage of updated installed base information.

Reasons for gathering installed base information in the case study

These business characteristics were notable in the service operations. All maintenance contracts had to be started with a detailed product audit that included for each process location the items, accessibility, and relevant installation interfaces. These records were necessary to suggest critical upgrades for the customer, to plan for correct field engineer training and spare-part inventories in the area, and to ensure appropriate tools and spare parts were available for each service job. These all were preparations for effective and efficient service operations based on purposefully gathered installed base information.

Whereas customer sites with service contracts had preplanned spare-part inventories, customers taking care of the maintenance operations by themselves ordered spare parts only when needed. Some of such part orders were for planned operations, and the needed parts were requested well in advance, but at times, spare-part needs could arise unexpectedly during a break. For these situations, the spare-part management hoped it would have a better picture of the installed equipment of important customers so that a share of spare parts could be stocked or prefabricated for the most critical demand.

Both sales and product management were interested in how well the different configurations suit particular customer needs. Sales saw opportunities for additional revenue through sales of updated equipment configurations, and product management was concerned with reliability and performance problems resulting from improper use of equipment.

From the product sales perspective, identifying old equipment in use was another key use for installed base information. The primary interest was in additional revenue through replacement sales, but it was also recognized that, for both the customer and the service provider, the maintenance costs could be significantly lowered. Improved product reliability and better on-shelf availability of spare parts for newer products would offer better service performance for both parties. After-sales service sales were seen to benefit greatly from more systematic records of installed base items. Currently, they suffered from the product sales through middlemen and the resulting lack of records on potential service customers, i.e. the end users for delivered products.

As for the interests of product management and product development, reliability issues were seen as an important application for more widespread installed base information. Improving the availability of service records was seen to enable more accurate analyses of product failure frequencies, as well as the identification and correction of reliability issues with specific product configurations. In addition, component subcontractors were seen to benefit from detailed reliability analyses in end-user application. Better linking of customer application data and expected environmental conditions from the ordering process to installed base records were requested for warranty resolution and application-specific product performance analyses.

Information needs on the installed base in the case study

As the variety of possible product configurations was extensive, and as a part of the products were engineer-to-order products, it was seen that all installed base items should be recorded by their serial numbers. Although product type codes would suffice for sales lead identification purposes, they would not disclose the exact variant of the product. Using only product type codes would reduce the utility of the information for spare-part identification, reliability analyses, and fabrication of replacement units.

Location characteristics of product interfaces and accessibility were already gathered in the customer audits. A uniform practice of recording corrosive agents and operating temperature were welcomed for replacement sales and reliability analyses.

As for the service events, in addition to the invoicing items, key additional information for systematic recording was changed components and failure reason.

Specific findings in the case study

The case analysis indicated that one key problem with using existing installed base-related information in the case organization was the absence of common product identifiers in the various subunit specific information systems. Whereas relevant information was gathered in sales units (process specifications, environmental operating conditions), service units (installed base audits, service events), engineering systems (product design and configuration data), and production systems (configurations, functional test data), each operated with different identifiers.

In particular, it was identified that a notable amount of product application and location-related information is received from the customer or generated within the organization before the physical product is manufactured and assigned a serial number. This information needs to be maintained and later connected to the physical product, based on sales order identifiers or the end-user process location.

Outlines of the interview protocols in Case B

The baseline interview protocol to uncover installed base information needs was similar to the one used with Case A. In addition, there was a separate baseline interview protocol for the interviews of information system managers. Both of these interview guides are presented below. Again, sidesteps from the interview guide were made if promising topics for further discussion were revealed during the interviews.

Interview guide for installed base information needs

1. Responsibilities of interviewee organizational position
    a. Please describe [the operations of the function/process you are involved with].
    b. What are the tasks you are responsible for in your position?
    c. What are the main decisions you are making in your position?
    d. What kinds of reports are you responsible for?
2. Current installed base information availability
    a. What is the main information you currently use in [performing your task, decision making]?
    b. What are the sources for this information?
    c. What kind of information do you use on the installed equipment?
    d. What kind of information do you get on the customers of your company?
    e. What kind of information do you get from the service process?
    f. What kind of information do you get from installed base audits?

