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Benefits of Digital Technical Information

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Akademisk avhandling som med tillstånd av Mittuniversitetet i Östersund framläggs till offentlig granskning för avläggande av filosofie doktorsexamen 2020-09-10, kl 9.00, F217, Mittuniversitetet Östersund. Seminariet kommer att hållas på engelska.

Benefits of Digital Technical Information

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To my grandmothers Elna Brodén and Elisabet Ahlin

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My inspiring academic journey was initiated by a desire to understand more of my work role as a R&D manager. This journey started off at the IT Management Program at the IT University in Gothenburg. Slowly, slowly I made my way through references, empirical material, and theoretical frameworks, with the guidance of Associate Professor Kalevi Pessi and his colleagues.

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To my family – Kristian, Alexandra, Frans, Tobias, Emma, Mum, and Fredrik – all my love! Dad, Catarina, and Morgan, I wish you were here to be part of this!

***Ab imo pector*!**

Östersund, May 2020

Karin Ahlin

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Abstract

In our daily work life, we use a wealth of information, including a category of information produced as a part of products and their life-cycle phases, named digital technical information (DTI). Manufacturing organizations focus more often on the product than on DTI, because DTI's impact seems almost invisible, despite its crucial role to the product and its life-cycle phases, development, production, maintenance, and destruction. Hence, the aim of this thesis is to describe DTI's benefits and the research questions: "What are the benefits of the DTI?" and "What are the perceptions of how to measure benefits of DTI?" The thesis contains five studies related to identifying and measuring DTI's benefits. The empirical material is based on semi-structured interviews and group interviews within five organizations and a survey among manufacturing organizations in Sweden.

I used three characteristics of the DTI and two pairs of previously known benefit categories to analyse the benefits. The analysis shows that the benefits are recognized in the particular product's life cycle phase where the DTI is published. However, the DTI continues to offer benefits in the product's other life cycle phases. In relationship to the product, the benefits evolve from supporting an individual product to supporting more general product lines or all products and a more complex product is said to increase DTI's benefits. DTI's structure adds benefits as synthesized or aggregated DTI, where the DTI is synthesized or aggregated automatically or manually. The categorization predetermined benefits related to the change are less numerous than the emerging benefits. The predetermined benefits are strategic by nature, and the emerging ones are mainly used to achieve operational goals.

Measuring DTI's benefits is of importance for a formal comparison of its development and is of special interest for managers. Perceptions from the initial stages on how to measure show that to establish common interpretations among the stakeholders of the measurement process is of importance, especially when it comes to what is viewed as a benefit. The benefits are viewed as intangible by the respondents, which creates difficulties when one is evaluating, using conventional measurement methods. The only perceived way to measure is when DTI reduces co-worker's workload and efficiency is achieved.

The thesis's contribution to academia consists of the analysis of DTI's benefits, showing details of the relationships between the DTI and its benefits. For practice, the contributions focus on the systematic evaluation process, which can be used for further development of the DTI and comparison of the evolvement of the DTI itself and relating to other resources. One proposal for future research is to use the analysed benefits and compare various approaches to digitizing DTI, e.g. Industry 4.0. Another proposal is to list, in detail, various ways on how to measure DTI's benefits and their usefulness. The latter can positively impact on any intangible benefits due to the general approach we have established of how to measure those benefits.

Keywords: digital technical information, benefit, intangible benefit, interpretative research, manufacturing organization

Summary in Swedish

Digital Teknikinformation (DTI) används ofta i arbetslivet och beskrivs som information som produceras för att stödja en produkt i dess livscykelfaser, utveckling, produktion, underhåll och destruktion. Tillverkande organisationer fokuserar oftare på produkten än på DTI och dess roll är nästan osynlig, trots sin avgörande roll för produkten i dess livscykelfaser. Därför är syftet med denna avhandling att beskriva nyttan med DTI. Forskningsfrågorna är: "Vilka är nyttorna med DTI?" och "Vad är uppfattningarna om hur nyttorna av DTI kan mätas?" Avhandlingen innehåller fem studier relaterade till att identifiera och mäta DTI:s nyttor. Det empiriska materialet är baserat på semistrukturerade individuella- och grupp-intervjuer hos fem tillverkande organisationer och en enkätundersökning bland tillverkande organisationer i Sverige.

Resultaten visar att DTI skapar nyttor inom respektive organisation. Nyttorna har analyserats i förhållande till tre av DTI:s egenskaper och två välkända nyttokategorier. De flesta av nyttorna anses uppstå i produktens livscykelfas där DTI publiceras, samt ett antal nyttor i andra av produktens livscykelfaser. I förhållande till produkten utvecklas nyttorna från att stödja en enskild produkt till produktlinjer eller organisationens alla produkter. DTI:s struktur supportar aggregerad och återanvänd DTI, vilket t.ex. ger upphov till nyttor baserat på statistik. Av nyttokategorierna fördefinierade och framväxande nyttor ses de fördefinierade används för att nå strategiska mål. De framväxande nyttorna var fler till antalet och stödjer organisationens operativa mål.

Beslutsfattare har användning för mätningar av DTI:s nyttor, speciellt för kommunikation och jämförelse av, bl.a., DTI:s utveckling. Studierna visar att gemensamma tolkningar är viktigt vid mätningar, t ex av vad som betraktas som nytta. De identifierade nyttorna betraktas ofta som omätbara av respondenterna, vilket medför svårigheter när det kommer till att genomföra mätningar. Den föreslagna mätmetoden blir därför att mäta de nyttor som skapar effektivitet, t ex när DTI kan minska mänskligt arbete.

Avhandlingen bidrar till akademin genom att synliggöra detaljer om DTI:s nyttor via den gjorda analysen. Dessa detaljer visas genom relationen mellan DTI och dess nyttor. Avhandlingens praktiska bidrag är underlag till utvärdering av DTI:s nyttor, vilket kan användas för styrning och vidareutveckling av DTI. Ett förslag på framtida forskning är att använda de analyserade nyttorna för jämförelse vid olika ansatser till digitalisering, t ex Industri 4.0. Ett annat förslag är att undersöka detaljer i mätmetoder av DTI:s

nyttor och dess användbarhet. Detta förslag kan ge ytterligare underlag för mätning av de så kallade omätbara nyttorna.

Nyckelord: digital teknikinformation, nytta, omätbara nyttor, tolkande forskning, tillverkande organisation

List of papers

I have written several articles and a licentiate thesis, from which I include material in this thesis. The arguments for including parts of the articles and licentiate thesis are to use the previously built knowledge foundation and to broaden the discussion and thereby knowledge contribution. I have included material from the following articles (#1 - #7) and the licentiate thesis (#8) in the text, whereas the licentiate thesis is not included in the printed doctoral thesis:

1. Persson Slumpi, T., Ahlin, K., & Öberg, L.-M. (2012). *Intraorganizational benefits from product configuration information–a complementary model.* Paper presented at the DS 70: Proceedings of DESIGN 2012, the 12th International Design Conference, Dubrovnik, Croatia.
2. Ahlin, K., & Saarikko, T. (2012). *A semiotic pespective on semantic interoperability*. Paper presented at the 35th Information Systems Research Seminar in Scandinavia – IRIS/SCIS Conference 2012, Sigtuna, Sweden.
3. Ahlin, K., & Saarikko, T. (2013). *Exploiting Information: Seeking Long-term Preservation of organisational knowledge.* Paper presented at the 22nd Nordic Academy of Management Conference, 21-23 August, 2013.
4. Ahlin, K., & Ingelsson, P. (2013). *Information management, Lean and efficiency: are we focusing on the customer?* Paper presented at the 16th QMOD-ICQSS; International conference quality and service sciences; 4th-6th September 2013; Portoroz, Slovenia.
5. Ahlin, K., & Slumpi, T. P. (2015). *A Communication-model for Intangible Benefits of Digital Information.* Paper presented at the American Information Systems Conference 2015, Puerto Rico.
6. Ahlin, K. (2018). *Design and test of a measurement method for the benefits of technical information.* Paper presented at the 41th Information Systems Research Seminar in Scandinavia - IRIS/SCIS Conference 2018, Odder, Denmark.
7. Ahlin, K. (2019). *Measuring the immeasurable? The intangible benefits of digital information.* Paper presented at the 52nd Hawaii International Conference on System Science, Grand Wailea, Mahui.

8. Ahlin, K. (2014). *Approaching the Intangible Benefits of a Boundary Object.* Licentiate thesis: Computer and System Sciences. Mid Sweden University, Östersund.

1 Introduction

Digital information plays an increasingly prevalent role in current business and professional life, and offers many benefits. One example is digital information related to business processes, affording benefits to co-workers while conducting work assignments. To gain the most from digital information, it is important to be knowledgeable and be able to manage it (see researchers like Best (2010) and Bytheway (2014)). Hence, research about digital information has taken place in the field of Information Systems, where researchers have described digital information for both organizations and employees. In particular, they have discussed digital information's relation to technology, the product development process, information systems, information policies, trust in online contexts, and theory development (Carter, Petter, & Randolph, 2015). One of these research trends is the digitization of businesses' information, described as the transformation of analogue information to digital information by researchers such as Yoo, Henfridsson, and Lyytinen (2010), Bhimani and Willcocks (2014), and Kagermann (2015).

One approach to managing digital information is to understand the relationship between digital information and its benefits (Bytheway, 2014). This topic is rarely discussed in detail, despite the potential for optimizing the beneficial use of digital information when we work. One exception is the research of DeLone and McLean (1992), who include digital information as part of their developed success model. Remenyi, Bannister, and Money (2007) frames digital information as too broad a concept to be understood in relation to specific benefits. Hence, there is a need to reduce complexity to create a manageable foundation so categorizing types of digital information is critical for further development of knowledge. One such category is digital information related to products, *Digital Technical Information (DTI)*. DTI is defined as digital information related to a product and the product's life cycle phases (Lundegård, 1998; Svensson, 2010), where these phases can be described as development, production, maintenance, and destruction. The digital part of the DTI refers to the electronic storage (Bollacker, 2010), the technical refers to its content related to products and their life cycle phases, whereas our pre-knowledge is used while interpreting the information (Langefors, 1995). The digital and the information part of DTI are further discussed in chapter 2.

The technical part, DTI's content, shows that DTI mainly provides product support or documents which fulfil legal requirements (Persson Slumpi, Ahlin, & Öberg, 2012). Product support varies across a number of information types including CAD drawings, manuals, production drawings, calculations, installation instructions, and user guides. DTI may be used in many ways. For example, it can be shared internally within an organization (e.g., as the product identification), or it can be used externally (e.g., manuals). DTI can save a lorry driver with mechanical problems from suffering a day without productivity. The driver can use the DTI, in the form of written instructions or even a video, to understand what to repair and how. In contrast to this everyday scenario where DTI is available, another example is the worst-case scenario of a catastrophe that can result from DTI not being available or accurate. Svensson (2010) describes DTI's extreme importance for aircraft maintenance mechanics. DTI is used as a foundation for decision-making when maintaining and repairing aircraft. The worst-case scenario from making the wrong decision based on the DTI is a plane exploding or losing power mid-air. A piece of EU legislation demands DTI for all European trade (Maskindirektivet, 2016). According to this, DTI is required in order to trade products without restrictions within the European Union. The goal is to harmonize essential health and safety requirements between countries and organizations based on standardized information. Because of common use, potential risk, and legislation, understanding DTI is essential when developing an information system specified for DTI.

There are other terms similar to DTI, such as product configuration information, technical documentation, product data, and technical communication. Product configuration information is related to one specific process, product configuration (Niknam & Ovtcharova, 2013; SIS, 2004), and thereby limited by both the product and a specific process, whereas technical documentation, is viewed as narrower than DTI, as it solely includes manuals for a product's specific life cycle phase (Wingkvist, Ericsson, & Löwe, 2011). Product data solely refers to information related to individual products and their versioning (Helms, 2002; Otto, 2012) and technical communication is broader as it includes scientific information in addition to technical information (Johnson-Eilola & Selber, 2013). The choice of the term DTI is made based on the perspective that it solely is directed towards information related to a specific product; it includes the product's lifecycle phases as well as its more extensive foundation in research, e.g. compared to product data.

Dicks (2003); Ward and Daniel (2012) emphasize the importance of understanding DTI's benefits as one way to investigate a resource for further development. Today, developing a resource can be related to its digitalization, e.g. changing from analogue to digital (Yoo et al., 2010). Such a change requires investments, like a new or upgraded digital platform, or updated business processes. Included in development is decision-making, predominantly orchestrated by managers. The decision-making behind such an investment could imply a necessity to understand and measure the gained benefits. Bossen and Ingemansson (2016) emphasize the importance of digitalization for Swedish industry, based on a directive from the Swedish Innovation Agency, Vinnova. They emphasize the importance of digitization for the Swedish manufacturing industry, which affects more than half million co-workers and almost one fifth of the nation's exports. Vinnova's intention is to promote a digitized Swedish manufacturing industry with the aim of strengthening Swedish innovation and competitiveness, with DTI playing an important role in the manufacturing of products.

DTI can be created in various ways, where one such is the conversion of analogue information to digital, described, e.g., in Thomson and Lynn (2008) or the use of implemented sensors in the concept of Industry 4.0, where DTI is created instantly as the product is manufactured (Zangiacomi, Pessot, Fornasiero, Bertetti, & Sacco, 2020). Highlighted in both these studies are the necessity of describing the benefits of DTI in relation to the change based on digitalization. Thomson and Lynn (2008) use the benefits for comparison, before and after the change, whereas Zangiacomi et al. (2020) use the benefits to manage the development of the investment in digital platforms. Managers predominantly orchestrate decision-making, and a more focused understanding of benefits can support the motivation for the decisions made, which extends to both maintaining and developing a resource.

I have found literature on DTI's benefits to be limited, despite constantly searching for it. One reason could be the focus on benefits from information systems or information technology (Ward & Daniel, 2012; Ward, Taylor, & Bond, 1996). However, some studies do discuss the benefits of DTI. Their discussion illustrates common themes such as a focus on different roles of stakeholders (e.g., organizational, consumer) (Marotta, Zhang, & Acquisti, 2015; Thun, Kamsvåg, Kløve, Seim, & Torvatn, 2019), different points in the production process (e.g., development, maintenance)(Barthelmey et al., 2016; Lundegård, 1998), different goals (e.g., communication, storage)(Cui & Xiao, 2019), and different types of resulting benefits (e.g., visualization, efficiency, safety) (Siikala, 2018; Thomson & Lynn, 2008; Thun et al., 2019). However, there are few studies investigating DTI's benefits from the perspective of comparing several organizations' DTI and their internal use thereof. Building on the aforementioned arguments and studies, it is of interest to further continue the work to build a broader foundation and increase the understanding of the commonly used DTI and its benefits adding to the field of DTI. Thus,

The aim of this thesis is to describe the benefits of Digital Technical Information

1.1 Problem statements

There are several problems related to the lack of descriptions of DTI's benefits. In practice, not identifying benefits can result in low-quality or inaccurate DTI (Dicks, 2003; Ingelsson, Löfstedt, Bäckström, & Öberg, 2015). The source of this problem can be found in organizations' view that DTI is secondary to their product rather than an integral part of the product. Organizations all too often place too much emphasis on the products while neglecting their DTI. This devaluation can, in the long term, result in the production of low-quality DTI, thus amplifying the previously described practical problems while developing or maintaining the product. Further, a tendency emphasized by Ingelsson et al. (2015) is that management may ignore co-workers' perspectives while developing the DTI. Neglecting co-worker knowledge leads to missed opportunities, such as the use of single sourcing for the DTI (Hart-Davidson, 2013) or using it to increase innovation in the manufacturing industry (Bossen & Ingemansson, 2016; Lundin, 2020). Therefore, the identification of DTI's benefits should be of interest.

In academia, the identification of benefits is rarely discussed (Braun, Ahlemann, & Riempp, 2009). As a result, the knowledge is limited to what impacts their identification and various ways to identify them. Often, conducted research focuses on identifying the benefits of an information system or information technology, such as Murphy and Simon (2001) investigating benefits of ERP systems and Meißner and Schnepp (2014) investigating benefits of e-health systems. Both of these studies show results, adding to the understanding of these two categories of information systems. Increasing the research activity about DTI's benefits could therefore add to knowledge on the commonly used DTI as well as the understanding on how to identify DTI's benefits. One initial step towards identifying benefits was taken in Ahlin (2014), establishing a foundation for further understanding of DTI's benefits. Hence, the first research question is declared as:

What are the benefits of the DTI?

A common activity after identifying benefits is measuring them, see e.g. Ward and Daniel (2012). For practitioners, the measuring of DTI's benefits is a fundamental task when comparing, communication, and developing DTI in organizations (Dicks, 2003). Remenyi et al. (2007) emphasize a few ways to measure DTI's benefits based on the understanding that they are mainly intangible, which means limited ways to measure them. Not measuring the benefits can however affect decision-making since it is hard to make formal comparisons of the development of the DTI. One example for comparison is the need to measure the added benefits of a change, such as digitization. Measurements are required for comparison and to manage those changes (Love, Matthews, Simpson, Hill, & Olatunji, 2014). One example, while digitizing, would to compare the added benefits and relate them to the investment of required software.

There are several examples of researchers emphasizing the necessity of measuring benefits, and Marnewick (2016) is one. The perception that DTI's benefits are intangible creates problems when using the most popular ways of measuring benefits (Khallaf, 2012). However, Ahlin (2019) shows in a literature review that academia has conducted studies, measuring intangible benefits, by interpreting them. This adds to the perspective of Lycett and Giaglis (2000), where they discuss how to measure, arguing that metrics are not facts; they see them as interpretations of reality. As the interpretation is something that needs to be shared, they emphasize the importance of a common interpretation shared by the stakeholders of the measurement process. Therefore, the second research question is:

What are the perceptions of how to measure benefits of DTI?

1.1 Thesis structure

This thesis consists of six chapters and two appendices, synthesized and described below. They all contribute to delivering knowledge to answer the research questions, including previously conducted research and empirical material. This thesis constitutes five studies: Alpha, Beta, Gamma, Omega, and a field study. The two first studies were conducted before the licentiate exam (fall 2011 and fall 2012) and were initially presented in that thesis. The later studies were all conducted after the licentiate exam and presented in the actual thesis (fall 2014, winter 2014, and fall 2016 - spring 2017).

This thesis starts off with an introductory chapter that lays out the background, problem statement, and research questions. Chapter 2 outlines previous research on DTI and benefits and a way to analyse DTI's benefits. Previous research includes a synthesized picture of terms related to DTI and narrows this thesis's particular research interest in the area of DTI; focusing on DTI, its characteristics, how to identify and measure its benefits. The identification of benefits is wrapped up with a summary of how to analyse DTI's benefits. Chapter 3 includes the method based on research design, included studies, and ethics. Chapter 4 shows the findings and analysis from the included studies. The results include an individual description of the study's context, the DTI and its characteristics, the benefits and their relations to the DTI's characteristics in various parts and ends the individual descriptions with how to measure DTI's benefits. The chapter ends with the claims of the findings of the DTI's characteristics, the benefits and how to measure them. The discussion is included in chapter 5, reflecting on the identified benefits, and how to measure them. The chapter ends with a discussion on used research method. Outlined in chapter 6 are summarized answers to the research questions and direction for future research. The first appendix consists of references and the second one the interview and survey questions.

2 Related research

This chapter relates to the *DTI* and the *benefits* of DTI. Described for the *DTI* are the DTI itself, digitization of the DTI, concepts closely related to DTI, and characteristics of DTI. My initial choice was to investigate research from the Information Systems field for the DTI and its benefits. The result from these investigations showed a sparsely researched area and therefore is research from the Engineering field used when necessary.

The *benefits* are initially described in terms of benefits in the information system's literature, such as identification and measurement of benefits. The following sections describe the benefits of DTI, synthesized in the DTI characteristics and the benefit categories for analysing the identified benefits, and measuring DTI's benefits.

2.1 DTI

For this thesis, I focus on digitally stored information and add that to the descriptions that DTI is information that supports development, use, maintenance, and destruction of products in a sustainable way (Ahlin, 2014; Ahlin & Saarikko, 2013; Lundegård, 1998; Persson Slumpi et al., 2012). DTI focuses on digitally stored technical information referring to a narrower subset of technical information as opposed to the broader meaning of technical information that may be stored anywhere. The argument for limiting my focus to digital information is based on practicality: most information related to products is stored electronically today. Included in each study is a presentation of information systems used for DTI and explicit mention of the digital aspects of DTI.

2.1.1 The concept information

In the beginning of the digital era, information was seen from a cybernetic perspective where it was simply an objective, logical artefact. We as humans would understand it equally, no matter our background (Wiener, 1948). The central view of digital information has now changed and is more related to subjectivism and understanding digital information comes from our individual knowledge base (Langefors, 1995; Liebenau & Backhouse, 1990; Zins, 2007). The subjectivism is built on our capacity for interpretation along with our pre-knowledge which forms our understanding and provides our own solutions to cracking the understanding code. Zins (2007) views information as subjective and resides internally in the individual, implying that it depends on the cognition of the individual and factors such as pre-knowledge. Information can reside externally, e.g. in social groups such as trade associations. He compares the subjective view on digital information with the objective view on data, which resides in external domains. Buckland (1991) holds a three-fold perspective on information; information as a process, where information is viewed as the act of informing, information as knowledge focusing on reducing uncertainty, and information as a thing. For the latter, information is attributed for objects, such as documents and having the attribute of being informative. Both Buckland (1991) and Zins (2007) add to the perspective of information, varying in their perspective from objective to subjective and relating it to various situations.

Emphasized in Ahlin and Saarikko (2013) are two ways of viewing information, both related to data and knowledge. One is that data forms the base of a pyramid, supporting the smaller, upper levels of information and knowledge (Rowley, 2007). The other, less used, is the reverse order: an individual's funds of knowledge form the base for information and data (Tuomi, 1999). While working, we have to build up this knowledge base to serve as a common base on which further knowledge building depends (Ahlin & Saarikko, 2012). The building of a knowledge base is done through a social process which includes interaction with others within and across communities.

2.1.2 Change related to digitization

The following paragraphs describe the change related to digitization of the DTI, of importance for this thesis as change is used for identifying benefits. The change used for identifying benefits for an implementation of an information system is often described (see, e.g., Ward and Daniel (2012)), where Yoo et al. (2010) focus change related to digital information as the transformation of analogue information to digital. Of interest here is their claim about the homogenization of data, which frames a looser coupling between the digital information than the analogue. They argue that digital information does not require a specific device or interface but is accessible by all devices. Increasing the focus on the digital perspective of DTI frames the interlinking and automation between the product and its DTI. For DTI, the digital perspective is increased when the DTI is produced at the same time as the product, e.g. via sensors, since this perspective does not include analogue handling.

We often take for granted the digital nature of the information and do not reflect upon it. Previously discussed was the digitization of information; for example, introducing e-health (Noffsinger & Chin, 2000), or e-commerce (Elberse, 2008). Included while discussing digital information are concepts, such as information, storage formats (e.g., analogue, digital). Bollacker (2010) uses several narratives to describe the long-time use of analogue storage of information, typically recorded on physical objects and accessible without computers, such as stones and papers. The difference is that digital information is stored electronically, using zeros and ones, and accessible only through interpretation by computer software, such as a typical, modern information system.

The framing of the transformation of DTI from analogue to digital varies. The initial stage (see Figure 1) could be framed by storing the DTI in a digital format, transforming it from analogue to digital storage. Today, this step may be viewed as straightforward, but strategies can vary: from solely storing the DTI digitally based on analogue input like hand-written notes, to using information systems that focus on DTI. In both cases, the input is transferred from analogue discussions or notes with informed co-workers to a digital format. The usable output of this DTI could, for example, be in the form of digital information systems or folders including various printouts (hard copies) or the DTI itself could be shown in an information system. One common view on the reasons for digitizing information is that the result of the digitization should create efficiency in time and resources (Longo, Fountain, Johnson-Eilola, & Selber, 2013). Using digitization in this way often means creating the same information digitally as would have been created in analogue. The difference is in the finalized form which could be an information system or a print-out (hard copy) given to the consumer. In the latter case, the information has been digitized and then is put back into analogue form.

Upgrading the D in contrast to the A in Figure 1 (stage 2) focuses on the design of the DTI in the form of information architecture (Hart-Davidson, 2013). He frames the development of the digitization to be used in the form of single sourcing and reuse of the DTI. In practice this could mean changing from using Word-documents with unstructured text relating to the product to structuring the information into various terms using meta-data and single source the terms. Single sourcing means that DTI is only available in one place which can be derived as master data. This master data may be stored in specific information systems for DTI or in general information systems. The reuse could easily be in the form of the DTI used for other purposes than the collected ones, such as other product life cycles, or other stakeholders, like customer support. The DTI is still produced by informed co-workers dealing with the DTI.

For stage 3, Durão, Haag, Anderl, Schützer, and Zancul (2018) discuss the concepts of Industry 4.0 and digital twin (sometimes referred to as digital avatar). In Industry 4.0, the DTI is produced in integration with the manufacturing of the product in a controlled environment, where the result is the possibilities to manufacture individualized products as well as having a decentralized production. The information belonging to the product is stored on the internet, providing several ways to access, update, and translate the DTI (Gattullo, Uva, Fiorentino, Scurati, & Ferrise, 2017). Therefore, stage 3 omits analogue information, which means that the A is invisible in comparison to the D, see Figure 1. One foundation in Industry 4.0 is that each product references its own information and transports it accordingly (Hermann, Pentek, & Otto, 2016).

During the manufacturing of the product, a digital twin is created via various sensors or other sources from the physical product, resulting in DTI stored in a database. Characteristics of the digital twin are that of real-time data for optimization of the product, integration of the physical model, and fidelity to confirm the physical model. Ríos, Hernández, Oliva, and Mas (2015) prolong the product's life cycle by using the digital twin to include all life cycle parts adding product information about the product's various states, described in terms of the former state, the current, and estimating future states. The use of a digital twin produces a significant volume of information, where the information systems and their interoperability are the link between the physical product and the digital twin.

Figure 1 synthesizes the various stages of DTI's digitization and declares its input/output as well as a visualization of the perspective of analogue and digital.

Stage of DTI's digitization	Input / output from the stage	Visualization of digitization from the perspective of analogue and digital
Stage 1	Information is created in analogue, then digitized without necessarily changing aspects of the information.	A → D
Stage 2	The input could be either analogue or digital, while the structure of the stored DTI is various terms related to meta-data.	A → D
Stage 3	The input is only digital through, e.g., sensors in manufacturing. The output is also just digital and from the sensors. The re-use is such that everyone can access the information since the repository is digital / master file.	D

Figure 1 The various levels of DTI's digitization

2.1.3 Terms similar to DTI

DTI is related to ***product configuration information*** (PCI), which is part of the configuration management (CM) process. The PCI describes how to configure products and incorporates requirements during all phases of a product's life cycle phase (Niknam & Ovtcharova, 2013; SIS, 2004). The process of CM involves identification, change control, status accounting, and auditing of the product. Incorporated in this process are actions for specifying parts of a product strategy; including roles for decision-making and change control. The Swedish Standards Institute (SIS) describes PCI as information related to configuration management planning, configuration identification, change control, configuration status accounting and configuration audit (SIS, 2004). In comparison to DTI is PCI solely related to a specific process, which makes DTI broader as a concept as it is not related to any specific process within an organization. DTI's content is broader as it can contain information, e.g., about how to develop and maintain a product, not solely its configuration.

Another term related to DTI is the ***technical documentation***, which Wingkvist et al. (2011) and Bader and Oevermann (2017) describe as user manuals. The manuals are used for solving support cases by either the customers themselves or intended for internal support usage. Technical documentation is related to a product and its declared life cycle phases, such as maintenance. Today, technical documentation is mainly digitally stored and accessed by customers via formats such as portable document format (i.e., *.pdf). Technical documentation provides a narrower approach compared to DTI as it solely is specified user information connected to one product's life cycle phase like maintenance.

One more related term is ***product data*** (PD). Helms (2002) and Otto (2012) argue that PD should solely describe individual products and thereby allow information about the version of the product. Otto (2012) classifies PD into three categories: specification data, life cycle data related to the product, and metadata. The first category describes aspects and properties of a product. Life cycle data is represented by the various stages of a product, from design to recycling or destruction, and indicates the movement of a product from one stage to another. The metadata describes both the content of the PD and in which life cycle the data contributes to. The PD is master data and used for diverse purposes, such as product brochures and e-commerce.

The PD is often related to *product life cycle management*, PLM, a concept invented and used in industry for the past few decades and mainly researched within the Engineering field (Ameri & Deba, 2005). PD plays a central role in PLM as the focal point in the product's life cycle. PLM is primarily a business approach introduced some decades ago. PLM is understood in research, supporting the product during its lifetime, including market activities (Främling, Kubler, & Buda, 2014). There are several examples of supporting activities such as managing the product data in the product development and using it for decision approaches. PLM is a strategic approach to the complete path of a product where the product data is the central supporting part. Therefore, it is mainly used in manufacturing organizations and the research is focused on engineering management, followed by related information systems. The driving factors for PLM vary; some researchers credit it as creating positive advantages like knowledge sharing along all of the product's life cycle phases, increased efficiency in the development of the product, or a way to meet both the increased global competition and legislation (Vezzetti, Violante, & Marcolin, 2014). Added to the supporting information are business processes and other resources, like co-workers' knowledge and tools, which in total is referred to as holistic PLM (Jamous et al., 2016). PLM could also include activities such as innovation and improvement of service control. The information mainly consists of PD, which refer to an individual product throughout its lifetime, and are in the form of CAD drawings or product data stored in various versions for traceability (Marra, Di Biccari, Lazoi, & Corallo, 2018).

A critical part in PLM is the product's life cycle phases, which several researchers mention as being divided into the beginning-of-life (BOL), middle-of-life (MOL), and end-of-life (EOL) (Essamlali, Taha, Sekhari, & Bouras, 2017; Li, Tao, Cheng, & Zhao, 2015; Penciuc, Le Duigou, Daaboul, Vallet, & Eynard, 2016). The BOL includes all the development phases of the product and ends with the delivery to the customer. Researchers, such as Li et al. (2015) refer to BOL as the most resource-intensive phase and it is the product's life cycle phase that has attracted the most interest so far. The MOL phase includes the implementation and the use of the product, including parts such as maintenance and an upgrade. Lastly, the EOL phase comprises remanufacturing or disassembly of the product into parts and the reuse, refurbishing, or recycling.

The information related to the product is expected to evolve as the product moves along through its lifecycle phases. An example of this is that PLM includes product data angled for various lifecycle phases and is therefore stored in various information systems. As PLM includes all of the product's life cycle phases, this means there are a variety of stakeholders (Penciuc et al., 2016). For example, these may be the organization's internal stakeholders who design the product, as well as the external stakeholders who use and carry out maintenance on the product. This means that the information should be accessible to most stakeholders, relevant from a variety of time and activity perspectives, as well as keeping different quality parts.

Occasionally, PLM is referred to as solely focusing on the information system containing information about PLM (Bernabei, Sassanelli, Corallo, & Lazoi, 2014). The central point is the integration of information, processes, businesses. The information system is viewed as the hub around which these parts circulate. There are information systems related explicitly to PLM, just like conventional enterprise resource systems (Arduin, Le Duigou, Abel, & Eynard, 2015). The information system as such can be one information system or a cluster of information systems, providing functionality for the required perspectives. The PLM system is viewed as master data for the product data, which imposes data quality requirements and interoperability. The former to provide data with good quality and the latter to provide stakeholders with the required information.

Another closely related term is ***technical communication*** (TC). TC is described by Johnson-Eilola and Selber (2013) as ways to describe scientific, engineering, or other technical information, which makes it a broader term than DTI. The European Association for Technical Communication (Tekom, 2017) describe TC as the process of defining, creating, and delivering information products for the safe, efficient, and effective use of products. They extend TC to include digital information related to the Internet-of-Things, which includes smart homes or products. Activities included in the production process of TC are analysing, planning, creating terms and information, producing media, delivering content, and collecting feedback. Focusing on the process of producing and delivering information, the work role of a technical communicator is of special interest in TC research. One example is given by Johnson-Eilola and Selber (2013), who argue that the TC co-workers' primary skills should move towards being information co-workers, moving away from pure linguistic work and viewing themselves more as part of the digital world.

The area for TC in organizations is broad. One such role of TC in organizations is that of being part of the supply-chain process to increase the competitiveness of the organization (Addo-Tenkorang, Helo, & Kantola, 2017). The supply-chain process includes TC, consisting of DTI, while developing the product as well as during the maintenance phase. Another way of looking at TC is that of designing master data, providing usability to the products, or as a standardized way of distributing DTI within the organization (Hart-Davidson, 2013). Comparing TC to DTI, one aspect is that it not only focusses on information related to the product, but also information related to science. One could therefore declare TC as a broader concept than DTI, where TC overlap DTI by its content, still partly focusing on information related to products.

2.1.4 Characteristics of DTI

Described here are the characteristics of DTI including the arguments for choosing these characteristics. The DTI's characteristics are the product's life cycle phases, the relation to the product, and the DTI's structure.

Previous research has revealed some ways to understand characteristics of DTI, however few researchers use characteristics to achieve a further understanding of DTI in relation to benefits. One of the few who does is Huang (2012). The study builds on the characteristics of product information for e-commerce sites and focuses on how DTI answers questions of what the product is and what it can do. The results are direct comparison possibilities and ways to evaluate the product information for e-commerce sites, which answers questions as how well it performs. Another example is founded on individual characteristics for DTI as foundation for decision-making (Aerts, Smits, & Verlegh, 2017).

At this point I should mention the characteristics based on the definition of DTI where the focus is on *the product's life cycle phases* and *DTI's relation to the product*, further described below. Added to these characteristics are one shown in the empirical material, the *structure*, also described by Wallace (2011) as the one of the main characteristics of digital information. Below are the selected characteristics listed and described fully:

- the product's life cycle phases
- DTI's relation to the product
- DTI's structure

The first characteristic of the DTI is the ***product's life cycle phases***. Ahlin (2014) describes the product's life cycle phases as development, production, maintenance, and destruction. The product's various life cycle phases are of importance as they require information from numerous operational aspects, which affect the DTI. One such example is the requirement on the DTI for developing a product in comparison to when the product is maintained.

There are various ways to detail activities within the product's life cycle phases. The development can be viewed as including individual activities collecting requirements, designing and constructing (Helms, 2002; Lee, Ma, Thimm, & Verstraeten, 2008; Öberg, 2007). Added to these activities are generally contextual activities, such as coding and testing for programming (Velmourougan, Dhavachelvan, Baskaran, & Ravikumar, 2014). Other ways to detail activities related to the product's life cycle phases are to use one or several life cycle phase, such as the production phase focusses on the use of the product; the maintenance phase also synthesizes with any on-going preservation efforts. The destruction includes finalizing the product, based on overall sustainable and environmental goals, including possible recycling. Viewing the product's life cycle phases from a marketing perspective shows life cycle phases, such as introduction, growth, maturity, and decline (Ljungberg & Larsson, 2012; Zheng, III, Sandborn, & Terpenny, 2013). Therefore, can the product's life cycle phases be viewed in various grades of detail and the DTI include information for solely **one activity within a life-cycle phase**, **one life cycle phase,** or covering **several or all the life cycle phases**.

DTI's ***relation to the product*** is evident for the DTI, even though the requirements occasionally are not based on the operational product assignments, such as development, operation and maintenance. There are other assignments, such as legal statements or quality information (Maskindirektivet, 2016). Stated in the Maskindirektivet (2016) is static information about the product, used to fulfil regulatory requirements for safe usage.

Detailing the DTI's relation to the product, there are several approaches to characterize it. One such is by its content, exemplified by German manufacturing and mechanical engineering (Oevermann & Ziegler, 2016). They characterize the DTI by its feature selection, token weighting, semantic quantifiers (often determiners and in explained as artificial metadata in unstructured text in the study), and confidence scoring. Their aim is to use documents with DTI and create content components for retrieval, reuse and distribution in relation to modifications of the product. Wellsandt, Hribernik, and Thoben (2015a) and Wellsandt, Hribernik, and Thoben (2015b) concentrate on the product's life cycle phase of production and outline its characteristics. Their examples of characteristics cover general perspectives on the DTI in the production and include metadata, such as product entities, appearance, level of abstraction (including customer reviews), originators, sources, life cycle activities, data formats, and scopes. They base their findings on various contexts, such as innovation and research projects and e-commerce sites. Their aim is to further describe the usage of DTI, which they describe as relatively unknown. Baysal and Roy (2014) investigate the product's life cycle phase destruction and the activity traceability and find that it requires other

DTI characteristics. They find that the characteristics are data on assembly limitations, design and product processes, the functions and behaviours of the product, and the design intent. Their intention is to derive a DTI integration model including the features of activities such as assembling and dissembling in relation to customers.

Several studies discuss the relationship to the product as the foundation for decision-making; one of these is Bougdira, Ahaitouf, and Akharraz (2016). Their study addresses organizations' decision-making that can be built on products' traceability and one of their findings is that DTI characteristics partially provides the foundation for the decision-making in logistic contexts. They describe the DTI in forms of standardized information, such as product information, and real-time information, like delivery information. The decision-making is made by either the delivery organization or the customer, waiting for the delivery based on the DTI.

Wowak, Craighead, and Ketchen Jr (2016) emphasize the relation to the product as occasionally troublesome and attribute this partly to the ambiguity of the DTI. They characterize the DTI ambiguity as product blending, product comingling, and product identification change. The product blending is the extent to which products are mixed together to manufacture them, the product comingling as the packing of products from various locations where they later can change identity. Schönberg, Weitl, and Freitag (2011) introduce a framework to verify the content of documents containing DTI, based on information extraction, temporal descriptions, and model checking. They extract the DTI characteristics based on automation, where the various DTI parts are analysed based on content and later checked on to enhance their quality. Bulavsky et al. (2017) elaborate further on the temporal aspects for managing the DTI as documents. They formulate the DTI characteristics based on its quality; emphasized in ways such as being informative, in compliance with standards, the completeness of modelling the product based on the DTI, the quality of the presented DTI, structured DTI, the relationship of the DTI to comply with a technical document.

The broad range of descriptions of DTI's relation to the product can be viewed from the perspective that DTI's relation to the product can take several perspectives. Leaving relations out, such as its content and the foundation (or only benefit) of decision-making and focus on the manufacturing process makes Wowak et al. (2016)'s perspective of interest. They characterize the relation to the product as depending on the product blending and synthesize the product blending as including a single product, to various products and to that of adding products. Relating this to the DTI's benefits, it is of interest to understand the characteristic of including content for only one individual product or on a more general level, like DTI for a complete series of products or product line.

One often described characteristic of digital information is its ***structure***. The structure of DTI can be either structured, semi-structured, or unstructured. Wallace (2011), Batini, Cappiello, Francalanci, and Maurino (2009), Päivärinta, Tyrvainen, and Ylimaki (2002) ,and Karjalainen, Päivärinta, Tyrvainen, and Rajala (2000) describe the structured information as related to metadata. The structured data is secure to form into hierarchies as it can be broken down into parts. Those parts can be reused in various ways to fulfil new goals (Lucky, Pasini, & Spagnolo, 2019; Tyrvainen & Päivärinta, 1999). Wallace (2011) emphasizes the unstructured information as not having an inherent structure and being difficult to link together. Therefore, is it harder to access and to break down. In-between is the semi-structured information, which has some structure as well as some inconsistencies.

The structured DTI is of importance for using XML. Priestley (2001) emphasize the reuse of structured DTI as either being based on its content or references to design and processes. The content reuse includes parts such as reusing the context without affecting the DTI or aggregating the DTI into new contexts. The latter includes aggregating the DTI in form of concepts, tasks, and reference topics. The structure is also frequently used to exchange DTI between various information systems as well as a way to structure DTI for interoperability (Bosschaart, Quaglietta, Janssen, & Goverde, 2015; Lucky et al., 2019). They describe a case where DTI is exchanged between various information systems for interlocking railway systems. XML is there used to standardize these information exchanges. The different XML standards are built upon marking a set of rules for encoding, which are readable by machines and humans (Lubell, Peak, Srinivasan, & Waterbury, 2004; Priestley, 2001).

Synthesising DTI's structure can it be used for DTI as-is or reused DTI, described, e.g. by Lucky et al. (2019) or Wallace (2011). Therefore, is it of interest to understand the DTI of including content based on the DTI **as-is** or **reused** DTI to the identified benefits.

2.2 The concept of benefit in the Information System's literature

The following sections include the presentation of the concept of benefit in the Information System's literature detailed in the term benefit, the term value, identification of benefits, and measuring benefits.

Often discussed in the Information Systems field are benefits gained by an organization from an information systems or information technology; i.e., by researchers like Remenyi et al. (2007), Peppard, Ward, and Daniel (2007), Ward and Daniel (2012), and Ahlemann, Hesselmann, Braun, and Mohan (2013). Despite its commodity, the term benefit is approached in a blurry way.

Both Breese, Jenner, Serra, and Thorp (2015) and Wowor and Karouw (2012), emphasize that the term *benefit* has various definitions. Wowor and Karouw (2012) discuss the imprecise way in which it is used and refer to the subjectivism of the term. The subjectivism is built on the perception that a benefit creates satisfaction for the various stakeholders and that it varies among the stakeholders. Satisfaction is delivered whenever the perception of a positive outcome balances or is more significant than the expectation. Ward and Daniel (2012) are on the same path and suggest that a benefit is an advantage in the eyes of a stakeholder or group of stakeholders. There are even examples of situations where the perception of what a benefit is has changed during a study. Nelson and Nelson (2003), while implementing an information system for credit unions, started off with the perspective that benefits are produced by reducing costs, and ended up demonstrating the creation of benefits through improved efficiency for customers. Bytheway (2014) emphasizes that benefits are improvements in efficiency, and argues that they help to improve and develop an organization. According to Bytheway (2014) is the organization at risk of stagnation if the benefits do not function correctly.

One common way to view a benefit is as efficiency. Luftman (2000) defines efficiency as 'doing things right'. Efficiency is often measured as a way of governing and managing, and may be used to introduce changes (Ljungberg & Larsson, 2012). Another way of understanding the term benefit is to base it on the usability of an information system from the user's perspective (Balic, Berndtsson, Ottersten, & Aldman, 2002; Ottersten & Balic, 2010). Their perception is that users see definite advantages in an information system's functionality when it helps them to carry out their work in an efficient way.

Another blurriness is the difference between the term benefit and value, which both derive their meaning from the way they are perceived; for example, a benefit could be viewed as anything positive, while value can be the subjective worth of something (Evans & Riha, 1989). Therefore, is it of interest to give a brief introduction to the term value.

2.2.1 Term Value

Discussing value brings you into several explanations, according to Bryson, Crosby, and Bloomberg (2014). One explanation embraces value as the material or monetary worth of a resource, another the worth of a resource compared to the price you paid, and the third as the value of standards of behaviour or the judgment of good behaviour.

2.2.1.1 Monetary value

Understanding the monetary value of a resource is intimately connected to the measurable benefits. One example is that value often is stated as the difference between benefit and cost. It starts in the means or the goals for the implementation of a resource. The goal for the implementation can be clear and in alignment with the organization's strategy or sliding into the unclear compared to the strategy (Thompson, 1988). As researchers discuss how to create the monetary value, they mention the same methods as for measurable benefits, such as Return-On-Investment, or Net-present Value. Therefore, can the difference between monetary value and measurable benefits be seen as minimal and the use of the words value and benefits interchangeable in this case.

2.2.1.2 The worth of something

A way to describe the worth of a resource is by declaring its intrinsic value. The intrinsic value is determined by the value of the resource as is, without considering its market value (Carmi, Oestreicher-Singer, Libai, & Yassin, 2011). Another way of describing the worth of something is declared in the subjective value theory. This theory refers to the value in the eyes of the beholder (Evans & Riha, 1989). This theory states that a resource doesn't have an intrinsic value. The subjectivity comes from different beholder's intention to pay different values, which means that a resource can get several values. The subjective value theory is a part of the lean movement and puts the power in the hands of the customer (Womack & Jones, 2003). Different views can appear from the internal and external customer of what is valuable and by how much. The lean-movement divides the manufacturing process into different value-adding activities to gain increased value.

2.2.1.3 The value of standard behaviour

Müller and Skau (2014) express the value of standard behaviour in forms of values, norms, and routine. One hinder for standard behaviour is individuals' behaviour, which can create barriers at implementing an information system's resource, and diminish the financial value of a project. The authors refer to education and training as a way to increase standardized behaviour for individuals, and they claim information system resources as one way to normalize values for the public sector. This industry is based on serving citizens in specific areas and driven by its values. These values are familiar beforehand, and determine the values the investment is compared with. General values for in implementation of public information systems in Sweden are legal security, equal treatment, democracy, and efficiency (Ilshammar, Bjurström, & Grönlund, 2005). These values are the general guiding principles at implementing an information system and one part used for evaluating the implementation. Bannister and Connolly (2014) emphasize the foundation for decision-making in the public sector as individual values, professional, organizational, legal, and public interest values.