3. Additional information requirements on the installed base
    a. What information would be needed on the installed equipment?
    b. How would [your actions, your decisions, the operations in the function/process you are involved with] change if you had this information available?
    c. What additional information would be needed regarding the customers of your company?
    d. What additional information would be needed from the accredited service partners?
    e. How should this information be available?
4. Development needs
    a. What are the most challenging aspects of [your task, the function/process you are involved with]?
    b. What are currently the most pressing development needs for [the function/process you are involved with]?
    c. What are the most challenging aspects in improving installed base information availability [for your function/process]?

Interview guide for information system descriptions

1. Overview of [the information system]
    a. What is the main purpose of the system?
    b. Which [subunits/tasks] are the main users of the system?
    c. How broadly is the system available to different subunits?
2. Use of [the information system]
    a. Describe the main process using the system?
    b. Who are responsible for the data in the system?
    c. Who are using the data in the system?
3. History of [the information system]
    a. What were the reasons for implementing the current information system?
    b. How was this information handled before the current system?
    c. How is the prior information currently available?
4. Coverage of [the information system]
    a. How comprehensively is [data] input in the system?
    b. Are there any parallel information management practices outside the system?

Interviewed personnel in Case B

Role (in alphabetical order)	Date of interviews
Customer	4.3.2005
Delivery Project Manager	11.10.2005
Development Engineer 1	24.11.2005
Development Engineer 2	25.10.2005
Development Project Manager	28.9.2005
Director, Service & Spare Parts	27.4.2005
Engineering Manager	24.11.2005
Manager, Data Warehouse Systems	28.10.2005
Manager, E-business Systems	11.10.2005
Manager, Engineering Systems	28.9.2005
Manager, Installed Base Audit Systems	13.10.2005
Manager, Technical Support	11.10.2005
Procurement Manager	28.10.2005
Product Director	1.11.2005
Product Manager	8.2.2005
Production Manager 1	28.10.2005
Production Manager 2	21.2.2005
Quality Manager	1.11.2005
R&D Manager	1.11.2005
Sales Director	1.12.2005
Service Director	28.9.2005
Service Manager	19.1.2005
Spare Parts Logistics Manager	25.10.2005

Workshops and other meetings in Case B

Working meeting at case company	4.8.2005
Working meeting at case company	19.8.2005
Working meeting at case company	8.9.2005
Working meeting at case company	12.9.2005
Working meeting at case company	11.11.2005
Working meeting at case company	12.12.2005
Results dissemination workshop	19.1.2006
Results dissemination workshop	30.1.2006

Case C

The author in cooperation with a development project manager of the case company performed Case Study C. The author was responsible for the overall design of the case study, but the design was influenced by the on-going development project improving the availability of global installed base information. Interview data gathering and the within-case analysis were performed together by the author and the development project manager of the company.

Case company C is a machinery and solutions manufacturer. The goal of the research effort with the case company was to investigate and describe the development needs in installed base information management to improve global support for after-sales service operations and product performance analyses.

Findings of the case study have been reported in Timo Ala-Risku, 2007, "Installed base information management with industrial service operations," 18th Annual Conference of Production and Operations Management Society (POMS), Dallas, TX, USA, May 4–7, 2007.

Research material from the case

The case study material was gathered during 2006 and consists mainly of interviews with subunit representatives.

The author and the key contact of the case company selected the interviewees. The selection was based on the author's *a priori* understanding of relevant subunits but was influenced by the focus of the on-going development project. Specifically, linking the installed base with information needs of product sales was omitted. Additional knowledgeable interviewees were identified based on suggestions of the interviewees. The interview material is stored as interview notes, recordings, and transcripts in a case study database. The interview protocol and interviewees are listed below.

During the case study, data in the installed base information system and data from service records were reviewed. Further, the interviewees presented formalized use cases they had identified for the installed base information development initiative. Intensive working meetings with the key contact at the case company were elemental in strengthening the company process understanding and contextual relevance of initial analyses.

Supplementary material for understanding the case company service business was gathered by attending academic workshops arranged by fellow researchers, as well as write-ups of research reports detailing the service delivery processes of the case company.