2.2.1.4 Value or benefit - the choice of concept for this thesis

The word benefit is used throughout this thesis. I will use the term to put focus on the individual benefits, recognized by the respondents, as well as the perceptions of how to measure them. Furthermore benefits will be viewed as any positive advantages (Ward & Daniel, 2012), gained from the DTI for either the co-worker or for the organization.

The concept of value is here described as looking into tangible values, perceived values or standardised values. DTI is rarely referred to as a tangible resource, and I have omitted that perspective for this thesis. The perceived value focuses on various stakeholders' intention to pay for a resource and could be problematic to investigate from an organization's internal perspective. The concept of standardised values solely refers to specified values, which is not of interest here for aim and context.

The aim of using the word benefit is to create a broad foundation of what co-workers and organizations recognize as individual benefits from DTI and create a foundation for how to manage the DTI in the future. Therefore, is it of interest to understand recognized benefits, which are referred to as one of the differences between value and benefit (Porter, 2008). On the other hand, value is described by Porter (2008) as something created. Still, benefit and value often do not have a specified definition and are used interchangeably, adding to the blurriness. The recognition will start by identifying the benefits.

2.2.2 Identifying benefits

The step of identifying benefits is rarely investigated according to Braun et al. (2009). They suggest that the absence of research is due to the low engagement in organizations as regards using benefit models or processes, which is in alignment with the findings from Hu et al. (2006). They describe the use of benefit models, including the step of identifying benefits, as a burdensome process and that organizations prioritize other assignments due to lack of time or profound understanding of benefit models. The usage of benefit model becomes, therefore, less strategic and hence less impactful than expected. Nevertheless, this step could be declared from understanding whether there are any benefits at all from the implementation, which is helpful as an initial step (Ward & Daniel, 2012; Ward & Elvin, 1999).

The identification could be understood by interviewing stakeholders, sending out surveys, or by organizing workshops with invited stakeholders (Gomes & Romão, 2016). The latter is helpful when there is a need to reach consensus on what the benefits are. Another way to identify benefits starts by the identification that originates in a problem that should be solved by some sort of information system implementation related to a business process (Changchit, Joshi, & Lederer, 1998). They then propose that organizations should iterate the identification after changes in the current business process, re-design the process, and thereby be able to conduct comparisons of found benefits before and after the re-design.

Magoulas and Pessi (1998) describe digital information as creating benefits. They discuss those benefits in general terms, emphasizing that benefits should exist, based on the logical reasoning that organizations are more and more dependent on digital information. Praditya and Janssen (2015) identify benefits from information sharing by conducting a literature review and do not state how they find the benefits. Their focus is more directed towards the information sharing, despite the headline including the word benefits.

Detailing the digital information to DTI, Persson Slumpi et al. (2012) investigate the benefits of DTI and like previous researchers, they do not discuss them in terms of how they can be identified. Ahlin (2019) briefly discusses the identification of benefits based on a literature review for finding measurements on intangible benefits for digital information. The findings show that the identification is made via predetermined benefits or interpretations of benefits, either as individual or areas of benefits. Predetermined benefits are determined in advance and mainly stated in surveys and interpretations based on results from interviews or observations. An individual benefit refers to one benefit, while areas refer to categories of benefits, such as domain specific categories of benefits. The operational way of identifying the benefits are individual or group interviews or surveys.

The identification of DTI's benefits is based on the co-worker's perspective, which are reflected throughout this thesis. Several researchers concentrate on the co-worker, often in the wider group as stakeholders, and declare their importance (Ahlin & Slumpi, 2015; Ward & Daniel, 2012). The co-workers are essential while identifying the benefits and especially in this thesis as they are parts of the respondents. Their answers include opinions about other DTI users and the benefits they derive from DTI while working. While scholarship offers no stable definition of "DTI user", here the term DTI user is approached from the perspective of using DTI in their work role to solve a work assignment, based on the internal organization's perspective. Ways to use the DTI in a work role vary between either seeking or retrieving information (Jansen & Rieh, 2010; Lundin, 2015). Lundin (2015) refers to DTI seeking as a way to find DTI created by co-workers to solve a work assignment. The co-workers select their way to find DTI based on their knowledge requirements. DTI users can also be described based on their proximity to organizational boundaries, often mentioned as an internal or external DTI user (Ingelsson et al., 2015). Internal DTI users include co-workers working with information or co-workers in other departments using the DTI. In both cases, they can extend their knowledge by reading information. External information users can be customers seeking product information to solve a problem. For this thesis the internal users are in focus, working as middle managers, and thereby providing knowledge about other internal DTI users. Their roles and knowledge are further discussed in the Method chapter.

2.2.3 Categorization of benefits

The next step after identifying the individual benefits is their categorization, which is of interest to get an overview of them (Shang & Seddon, 2002). The overview can be utilized for communication or as a foundation for decisions. Here, the presented categories are mutually exclusive and presented in pairs. The presented categories are predetermined and emerging as well as strategic and operational. The predetermined and emerging benefits relate to change and time, such as digitization, where predetermined are decided before change and emerging benefits occur after. Using the categories predetermined implies the organization's or co-worker's determination on how to manage the change and the emerging on existing and additional use. The strategic category includes benefits supporting strategic goals within an organization, whereas the operational supports operational goals. These categories are of interest to understand the goal DTI mainly influences in the organization, adding to its role in the organization. The results from all these categorizations also add to understand who should be involved in designing and managing the DTI as well as evaluating its benefits.

2.2.3.1 Predetermined benefits

Ward and Daniel (2012) emphasize their view on predetermined benefits, which are related to a planned change. They describe the importance to connect a change owner and also that the benefits are related to measurements. They refer to predetermined benefits as part of an ex-ante evaluation, focusing on identifying benefits. Dameri (2012) is on the same path when it comes to measurement and sees them as essential outputs from both the ex-ante and ex-post evaluation for comparisons reasons.

There are several ways to conduct such an ex-ante evaluation, where one is proposed by Papadopoulos and Kanellis (2007). They construct a model determining the benefits and risk with implementing an information system. The model includes a process, where they propose interviewing respondents on their perception of strategical, operational, and tactical benefits as well as risks related to organization and the technical implementation. Dameri (2012) creates a desk-top model for the implementation of information systems for public organizations. The model includes requirements from the public and the offer from the public organizations as well as contextual constraints, such as regulations and technological limitations. Fitterer, Rohner, Mettler, and Winter (2010) build a conceptual framework from literature and detail the factors in the framework by using, e.g., DeLone and McLean (1992)'s

Information Systems Success Model. Their result shows a taxonomy for ex-ante evaluations within the health organizations. Krauth, Moonen, Popova, and Schut (2005) are on the path for decision-making and use Key Performance Indicators as a method for those decisions. They develop a framework for such a decision, built on long- and short-term time perspectives and factors, like effectiveness, efficiency, satisfaction, and IT utilization and innovation. Frisk, Bannister, and Lindgren (2015) suggest a design approach for ex-ante evaluation. The method includes three stages, built on double learning, individual user learning, organizational learning, and collaborative learning among managers resulting in investment decisions for public organizations.

Synthesizing predetermined benefits show that someone decides them before a change, e.g. an implementation of an information system, and that they should be measurable, and often summarized in a domain-specific model or framework. Here used perspective on predetermined benefit focus on the planned change and reflects the individual organization's choice, omitting the requirement on measurement as well as the use of any specified model or framework.

2.2.3.2 Emerging benefits

Further emphasized is the importance of a post-evaluation of benefits, where emerging benefits can be visible (Ward & Daniel, 2012). The structures of the emerging benefits give information about the business effects, and the measurements align with business goals. Later this view is changed, at least for the identification, to an iterative path for identifying the benefits and the problems in mastering the central role, played by the identification of benefits. Legner, Urbach, and Nolte (2016) focus on post-evaluation for design purposes. They derive requirements by understanding benefits from an evaluation of information systems. They use an analytical framework for such an evaluation and detail user requirements while conducting the evaluation. Federici (2007) focuses on the post-evaluation of ERP systems and synthesizes recognized benefits on an overall level. He declares the benefits as relating to organizational innovation, detailing identified benefits as smoother information retrieval, improved management of the organization's performance, and somewhat increased efficiency. The findings show that context is over-estimated for emerging benefits and that the stakeholders perceive the implementation as successful and of great importance for the organization.

The common perspectives on emerging benefits focus on the post-evaluation of a change, sometimes referring to the importance of measuring the emerging benefits. The perspective here is that emerging benefits occurs after a change and do not related to measurements.

2.2.3.3 Strategic benefits

Strategic benefits are approached from different perspectives. Piotrowicz and Irani (2010) claim that strategic benefits are non-financial and also intangible, like improving cooperation and communication with other business units or increasing organizational control. Attaran (2001) relates the strategic benefits to e-procurement system. In this study, strategic benefits are said to improve finances and efficiency for the e-procurement supplier, describing strategic benefits as benefits recognized in the organization's prioritized areas. The context of Cho and Shaw (2009)'s study is the implementation of an information system. Their claim about strategic benefits is that those benefits should be long-term and aligned with the organization's strategy and improve the organization's competitive advantage. Bhattacharya, Seddon, and Scheepers (2010) emphasize that strategic benefits are aligned to the organization's context where they improve efficiency, increase the speed of globalization, and extend the value chain. Li, Huang, and Song (2019) describe the strategic benefits of an CRM system as increasing customer satisfaction, which helps the organization gain profitability and market valuation. They claim that strategic benefits increase the competitiveness of an organization in the long run. Thereby, their perspective is that strategic benefits are related to the domain of the information system with a longer time perspective.

Love, Irani, and Edwards (2004) concentrate on strategic benefits for small-and-medium-sized production organizations that make minor investments in information technology. Their strategic benefits from the investments differ, ranging from improving growth and success via improved customer relations to becoming a leader in new technology. Väyrynen and Iivari (2015) argue that information technology gives strategic benefits by adding competitive sustainable benefits to the organization. Basahel and Irani (2010) discuss strategic benefits which follow an organization's strategic planning. Their view is that an information system should have its own strategy that is aligned to the organization's strategic planning. They divide the strategic benefits into strategic analysis, competitiveness, or alignment. Examples of strategic analysis benefits are to "support decision-making process" and “reduce cost”, examples of competitiveness are to “support innovation” or “become a leader in new technology”, and examples of alignment are to “improve resource control” or “create standards”.

Synthesizing the perspectives on strategic benefits shows that benefits either can be related to the organization’s overall strategy or to the information system’s specific domain, such as improving customer relations by using customer relationship management systems. The time perspective is often long-term which means that the gain can take time in order to fulfil strategic goals.

2.2.3.4 Operational benefits

Operational benefits are also viewed from different perspectives. Piotrowicz and Irani (2010) point out the operational benefits of e-procurement systems support. They mention operational benefits as including increased efficiency and effectiveness in operational departments, such as manufacturing or maintenance. The time perspective is often short in terms of direct and immediate operational impact. Other given characteristics of the operational benefits are that they are tangible and financial. Attaran (2001) uses the same category of information system, e-procurement, to give examples of operational benefits, such as to ‘Eliminate paperwork resulting in great saving’ and ‘Improve financial control by making it easier to match orders’. Both of these can be categorized as efficiency. Further, Cho and Shaw (2009) comment that IT projects adding operational benefits are of less risk compared to IT projects adding strategic benefits and thereby result in lower returns. On the other hand, implementation of IT project adding operational benefits is said to be easier to estimate and safer in the prediction of benefits.

2.3 Measuring benefits

One way to analyse benefits is by measurements, which is described as important by several researchers, such as Hitt and Brynjolfsson (1996), Hendricks, Singhal, and Stratman (2007), Ward and Daniel (2012), and Mcloughlin, Scheepers, and Wijesinghe (2014). There are several underlying assumptions why the measurements are of importance. One assumption, stated by Murphy and Simon (2001) and Khallaf (2012) is that stakeholders require financial output as a *decision base* before a go/no-go of an investment project. The financial output will be used for *comparison* or for *follow-up* decisions. Another assumption is that measurement is needed for a *change to* *be managed* and *to fulfil its goals* (Giaglis, Mylonopoulos, & Doukidis, 1999; Giaglis, Paul, & O'Keefe, 1999). Hallikainen, Kivijärvi, and Nurmimäki (2002) argue that there is a need to *see the total benefit picture*, which only can be done via measurements. As a summary, these examples refer to benefit measurements as a way to *compare and communicate* the status of a change as well as *agreements* among stakeholders.

Benefit models often require measurable benefits, e.g., the gain from implementing an information system (Ward & Daniel, 2012). The tangible benefits are over-represented in benefit models as they can be measured and thereby easily represented, presented, and compared. Benefits of DTI, or other categories of digital information, perceive as intangible by researchers like Remenyi et al. (2007). Researchers, such as Ward and Daniel (2012), describe benefits on a scale and contradicts the perception of mutually exclusive. They describe benefits by their explicitness of their contribution and use the steps from observable, measurable, quantifiable, and financial. Informed stakeholders decide if observable benefits are realized whereas measurable benefits can be measured in the moment. Quantifiable benefits can be forecasted and benefits with financial explicitness can be used in a cost-benefit analyses. Here, I focus on measuring DTI's benefits and use the more commonly understanding of benefits as either tangible or intangible and bear in mind that there are close ways to look upon this. Therefore, is it of interest to further understand perspectives on tangible and intangible benefits.

2.3.1 Tangible benefits

In Gupta and Jana (2003), tangible benefits are mentioned in connection to cost- benefit analysis. One example of such analysis is Net Present Value (NPV), which is explained as the difference between the present value of cash inflows and the present value of cash outflows (Remenyi et al., 2007). The methods used for financial outcomes are often viewed as easy to interpret, giving the same output all the time. Despite this view, Bailey (2011) shows that the same financial method, used in projects implementing the same information system, give varied results. Bailey (2011) explains this by looking at the organizations' long-term goals for the information system, which differs in the cases which are interpreted in various ways.

Focusing on the digital information, one approach is that of Wixom (2014) who claims that selling digital information can yield financial incomes, other exchanges such as products, or expected higher revenue. The results are all related to the digital information and not specified to any specific benefit.

2.3.2 Intangible benefits

To some extent, intangible benefits are viewed as harder to deal with than the tangible ones. This is due to them not being measurable and therefore difficult to fit into existing cost- benefit models (Kim, Kim, & Kang, 2010). Usually, the cost-benefit models include solely financial measurements and the intangible benefits are overlooked. Other designations for intangible benefits are qualitative or soft benefits (Frisk, 2007).

In addition to not being measurable, intangible benefits can be viewed from various perspectives. Murphy and Simon (2001), give one such example where they discuss intangible benefits from the perspective of either improving the internal organization's operational performance or output performance. Jacks, Palvia, and Schilhavy (2011)'s example focusses on a framework for the impact of an investment in an information system, adding profit, increased productivity, or by an intangible benefit. The intangible benefit split between seven items: customer satisfaction, industry performance, human resource management, number of downloads, public image and client loyalty, quality improvement, and social productivity. Chircu and Kauffman (2000) examine intangible benefits in organizations and assert the intangible benefits' uniqueness to the respective organization. Therefore, they view the intangible benefits as hard to replicate in another organization without effort. They also imply that time is of importance for the intangible benefits, and distinguish between the actual benefits directed towards the internal organization and the future ones to give foresight and adaptability. They mention that describing future intangible benefits is harder to forecast due to the time perspective.

Researchers like Brynjolfsson (1993) and Frisk (2011) emphasize the obvious while describing intangible benefits as contributing positively to the organization. Nowadays, this might seem obvious, but the intangible benefits have often been left out while discussing an information system's contribution to the organization due to the problem of measuring it (see e.g. researchers such as Brynjolfsson (1993) or Hitt and Brynjolfsson (1996). Therefore, it is of interest to discuss the contradiction between intangible benefits and measurement. Regardless of the fact that there are ways to measure the intangible benefits (Ahlin, 2019), one can view this as something of a contradiction. The contradiction is built into the striving to measure the intangible benefits that by their very nature can be viewed as hard to measure. The measurements that are the respondents' interpretations of, for example, interview questions should be treated as interpretations. This means that they should be used with comparable measurements, such as equivalent results from the previous year or organizational goals that are viewed as equal. Along with Lycett and Giaglis (2000), these interpretative measurements are viewed as a practical way to increase the stakeholders' interest in a resource.

Connecting intangible benefits to digital information, Remenyi et al. (2007) explain intangible benefits of digital information as few and mention one benefit, foundation for decision, which they refer to as intangible. Their perspective on few benefits from digital information could refer to the view on cost-and-benefit analysis, where the implementation refers to the information system, not the digital information. The information system is what brings the benefits, not the content of the information system.

Detailing the digital information to DTI Persson Slumpi et al. (2012) take the first step by investigating benefits of DTI and finding several of them. Later those benefits are defined as intangible by Ahlin (2014) and visualized by eye-measurements. Focus for these studies are the DTI, which could be one explanation of the findings in comparison to Remenyi et al. (2007). As with previous researchers, none of these discuss them further in terms of how they can be measured.

2.3.3 Measurement methods

Introduced here are overall perspectives on measuring benefits, whereas more are to read in Ahlin (2019). Renkemaa and Berghout (1997) categorize measurement methods related to benefits, according to (1) the financial, (2) multi criteria, (3) 'ratio', and (4) 'portfolio'. The financial approach means that the method is expressed in monetary terms and focuses on the incoming and outgoing cash flows related to the investment. Operationally used financial methods are (1) repayment period, (2) internal interest rate and (3) net present value (NPV). The multi-criteria approach is initially designed with several goals or decision criteria and subsequently assigned scores. Related to the criteria are weights and the final score is multiplied as weight and the score. The ratio approach focuses on the organization's efficiency, presented in various ways. One characteristic is the return-on-management method, comparing different organizations' efficiency and annual development. The portfolio approach selects a specific area, such as upcoming suggestions for investments and evaluates them as per their contribution, e.g., to business goals, technology goals, and financial consequences.

Stockdale and Standing (2006) investigate various existing measurement methods related to interpretative evaluation and base them on the Context-Content and Process. It answers the following questions: (1) what should be measured ('content'), (2) how should it be measured ('context') and (3) when should the measurements be made ('process') (Stockdale & Standing, 2006). What needs to be measured has varied from quantifiable concepts to even non-quantifiable concepts. This can be explained by the view that IT has shifted from being purely technical systems to socio-technical systems. The organization's environment and stakeholders influence the content of what should be included in the measuring. How measuring should be done depends on the external and internal context in which the organization is located. The external context is described by social, economic and technical factors and the internal context is the structure, goals and strategies of the organization. The when is emphasized as a continuous process starting at pre-implementation and stretching as far as desired in the post-implementation phase.

However, there are opinions that measurements do not add that objectivity, and thus can be compared without discussion. There are several views on the grade of measurement and its related objectivity. Kaner and Bond (2004) are more explicit about measurement and use the definition: "measurement is the empirical, objective assignment of numbers, according to a rule derived from a theory, to attributes of objects or events with the intent of describing them." In contrast, Lycett and Giaglis (2000) argue that metrics is not facts; they see them as interpretations of reality. As the interpretation is something that needs to be shared, they emphasize the importance of the same interpretation, shared by the stakeholders of the measurement process.

2.4 Benefits of DTI

Presented below is the previous research on the benefits of DTI, both identifying and measuring the DTI. The identification is synthesized in the DTI characteristics and benefit categories for analysing the identified benefits.

2.4.1 Current literature on DTI benefit

As previously discussed, I have found literature on the benefits of DTI to be limited, despite continuously searching for it. Besides the focus on benefits of information systems and information technology, one reason for the low interest in DTI and related benefits could be the perception that DTI solely provides benefits such as a foundation for decision-making (Schönberg et al., 2011). However, some studies do discuss the benefits. The studies are wide-ranging, focusing on various definitions of DTI and different perspectives of its benefits. I present some examples below.

Zhi et al. (2015) define software documentation as DTI and categorizes its benefits into four categories that focus on benefits to the organization: (1) maintenance aid, (2) development aid, (3) management decision aid, and (4) other. The first two benefits refer to transferring knowledge between co-workers for proper use of the software's architecture in its maintenance and development. Thomson and Lynn (2008) describe gained benefits, for the organization and users, resulting from the change from paper-based storage to digital storage. The gained benefits refer to the use of the new format which adds new possibilities for visualization as well as easier access for the user. Barthelmey et al. (2016) focus on another change: that of integrating content from production (manuals and sensor information) into DTI which is easily accessed by a whole plant. They recognize the benefits from the change which will result in increased efficiency and adaptable production processes as well as increasing the ease of customizing the DTI. One possible result could be fewer errors and smoother maintenance of the DTI. One goal of the integration is to provide DTI as a continuously updated service. Thun et al. (2019) address which work role benefits most from the digitization in Industry 4.0. They claim that the benefits of DTI improve quality of work by increasing efficiency and work routine safety. Their findings show that work roles with the highest competence within information system gained most from the DTI.

Siikala (2018) focuses his work on an organization's publicly available DTI and its recognized benefits. The results show five categories of benefits, namely: financial savings, safety and standards, quality, professionalism, and customer satisfaction. The organization focused on the financial savings for itself, leaving any gains for the customer unmentioned. Cui and Xiao (2019) discuss the difference between market information and DTI based on product development. Their findings show that organizations with technically complex products gain more from DTI in terms of 'Product development' than they do from market information. Nevertheless, this study is focusing on one individual benefit gained from DTI. Another example is Marotta et al. (2015), who collected massive amounts of DTI in the form of consumer information from various online advertising. They focused on three roles in their research: the organization, the consumer, and an intermediary. Added to these roles are three scenarios focusing on consumers' preferences, consumers' purchasing power, and a mix of them both. The benefits are in favour of the intermediary when targeting consumer information, whereas consumers derive more benefits when personal information is added to their preferred brand.

2.4.2 Synthesizing DTI characteristics and benefit categorizations

The previously described DTI characteristics and benefit categorizations will here be used as a way for the researcher to further understand the empirical material and making it visible for the reader (Gregor, 2006). They will be used as a way for analysing benefits allowing the researcher to find similarities and gaps. Before, the recognized benefits were all described in individual lists for each study, leaving the researcher without a tool to find interesting results and for the reader to make the analysis by comparing the lists.

The DTI characteristics, benefit categories, and their subgroups are as follows:

- The DTI characteristic product's life cycle phases, where the benefits cover the subgroups of either **one activity within a life-cycle phase, one life cycle phase, or several or all the life cycle phases**,
- the DTI characteristic the relation to the product, where the benefits range from covering the subgroups of only one **individual product** or on a more **general level.**
- the DTI characteristic the DTI's structure, adding to the benefits build on the subgroup of either **as-is** or **reused** DTI
- the benefit categories **predetermined/emerging** benefits
- the benefit categories **strategic/operational** benefits

The arguments for using the DTI characteristics and benefit categories to further understand the recognized benefits relate to deepen the description of them. In the longer run can this description be used as ways to evaluate, manage, and design DTI. For further elaboration on the DTI characteristics and the benefit categories, see the method section 3.1.2.