Main findings within the case study

The main motivation for the study was to understand what data items should be systematically gathered to enable globally uniform analyses on both company's own installed equipment and third party equipment with service contracts. As some service units would need to gather and update the data to the installed base system manually, this required the identification of strong enough business cases for each data item to be included in the data set. The focus of the study was on the interdependency among service units and back-end operations such as service resource planning, product management, and product development.

The particular characteristics of the case business context were that the service markets were highly competitive, and upgrade and replacement sales were a major source of revenue. From these, it follows that the case company was not the original equipment manufacturer for a major share of serviced equipment, and there were frequent changes in the customer sites and equipment in service at most local service units.

Reasons for gathering installed base information in the case study

For the case study, the major reason for maintaining installed base records at local service units was that the service operation effectiveness and efficiency depended on the information. Although the practices of assigning service jobs and customer sites varied among local service units, each unit made dispatching decisions for urgent repairs based on the location, accessibility, and the product type to be serviced.

Further, the local resources were managed based on the installed base with service contracts. Field engineer headcount and inventories in service vehicles were based on the items in the service area. These decisions also contributed to the success and efficiency of the service operations. The possibility of uniform installed base records across the service units were welcomed for global spare-part management. Analyses of commonalities across service units and geographical areas could be used to reduce costs of spare-part supply through improved sourcing and inventory location decisions.

With the replacement and upgrade sales being important for the case company, the sales function was the second major user for the uniform installed base data. Improved product sales revenue was seen to result from easier identification of upgrade potential and from more accurate sales offers that could rely on the technical product data in the installed base records. Renewals of service contracts were also benefiting from installed base information, as contract profitability in terms of scope and pricing could be assessed based on product performance analyses in that and similar customer applications.

Product managers saw uniform records of both installed items and service events important for analyses of recurring problems. Installed base information could be used for identifying reliability issues in a product type in general or in a production batch, and decisions on product changes could be based on analyzing the scope of involved items and customers. The changes would also be easier to implement with high coverage if global records could be used to inform all service units required to take action. The reliability analyses could also be used as evidence on scope when discussing component quality problems with suppliers.

Product development welcomed uniform installed base records, both for identifying needs for new replacement or upgrade products and for making volume estimates for analyzing market size for new replacement and upgrade products. Service process development could identify process improvement needs by analyzing service events among service units and maintainability and serviceability problems in products by comparing service event durations between product types.

Information needs on the installed base in the case study

It was seen as necessary to record the installed base item data with globally unique identifiers for the products. This was necessary as some components and subassemblies of the products could be updated and, thus, make a reference to a product type uninformative. Whereas product type and original manufacturer would be recorded for simple cases, partially updated products would require a different treatment—indication of product type, for example, for field engineer selection or for replacement sales leads would be interpreted from the current main components of the specific product.

Location was seen as an attribute of the product, but location characteristics in terms of the mechanical and electrical interfaces used by the product were seen relevant when configuring replacement offers.

Service event records on invoicing items were necessary for customer reporting, but for analytical purposes, changed components were seen of most interest. This data would be useful for planning spare-part inventories for third party equipment and for analyzing reliability issues among products and geographical regions.

Specific findings in the case study

The results of the case study indicated the need for a set of core data on technical characteristics of the products, with the possibility to append the data for specific purposes (such as planning for upgrades). The installed base analyses desired in different subunits also required that the already implemented global product identifiers be taken into use with service records to enable uniform product and service performance analyses.

Another important finding in the case was related to the relevance of third party items as part of the installed base information management effort. For the service operations, field engineers and spare parts need to be identified and the service capabilities maintained independent of the original equipment manufacturer. To support decisions related to resource investments and inventory locations, the installed equipment and service performance need to be uniformly analyzable.

Outline of the interview protocol in Case C

The following interview guide was used as a baseline to construct individual interview questionnaires. The interview questionnaire used in each interview accounted for the *a priori* information that the author had on the interviewee's task.