2.4.3 Measuring DTI's benefits

For DTI, a resource that rarely is related to a change and that can be produced internally by the organization; there is limited support on how to measure its benefits. The few attempts to measure benefits of any category of digital information are all based on the presumption that benefits of digital information can be treated in the same way as an information system or information technology, discussed by, e.g., Wixom (2014) or Koski (2015). This is a presumption we do not know much about and could be discussed with background to the way benefits of information systems were measured while they were introduced, see, e.g., Brynjolfsson (1993) and his discussion on the productivity paradox. Despite this, can organizations or co-workers require measurement methods.

There are some approaches where DTI is in focus or partly involved. One of the first of these is that of Flowerdew and Whitehead (1975), who comment on the problems of estimating the benefits of DTI as these can't easily be understood in monetary values. They choose the cost-benefit analyses as an approach to understanding the benefits, where the benefits are based on customers' demand for the DTI. Later, an approach to understanding the benefits of digital information was Information Economics, primarily developed by Parker, Benson, and Trainor (1988). They emphasize that digital information impacts decision-making, which results in economic benefits or losses for the organization, basing it on gaming models such as Monte-Carlo methods. Their view was that the presence of digital information naturally leads to better decision-making, determined by the alternatives from which the decision-makers can choose and would thereby improve the organization's possible outcomes. Therefore, buying and selling digital information was of importance in Information Economics, and was compared to the trade of goods between customers and suppliers. Their comparison focuses on examples such as the fact that the same digital information can be purchased by several customers and thereby sold multiple times. This approach is related to Wixom (2014)'s research. She investigated what happens when organizations try to apply financial measurements to the benefits of digital information and found that it is connected to exchange with external partners. This exchange is known as data monetization and is emphasized as the exchange of information-based products and services for legal tender or something of perceived equivalent value. The measurement is emphasized as one of the key challenges, when organizations want to understand the benefits of the digital information in form of fixing its price or when doing internal bartering with the digital information.

Two recently devised approaches on how to measure DTI's benefits are found in Ahlin (2018) and Ahlin (2019). In Ahlin (2018) a measurement method is designed and tested, based on Kaner and Bond (2004) and Ljungberg and Larsson (2012). They describe measurement methods as follows: collect the input to the method, make the measurement via a rule, and describe the output. Suggested ways to collect the input include interviews (Chircu & Kauffman, 2000) , surveys (Kim et al., 2010) , or occasionally, goal-oriented (Hallikainen et al., 2002). Usually, the rule is built on a theory and when operationalized it is characterized by the measured resource. The output from the measurement method depends on the rule. This process of conducting measurements is shown in Figure 2.

Figure 2 Design of a measurement method

Ahlin (2019) elaborates on Ahlin (2018) by investigating ways to measure intangible benefits based on a literature review. The underlying assumption is that the main part of DTI's benefits is viewed as intangible. The findings are that there are several approaches for measuring intangible benefits, based on the design as mentioned earlier of a measurement method (Kaner & Bond, 2004). The approaches, shown in Ahlin (2019), explain that the input consists of identification of benefits, *either* as predetermined benefits *or* interpretations of benefits. The interpretations are often based on interviews or observations. The predetermined benefits are *either* individual or areas of benefits or a mix of them, mainly used in surveys. One way to relate these two ways are by identifying benefits via interpretations, in interviews, and later measured their frequency as pre-determined benefits, e.g., in surveys.

The literature showed that the rule could be based on a previously declared theory or similar or one's own created rules, where the first can be a theory such as Analytical Hierarchal Process (Ahlin, 2019). The individually created rules are aligned with strategic goals, operational goals, or customer satisfaction. One example of such a rule is a Key Performance Indicator, which can be focused on strategic or operational goals. The literature showed no relation between the previously declared rules or individually created rules. Each study used one rule without input from another. The rules were all further detailed in each study, e.g., in cost-benefit analysis or Balanced Score Card's methods. The output is measurements, either in financial or non-financial metrics, where the latter is the most significant.

Figure 3 Approaches to measuring intangible benefits (Ahlin, 2019)

3 Methodology

The methodology chapter includes ***the research design***, and ***ethics for the included studies***, where the research design section describes the goal of the thesis, related research, research questions, the method, the data collection, and the data analysis. The ethics section focuses on the ethics in the field of Information Systems as well as in the interview situation.

3.1 Research design

There are several ways of describing what research design is. One, a frequently used and detailed description of qualitative research design, is that of Maxwell (2012). He focuses on the design and validity of qualitative research studies with respect to constructing coherence of goals, the conceptual framework, the research questions, and the methods, all cantered on answering the research questions. He frames a study's goal as responding to desired contributions and answering why the study is worth doing. The framework synthesizes the theoretical and empirical framings of the study, and the methods are based on the research questions and describe the collection and analysis of the empirical material. Lastly, validity is emphasized as the legitimacy of the study. Therefore, the following sections are based on Maxwell (2012)'s intention with research design: (1) the goal of the research, (2) the conceptual framework, (3) the research questions, and (4) the method, whereas the validity is discussed in the method discussion, see chapter 5.5.

3.1.1 Research goals

Maxwell (2012) emphasizes that goals of a research study can be identified by the researcher's intention to add knowledge, the clarifications, and whom should be interested in the results.

By this thesis, I want to describe DTI's benefits, adding to the sparse knowledge on DTI's benefits in the field of Information Systems. Carter et al. (2015) describe that the meagre research activity on digital information in the Information Systems field is problematic, e.g., by not understanding how the resource adds efficiency to information systems. From the perspective of benefits to the study of DTI, there is research focusing on benefits of other categories of digital information, e.g. on Open Government Data (Janssen, Charalabidis, & Zuiderwijk, 2012; Praditya & Janssen, 2015). Still, the lack of a systematic overview of the benefits of DTI creates practical problems, e.g., when describing the importance of DTI in organizations and designing and developing the DTI, since the focus is always on the product (Hart-Davidson, 2013).

The clarification I want to make by this thesis is, therefore, to contribute to the identification of DTI's benefits and further analyse them and by this bring knowledge of DTI forward, benefiting research as well as to organizations directly. Initially, the clarification was to understand if it was possible to identify benefits and later how to analyse them in a systematic way, not previously done for DTI in several organizations. Here, the identification of DTI's benefits will show that there are ways to identify the benefits of digital information, related to the necessary change for evaluation purposes. In Ahlin (2018) and Ahlin (2019), I clarify various ways to measure DTI's benefits, despite the rare use of measurement methods in practice.

The results are of interest both for academia and practice. Academia has rarely investigated DTI's benefits or other categories of digital information, impacting ways to understand how to conduct such studies. The results show ways to conduct such investigations. For practice, the identification should be of interest while designing and developing the DTI and also on how to evaluate the DTI. The results from measuring DTI's benefits should be impressive both for practice and academia. For practice, measurements are ways to communicate and compare the development of the DTI, and for academia are the results of interest to investigate further, e.g., contextual impacts on sufficient measurement methods.

3.1.2 Conceptual framework

Maxwell (2012) stresses that the conceptual framework includes, among others, previous research, literature, and theories included in the research design. Inspired by Maxwell (2012)'s description I present examples of how I found related research, primarily from the Information Systems field, as well as the presented DTI characteristics and the benefit categories. The DTI characteristics and benefit categories are used here for the purpose of analysing the recognized benefits.

As this thesis originates within the Information Systems field, the primary literature investigations are conducted within this field, despite two integrated components which are closely related to other fields. The first is the DTI, used in other fields, such as Engineering. This field is further divided into areas, like Mechanical Engineering or Software Engineering. I have found literature related to DTI and its characteristics in the field of Engineering after looking for it in the Information Systems field. For the benefits, the literature is related to the Information Systems field, although it in itself is affected by Economics, such as understanding financial outcomes.

Searching for related research has been an ongoing process throughout the whole period of work on this thesis. Here follows a brief description of one search for literature. The search began in databases, such as SCOPUS and IEEE, both of which provide access to the Senior Scholars' Basket of Journals, along with numerous other Information Systems journals and others from areas such as natural science, medicine, social science and technical science (Digital, 2015; Scopus, 2015). During my time at Michigan State University (MSU), I used their access to research materials, which meant additional access to relevant literature, not provided by Mid Sweden University. An example of this was the journal Technical Communication Quarterly. Nevertheless, the research activity combining DTI and benefits is low, resulting in limited reporting from the Technical Communication Quarterly.

The choice of the DTI characteristics and benefit categories have been iterative, such as in the case of Shang and Seddon (2002). One approach was to identify characteristics related to DTI, where the identification of the DTI was one base. Therefore, the product's life cycle phase and the relation to the product was of interest and how they affected the recognized benefits.

Initial work for identifying the DTI characteristics was by investigating interesting characteristics of DTI and digital information as well as of benefit categories by reading literature and investigating the empirical material. This iteration gave that the product's life cycle phase was more focused and solid in literature. In contrast the relation to the product was more widespread and investigated in various ways in the literature. Despite this, did the empirical material show focus by starting as related to an individual product and evolving to a product line, when possible. Often described in the empirical material were the structure of the DTI and the possibilities related to it, such as using XML and re-use the DTI. Literature has investigated this characteristic, using both digital information and DTI (Tyrvainen & Päivärinta, 1999; Wallace, 2011).

The DTI's characteristics have changed during the iterative process. Initially, the DTI characteristics included others, such as DTI's presentation, and preservation. The presentation is of interest since it affects the DTI's benefits, described by researchers such as Davison, Murphy, and Wong (2005), Wysocki (2013), Lieu (2009), or El-Chaar, Boer, Pedrazzoli, Mazzola, and Dal Maso (2011). The argument for removing this characteristic was that it was affected by the information system, not the DTI as such. The interested in the DTI's preservation was initiated from Ahlin and Saarikko (2013), showing benefits of long-term preservation of the DTI. The benefits of preserving DTI appears in the preservation process, not explicitly researched in all studies.

The used benefit categories (strategic/operational, predetermined/emerging) are some of the most well-known benefit categories, see, e.g. Frisk (2007). Besides being frequently used do they focus on the internal organization's perspective, the same as for this thesis. The understanding of these benefit categories adds to the description of the benefits as well as to understand how to manage and develop the DTI. In contrast to Ahlin (2014), I have not used the benefit category direct/indirect, since they were not part of the empirical material. The benefit category tangible / intangible was here more suitable to be part of the second research question, the perception of how to measure since the benefits were considered as intangible by the respondents.

3.1.3 Research questions

Maxwell (2012) emphasizes the research question as a signpost to what the researcher wants to understand. Further, the research question focuses on the included studies as well as giving guidance on how to conduct them. The primary issue that I wanted to understand was if it was possible to identify the benefits of DTI, since previous knowledge is lacking. The sparse research about DTI's benefits is, for example, related to knowledge sharing (Svensson, 2010), and does not explicitly take other benefits into consideration. The next step was to detail the knowledge of DTI's benefits by analysing them against the characteristics of the DTI. The results show further identification of DTI's benefits, detailing the gain DTI gives to organizations and showing how the DTI's benefits can be developed and evolved in the organization.

The second research question focuses on the perception of how to measure the benefits, which should provide another step on the path to evaluating DTI on the same premises as an implementation of an information system. The exploration on how to measure DTI's benefits are on the same path as for the first research question. Initially, I wanted to understand the premises for the work that had to be done in advance and later if it was possible to measure the benefits. The clarification of this was made in several studies and in Ahlin (2019), where the results show various ways on how to measure the intangible benefits.

3.1.4 Method

Maxwell (2012) view on method focuses on the relations with those that you study, the selection of respondents, data collection, and the data analysis. Described here is this thesis's method, followed by the included studies, data collection, the selection of respondents and the data analysis.

3.1.4.1 Interpretative research

Presented in this section are interpretative research, its limitations, and this thesis's approach to interpretative research. Argued for here is that one significant part of interpretative research is the data description, including context descriptions and interpretations (Schultze & Avital, 2011) and that the two roles included in interpretative research are the researcher and the respondents, when they both meet in the interview situation (Alvesson, 2011; Creswell, 2014; Kawalek & Jayaratna, 2003; Patton, 2002).

At the time that interpretative research was introduced and viewed as a way to conduct research in the Information Systems field, Klein and Myers (1999) recommended interpretative research as building on the complexity of human sense making and understood by the meanings they assign them. Interpretative research is often equated with qualitative research, a stance denied by Klein and Myers (1999). One perspective on qualitative research relates to the material that is interpreted. The common opinion is that the material in qualitative research is written or verbal in some sense. Schultze and Avital (2011) argue that the material should include a description of both the physical and context all guided by the researcher's interview protocol. Focusing on this thesis, the context is included as the description of the studies, the results from the studies, and the interview protocols. The interpretations derive from multiple individual and group interviews with informed middle managers that deal with DTI. I have mainly used the interpretative perspective, but I include one survey, used as foundation for a statistic analysis, to include more empirical material. Surveys make it easier to reach a broader group of respondents, in comparison to interviews (Patton, 2002). The interview situations gave me the ability to gain understanding of the empirical settings and foundations as answers to the research questions.

The researcher acts as a close observer in the conducted interviews, observing a group of respondents, in contrast to actively taking part or acting as a change agent. Kawalek and Jayaratna (2003) describe the researcher's role and the respondents', as those of importance in interpretative research. For the researcher, they emphasize that he/she can gain learning opportunities and that they should be detected as such. In framing the respondent, Alvesson (2011) emphasizes the local context that the respondent represents. The respondent should be determined to discuss this context, which leaves the researcher with the assignment to make general statements and values details concerning the interview situation. Schultze and Avital (2011) frame the respondent's contribution by the descriptions, which are grounded in the respondent's own experience, the acknowledgement of their experience, and the guidance of them through the interview, all referring to the researcher's way of managing the interview situation.

The limitations with interpretative research are several, where Kawalek and Jayaratna (2003) emphasize the interpretations as one limitation, where they describe an interpretation as explanations of what is studied. The interpretations are conducted by one or several researchers by their mindsets and thereby viewed as contributing to knowledge. One of the recurrent questions is: who legitimizes the interpretations as valid and who determines what is not valid research? Kawalek and Jayaratna (2003) discuss the choice of respondents upon which the knowledge is partially built. The respondents' impact is discussed with respect to how the researcher can verify their background and their contributions as being part of the community. Other limitations include the potential for generalization, described by Polit and Beck (2010) as drawing broad inferences from particular observations. Lee and Baskerville (2003) limit generalizations by the quantity of data, whereas Creswell (2007) emphasize the importance of quality in qualitative research, not the quantity of data. They all stress the norm for generalization is referring to quantitative research, which typically is seen as the only way to view generalization. By broadening the perspective on generalization, they discuss generalization from empirical perspectives and theoretical perspectives, where both are summarized as either empirical or theoretical statements. For the theoretical and empirical statements, they are referred to generalizations in further descriptions, claiming the generalization as valid. Polit and Beck (2010) emphasize generalizations in qualitative research as of less importance, focusing on adding understanding from descriptions of specific contexts.

3.1.5 Data collection

The data collection includes the research context for this thesis and the context for each study. The path includes two parts, that of identifying the benefits of the DTI and the perception on how to measure them. The benefits are here described from the side of their identification, analysed in relation to the DTI characteristics and benefit categories, and how to measure them.

The data collection is conducted via five studies. The base for the studies is four organizations, here named Alpha, Beta, Gamma, and Omega, and a field study initiated at Rho. Rho is a national board associated with DTI, where each board member represented their organization. The organizations were chosen based on a purposeful sampling. Patton (2002) emphasize purposeful sampling as identifying and selecting respondents who are knowledgeable and experienced as well as interested in contributing. The purposeful sampling is further divided into various categories, where the expert sampling is suitable based on the novelty of the conducted research. The research gains from their deep knowledge while building the knowledge foundation. The choice of organizations is based on their knowledge of DTI within the organization, which means, for example, that one like Rho is of interest. Alpha, Beta, Gamma, and Rho were initially identified based on their partnership in the research projects TIC II[1] and KATI [2]. The research projects included other organizations as well. This partnership included interest in

[1] TIC II aimed to strengthen and develop technical information companies with operations in the region of Jämtland/Härjedalen and resulted in more efficient methods, skills, and network building

[2] The aim of the research project KATI, KundAnpassad TeknikInformation (Customer Adjusted Technical Information), was to create the conditions for efficiently producing customized technology information in smaller companies in the region of Jämtland/Härjedalen.

contributing with their knowledge about DTI and their benefits, adding to the purposeful sampling. The initial choice of Omega was also based on expert sampling, adding their deep knowledge and interest in DTI, even though they did not participate in TIC II or KATI.

The secondary factor, which varies among organizations, is their connection to the DTI. For example, most organizations have a connection to the products they manufacture, such as Alpha, Beta and Gamma. For Omega, the term of manufacturing is expanded to include production, as it also produces software. Mainly, manufacturing organizations are thought of as organizations producing physical products, such as cars, lorries, and boats. Here, the focus is both on the making or processing of a product and the product's life cycle phases. Therefore, manufacturing organizations are referred to in a wider range than might be usual and the focus is on both physical and non-physical products. For Rho, the organizations focus on either manufacturing industry or consultancy organizations, with the primary business within DTI.

The third factor was the organizations internal use of the DTI. They were all using the DTI for internal purposes and related the purpose to the product. The organization's purpose for producing the DTI varies, where one could compare, e.g. Alpha's purpose of tracing product deliveries with that of Omega's producing comparable products. Despite, the internal use, did all of the organizations start producing the DTI to better fulfil customer requirements.

The overall geographical location of the studied organizations is within Sweden, except for Omega, which is located in the United States. Organizations located in Sweden and other countries, member of the European Union, need to follow the Maskindirektivet (2016). This legislation contains requirement of product documentation during production and for maintenance. Besides this difference are all organizations private, where one part is to focus on their profit.

The interview situation included both individual and group interviews. The group interviews were used to collect rich empirical data on a specific subject, where all participants´ aspects are of interest (Hennink, 2014). The discussions' goal is to scrutinize, not to reach consensus. Hennink (2014) proposes that the number of participants should be between five to ten persons all of whom should have the same level of knowledge about the subject. The advantage with group interviews is rich empirical material with various perspectives in a specific question, which raises the demands for detailed analysis. For this thesis, group interviews were used in study #3 and #4 (for #3 to understand the benefits of a DTI production process and for #4 on how to measure benefits). Both group interviews were held with the argument mentioned by Hennink (2014), collect rich empirical material with various perspectives, as both group interviews included themes rarely investigated or discussed. The studies included individual interviews to avoid results from group thinking.

Detailing the discussion about the interview situation, Alvesson (2011) describes the practical aspects of interviewing namely creating trust by planning the interview to establish trust. His way to do this is by structuring the interview in sections, using the second section to find answers to the study and finally opening up for the respondent's own ideas and thoughts about the themes. Hence, the interviews in this thesis are built on themes and as conclusion the respondent is offered the chance to bring up any related subject, see appendices 2, including interview question to study #1, study #2 etc.

In Table 1, the respondents from each study are described in terms of numbers, summarized length of interviews, and other studied documents.

Study	No of respondents	Summarized length of individual interviews (minutes)	Summarized length of group interviews (minutes)	Other studied documents
#1	7	540	N/A	Alpha's configuration management process
#2	5	330	N/A	Beta's DTI production process
#3	7	150	345	Gamma's DTI production process
#4	7	407	71	Omega's website
#5	6	225	N/A	Rho's website and the organizations' external websites, focusing on DTI
Total	32	1652	416	N/A

Table 1 Study and number of respondents

3.1.5.1 This thesis's respondent group

This thesis's respondent group is middle managers, located somewhere within the executive level, enabling us to focus on the organization's overall strategy, and the operational level (Shang & Seddon, 2002). One argument for limiting the respondent group to middle managers are that they are characterized as experienced in executive and operational levels in an organization. Often, this experience is based on understanding the knowledge of the other levels in an organization, as well as their respective perspective. Another argument focusses on the combination of DTI and its intangible benefits. Shang and Seddon (2002) discuss middle managers as more suitable for answering questions concerning benefits, as they do not solely take a financial perspective, as the executive level tend to do. They continue their discussion by comparing the operative level that is focused on operational benefits of an information system resource, such as data quality, with the middle managers' broader perspective.

As regards the position of the middle manager in the organization, their work assignment consists of managing, supporting and communicating to the operational and executive levels in various ways (Ljungberg & Larsson, 2012). Finding the balance in their work assignments is frequently referred to as being difficult. They are frustrated as they are caught up in the hierarchy of the organization, whereas some refer to them as being experienced in executive and operational levels in an organization. Besides understanding other levels within the organization, Vannoy and Salam (2010) emphasize that middle managers' views are of particular interest. They control how work is executed, based on their work assignments, and the meaning of actions. For this thesis, the respondent group therefore affects the results based on their various perspectives on DTI and its benefits. For the DTI they are knowledgeable in their various characteristics and for the benefits they understand not only financial perspectives but also have an understanding of the operational and executional levels in their organization. The simple act of gathering empirical material from this respondent group has made their voices heard.

There are a variety of descriptions as to who is a middle manager. Norzaidi, Chong, Salwani, and Lin (2011) suggest that middle managers should be above first-level decisions, but not directly responsible for strategic decisions. Livian and Burgoyne (2005) give another view on who can be classified as a middle manager as they include the lack of responsibility for loss or profit in their description. The decision-making is another angle, where middle managers make a multitude of small decisions, all of them having impact on the organization. Livian and Burgoyne (2005) synthesize their perspective on middle managers into two groups – one group is those in charge of other co-workers' assignments and having some hierarchical power in the organization. The other group is the co-worker with special technical skills, who influences others due to their competence and who owns their own work assignments. They continue by describing the future for middle managers as uncertain, since information technology will make their paperwork redundant and thereby their work role. Another perspective on the decrease derives from the birth of other approaches, such as the network or project-based organizations.

Two perspectives on middle managers are used in this thesis. One sees them as co-workers who have a hierarchical position within the organization to influence decisions about DTI, both decisions concerning strategically questions and on an operational level. The other perspective is that of co-workers with special skills connected to DTI, despite the fact that they do not have a specific hierarchical position within the organization. The groups both have an in-depth knowledge of the DTI and its benefits, as well as knowledge on how the other parts of the organization look at these. For this purpose, the following work roles are represented in the studies. Table 2 shows the included work roles for each study as well each study's minimum and maximum work years in the actual work role.

Study	Represented work roles and numbers	Education	Gender	Min and max work year
#1	Project managers (3), DTI owners (2), Team leaders (2)	High school (3), Bachelor's degree (1), M.Sc. (3)	Female (2), Male (5)	4 and 27
#2	DTI production managers (3) and project managers (2)	High school (4), M.Sc. (1)	Female (3), Male (2)	1 and 34
#3	DTI production managers and project managers	High school (5), Bachelor's degree (2)	Female (2), Male (5)	5 and 22
#4	Project managers (5) and development managers (1)	Bachelor's degree (6)	Male (6)	5 and 20
#5	Team leaders (2), DTI owners (1), DTI Consultant Managers (3)	Bachelor's degree (6)	Female (4), Male (2)	10 and 32

Table 2 Each study's represented work roles, education, gender, and min and max work years in the actual work role

3.1.5.2 Study #1

Research design: this study intended to investigate the research question *"Which are the benefits of the Configuration Management (CM) process in a manufacturing organization?"* by a qualitative study. The research question functioned as the initial step to describe the benefits of DTI and was also based on previous research in the TIC I- project. For the latter, this study was viewed as a step for further development of this research, based on the DTI and the CM-process.

Context: The studied DTI was Product Configuration Information, related to the CM process. The choice fell on this DTI and organization since both were well-known within the TIC II context for their long-term use within the organization and high quality. The DTI belonged to the CM-process within the organization, which here is named Alpha and works as a Swedish defence contractor.

Data collection: I made seven individual semi-structured interviews with middle managers such as development project manager, team manager software development, team manager customer support, team manager customer documentation, team manager mechanics construction, and process coordinator configuration process in this study. Another co-worker at Alpha, closely related to the TIC II project, picked the respondents based on this study's research question. All of the respondents had long-term experience of the chosen DTI and the CM process. I conducted the interviews on site and they lasted between 40 and 90 minutes. The respondents were all interested in participating in the study, while their allocated time and attention during the interview varied.

Knowledge contribution: The results of this study were the starting point for this thesis, since the result showed the DTI added significant benefits within the CM process, such as 'semantic interoperability and knowledge for product development. Semantic interoperability should be viewed as a standardized language, which offers possibilities to discuss without defining or using, e.g., pictures as explanations. Those benefits were identified during the interviews and later interpreted from the interview material. The study's DTI was investigated as part of the study, included as interview questions from the second interview and later in a follow-up interview with the person responsible for the DTI and the CM process. These results created the starting point for the interest in investigating the DTI and its benefits. The benefits found formed input to identification of the benefits.

Publications based on the study's empirical material: Persson Slumpi et al. (2012), Ahlin and Saarikko (2012), Ahlin and Saarikko (2013), Ahlin, Slumpi, and Öberg (2013), Ahlin (2014), and Ahlin and Slumpi (2015).

3.1.5.3 Study #2

Research design: Study #2 concentrated on providing a basic understanding of measurements of benefits, besides the investigated DTI. The study's research questions were: "*What are the activities adding benefits in a DTI production process?*" moreover, "*How can efficiency be measured in a DTI production process?*" by a qualitative study. The study was designed as a qualitative study, using individual interviews as a method for collecting empirical material.

Context: The studied DTI was various information in the form of manuals, aimed at operation and maintenance of the products. Beta is a Swedish global construction company in the paper mill industry with an outsourced DTI production process. They manufacture their products internally in the organization and deliver them with the DTI. The DTI is also used for internal purposes.

Data collection: The study, initiated by the organization holding the outsourcing contract, focused on the production process of DTI. Beta's production process, see Figure 5, include activities like order reception from the development department, collection of facts and form of product implementation, production of new instruction, proof-reading, and publishing of DTI.

The respondents were all picked by the outsourcing organization as informed respondents based on the research questions. The interview questions included parts like the DTI production process and its development and perspectives on the existing measurement process. Initially, three interviews were planned but this was increased, as the results showed little benefits of DTI due to the internal view of DTI. On my request, two semi-structured interviews with the project managers were added. The first respondents described the tension between the outsourcing partner and Beta, resulting in negotiations about efficiency from DTI and its production process. I conducted all the interviews on site and they lasted between 40 and 85 minutes.

Knowledge contribution: The results indicated several problem areas where how to measure was in focus. One example is what is perceived as immeasurable and another the importance of consensus on the measurement process. These results have been significant in the further understanding of how to measure the intangible benefits, such as in study #4.

Publications based on the study's empirical material: Ahlin (2013), Ahlin and Ingelsson (2013), Ahlin (2014), and Ahlin and Slumpi (2015).

3.1.5.4 Study #3

Research design: was a joint study, conducted together with a Ph.D. candidate from the Department of Quality Management at Mid Sweden University. The study's research question was: *"Which are the benefits DTI creates throughout a manufacturing process?"*. This study aimed at re-iterating and further investigating the benefits. The research question was investigated via a qualitative approach, using individual and group interviews to collect empirical material.

Context: The studied DTI was digital information in the form of assembly instructions, used both for internal assembling, quality assurance, and repairing the manufactured products. The DTI contains product information about the inherent components as well as information for how to assemble the products. The empirical material was collected at "Gamma", which is a Swedish construction engineering company with 150 employees. The organization bases its manufacturing on a hydraulic invention used in excavators.

Data collection: The study included three parts: the group interviews, the individual interviews, and an individual follow-up interview to confirm the identified benefits. The group interviews followed the production process of the DTI and the benefits derived from each included activity. This part of the study created the foundation for understanding the benefits, both by discussing them in the natural environment of the manufacturing process. The discussions took place in the production area and were further discussed in an office. The choice for the initial step was to give the respondents the possibility to be comfortable in their own environment. The first part of the group interviews was based on benefits derived from the DTI's production process, focusing on their included activities. The group interviews lasted for five hours. The respondents were chosen by the DTI owner, who participated in the KATI research project.

The next step after the group interview was individual interviews with the development manager and the executive manager, where they described their perspective on the benefits of DTI. I conducted these interviews, which lasted between 30 and 80 minutes. Later, I conducted an additional individual interview to confirm found benefits. This individual interview deepened the understanding of the benefits of DTI in a manufacturing process. This final individual interview was semi-structured and lasted 45 minutes and the respondent was the previously interviewed DTI owner. The DTI at Gamma is of interest as it, in contrast to another studied DTI, solely contains DTI for one activity in one of the product life cycle phases (the development).

Knowledge contribution: The result shows that DTI creates both general, as shown in study #1, and contextual benefits. General DTI benefits, recognized in all studies, are such as semantic interoperability and knowledge transfer within organizations. Recognized as contextual benefits relate to the individual organization and its internal processes, such as manufacturing. The results are also used for analysing the benefits in relation to the product's lifecycle phase. This result indicates that most of the benefits are recognized as the DTI is published, but also in other of the product's life cycle phases. A visible result of the whole study is that Gamma has created its own DTI department.

Publications based on the study's empirical material: Ahlin and Slumpi (2015); Ahlin and Åslund (2014)

3.1.5.5 Study #4

Research design: The thesis's fourth study aimed for further understanding of measuring DTI's benefits, which mainly are viewed as intangible. One reason for that is the problems to identify DTI's benefits in financial terms and thereby use cost-benefit analysis. The foundations for this study were the licentiate thesis, study #2, and Ahlin (2019). The licentiate thesis gave fundamental knowledge on visualizing the gained benefits and Ahlin (2019)'s general knowledge on how to measure intangible benefits, which needed further detailed investigations to understand how to measure DTI's benefits. Therefore, the research question was: *"How can benefits of DTI be measured? ".* The foundation for collecting the empirical material was by a qualitative approach.

Context: Here, the DTI was their newly implemented requirements for product development, named charters. The DTI included parts such as aim for development of the product and detailed parts for the development. The empirical material was collected at Omega, which is an American technology company that bases their production on software products and services. The number of employees is close to 300, and their customer's geographical locations are in 180 countries.

Data collection: The researcher conducted seven individual, semi-structured interviews at Omega, with middle managers producing the DTI; followed up by one group interview with four out of the seven respondents. A co-researcher, from MSU, took part in three of the semi-structured interviews. The group interview included a discussion on how to measure the benefits based on input, rule, and output. The individual interviews gave input to the measurements and the group interview gave the output from the measurement test. This study ended the discussion about measurement for this thesis.

The respondents all held middle manager roles such as project managers for development and development manager and were all somehow responsible for the newly implemented DTI. At the time of the interviews, the researcher held a position as visiting researcher at MSU and the respondents were picked in collaboration with the supervisor and a graduate student working at Omega. The on-site interviews lasted between 45 to 90 minutes. Omega's interest in participating was due to a wish to develop the newly implemented DTI as well as the organization's organizational and financial growth.

Knowledge contribution: the discussion for measuring were based on an existing theory, boundary object. Boundary objects, in short, is based on communication of information used by various communities (Bowker & Star, 1999). The boundary objects are by nature inter-contextual and therefore required to hold either a common language or syntax between the disparate stakeholders, professionals, and divisions (Boland & Tenkasi, 1995). The knowledge contribution showed that measuring the intangible benefits is an accessible route, but with some limitations. For example, it takes time to create the basis for the measurements and also to perform these. The first part of the study focused on individual interviews, finding answers to the identification of benefits and the view on measurements of benefits of DTI among others. The second part of the study was based on a group interview, further detailing the understanding on how to measure the benefits. The overall results showed different benefits of the DTI and a doable test of the measurements, with several aspects to discuss, such as need for both agreements on how to measure and a semantic understanding of included parts in the measurement method.

Publications based on the study's empirical material: Ahlin (2018).

3.1.5.6 Study #5

Research design: The fifth study followed the analyses from study #3, where the product had shown some impact on found benefits**.** The purpose was to understand middle managers' view on how DTI is adding benefits to their own manufacturing organization. The research questions were: *"What is* *management's view on DTI as an internal resource?"* and *"Do managers view DTI as less valuable in comparison to its products?"* The research design was based on mixed method. One of the arguments for using mixed methods was to get a richer picture of empirical material than previously when collecting qualitative data. The study started with the qualitative study, which was analysed and the results were used as input to the quantitative study. This way of conducting a mixed method study is described as the quantitative method being used to embellish qualitative findings (Creswell & Clark, 2011)

Context: The qualitative part of the study was initiated by interviews at the organization Rho and its relation to the product. Rho is a trade association for technical information in Sweden. This organization was built as a consequence of the Technical Information Centre Project, held at Mid Sweden University 2007 – 2014. The survey question aimed at deepening the relation to the product, based on statistics. The survey was sent to middle managers in Swedish manufacturing organizations, see sample description below.

Data collection: The empirical material was collected in two steps. In the first step, six middle managers were interviewed all part of Rho's board organization. One board member invited a colleague, with 25+ years' experience of DTI, which gave the study the sixth respondent. The respondents all held middle management roles in various Swedish organizations and either worked in an organization or as a consultant with DTI. The organizations were geographically spread throughout Sweden. The questions' themes were concerned with the benefits of DTI and organizational aspects on the resource DTI. The output from the interviews was used as input to the survey, directed towards middle managers in organizations working with DTI.

The major understanding after analysing the individual interviews were that manufacturing organizations producing complex products were more interested in the DTI than other manufacturing organizations. The indicated reasons seemed to be that complex products are expensive and therefore more valuable to the organization and that they required more knowledge to maintain because of their complexity. The survey was focused on DTI's relation to the product with questions related to benefits of DTI. I based the hypothesis on the purpose of the study and the results from the qualitative study: (H1) *Manufacturing organizations producing complex products for other* *organizations are more interested in DTI than the manufacturing organizations producing less complex products.*

The survey, conducted in Swedish, was directed towards manufacturing companies in Sweden located in the Swedish industrial classification (SNI code) 25 – 30. The SNI code 25 – 30 include organizations manufacturing metal goods (25), computers and electronic goods (26), electronic goods (27), products for common purposes (28), motor vehicles (29), and manufacturing of other transport vehicles (30). Additional selections are that the organization should be the head office and a corporation. I choose head offices to avoid smaller sub-contractors and corporations in alignment with previous studied organizations. The population for this selection was 10755 organizations. The selection for each organization, was one respondent, on a falling scale: (1) product manager, (2) construction manager, (3) production manager, (4) development manager, (5) product developer manager, (6) research manager, (7) project manager, or (8) supplier manager. The logic behind this is the connection to DTI. A product manager is assumed to get in contact more frequently with DTI than a supplier manager and thereby be more knowledgeable about DTI and so on. The survey was sent to 1114 respondents, correlating to a confidence interval group of more than 99% and margin of error of less than 5%. The survey was sent four times to the respondents and the answer rate was 9 % (104 answers). The non-response was handled by telephone, where I picked 30 new respondents and 14 of them responded to the telephone survey. The telephone interviews were based on the survey questions and the choice of respondents made via a random number generator, correlated to a list with the 1114 respondents, except those who had answered the mailed survey.

Knowledge contribution: The study contributes with knowledge about the DTI's benefits (part of the survey) and further details on the DTI characteristic relation to the product, both part of the first research question. The result shows that the product is considered to be more valuable than the DTI, and it is said to depend on the complexity of the product, not shown statistically. The material was analysed based in the software SPSS based on the hypotheses. Used as way to analyse the hypotheses were the Kruskal-Wallis test based on the assumption that the dependent variable for the three hypotheses are not equally distributed and that there are three or more groups of answers to the question. The later refers to the Likert scale answers, which i.e. for hypotheses one and the question about the complexity of the main product or product group is low, medium, or high complexity. For the statistic test there is no significance that the complexity of the product affects the organization's view on DTI. The p-value is 0.589 and to get significance is should be less than 0.05. The perception that the complexity of the product influences the view of DTI is a perception, which seems logical at first glance, but not verified statistically. The same perception is issued in the non-responsive analysis. The underlying causes may be that this view is incorrect, that the complexity of the product is estimated in the survey and that it may be a more positive view of the DTI as stated in the survey.

3.1.6 Data Analysis

This section includes the core coding method and description of analysis for the first and second research question.

3.1.6.1 Core coding method

To answer the research questions, the analysis is conducted in an inductive way searching for themes based on findings in the empirical material (Alvesson & Sköldberg, 2008). Patton (2002) stresses the inductive analysis as understanding the richness, depth, meaning, and contribution to interpretative research. The analysis begins by understanding the empirical material from one study and after that combining or aggregating it with further studies. The synthesized material is after that built into themes to answer the research questions. This approach is labelled conventional coding analysis by Hsieh and Shannon (2005). They describe this way of coding as usual when the existing theory is restricted and therefore there are few existing themes to utilize. The themes therefore emerge from the empirical data, where the researcher uses his/her skill to develop these themes.

The analysis is conducted via content analysis, based on concepts like meaning units, condensation, category, code, and theme (Bengtsson, 2016; Elo & Kyngäs, 2008; Erlingsson & Brysiewicz, 2017). They emphasize content analysis as a path forward while doing interpretative research and analysing transcribed interview material. Erlingsson and Brysiewicz (2017) frame meaning units as the foundation and base them on the understanding of the transcribed interview material, where the material is re-read and thereby a detailed understanding of it is achieved. Their conclusion is that the meaning units are the basis of the material, and they stress the importance of extracting the essential parts. Here, I used the software Nvivo as a productive path forward to find and store the meaning units. The condensation includes synthesizing the meaning units by extracting the respondents' expressed meaning. The meaning units were then used for condensing each study's empirical material into categories and then themes. This work included putting a code on the condensed material, labelling it. The codes are categorized by similar grouping codes, where the detailing level varies depending on the codes. Lastly the categories are emphasized in themes, which can include one or several categories.

3.1.6.2 Analysis for identifying benefits

The initial effort for the *identification of benefits* was found by thorough reads of the empirical material for each study, stated as positive advantages of the studies' DTI. The study at Alpha gave raise to focusing the thesis work on finding the benefits of DTI. The focus on DTI came from the finding that Alpha recognized the benefits 'Base for after-market decisions' and 'Common language for design' as benefits of DTI, not from the CM process as such.

The interview questions to find the benefits were direct and indirect. The indirect interview question offered answers to their reaction to the lack of DTI and the direct their recognition of benefits. The interview material also offered other benefits, such as the respondents' description of positive advantages while using the DTI for solving work assignments. Then, the search for benefits in the empirical material included all the possible positive advantages, without excluding any of them or searching for any specific benefit. The transcribed interview material was uploaded in Nvivo where I looked for meaning units including benefits. These meaning units were then condensed into categories including meaning units with similar content. The condensed material was synthesized into categories and labelled with a theme. These themes were viewed as the benefits. Later, the organizations confirmed the benefits, such as for Gamma and Omega, or analysis conducted with research colleagues, such as for Alpha.

The second step for analysing the benefits was to use the three characteristics of DTI and two categorizations of benefits and their subgroups. I used the recognized benefits for each study and related them to the subgroups. The benefits were listed in a document for the DTI characteristics as well as the benefit categories. For each benefit, I re-read the empirical material to identify suitable subgroups.

3.1.6.3 Analysis of the perceptions on how to measure benefits

The analysis for the second research question also refers to the inductive analysis. The data analysis refers to the findings for the respondents' perceptions of *how to measure the benefits of DTI*. The interview questions for measuring focused on the perceptions of whether the DTI's benefits were measurable or immeasurable. Then, the interview questions continued by addressing questions such as the input to measuring, including preparation for measuring. Additional questions on measuring were questions about topics like the way the respondents conducted the measurement process and their intentions when conducting it.

I interpreted Kaner and Bond (2004)'s view on measurement method to analyse the empirical material for this research question. Based on Kaner and Bond (2004) I divided the measurement method into input, rule, and output. Here, the input includes the preparation for measuring as well as the ways to find the input, equalized as the recognized benefits. The rule includes the ways to transform the input to the decided output, e.g., boundary object theory (Ahlin, 2018). The output focuses on the measurement, e.g., in financial terms. I looked for anything related to the input, rule, and output in the empirical material, focusing on finding an answer to the second research question.

Likewise, as in the first research question, I used Nvivo software, and the same path for meaning units, condensation, code, category, and theme. The meaning units contained interesting answers from individual respondents, the condensation synthesized individual answers, code and category synthesized individual answers from the included studies into aggregated perspectives. The themes included the final perceptions, such as opinions as to whether measuring DTI's benefits is doable and not doable. During my analysis, I did not find any respondent claiming that the output from measurement methods can be directly evaluated in financial terms. The identified perception was, up until the study at Gamma, that measuring DTI's benefits was hard. That was a trigger for the study at Omega (Ahlin, 2018) and also the origin point for the desk-top research in Ahlin (2019).

3.2 Ethics

One part of being a researcher is to take an ethical perspective. Just as in ordinary life, morality is discussed in research ethics, with arguments about the meanings of good, bad, right or wrong. Research ethics is categorized as professional ethics, which the Swedish Research Council (CODEX, 2016) describe in three general subsets. They are: (1) conducting good work, (2) following national and local rules, and (3) following professional codes of ethics. Focusing on the Information System's field in Sweden, Dahlbom and Mathiassen (2017) have made an interpretation of the American Association of Computing Machinery's Code of Ethics. They emphasize the general professional ethics as well as the connection between the Information Systems field and the user. Dahlbom and Mathiassen (2017), argue that the researcher should work in close collaboration with user groups to satisfy them, show them respect, focus on healthy work environments, and protect individuals from harm.

Based on this short introduction to ethics, I will continue by looking at research ethics in this thesis. The discussion focuses on general and specific professional ethics in various ways. Starting with the general aspects and focusing on doing good work, one way to do this for interpretative studies is to protect the respondents. Here, it has been done in various steps. At the introduction of interviews, I informed the respondent of their voluntary participation in the interview, their right to not answer a particular question, and the right to withdraw from the interview at any time. All interviews were recorded, stored with password protection, and I transcribed them verbatim, except for study 3. Another researcher participated in this study, which meant a shared workload. For the second subset, to follow national and local rules, I used the ethical rules and guidelines at MSU. There, studies must obtain approval from an Institutional Review Board (IRB) (Berg, 2009). The IRB functions to protect human subjects from harm (Program, 2016). Adopting their rules, where one is to undergo an on-line education and accomplish a test, I accomplished it and succeeded in reaching the goal for this education. The IRB approved my application for studies, in which I described the purpose of each study, how to protect the respondents, collaboration with MSU, presentation of the results, etc. At each interview, the participants were given a consent form to sign. This form gave detailed information about the study and how participants were protected.

Turning to ethics of the field of Information Systems, the users are in focus. Practically, this is done in different ways. One strategy is to listen carefully when interviewing them and rephrasing their well-informed voices to create shared and accessible knowledge. Another way, which should be viewed as being relevant to the overall aim of this thesis, is that of creating a healthy work environment, especially for those producing the DTI. In the longer-run an understanding of the benefits and other perspectives on DTI, can create a better work environment, at least according to Dicks (2003).

The primary empirical material in this thesis was collected through interviews, both in groups and with individuals. Therefore, it is of interest to discuss the ethics for interviews. Kvale and Brinkmann (2014) do this in various steps. Informed consent was discussed earlier along with ensuring confidentiality by not using either the organizations' or participants' real names. Hence, I used the Greek alphabet to name the investigated organizations and for respondents' titles.

An additional aspect of interest in the planning is to consider reflection. Kvale and Brinkmann (2014), emphasize this as re-thinking and discussing the plan with other researchers. e.g. supervisors and colleagues, as well as during the study. In one study, the second one, I chose to add respondents to the original setting, to broaden the empirical material and add more voices to the study. Another ethical aspect for interviews is the transcription, which Kvale and Brinkmann (2014) argue should both secure the respondent's confidentiality and provide transcriptions loyal to their answers. The time-consuming transcription is done verbatim to capture the respondents' real answers. Transcribing verbatim is usually not a problem; however, the construction of sentences is harder, especially when it comes to a language which isn't your mother tongue such as American English in my case. One of the last steps for interview ethics is the analysis. Kvale and Brinkmann (2014) discuss how much the researcher can put into the respondents' answer. Here, this is a question to be answered on a general level – how do we interpret our material and how can we generalize in interpretative research. Turning focus to the interview material, it has been shared with and discussed with supervisors, both at the Mid Sweden University and at MSU. In study #3 and #4 the analysis has been considered with the respondents, e.g. by discussing found benefits of DTI. Continuing reflection on how to verify, Kvale and Brinkmann (2014) discuss that the researcher has to use verified knowledge as far as possible. As the DTI is rarely investigated in the Information Systems field, or digital information in the form of its benefits, this has been a challenge for this thesis. The lack of investigated experience has proved to be a hindrance in terms of finding and using theory at its fullest for DTI.

4 Findings

Included in this chapter are: the contextual descriptions of each organization; the studied DTI and its characteristics; and a presentation of the analysed benefits. Also presented are the findings on how to measure the benefits. The chapter ends with synthesized sections, reflecting the findings from the studies in relation to the research questions.