1. Responsibilities of interviewee organizational position
    a. Please describe [the operations of the function/process you are involved with].
    b. What are the tasks you are responsible for in your position?
    c. What are the main decisions you are making in your position?
    d. What kinds of reports are you responsible for?
2. Current information availability
    a. What is the main installed base information you currently use in [performing your task, decision making]?
    b. What are the sources for this information?
3. Information requirements on the installed base
    a. What technical information is needed on the installed equipment?
    b. What performance information is needed on the installed equipment?
    c. What service history information is needed on the installed equipment?
    d. What customer site information is needed?
    e. How would [your actions, your decisions, the operations in the function/process you are involved with] change if you had this information available?
    f. How should this information be available?
4. Development needs
    a. What are the most challenging aspects of [your task, the function/process you are involved with]?
    b. What are currently the most pressing development needs for [the function/process you are involved with]?
    c. What are the most challenging aspects in improving installed base information availability [for your function/process]?

Interviewed personnel in Case C

Role (in alphabetical order)	Date of interviews
Assistant VP of R&D	12.3.2007
Assistant VP of Service Development	19.9.2006
Assistant VP of Service Quality	2.11.2006
Field Operations Development Manager	24.11.2006
Product Manager 1	17.10.2006
Product Manager 2	31.10.2006
Product Performance Analyst	31.10.2006
R&D Director	31.10.2006
Service Development Manager 1	17.10.2006
Service Development Manager 2	27.10.2006
Service Development Manager 3	19.9.2006
Spare Part Business Manager	17.10.2006
Spare Part Logistics Manager 1	20.3.2007
Spare Part Logistics Manager 2	14.8.2007
Vice President of Service Delivery Process	4.10.2006
Vice President of Spare Part Supply	22.5.2007

Workshops and other meetings in Case C

Working meeting at case company	19.9.2006
Working meeting at case company	4.10.2006
Working meeting at case company	17.10.2006
Working meeting at case company	17.11.2006
Working meeting at case company	23.11.2006
Working meeting at case company	14.12.2006
Research results dissemination	19.12.2006
Working meeting at case company	15.1.2007
Working meeting at case company	14.5.2007
Service delivery benchmarking workshop	14.8.2007
Working meeting at case company	28.8.2007
Service supply chain management seminar	28.-29.10.2007
Service delivery benchmarking workshop	8.2.2008

Case D

The Case study D was performed by the author in cooperation with a development project manager of the case company and a steering group. The author was responsible for the overall design of the case study. The data gathering and the within-case analysis were performed by the author but with frequent collaboration with the case company steering group. The close collaboration with the steering group was especially fruitful, as several initial interview findings were contested by the steering group, and additional interviews were performed in cases where biased views within the organization were suspected.

Case company D is an electronics equipment manufacturer. The company had an on-going development project to improve the global availability of uniform installed base information. The goal of the research effort with the case company was to investigate and describe the development needs in installed base information management to improve global support for after-sales service operations and product and service performance analyses, as well as new service development.

Research material from the case

The case study material was gathered during 2007 and consists mainly of interviews with subunit representatives.

The author and the installed base development project steering group of the case company selected the interviewees. The selection was based on the author's *a priori* understanding of relevant subunits but was influenced by the focus of the on-going development project. In particular, as software products were considered an integral part of installed items in the case company, software product development, product management, and delivery operations were included in the subunits of interest. As with the other cases, additional knowledgeable interviewees were identified, based on suggestions of the interviewees and when missing viewpoints were identified in the discussions with the steering group. The interview material is stored as interview notes, recordings, and transcripts in a case study database. The interview protocol and interviewees are listed below.

During the case study, data in the case company's installed base information system and data from service records were reviewed. Working meetings with the steering group, where the research material and tentative results were reviewed, provided additional insight into the processes and practices used at the organization.

Supplementary material for understanding the case company service business was gathered by attending academic workshops arranged by fellow researchers, as well as write-ups of research reports detailing the service delivery processes of the case company.

Main conclusions within the case study

The main motivation for the case study was to understand what data items and, in particular, what level of detail should be systematically gathered to create globally uniform installed base information. Again, there was a need to understand the uses for different data elements in the different subunits to select a feasible configuration for information gathering.

Particular characteristics of the product and service businesses of Case D were the fast pace of introducing new product generations and software items being a notable component in the installed base. New product introductions and sales meant either that older items in customer systems were replaced or that the customer systems were extended. For planning the service resources, it was relevant to understand which of these changes occurred in the local installed base.