DTI plays an essential role in this thesis as the fundamental resource in focus, from which organizational benefits are recognized. The DTI has not been deeply described in the Information Systems field and is therefore not well understood. Thus, it is of interest to first describe the DTI in each study's presentation to show its benefits, using the previously introduced DTI characteristics and benefit categories. The first section of each individual presentation contains a description of the organization, their setting, the studied DTI, and characteristics of the DTI. The organizational description includes a brief overview of the manufactured products, the organization's context, and the organization's operating domain.

The second part in each presentation is structured as follows: identification of benefits from each study; identification of benefits in relation to the aforementioned DTI's characteristics; and categorization of the benefits. The benefit identification is based on positive advantages identified by the respondents, where the advantages apply to both individual co-workers and to the organization. The identification of the benefits was started in this thesis's initial phase and introduced in Ahlin (2014). Subsequently, the presentation here includes newly analysed material from studies #3 - #5. Added to the previous analyses are the respondents' underlying goals for the digitization of the DTI, which is performed differently in the various organizations and initially described in each study's presentation.

The following sections provide results on the perception on how to measure the benefits of DTI. Measuring benefits includes fundamental empirical perceptions into the measurement process as regards *how* to measure. The how is initiated by the discussion of aspects of benefits and whether the benefits of DTI are tangible or intangible. That is, whether benefits can be measured, such as saving time or money, or not: such as, facilitating communication between co-workers or utilizing a common fund of knowledge. The *how to measure* is based on this discussion due to existing benefit models.

The results are based on the following organizations' DTI and the produced and used product life cycle phases:

Alpha, where the DTI is Product Configuration Information, produced during the development and used in all life cycle phases of the manufactured products,

Beta, where the studied DTI is Operation, Maintenance, and Quality manuals, used for production and maintenance,

Gamma, where the studied DTI is an Assembly Instruction, used for development and maintenance,

Omega, where the studied DTI is the initial development requirements, named charters, used for development related assignments, and

Rho, where the studied DTI is related to the manufactured products, simply facts and mostly related to development, production, and maintenance.

4.1 Organization Alpha

Alpha belongs to a global concern, working in the defence sector, and has around 12,500 co-workers. The concern has five business areas: aeronautics, dynamics, electronic defence systems, security and defence solutions, and support and services. Alpha belonged to a large Swedish communication company until the mid-2000s, when it was sold to its current global owner. Alpha has several domestic and international offices. The headquarters is located in southern Sweden, and it has sub-offices in the Swedish capital region, Asia, North America, and Africa. Alpha works with the production and maintenance of electronic defence systems, mostly radar systems. Their radar systems are sold worldwide and are both airborne and ground-based, produced along with other sensors. The company rarely focuses on developing new products; almost all new releases are based on existing products, focusing instead on ways to customize each delivery according to an order. Internally, they have discussed changing to a more understandable logic where the production is focused on a few base products, from which customers can choose different product options.

About fifty years ago, Alpha started to use configuration management (CM) as their broad spectrum of products required a management system that could keep track of them and give the organization an overview. The foundation of the CM process is product information and various perspectives on the information's usage. The initiative to use the CM and the development of their product identity came about as the result of a huge order from the international market, a fact which was emphasized in lively discussion by several respondents. The CM originated in collaboration with other departments at their former owners, which was initiated in the mid-1950s. As the products contained --and still do contain-- a large number of components, respondents emphasize the need to keep them organized and easy to track. This information is especially important for installations far from a company office or from availability of service technicians.

"We need to know the exact customer products, we have [maintenance] agreements. We have agreements for spare parts and service and so, for a long time to come. We need to know what components we need to bring as we travel cross half the world. […] We must know which the products are and there is a lot of information associated with them." (Product Project Manager, Alpha)

Additionally, Alpha send the DTI to some customers during ongoing product development. Alpha is obliged to provide them with this DTI to meet the requirements of international quality management standards certification. This process is usually managed by the quality department with assistance from the development project and described as time-consuming but necessary. Today, the CM process contains solely digital information, stored in various information systems used by one or several departments. One of the information systems serves as the master data system.

At the same time, market and political forces have a powerful influence on the sector in which Alpha operates. Market forces impact on components due to the fact that several global organizations are producing similar products, which creates the need for a competitive edge for Alpha. As a military radar system belongs to military surveillance, the customer's government often participates in the management of the purchase. The defence systems domain is described as inflexible, at least, when it comes to accepting an offer and its delivery.

"It usually takes between eight to ten years, after the customer has signed the order, before the product is ready to deliver." (Manager spare products, Alpha)

Besides the market forces, political forces, and legal requirements, this inflexibility can result in an extended period between placing an order and delivering a radar system. In addition, the radar system itself is a complex product, which takes years to produce. All these forces and the complex products affect the DTI, seen as one of the cornerstones in Alpha, not least for the production and maintenance. Here, one of the respondents proudly and with respect describes the cornerstone, built on an essay in a small book:

"The respondent (R): I brought a small little book. Have you seen it before?

The interviewer: No.

R: I take great care of it and there are a lot of others here as well. The book is pretty old, it was published in 1993. And of course, it comes from the [the previous organization's name]. Described here is the basis for all our configuration management and how to handle products and documents. And we still use the same system. "(Manager software development, Alpha)

4.1.1 Alpha's DTI

Alpha uses their DTI as standardized product identification for the Configuration Management Process. The DTI constitutes one part of a comprehensive, logical system, including both product and document identification. This section solely describes the product identification, even though the document identification is part of the same logic. The DTI uses a hierarchical system, which provides knowledge about the original product's inherent components, updated product components and related status. The DTI consists of the letters and numbers as in the English alphabet and does not distinguish between upper- and lowercase letters. In comparison to the actual global organization's DTI, it is built with inner logic, not solely just a serial number. The base for the product identity is a product number and versions, see Figure 4.

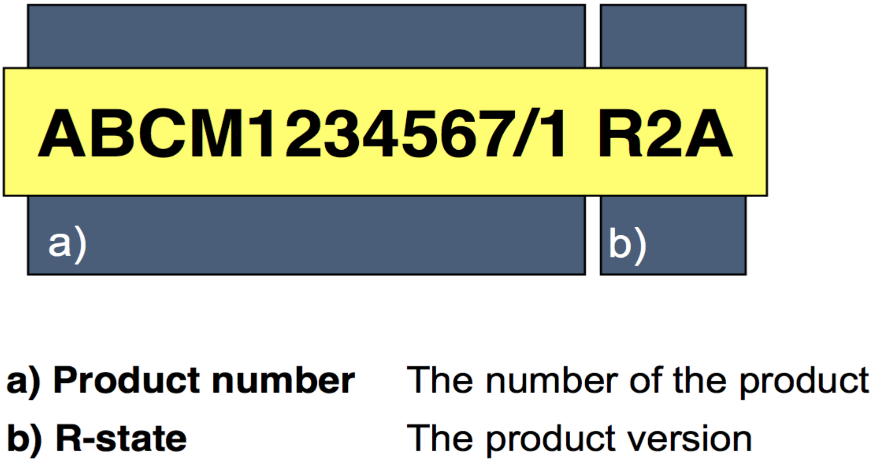


Figure 4 Alpha's DTI, consisting of its product number and version

The owner of the DTI enthusiastically, almost without stopping to take a breath, describes its overall foundation like this:

" Then, we have our product numbers, which are based on an ABC class that tells us what type of product it is. There is logic in that the letter A means something, the letters A and B mean something and ABC means something. So, it's like a classification. […] But in any case, we have an ABC class. For the ABC class, one has a type class that further clarifies what type of product it is. Then you have a stupid serial number, completely without significance. Then you can create slash-1, slash-2, slash-3 that are variants of the basic product. Can be different colour and such things." (Process Owner Configuration Management Process, Alpha)

The DTI in Alpha, based on both the product number and the versioning, provides a very flexible system, which Alpha staff members view as a strength. In its fundamental structure, it is described as simple, adding a lot of combination possibilities. One advantage with the DTI is that it provides many opportunities however it is hard to understand as a newcomer. Most of Alpha's co-workers are specialists, meaning that they only use some of the combination options available, either from the DTI's product numbers or versioning options. The time to learn the necessary parts of the DTI is usually more than six months, described in Ahlin and Saarikko (2013). As the DTI is a fundamental part in Alpha's manufacturing processes, it is absolutely essential to learn its logic. It is such an integral part of Alpha that wanting to change it is doomed to fail by one respondent:

"If you are an experienced [co-worker] and want changes and then, then you need to re-think staying at [Alpha], because you do not change this place so easily. Because it's a fairly big colossus to turn around." (Manager for Software Development, Alpha)

4.1.2 Digitization of Alpha's DTI

The digitization of Alpha´s DTI is viewed as relating to the second grade. The co-workers working with DTI are loading it into an information system relating to CM. Their work is analogue, based on adding the input to the information system. The change for the digitization of the DTI is that integration has been added from the master data system, though it is not automatic. Previously, the master data had to be added to all the various information systems by co-workers, creating possibilities for incorrect or missing information. The integrations had improved the reuse of the DTI and when the DTI is easily found for more of Alpha's co-workers do the possibilities for semantic interoperability and knowledge transfer increase within the organization.

4.1.3 Product's life cycle phases related to Alpha's DTI and DTI's production process

For Alpha, the product's life cycle phases and the DTI production process are intertwined and hard to separate, e.g. described in Ahlin and Saarikko (2012) and Ahlin and Saarikko (2013). Therefore, the two headlines are combined here. In the first phase of product development, the DTI is set as preliminary, as each product is custom-made and therefore designed for new requirements and planning. The preliminary DTI is automatically assigned to a new product and changed by the co-workers focusing on configuration management in the product's development project. Several respondents discuss configuration management as a part of the leadership in the development projects:

"Configuration managers adds structure, and they act as leaders for the products' structure. Moreover, that is pretty good, too. They can help and follow up. For example, a project CM is responsible for what we call CCB, Change Control Board. Additionally, then there's a decision forum for, for example, if we are going to make changes, we will make this requirement changes. That kind of questions, change management thus. If another project changes a product, then we can decide if we

will use the change or not. It is a typical decision there. They follow up that things get in place on time, for example, when building up the product structure, the project needs to have some things in place at a given time. The project also needs to release the purchase and production documentation for production at certain times. Make sure everything is done to make sure it is released. They help the project leader in their work." (Project Manager Development, Alpha)

This set-up is in collaboration with other project members, such as the project manager, quality assurance, the mechanical constructors, and software developers. Changes to the DTI can occur at any time during this life cycle phase. After that, the DTI changes status to active, meaning that it is being produced, tested and verified by various project members. The DTI is thereby locked, and no components can be added or removed, and they must be set in the same status. When the product changes status to production, meaning that it is being released and delivered to the customer, the above-discussed versioning is used for maintenance and repair. Initially, the version is at its first level and thereby increased while changed for maintenance. The status of the DTI is obsolete when the product is destroyed or not in use. The radar systems life cycle varies from 40 to 60 years, while the components' lifetime vary. In reality, the end of the life cycle means that the product cannot be offered or ordered, purchased or produced, or repaired or delivered and the DTI cannot be edited anymore.

Alpha's CM process does change rather slowly as a result of its stability and its long-time use. The owner of the process releases new features every third month and has a budget connected to the process. Strangely enough, these changes are linked to the process and not to the digital information or information systems associated with the CM process. The reason given is that there is no strategic IT management at Alpha. Therefore, the executed changes solely relate to the process, such as the Change Control Board. Thus, there are several identified temporary solutions in the digital DTI, especially after Alpha was incorporated into the current global group.

4.1.4 Structure of Alpha's DTI

Alpha's DTI is structured as it is built on declared meta-data and fixed fields (Wallace, 2011). The product number contains six different parts: a prefix, the ABC class, an origin notation, the type class, a sequence number, and last a suffix, see Figure 4. The prefix indicates whether the product is a subordinated or a set of parts; the ABC class classifies the product, the origin notation or lack of it means the product's construction before or after Alpha's incorporation to the current global organization. The type class classifies the product within the ABC class; the sequence number is used just as a sequence number, and the suffix to separate variants. Added to the product number, and thereby classified as the product identity, is the versioning. The versioning contains the status preliminary and ordinary, used in different ways for the product and the software development. Alpha can make the versioning one or two-way interchangeable. Illustrated are one-way changes by adding functions to the products, and the two-ways are the change of realization. The result of both the product number and the versioning is that it is possible to replicate a product accurately and thus create a copy of the customer's product in use.

"If you take our versions of our products, for example, there are some R-positions. And the first R mode that you create is always R1A, then you can choose to redo it again. If you make a realization change, for example, we replace a screw with another screw or something like that, then we change the letter. By this they are two-way interchangeable, it does not matter which one we choose because they have the same function. If someone makes a mistake, we will change the number and then a higher number will always replace a lower, but not the opposite. That's how simple the logic is built and that's what makes us able to manufacture it [referring to the lower number] 40 years ago, and we can manufacture exactly the same product with a completely different R mode and it's always backward compatible." (Process Owner Configuration Management Process, Alpha)

4.1.5 Information System of Alpha's DTI

The information system of Alpha's DTI is a client-server-based Product Development Management System (PDM system). This is a legacy system from a leading Swedish IT-supplier. This information system was implemented into Alpha when they became part of the current global organization in the mid-2000s. The PDM system is integrated with several information systems, such as a CAD system for mechanics and electronics, a material planning system (MPS) for production, information system for logistics, and maintenance system, traceability system for production, a system for versioning of software, and an information system for identification of delivered goods. Most of the systems use a client-server technology. The PDM system is the master system, with limited automatic integration to the other information systems. The DTI is updated manually several times a week or at the release of an entirely new product. The use of a manual update is due to the fact that their MPS is from 1980. They describe it as a locked-in situation that causes technical problems for adoption to newer information systems and difficulties when searching for information. All the co-workers in Alpha's development department can modify the DTI, and everyone at Alpha can access it.

4.1.6 Alpha's benefits

Findings show that DTI generates benefits based on the Configuration Management Process (Ahlin, 2014; Persson Slumpi et al., 2012). Persson Slumpi et al. (2012) show Alpha's benefits from DTI, namely 'Knowledge base for after-market decisions' and 'Semantic interoperability'. At Alpha, the result of the 'Knowledge base for after-market decisions' is knowledge for, i.e. designing a flexible spare parts warehouse. The foundation for the 'Knowledge base for after-market decisions' is statistics, which gives the opportunity to store the most frequently requested spare products and thus provides aftermarket service contracts with fast delivery time. The DTI provides the benefit 'Semantic interoperability' as a standardized language, which offers possibilities to discuss various products without having to define them for each other in the discussion or using pictures to explain further explain the aimed product. Semantic interoperability is discussed in detail Ahlin and Saarikko (2012).

The origin point for the DTI is the 'Order and control', which was explained in a logical way by one of the respondents:

"However, if you have very many different products that look very different and you are a big company where things happen, then you have to have order and control. The organization needs to know precisely what their co-workers have delivered. How does the configuration of this product look for each customer? This organization has a lot of customer-unique parts, customer adjustments, which also means that they have to keep track of each customer's product and configuration. The organization can build complex systems and the like from the same components and the customer benefits very much depending on how the different parts are put together and how they are configured.

Moreover, the organization also needs to have everything in order. Spare part management is also important to know then. What is there at the customer, which spare parts should the organization send to the customer? It cannot simply be in someone's head if the customers are located around the world and you have many *products out there. One must have it in a system, and I think that is how the system has emerged." (Project Manager, Alpha)*

All the respondents discussed the fundamental 'Order and control' while manufacturing as the benefit that needs to function all the time, and thereby during any kind of digitization. Here is one respondent, emphasizing this benefit:

"But order and control are somehow the keywords, knowing what we have done, knowing what we are doing now, and knowing what we are likely to do in the future. That's what it's all about. The lifespan of our products is thirty, forty years, so that's the big factor." (Process Owner Configuration Management Process, Alpha)

The predetermined benefit is clearly stated as giving 'Order and control', both while developing, manufacturing, and maintaining the product. Several respondents described that another predetermined benefit is the 'Traceability of product' and the recorded changes to the product. This is viewed as an additional fundamental part for their long-time maintenance support, added as a result to the merging benefit of 'Knowledge base for after-market decisions' described in Persson Slumpi et al. (2012). Collectively these two benefits make it possible for Alpha to offer maintenance support with fast delivery time.

An on-going discussion at Alpha is how to reduce the cost of product development. A draft proposal is to use the DTI and thus create a base product and then add functionality when the customers require so-called optional functionality.

"The basic idea is to choose one of our radar products. There are two that exist and one intentionally. Then we have tried to look what they have in common and tried to create an idealized product model that consists of what's in common. Moreover, all that is not in common is managed as options, and in some cases, it is an option that is selectable, and in some cases, it is an option that is compulsory depending on the application. Moreover, we have tried, especially for the base product, to see the required choices." (Process Owner Configuration Management Process, Alpha)

The use of DTI creates unintended benefits among the individuals in a development project, both regarding knowledge sharing and nondependency on other co-workers. Here, expressed as a benefit by one of the respondents:

"Yes, of course it does. If everyone finds, within the assignment one has, if you know where to find the information, so of course. Then you're not dependent on one person, you don't have to talk to your colleague. If the colleague isn't there. you still know where to find the information. This could of course be achieved by storing all the documents in one place. That's a bonus. However, I think that we create personal independence with our DTI. That is probably one of the big things." (*Project Manager Development, Alpha*)

The manager for customer education expresses their benefit gained by the DTI, starting off in the CM process and ending in required information:

"If you look at our products, we have a CM instruction on customer documentation and also for the courses. We own it because it is linked to the process of developing customer documentation and developing and implementing customer training. So that we control what we think is most efficient, what information we need for products in our education material." (Manager Customer Education, Alpha)

4.1.7 Alpha's analysed benefits

Alpha's benefits are analysed according to the product's life cycle phases, the relation to the product, the DTI's structure, predetermined/emerging, strategic/operational. The analysed benefits are shown in Table 3.

Most of the benefits are recognized during the *product's life cycle phase* of development. Alpha also derives benefit from the DTI in the production and maintenance, both as it is and by co-workers who have used the DTI for other purposes than the original ones. Despite this, one of the benefits is supporting all of the product's life cycle phases, that of the 'Semantic Interoperability'. The result of this is that the majority of the benefits are recognized in the product's life cycle phase when the DTI is published, however it still offers support in other of the product's life cycle phases. The relation to the product starts off as individual and is later shown as general, see Table 3.

The DTI delivers benefits like 'Control and order while manufacturing' and 'Sharing knowledge within the development team' for the individual products during the development phase. Alpha gains benefits such as 'Semantic interoperability' and 'Part of internal education material' during and after the development. The DTI delivers the benefits 'Tracing product deliveries' and 'Knowledge base for after-market decisions' during production and maintenance, and the latter can be used for individual products as well as general product lines. The benefit 'Standardized product development' is focused on development, production, and maintenance for general products. The DTI delivers the benefit 'Standardized product development' provided that the management has made a strategic decision to build this foundation for standardized product development and use the DTI as statistics for understanding, e.g., used versions of components.

The *structure* of Alpha's DTI is highly structured and that generates several benefits. The content is built on the structure and adds several benefits as-is, such as the 'Control and order while manufacturing' and 'Tracing product deliveries'. As regards the benefit 'Knowledge base for after-market decisions', co-workers in Alpha can automatically reuse the DTI based on its structure, showing the requirements for goods in stock in a warehouse.

In Alpha, the *predetermined* benefits are recognized as 'Control and Order while manufacturing' and 'Tracing product deliveries' based on management's desire for continued high product quality and customer satisfaction. Because management designed the creation of DTI to facilitate production and shipping goals, this analysis classifies 'Control and Order while manufacturing' and 'Tracing product deliveries' as *strategic* benefits. These benefits are recognized by using the DTI internally in Alpha's specific context and also when supporting what is provided to the customer. Alpha is using the DTI as it is, while gaining these benefits.

Alpha's *emerging* benefits, listed as #3 - #7, are further categorized as either operational or strategic. Both the strategic categorizations, 'Knowledge base for after-market decisions' and 'Standardized product development', aim to support the business side by developing the manufacturing and maintenance process. The remaining emerging benefits can be considered as operational, where they recognize solving needs on the business side, such as 'Part of education material', or solely emerging based on the DTI, 'Semantic interoperability' and 'Sharing knowledge within the development team'. The emerging benefits consist of both the DTI as it is and DTI synthesized as statistics ('Knowledge base for after-market decisions').

Benefit	DTI characteristic Used product life cycle phase(s)	DTI characteristic DTI's relation to the product	DTI characteristic DTI's structure	Benefit category Predetermined / Emerging	Benefit category Strategic / Operational
Control and order while manufacturing	Development	Individual	As-is	Predetermined	Strategic
Tracing product deliveries	Development	Individual	As-is	Predetermined	Strategic
Knowledge base for after-market decisions	Operation and maintenance	General	Reused	Emerging	Strategic
Sharing knowledge within the development teams	Development	Individual / General	As-is	Emerging	Operational
Semantic interoperability	Development, operation, and maintenance	Individual / General	As-is	Emerging	Operational
Standardized product development	Development, operation, and maintenance	Individual/ General	Reused	Emerging	Strategic
Part of education material	Operation and maintenance	Individual / General	As-is	Emerging	Operational

Table 3 Alpha's analysed benefits

Table 3 describes Alpha's recognition of the benefits of DTI. Some recognized benefits relate to product's life cycle phase development, while others relate to operation and maintenance. The benefits can be viewed as relating to Alpha's specific context or be more general in their nature, such as 'Semantic Interoperability'. The DTI is published during the development phase of the product's life cycle phase, and the table shows that Alpha recognizes the main benefits of DTI as occurring in that phase. Alpha recognize additional benefits occurring in the production and maintenance phases. The benefits evolve from an individual product and develop to provide benefits for both individual products and a product line or all products (general). The benefits from the DTI when it is originally published ("as-is") and then benefits from reusing the DTI. These latter benefits derive from the DTI's structure (e.g., able to be synthesized for general use across product lines). Despite the development of DTI to provide predetermined benefits for the manufacturing process, the main part of their perceived benefits is categorized as emerging, benefiting other internal processes in addition to the manufacturing process. Recognized benefits are mainly categorized as supporting the strategic goals, with some benefits adding to operational goals.

4.1.8 Measuring benefits at Alpha

The respondents describe the benefits as intangible, perhaps because the internal culture is engineering. Even though measurement is in focus for engineers, is it hard for the respondents to grasp how to measure DTI's benefits. One example of the internal culture is that projects are strictly financially driven and that KPIs are used for every internal process, varying from the entire process to parts of it. One reason given for not measuring the DTI is the long lifetime of Alpha's product, which causes problems when measuring the DTI.

Interviewer: "Do you measure or in any other way follow up the benefits of the DTI?"

Respondent: "No, not directly. It gets too complicated due to the long lifetime of many of our products." (Process Owner Configuration Management Process, Alpha)

The DTI is viewed as supporting the product development and creating efficiency, which occasionally can be measured. However, there is a difference when it comes to the benefit 'Standardized product development', for which a budget has been created.

Respondent (R): "Yes, we have made a foundation, although it may not be statistical. So, the goal is to remove all customer customizations deep down in our product structure, and instead offer them as a small bonus. So, when we look at our customer delivery, it will consist of a basic product, X number of options, and then the customer customizations that the customer requires. However, there will be three entirely separate concepts."

Interviewer: "You say that there are organizational incentives, the different departments will have better control over their revenue?"

R: "Yes. "(Process Owner Configuration Management Process, Alpha)

4.2 Organization Beta

Beta is a manufacturing organization in the process industry located in central Sweden. Beta is a part of a global organization with over 27.000 employees, which includes business areas such as mining, construction, recycling, pulp and paper, power and oil, and gas. Beta's focus is on manufacturing, maintaining equipment and services for the pulp and paper industry and has approximately 700 employees. Beta started as a local firm in the mid-19th century and has slowly switched from ironwork, after that producing tugs and steam engines, until today's manufacturing of paper machines. Beta has offices worldwide, where paper and pulp are in focus. Beta's products are produced locally in Sweden, based on standard products, which are customized to the customer's requirements and delivered to the relevant paper mills.

The paper and pulp machines are rarely replaced by newer models due to their high price and a recession in the paper industry. Therefore, Beta is rather sensitive to fluctuations in the paper industry, which was one reason for outsourcing the production of their DTI production process in 2010. Another reason for the outsourcing was a wish to concentrate on the manufacturing processes; a move that surprisingly did not include commonly outsourced functions, such as the reception or switchboard roles in Beta. The respondents also described the problematic situation for hiring the right co-workers in these parts of Sweden.

A consulting organization focused on DTI won the out-sourcing contract against several competitors. This organization is specialized in management and operational development of DTI and has operated in the field since the mid-1990s. The headquarters of the consultant organization are on the west coast of Sweden and it operates in seven countries around the world. They have around 600 employees. Besides the focus on DTI, the organization provides its customers with Information Management and Software and Embedded Design. The outsourcing contract specifies the DTI production and delivery process as the main parts. The co-workers, former Beta employees, are now employed by the consulting organization. Their work assignments are still the same as before the outsourcing and Beta refers to them as consultants who should provide Beta with fresh input for the DTI production process. One respondent mentioned Beta's mistrust of them and gives an example of how it affects one of their work tasks by discussing the deliveries:

"...we are consultants now. We must keep a line of retreat now, and therefore we got this Excel sheet to describe our deliveries.

And if they come and say you have not sent it and you have not done that. And then you can just go inside and check; we have done that." (Team leader DTI, Beta)

The sector Beta acts in is described as by the respondents as a competitive field with several global organizations producing the same products. The products have a long lifetime as they are expensive and relatively complicated. The long-term usage means that there are many old machines in use, which create constraints on the DTI produced. Both the long-term usage and the outsourcing purposes results in the respondents' descriptions of DTI as a burden, not adding any benefit to the product. The manager for DTI demonstrates the low-status view in this quote:

"We have always struggled with the problem that this area is not a priority. It is only a priority when our customers are upset. When they are not satisfied or when they have not got the material on time. Then it suddenly becomes a priority. But besides these occasions, DTI has been considered only as a cost. Still, that is the general view. I claim that this department works in headwinds. They must always defend their existence. "(Manager DTI, Beta)

One of the co-workers synthesizes the sector Beta works in and the view on DTI while discussing the outsourcing agreement:

"When you sign this agreement, it is as if you are signing an agreement on invisibility. And I fight to enable us to cooperate. We can do things very well and develop this, but we need help, we need cooperation. We need good cooperation, that's when we can perform well. Otherwise, I do not believe in this." (Project Manager DTI, Beta)

These are quotes from two of the three first respondents, which was confusing during the interviews. To investigate this attitude deeper, more interviews were made at Beta than was initially intended. The purpose was to find out whether the attitude solely occurred among those producing the DTI or if it was present among those who delivered the DTI to customers and used it internally. Those who acted as development project managers showed a similar attitude, which manifested itself in their attitude of solely wanting the DTI to be delivered at the right time and to the right quality. One other sign of the mistrust and low level of collaboration is the shown in the DTI production process, including few points of collaboration or human interaction.

4.2.1 Beta's DTI

Beta's DTI consisted of manuals for Beta's manufactured products. The content is Installation, Operation, Maintenance, and Quality produced and delivered by requirements from the product project in the required sequence.

"We are responsible for all documentation delivered to the customer. […]. Surely [name of Manager DTI] has told you that there are drawings, specs, manuals and subcontractor documentation, and it is about automation and it's all that bit then." (Team manager DTI, Beta)

The users of Beta's DTI are both internal and external customers, such as the installation and maintenance companies, end users, and auditors. The DTI is used actively, for example during installation or maintenance; the exception is the DTI focused on quality. This information is often said to remain untouched by the customers. Beta's DTI have four customer audiences, expressed like this by a DTI co-worker:

"Because we have a project, then we have four [customers]. You have the actual customer, a construction company, an engineering company, and then Beta. So, all four can be customers." (Team manager DTI, Beta)

The customer perspective on the DTI is obvious for the DTI co-workers. They describe the effort on producing text and visualizations as reducing the frustration while using or maintaining the products. Of interest is their description of their DTI as a "knowledge hostage" by external customers' management. The folders are locked in specific rooms with few access possibilities for the co-workers who are supposed to operate or maintain the products. The result of this action, which occurs in several organizations, is that products are not properly maintained and there are an increased number of calls to Beta's customer support or sales representatives.

4.2.2 Digitization of Beta's DTI

The digitization of Beta's DTI is viewed as relating to the first grade, see Figure 1. The co-workers working with DTI are initiating the DTI in an information system which derived from office work. Their work is analogue, based on adding the input to the information system. The change for the digitization of the DTI is the output, which nowadays can be made in a digital format, even though many customers are forced to use or perhaps prefer printouts as output.

Interviewer: "Previously, you said that you are delivering traditional technical information. Is it because the industry that you deliver it to is traditional or because of the conditions of the industry? You mentioned those who have no electricity before."

Respondent:" I think it is both. One is that we are used to delivering these paper folders. Even in Beta you can be a bit traditional if I say so. Things happen with what we write all the time, so things happen all the time. So, it gets better and better all the time. But much is about the fact that the customers are in such places and have the education that they cannot take advantage of anything else. But sometimes I think you have to do a test and also say that now we have added these opportunities as well. Now you can get this, but it's challenging to get there. But currently we are not working on that issue, but we are working on changing from Word into XML because it opens up that you can present things on the intranet and other portals that customers can have access to and that is, after all, a way to get closer to another." (Manager DTI, Beta)

Internally in Beta, the change from customized CDs to adding the DTI on a server accessible to everyone in the organization, has had implications. Other information systems, such as Lotus Notes, are more easily updated with information about the manufactured products. To some extent there are integrations between Word and Lotus Notes and to some extent the work is done manually by using copy and paste. Thanks to this possibility for integration, the digitization is increased and the analogue part decreases in small steps. Like in Alpha, the result is the adding of some degree of reusability. This is an act that improves the semantic interoperability and knowledge transfer within the organization.

4.2.3 Product's life cycle phases related to Beta's DTI

The packaging of the DTI is directly related to one of the product's life cycles, such as the manual for operation or maintenance. The information content is adjusted to the product's life cycle phase and relates to required actions or occurrences during the life cycle phase. One example is when to grease a part of a machine to prevent it from being damaged. Subdivisions of DTI are found within various of the product's life cycle phases, such as information in the production manual can be found in the maintenance manual and vice versa. Therefore, the desired future situation is based on the information instead of the packaging, one part of streamlining production and also increasing the standardization of information content. Nevertheless, the relation between the information parts and the various life cycle phases will be a part of the knowledge required by the co-workers. One example is that co-workers at the product development department continue to describe how to operate the product or that co-workers at the DTI production department gain this specific knowledge. This relation between the DTI and the various product life cycle phases need to be clarified as the output of Beta's DTI is heavily related to the products' life cycle phases and is not under discussion in any way. Therefore, the respondents' view seems to be that the product's life cycle phases are scarcely related to the DTI.

4.2.4 Structure of Beta's DTI

The DTI consists of continuous unstructured text from which the content depends on the orientation, the product, and requested language. Usually, the development project first orders the Installation, after that Maintenance, Operation, and Quality. Most of the DTI is manually produced, except DTI from sub-suppliers, inserted drawings, and master information. The master information consists of product number and product descriptions, described in one language. The remaining content is based on knowledge from members of the product project, mostly constructors and engineers and presented in a standardized way with short instructions with drawings. The exception is the Quality documentation, which needs to be signed as various tests are successfully carried out or test values are verified.

4.2.5 Information Systems of Beta's DTI

The information systems used to produce, present, and deliver DTI are standardized office systems like Word in Microsoft Office, ordinary file servers, Lotus Notes, and specific systems for project planning, drawings and delivery of the customized DTI. The DTI production is planned via a particular information system used for overall project planning, specifying dates for customer deliveries of the DTI. The delivery requirements from each customer, which varies from one to fifty times per project, are all noted in this project planning system. One output from this system is the internal project resource planning for the DTI co-workers. The actual production of DTI is done with Word and continually updated via either the file system or a versioning system, both for the real work and the deliveries. This versioning is viewed as each customer project and named after the customer. The part of DTI that consists of images is created in various information systems and pasted into the Word-documents. The versioning system is considered to be hard to manage as it requires inputs on a level that is too detailed. The DTI is delivered from a FTP-area for those customers using the DTI in digital form where most of them later format and integrate these into their maintenance- or Enterprise Resource Planning system.

Beta views the downside of using older standardized office systems as a lack of functionality for the DTI, such as presenting on Intranets or other portal solutions. This is synthesized in the problem of patterned integration possibilities. The perceived solution is to use XML, which adds the integration option as well as the efficiency of the DTI production process. Setting up a standard library with DTI terms creates efficiency, increasing usage potential. The XML solution has been presented to an interested management at Beta but is not prioritized due to the current business cycle. One respondent expresses her view on these old-fashioned information systems like this:

"When I started at [former employer], which was my first job with technical information. It was in the late 80's and SGML worked. It is similar to XML, you tag information, etc. And that's where we are heading here now, just that it is called XML nowadays. So, it depends on which industry you are in, so [former employer] and that type of company they were very far ahead while here, where I am now, is very traditional." (Team leader DTI, Beta)

4.2.6 Production process for Beta's DTI

The production process for creating the DTI is mainly related to the development of the product. Despite this, the DTI co-workers are not invited to participate in these projects. They are often invited to the project's start-up meetings and are then ultimately viewed as a separate process outside the project, even though they can affect it if delays occur. One development project manager expresses it like this:

"Well, I don't see why they should be participants in the project. I just want the documents to be delivered on time." (Development Project Manager, DTI)

This view is apparent when looking at the production process of DTI, where there are clear meeting points between the product's manufacturing process and the DTI production process, see Figure 5.

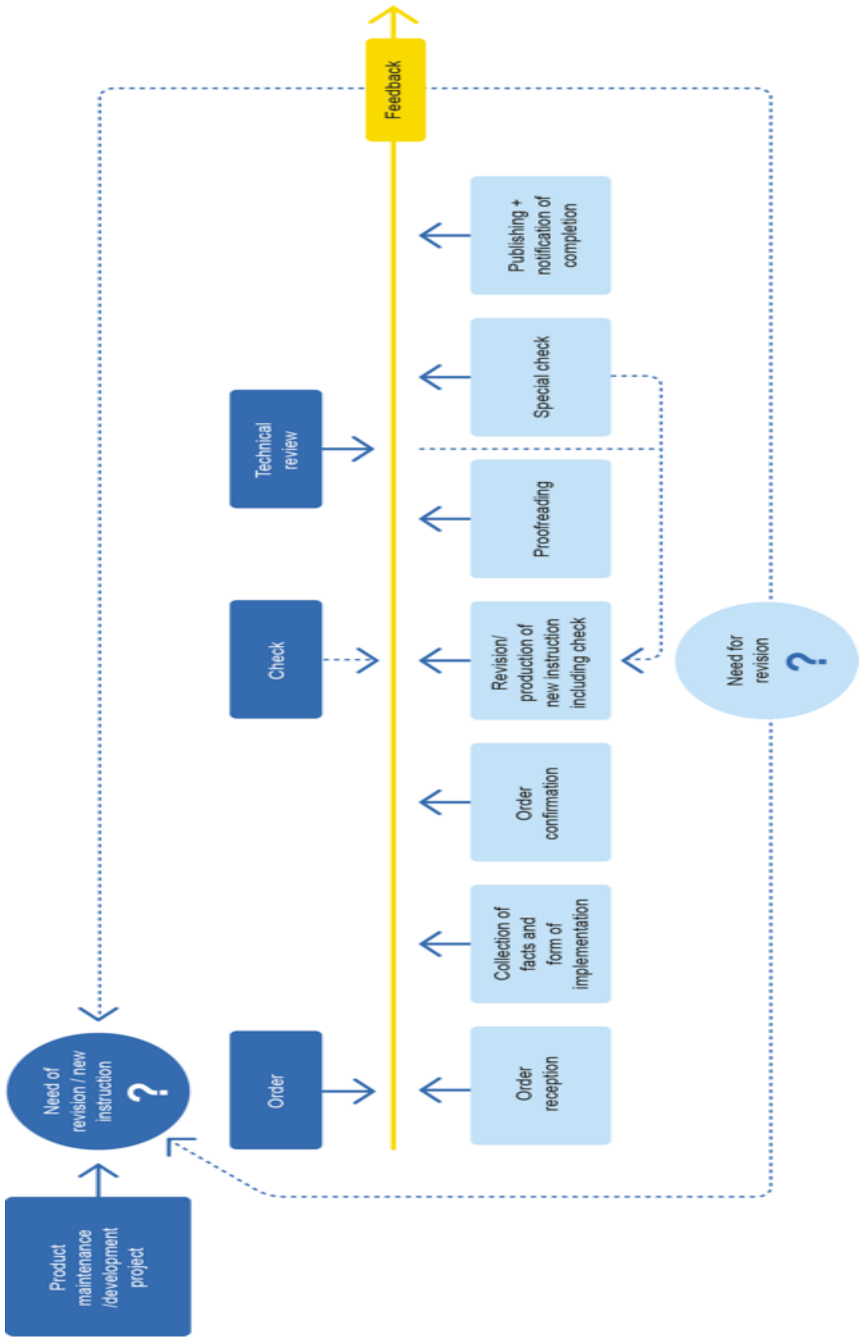


Figure 5 DTI production process at Beta

The DTI production process at Beta starts with an order reception, from the product's production project to the DTI co-workers. Occasionally, the DTI co-workers do the order as it is often forgotten by the product's production project. The order consists of overall description of the DTI requirements, as well as requirements directed towards sub-suppliers. The latter is often forgotten which causes stress when this is found out. The co-workers then collect facts about the product development and the order is then officially confirmed. The confirmation includes a time estimate for producing and delivering the DTI. This collection is done in an informal way, simply by chatting or mailing back and forth. The assignments in the process consist of producing, revising, auditing, and delivering the DTI, and a lead engineer performs the trial.

The collection of facts and revision are assignments that are frequently called into question by the product development department, especially after the outsourcing. They question the responsibilities of teaching others and view this as a waste of time as they believe they can produce the DTI themselves in a shorter time.

"I know that it is a wish of the construction department that they should be relieved of this task and not have this qualified secretary in front of them, and I can understand that wish. They want new staff to be knowledgeable and work a bit more independently with pieces that technology engineers naturally will master. However, then there are new employees here, there is no library here that contains Beta's products so that you can learn in advance and be hundred percent when you come here." (Manager DTI, Beta)

On the other hand, the DTI co-workers feel that they completely have to adapt themselves to the engineers' schedule, which they perceive as stressful. Management plan to introduce mandatory product meetings to minimize friction between the departments. When the collaboration works, DTI co-workers sees it as a fruitful dialogue, which provides a compelling basis for their work and reduces a sense of isolation at work. From the project managers' viewpoint, they want as little collaboration with the DTI co-workers as possible and only invite them to the initial project meeting.

The DTI delivery causes a headache for Beta, especially from a time perspective. Part of this is that there are many partial deliveries to be made as this is how Beta delivers its DTI. The number of deliveries depends on what is to be delivered. There is, for example, a difference between the delivery of a single machine and starting a brand-new factory. The latter involves an increasing number of deliveries. One customer project contains 20 deliveries of the same DTI, only updated at those deliveries. Several of the respondents anticipate the number of deliveries is due to DTI viewed as the knowledge that is locked in cabinets, showing power to the owner. Beta offers several ways for DTI delivery that are more or less time-consuming. The most common way, and a very time-consuming way too, is to print the DTI and file it into binders for customer delivery. The reason for this way of delivering DTI is that it is said to be an industry requirement due to old habits and the availability of digital tools everywhere in the world. Beta has recently been trying to get rid of this form of delivery by adding a fee, removing it upon customer demand.

"Our sales department is very clear about the fact that this [delivery of the DTI] should not be a source of argument with the customer. If the customer wants paper, they will get the paper. So that is the priority. Even though we have shown them the calculations on our savings by delivering only electronically. Moreover, what the benefits are, but again, this is no area that is the focus of everyone in the organization. The documentation is a necessary evil." (Manager DTI, Beta)

The DTI is fully accessible to the DTI co-workers and for reading by the others of Beta's co-workers. Previously, all co-workers had full access to read or edit the DTI. Unfortunately, the access had to be changed to "read only" as it was erased accidentally several times by co-workers outside the DTI department. The DTI is not archived for reasons such as a product's destruction. It just remains on the file server and is accessible as long as wanted. The accessible DTI is viewed as the archive instead of the CDs, on which the DTI mainly is delivered. The reason for this view is that the CDs disappeared somewhere in the organization. The archived DTI is sought after despite its low status within Beta. The development managers ask for the archived DTI to find information about previously delivered products or as a foundation for new offers. The use of the archived DTI adds to DTI's low status within the organization. One example is that one of the project managers enthusiastically describes that it is easier to make new customer offers with access to the archived DTI.

4.2.7 Beta's benefits

Beta's benefits from their DTI are several and previously shown in Ahlin (2014). One benefit is that of knowledge for operations, as the DTI consists of manuals for operation and maintenance. Several respondents described it as an essential resource for both internal and external customers as the DTI is seen as a knowledge base for anyone who is using it. The customers can freely choose their partner for operations and are not dependent on Beta.

"It [The DTI] is used a lot by our site organization. So those who are on site at the customer, they must install what we deliver, start up what we deliver. They are very dependent on this documentation because it will be their suggestions when they are going to do their job many times." (Project Manager for Development, Beta)

"The customer must have their folders if there are any problems with their products or if they need to do maintenance. Then they must be able to take their folders and make a drawing if they need to change something. Where is the component located or if it is something that they know is breaking down? Then they should be able to find it there and buy it. Alternatively, they can ask another organization to help them. They should be able to order new spare parts when we send them the spare parts documentation; there are also new variants. They should be able to buy them from another supplier. Our documentation should be detailed and explain which supplier or what detail in the supplier's language. The standard is that we give - if it is a machine that we manufacture - if we have bought something from someone else [...]. So, then they can always come here and buy it. However, it is that kind of - that's what they use the documentation for. They must be able to maintain their equipment; they must be able to find details if they want to order something new. "(Project Manager for Development, Beta)

Respondents discuss the DTI as forming parts of the standardized product development, where the DTI is used as knowledge for new product development, inspiring the engineers to use proven products and their designs.

"It is the significant bit that you try to find solutions that make it possible to reuse - partly because it is something you know works. It can also be a concern with such resources that it is not at all sure that it goes as you wish. Something that works, one wants to be able to do it cost-efficiently. The procedure is that what we want for the future, to try to find standardized solutions for our products." (Project Manager for Development, Beta)

The DTI is referred to as a part of Beta's educational material, both regarding learning how to use it and as a resource. Here one respondent expresses how newcomers can become more efficient when answering complex questions:

"Moreover, I usually try to get them to find things in the manual. They want to know what is in there and so I always use it as part of the education. I tell them that they can get a copy of these manuals, and put them in here. Then you can take some examples if someone has a complicated question [...], and then you can look it up and you will see the answer." (Project Manager for Development, Beta)

4.2.8 Beta's analysed benefits

Beta's benefits are analysed according to the product's life cycle phases, the relation to the product, the DTI's structure, predetermined/emerging, and strategic/operational. The analysed benefits are shown in Table 4.

Starting with the *product's life cycle phase*, the main part of the benefits is gained in operation and maintenance. Beta is also gaining benefits from the DTI in the development phase, mainly by co-workers manually synthesizing the DTI and transferring it to other information systems. One of the benefits gained throughout all of the product's life cycle phases is 'Semantic Interoperability'. The results show that the main parts of the benefits are recognized in the product's life cycle phase where the DTI is published, however it still offers support in other of the product's life cycle phases.

The recognized benefits are initially related to individual products. They are perceived as 'Knowledge base for operations', 'Knowledge base for customer support', and 'Part of internal educational material'. Later, operational management are using the DTI as foundation for standardized products, while offering customers new products. The benefits start by relating to the individual products and are then changed to general products, such as a product line. The unstructured DTI is manually synthesized across individual products, which creates this general relation from the DTI to the product.

The benefit 'Standardized products' is gained and is based on manually synthesized DTI despite the fact that the *structure* of Beta's DTI is unstructured. The respondents describe the structure as an obstacle and were looking forward to implementing structured DTI to gain more benefits.

There is only one *predetermined* benefit here, 'Knowledge base for operations', which is based on the strategic goals with the DTI. This DTI is used both for internal and external operational purposes to support the product as decided by the management. Therefore, the strategic categorization can be added as a predetermined benefit. Being a benefit aimed to support operations is not specifically adjusted for Beta's context, merely the content of the DTI.

Beta's *emerging* benefits, declared as 'Knowledge base for customer support', 'Standardized products', and 'Part of internal education material', are further categorized as either strategic or operational. The strategic, 'Standardized products', aim to support strategic goals on the business side, even though the idea is brought up by co-workers on the operational side. The remaining benefits are perceived as operational, where the recognition is to solve needs on the business side, such as 'Knowledge base for customer support'. The emerging benefits consist of both the DTI as is or DTI converted to, e.g., a service ('Standardized products').