As software products were a considerable part of the systems offer for customers, services to maintain these were also provided by the case company. This meant that part of the after-sales services could be provided remotely, as software-related problem solving or software updates did not necessarily require a customer site visit. These remotely provided services could be centralized so that a number of customers could be served from a single service center. The resource planning of the service centers, as well as the technical support provided remotely, required thus an understanding of the installed base in a wider geographical area than in a local field service unit.

Reasons for gathering installed base information in the case study

Although the exact practices varied, in general, local service units had records of the installed base in their area. The service events were required to be initiated with reference to the target products. Repair and replacement services with physical products used product serial numbers to track the whereabouts of individual products, and software-related services recorded the software product and version updates done with the customer case. These records were necessary, especially for the technical support services, as they needed to solve customer problems that often related to the combination of hardware and software, rather than either separately. Depending on the customer, technical support services might, in addition, have remote access to the customer system to poll the identifiers of major components of current hardware and software configuration to help in the analysis of a customer problem. In customer cases where no remote access was available, the problem solving process was considered much slower because of additional information requests to customers.

Another important reason for maintaining installed base information was in prioritization of customer service tasks. The target service response times could depend on the criticality of the item even within a single service contract. Being able to tend to urgent requests faster helped in complying with service level agreements of service contracts and, thus, service profitability.

The planning of support engineers for each service unit also used the installed base records available, as well as service event histories to forecast service workload. The event histories of prior product generations were also analyzed with new product introductions to estimate the behavior of support workload during early phases of product life cycles.

For spare-parts inventory planning, the inclusion of item-specific service levels in contracts made installed base information relevant. Positioning spare-parts inventories with 4-hour delivery lead-times is much more costly than with 12-hour delivery lead-times. Appropriate balancing of the investments in spare parts and service levels could be achieved with installed base analyses. Likewise, removals of older items from customer systems were seen as important to track to enable withdrawal of spare parts for other uses.

Because of the frequent new product introductions, upgrade sales opportunities could be identified by analyzing the installed base at each customer. However, at the time of the study, the systems used in service operations and planning were not fully supporting product sales purposes. It was understood that the installed base information could better support the identification of capacity extension needs, system performance improvement opportunities, and new feature additions.

The gathered installed base was better suited for service contract sales negotiations. Here, the installed base information was used to agree on specific service levels for the items in the customer system. Such detailed contracts were necessary in some situations to balance the profitability and customer pricing of the service contracts. In cases of service contract renewals, servicing cost analyzes for the customer's installed base were made based on historical service events to have a benchmark for pricing. With software products, service contract pricing with customers was based on numbers of installations. Similarly, for some third party software, the service operations were outsourced to their respective suppliers, again with pricing related to installed quantities. Therefore, the accuracy of installed base data concerning software had a direct impact on profits.

The installed base information in the service systems was used also for product management purposes. Recurring problems were sought to identify product reliability problems and narrow them down to specific production periods when possible. Possibly problematic production batches were then reflected to the installed base records to identify involved customer sites. At the time of the study, this was a manual process requiring specific gathering data from service units and manufacturing databases. In terms of product reliability analyses, mean-time-between-failure figures were calculated based on the service event records gathered from units worldwide. The challenge with those was that the reference quantity of total number of items in use was less comprehensively available.

Service process performance was analyzed based on service event records by event type, products involved, and participated personnel. These were used to identify development needs to improve service quality and profitability. Further, pricing support was given by product and service performance analyses to identify mean servicing costs for product types, although more comprehensive and accessible data was hoped for.

Information needs on the installed base in the case study

For each installed base location, the item data of interest was for most purposes on the product type level, although the hardware repairs and warranty processing also needed serial numbers to operate. Location characteristics of main interest were related to operating temperature, humidity, and corrosive agents that might damage the products. Service events were already well recorded, but more details on service reason, component changes, and reasons for change were desired for reliability analyses and warranty processing.

The results indicated various levels of data aggregation that could be used in the business processes of the systems supplier. Front-end activities of sales and after-sales services could be improved with each additional fully covered customer system in the installed base information system, whereas most of the identified analyses for back-end decision support would require considerable coverage to provide reliable analyses for the information users. The level of detail required from installed systems varied from an overview including just the total number of system components, down to component serial numbers and software version numbers. Likewise, for some purposes, it would suffice for the information to be updated monthly, whereas some service operations would use real-time access to the customer systems.

Another important finding was related to the installed base information connectivity to other information systems. Whereas many of the case company purposes could be supported with analyses based on the installed base hardware and software items and their respective locations, full analytical benefits would require easy data integration with service events of both on-site maintenance and remote technical support, as well as with service contracts.

Outline of the interview protocol in Case D

The following interview guide was used as a baseline to construct individual interview questionnaires. The interview questionnaire used in each interview accounted for the *a priori* information that the author had on the interviewee's task.

1. Responsibilities of interviewee organizational position
   a. Please describe [the operations of the function/process you are involved with].
   b. What are the tasks you are responsible for in your position?
   c. What are the main decisions you are making in your position?
   d. What kinds of reports are you responsible for?
2. Current information availability
   a. What is the main installed base information you currently use in [performing your task, decision making]?
   b. What are the sources for this information?
3. Information requirements on the installed base
   a. What technical information is needed on the installed equipment?
   b. What performance information is needed on the installed equipment?
   c. What service history information is needed on the installed equipment?
   d. What customer site information is needed?
   e. How would [your actions, your decisions, the operations in the function/process you are involved with] change if you had this information available?
   f. How should this information be available?
4. Development needs
   a. What are the most challenging aspects of [your task, the function/process you are involved with]?
   b. What are currently the most pressing development needs for [the function/process you are involved with]?
   c. What are the most challenging aspects in improving installed base information availability [for your function/process]?

Interviewed personnel in Case D

Role (in alphabetical order)	Date of interviews
Product Delivery Project Director	11.6.2007
Product Delivery Project Manager 1	13.2.2007
Product Delivery Project Manager 2	13.2.2007
Product Delivery Project Manager 3	14.6.2007
Product Development Director	31.5.2007
Product Manager 1	19.2.2007
Product Manager 2	5.3.2007
Product Manager 3	27.2.2007
Product Manager 3	13.6.2007
Product Performance Analyst 1	7.3.2007
Product Performance Analyst 2	15.3.2007
Product Performance Analyst 3	11.6.2007
Product Performance Analyst 4	15.6.2007
Product Service Development Manager	13.2.2007
Product Technical Support	25.1.2007
Remote Monitoring Product Manager	29.8.2007
Sales and Marketing Director	24.7.2007
Service Business Development Manager 1	14.3.2007
Service Business Development Manager 2	20.2.2007
Service Contract Database Manager	4.9.2007
Service Customer Account Manager 1	9.3.2007
Service Customer Account Manager 2	28.2.2007
Service Customer Account Manager 3	4.6.2007
Service Director 1	9.3.2007
Service Director 2	27.2.2007
Service Marketing Manager	27.2.2007
Service Product Manager 1	5.3.2007
Service Product Manager 2	7.3.2007
Service Product Manager 3	21.6.2007
Service Resource Manager	13.6.2007
Software Delivery Development Manager	30.5.2007
Software Delivery Development Manager	23.8.2007
Software Delivery Manager	22.8.2007
Software Product Director	14.2.2007
Software Product Manager 1	21.2.2007
Software Product Manager 2	19.2.2007
Software Product Manager 3	20.2.2007
Software Service Development Manager	4.6.2007
Spare Parts Manager	12.12.2007
Technical Support Development Manager	21.2.2007
Technical Support Manager	21.6.2007

Workshops and other meetings in Case D

Working meeting at case company	18.1.2007
Working meeting at case company	30.3.2007
Working meeting at case company	13.4.2007
Working meeting at case company	15.5.2007
Working meeting at case company	29.5.2007
Working meeting at case company	4.6.2007
Service delivery benchmarking workshop	14.8.2007
Working meeting at case company	17.8.2007
Working meeting at case company	27.8.2007
Working meeting at case company	31.8.2007
Working meeting at case company	4.9.2007
Working meeting at case company	11.9.2007
Results dissemination workshop	17.9.2007
Results dissemination workshop	24.9.2007
Service supply chain management seminar	28.-29.10.2007