Benefit	DTI characteristic Used product life cycle phase(s)	DTI characteristic DTI's relation to the product	DTI characteristic DTI's structure	Benefit category Predetermined / Emerging	Benefit category Strategic / Operational
Knowledge base for operations	Operation and maintenance	Individual	As-is	Predetermined	Strategic
Knowledge base for customer support	Operation and maintenance	Individual	As-is	Emerging	Operational
Standardized products	Development	General	Reused	Emerging	Strategic
Part of internal education material	Operation and maintenance	General	As-is	Emerging	Operational

Table 4 Beta's analysed benefits

Table 4 describes Beta's perception of DTI's benefits, recognized as adding positive advantages to the product's life cycle phase operation. The DTI is published during the operation and maintenance phases of the product's life cycle phase, and the table shows that Beta recognizes the main benefits of DTI as occurring in these phases. Beta perceives additional benefits occurring in the development phases. Beta recognizes DTI's benefits, starting by adding benefits for an individual product and ends up in gaining a product line or all products (general). Beta benefits from the DTI when it is published initially ("as-is") and then benefits from manually reusing the DTI. Beta gain from reused DTI, despite that it is unstructured due to co-workers' manual work of synthesizing the DTI across product lines. Most of the DTI's recognized benefits categorizes as emerging, adding to the product's operation and maintenance phases as well as the product's development phase. Recognized benefits are categorized as gaining Beta's strategic goals, as well as operational goals.

4.2.9 Measuring benefits at Beta

At Beta the benefits are viewed as intangible, despite their opinion that there is always a way to measure. The limited numbers of benefits and the status of the DTI create the foundation for their problems when measuring the benefits. The respondent at Beta emphasized several ways to measure other intangible things, such as the DTI production process. Their way of measuring is built on cost-benefit analysis, using spent hours in the project for developing the DTI to estimate the cost. The benefits of the DTI's production process are shown via the development project for the product(s) and the estimated customer price.

Among the topics discussed in the interviews were how to measure, what can be measured, and related problems. Overall, respondents at Beta focused on the struggle between deciding the level at which DTI becomes beneficial, and convincing management that DTI should have a higher status based on savings in time and efficiency. They referred to this struggle as a part of how to measure the benefits. They discussed their struggle in quantifying the savings by transforming a written log of savings into a precise report. The strategy and overall goals in Beta were quality before delivery when needing to prioritize. Despite this, the quality is supposed to be "good enough", meaning DTI does not need to answer every possible question from users, but should answer questions at a predetermined level. The team manager of DTI expresses the view on quality of DTI in this quote:

"We should be "good enough": these are the words we are using. We have determined the level just to know how much time we should spend on various cases. You can work forever on instruction, but then it can be "best-in-test". It is "good enough" that is enough. We assume that the users have a certain level of technical knowledge; we do not start from the beginning and educate them." (Team manager DTI, Beta)

The focus on good enough creates the foundation for the outsourcing agreement, synthesized in various measurements. The organization aimed to discuss the benefits in terms of measurements and dealt with several problems as they approached this discussion. They consider that DTI is of low status and that benefits from it are based on efficiency, solely achieved through cost savings or avoiding payment of penalties. One example of a cost-saving would be a single-source architecture for the DTI, which include language translation. By using the single-source architecture, efficiency would increase thereby improving cost savings. Introducing this architecture was postponed due to a recession in their business sector.

Several of Beta's respondents discussed their confusion and distress about what ought to be measured. The reason for the confusion was the lack of detailed descriptions in the agreement and, as they felt, the difficulty of agreeing upon detailed descriptions and specifications of the cost savings.

"They are so fuzzily described, and I feel disheartened that they are not described in more detail. However, my only experience is from another agreement, and that was pretty good, and I miss those details. Sometimes I think about my contribution and feel powerless." (Team manager DTI, Beta)

The frustration and difficulty in agreeing upon measurement made the co-workers unsure on what to measure and they guessed at strategies to fulfil their compulsory work assignment. Another part of the problem with measuring the cost savings were that only parts of the savings could be measured. That is, there were savings in costs and efficiency that were not measured. About this, one respondent discussed the problem of what could be measured as cost savings and gave examples on how to measure intangible benefits:

"I can tell you that we have found millions of places (for cost savings). One example of a soft cost saving is when I can approach a person informally instead of in a more formal way. Moreover, that is because I have created a relationship and

can get the information in five minutes, something which normally would take four hours. "(Team manager DTI, Beta)

The measurement process in Beta includes calculate its cost savings; described in a written log. This log describes activities that may contribute to cost savings. The next step is to determine whether the proposed cost saving is a cost saving or not, based on the outsourcing agreement; following such discussions, the percent efficiency increases by enacting proposed changes in the activity. One respondent discussed the difficulty with translating the written log to a precise report of increased efficiency.

"I have a log of everything we have done, all the improvement work. I have a long list of what we have worked with, and I have documented everything. However, then the problem is how to put it together to show the company that you have saved this 30 % or 10% per year." (Team manager DTI, Beta)

Another part of the measurement process that creates frustration is to understand what to use as outputs and the reference points as Beta have altered their financial system several times in a short period.

"Unfortunately, we have changed the financial system several times. In this system, we have the opportunity to follow up where we spend time, planning costs. We divide up several accounts (…) Then we can make follow-ups and see if there are any deviations or not. So, both experiences from previously finished projects and current ones are relevant. "(Project manager construction, Beta)

Synthesizing the findings at Beta includes the importance of drawing on several aspects while measuring. Despite frustration from the respondents, based on various non-communications, there are some interesting findings. One is the desire for a shared and agreed upon "roadmap" of what should be achieved, meaning that the goals are to be jointly discussed and decided. Frustration occurs while performing the operative work and translating the agreements into the how to measure and the importance of comparison from year to year. One reason for this frustration is the interpretation of the agreement on the operational level since the written agreement is not on a specific level. Therefore, the operational interpretation is not discussed and agreed upon. The historical comparison between different metrics for efficiency is also essential. In the long run, it means an agreement on how the various organizations perceive the benefits to give them a common language base. For the measurement of intangible benefits, it can be described as doable and that the main consideration is on how to interpret the intangible benefits.

4.3 Organization Gamma

Gamma is a manufacturing, engineering company with headquarters located in Mid Sweden, with 150 co-workers. The organization bases its manufacturing on a hydraulic invention used on excavators named tilt-rotator. Gamma's business idea is relatively new; the company started in 1990, as an entrepreneurial garage start-up, and has had a high rate of development since then. The founders bought the hydraulic innovation patent and developed it further into a marketable term. Gamma's foundation is an innovative family-owned organization, located in a small city. Those two factors cause the family feeling to remain, even though the size of the company has grown since its start. Nowadays, Gamma consists of several subsidiaries with offices in Europe and sales representatives in North America and Australia. The manufacturing and product development are located in Sweden, concentrated in one particular city. The manufacturing consists of the assembling of various components that create the tilt-rotator and other tools for excavators.

The particular market sector that Gamma acts within is relatively young, compared to the overall production of major construction machinery. Despite this, and perhaps as a result of being a niche branch, the respondents emphasize that the sector functions as a mature industry. Therefore, the CEO discussed the DTI as being of interest in order to compete with other organizations within the same domain, focusing on the knowledge advantage:

"Yes, given the service and aftermarket, the technical information is important. It is becoming more and more important to provide good technical information and documentation. Especially, when we enter new markets that are not as mature as our old ones. Then we need more documentation and information." (CEO, Gamma)

One result of this view is that a DTI department is under construction. In this department, co-workers work part-time and contribute with various skills. Gamma has also recently created a new position that is responsible for DTI and its development, confirmed in a follow-up interview.

"A year ago, we started a new department, who works with documentation; solely assembly instructions. We have developed a completely new format for the

instruction that is used both in production and those that you saw hanging at the assembly line. They are also used as an exploded view for aftermarket. It's like a combined, before we had two different documents. Now we create one with multiple purposes." (Team manager DTI)

4.3.1 Gamma's DTI

At Gamma, the respondents describe all product information as DTI. In practice, this includes any product-related information from exploded views to service manuals and service announcements to internal and external sales materials. The DTI functions as both internal and external information, where the external is used for their external website, Facebook, and Twitter. DTI is mainly stored as documents or drawings at Gamma, even though there is a wish to use digital DTI production, such as recording movies for assembly and maintenance instructions.

The co-workers refer to DTI as interesting and are unusually enthusiastic about working with it. The CEO discusses DTI as sales material, and the development manager sees the website as an important component for efficiency, focusing on lead-time for the customer as well as efficiency in time-use for co-workers. The CEO, and the management team all view DTI as a "unit of selling point" where the salespersons should find all facts about the products. No respondent discusses DTI as project information and they declare that it is technically- based product information that is Gamma's DTI.

The DTI is intended to serve internal co-workers when assembling. During our visits to Gamma, the printed DTI was posted at the start of the assembly line and occasionally contained written corrections or comments. The DTI is obviously one part of the Gamma's focus on increasing the product quality, as it is so easily found by the assembler. The external customers can view parts of the studied DTI on Gamma's website, see Figure 7. The DTI, in the form of the assembly instruction, is part of an instruction book, including quality information, certificates, usage and maintenance information. The subsections, which the external customer can access, are information such as the exploded views or CAD-drawings.

4.3.2 Digitization of Gamma's DTI

The digitization of Gamma's DTI is viewed as relating to the first grade, see Figure 1. The co-workers are synthesizing information from the ERP-system and adding it to other information, such as analogue input and digital photos. The change is related to the input, since there was no previous DTI providing this content. By adding the DTI, the organization has made it somewhat more accessible to the co-workers, even though the number is strictly limited but is increasing upon request. Parts of the DTI are fully accessible, namely the product information stored in the DTI, and other parts of the DTI are accessible through the website for customer support. This handling of storage makes the complete DTI hard to access for all the co-workers, whereas the essential parts are accessible for those who need it.

4.3.3 Product's life cycle phases related to Gamma's DTI

Gamma's DTI, the assembly instructions, is published in order to enable usage for one activity in one of the product's life cycle phases, the development of the product. Despite the emphasis on the development phase, it is also used in other life cycle phases of the product, such as maintenance by the customer support. Additionally, the DTI can be utilized in the same life cycle phase for other purposes, such as the foundation of knowledge in quality testing. For Gamma, the connection between the DTI and the product's life cycle phase is evident as the assembly instructions are directed towards one activity in a life cycle phase. Nevertheless, the connection is relatively vague since there is no packing that states that DTI is to be used for a particular product life cycle phase or that it has some form of product life cycle phase status attached to it. Therefore, the overall impression is that Gamma views the DTI as related to the product, although they are nowadays referring to it as the foundation for specific actions, not related to any particular one of the product's life cycle phases. Therefore, one cornerstone for Gamma's longer-term wish to build a total repository for the DTI can be the actions related to the products or the more vaguely used product life cycle phases. These two, the action or the life cycle phase, are today relying on various co-workers' knowledge as they produce the specific DTI in their DTI production process. These co-workers even received their own nickname within the organization, midwife:

"Yes, but over there at [Gamma] where I am like a midwife then. It is so much fun because I do everything from electronics to hydraulics to test runs. I know everything. So, this is the thank-you for using an excavator for five years. Yes, I used that knowledge daily. So, then you have seen some things that are good and others maybe less useful and so. "(Manager practical construction, Gamma)

4.3.4 Structure of Gamma's DTI

The studied DTI consists of product information, continuous text, CAD-writings, and exploded views. Attached to the assembling is an assembly instruction, which is used internally by the assemblers, quality assurance, and customer service, as well by external customers. Internally is it used for manufacturing the product, knowledge foundation, and the external customers use it for maintenance purposes.

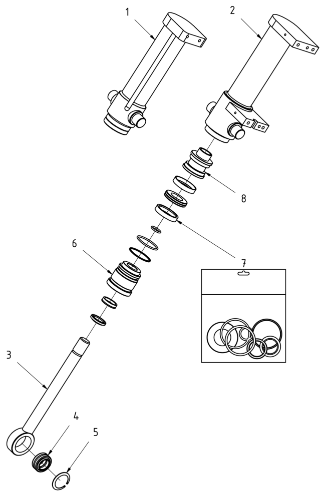
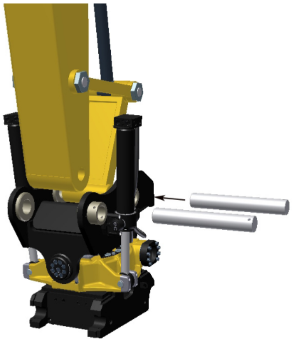


Figure 6 Example of Gamma's DTI, an exploded view of a cylinder

The format of the studied DTI is mainly unstructured, except for the included structured product information, which results in semi-structured DTI. The product information consists of product identifiers and description, partly for the primary product and integrated components. The product information is static and is the same everywhere in comparison to example the position, which varies depending on the various products. The DTI's continuous text describes how to assemble the different components into the product. The current text is presented in number order along with photos, CAD drawings, or exploded views, see Figure 6 and Figure 7. The assembly instruction in Figure 7 describes how to assemble stub shafts by first assemble O-rings if necessary (step 1), and then align switch links with intended holes in the top of the tiltrotator / rotator (step 2). Assemble the stub shafts in step 3.



Montering

1. Montera O-ringarna om sådana ska användas.
2. Rikta in brytlänken så att den överensstämmer med avsedda hål i tiltrotatorns/rotatorns överdel.
3. För in avsedd axeltapp.

Figure 7 Example of Gamma’s DTI, part of an assembly instruction

The DTI’s structure is based on the document produced related to a product’s life cycle phase, not on the required DTI. One future wish at Gamma is to create DTI based on the information needs, not for a particular operation or event. Some respondents discuss the advantages as more efficient DTI production, higher information quality, e.g., same product descriptions and easier DTI production of another required DTI. They haven’t made this investment due to relatively high cost, which is considered to be too high for a small organization such as Gamma. The cost involves a significant investment to introduce such a system and also to start its application.

“Still, we don’t have a common database. As we manufacture a new product, we leave product information to our marketing department, who are responsible for all marketing documents. Then they want to add information and submit it to our websites. They submit it to all our available websites that are in several different languages. They need to change all the product sheets and all promotional materials. We rarely succeed. But I have seen that there are programs. [...] So far, we are too small for the required investment. “(Development Manager, Gamma)

4.3.5 Information Systems of Gamma’s DTI

Gamma uses a plethora of information systems for producing and presenting the DTI. They use Microsoft Word to create and store it on a file server. Then photos, CAD-drawings, or exploded views are added to the DTI, along with the text. The assembly instruction’s product information, such as product number and name, is stored in a legacy system, mainly used for product planning. Every co-worker at Beta can fully access the product information in the legacy system, which occasionally causes problems, as it is incorrectly updated. Those responsible for the DTI also manage the product information and can update it, e.g., correct any errors. The external users access the DTI via an e-commerce web portal, requiring log-in. The salespersons and customers can access the assembly instructions and additional information, such as spare parts, and service information for their products. There are automatic integrations between the legacy system and the web portal, transferring product information, CAD drawings, and exploded views.

4.3.6 Production process for Gamma's DTI

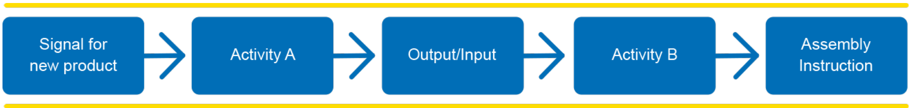


Figure 8 Gamma's DTI production process

Gamma's DTI production process, see Figure 8 is initiated by a required update or lack of DTI. The process starts by an automatically generated signal from the legacy system as the product identification is created or a co-worker who requires the DTI in the legacy system or at the assembly line. The start can be communicated by any co-worker to a person in the DTI group. They start to build the DTI via the product's number, name, and related components. An assembly instruction identifier is a serial number from a self-built information system. Added to this information system is a description of how to assemble and later product information. Here, they download a similar product's guide to supplement it with a new product.

The co-workers communicate from one activity to the other via manually written email. This manual handling, and that there is no standardized way to perform the DTI production process activities, can cause problems, such as communication breakdown or a negative effect on the DTI's quality. The unforeseeable handling is discussed by the respondents as a tradition from the start-up days and not adjusted to Gamma's current situation.

The output format is decided by the actual co-worker and can be hard to understand. One example is when a photo was taken and included in a semi-finished assembly instruction done as the last activity before the co-worker went for parental leave. The co-workers use much of their knowledge to create the DTI, which can lead to the problem mentioned above. At the same time, the DTI is designed to make this knowledge available to all co-workers at Gamma.

The preserved DTI is solely found on one PC, giving limit access to the DTI for other co-workers at Gamma, except the product information stored in a legacy system. The limited access to the DTI renders problems, as there are only a few co-workers who can modify the DTI or even use it digitally. One mentioned solution is to use the customer web-portal and by finding interesting DTI. There are no guidelines for how to preserve the DTI.

4.3.7 Gamma's benefits

Gamma's DTI originates in the manufacturing of a new or changed excavator component and is the assembly instruction used in their assembly line. The DTI is from the organization's perspective predetermined to create standardized products and to avoid time-consuming trial and error paths. The DTI was introduced a couple of years ago as customers requested higher product quality and the organization grew beyond a start-up. Gamma's perspective is therefore that the DTI is one of their knowledge foundations.

"At the assembly line, they feel that they know how to assemble without looking at the assembly instruction. We are challenged by this and are working on how to highlight changes in the assembly instruction. How can we do this properly? Because it is important that our assemblers keep an eye on them and look at them. If they assemble from memory, it is hard to recognize any changes, if you're not very careful." (Team leader DTI, Gamma)

The respondents mention one unexpected benefit from introducing assembly instructions, which was the standard language usage. They noticed this as for the first time, they started to use same name when referring to the various parts of the assembly instruction and later even details in the drawings. Their discussions are far more efficient, as they use the same name for each component. The development of a common terminology has increased efficiency both within and between Gamma's departments.

Other departments in Gamma, such as customer support, sales associates, and quality assurance, use the assembly instructions and comment positively about this. The quality assurance department tests and verifies the product's components after assembly. Their intention to use the assembly instruction derives from testing activities, where the DTI is a source to examine the root source if the test fails. The DTI provides knowledge for the verification activities, such as quality control.

"They use it to check how a hose can be, for example. They use the assembly instruction to check if they are uncertain how it should be. There might be variants that are built very rarely." (Team leader DTI, Gamma)

The use of the assembly instructions at the customer support department is to gain knowledge about sold products and to help customers via publishing the DTI on Gamma's website, which saves them time.

"…when thinking of support, it is a great gain to have the right DTI. The first thing is fewer support assignments as the customers troubleshoot by themselves. When customers call for help, the customer support can assist the customer considerably faster by referring to the DTI." (Research and Development Manager, Gamma)

The respondents emphasize the benefits for the sales associates such as gaining knowledge, used in a situation like training or sales pitching. This request originates from higher management, who stress the importance of high-quality DTI. Since the DTI is of high quality, it can be equally well be used for sales associates. Another benefit of the DTI is educational material for training, relating to DTI as a crucial knowledge foundation. One respondent emphasizes that the sales associates themselves are asking for the DTI when preparing for sales pitches for customers at various occasions.

4.3.8 Gamma's analysed benefits

The benefits are analysed according to the product's life cycle phases, the relation to the product, the structure, predetermined/emerging, and strategic/operational. The analysed benefits are shown in Table 5.

The relation to the *product's life cycle phase* is strongest in the development phase, where the DTI supports the activity of assembling. Gamma also gains benefits from the DTI during production and maintenance, where 'Customers are gaining lead-time' based on synthesized DTI shown in a customer web. The benefit 'Semantic Interoperability' supports all of the product's life cycle phases. The result of this is that the majority of the benefits are recognized in the product's life cycle phase when the DTI is published, however it still offers support in the product's other life cycle phases.

Shown in Table 5 are the benefits and their transfer from the individual to the general in *relation to the product*. The first two benefits relate to the product's production process, followed by quality assurances from management. The customer support then gains benefit while using the DTI as product knowledge. The transfer to a more general relation to the product starts with the 'Semantic interoperability', where the DTI serves as a foundation both for individual products and as a relation for general products. Gamma's approach for a more general relation is that of 'Standardized customer product' and 'Standardized product development', still offering individual relations to the product.

The *structure* of Gamma's DTI is semi-structured and that structure generates benefits, such as 'Faster customer support' built on the unstructured DTI. There is some desire to build their DTI on structured information, but the implementation is perceived as too burdensome and costly.

The *predetermined* benefits are recognized as three for Gamma, 'Assembling for production', 'Standardized product development', and 'Standardized product development'. They all focus on strategic goals in Gamma. The predetermined benefits are recognized while using the DTI inside of Gamma and to increase quality of the product development and the product the customer can buy. The benefit 'Assembling for production' is adjusted to Gamma's context, while the other predetermined benefits are perceived as general in their nature. The benefits are recognized from the DTI as it is, not transformed or aggregated in any way.

Gamma's *emerging* benefits, declared as #4 - #10, are further categorized as either strategic or operational. The two strategic benefits, 'Knowledge about new products for sales associates' and 'Description of product advantages for sales associates', derive from Gamma's intention to position themselves on their market by knowledgeable sales associates. The operational benefits are recognized as either the general benefits of DTI, such as Semantic Interoperability or benefits where the gain is to solve needs on the business side, such as 'Knowledge foundation for quality assurance'. The emerging benefits consist of both the DTI as it is or synthesized DTI (e.g. 'Foundation for education material').

Benefit	DTI characteristic Used product life cycle phase(s)	DTI characteristic DTI's relation to the product	DTI characteristic DTI's structure	Benefit category Predetermined / Emerging	Benefit category Strategic / Operational
Assembling for production	Development	Individual	As-is	Predetermined	Strategic
Standardized product development	Development	Individual	As-is	Predetermined	Strategic
Standardized customer product	Development, operation, and maintenance	Individual	As-is	Predetermined	Strategic
Product knowledge for customer support	Development, operation, and maintenance	Individual	Reused	Emerging	Operational
Knowledge foundation for quality assurance	Development, operation, and maintenance	Individual	Reused	Emerging	Operational
Knowledge about new products for sales associates	Operation and maintenance	Individual	As-is	Emerging	Strategic
Description of product advantages for sales associates	Development, operation, and maintenance	Individual/ General	As-is	Emerging	Strategic
Semantic interoperability in organization	Development, production, and maintenance	Individual/ General	As-is	Emerging	Operational

Table 5 Gamma's analysed benefits

Table 5 shows Gamma's perception of DTI's benefits, recognized as adding positive advantages to the product's development phase. The recognized benefits add to other of the product's life cycle phases, such as operation and maintenance. The DTI is published during the development phase of the product's life cycle phase, and the table shows that Gamma recognizes the main benefits of DTI as occurring in this phase. Gamma perceives additional benefits occurring in the operation and maintenance. Gamma recognizes DTI's benefits, starting by adding benefits for an individual product and ends up in gaining a product line or all products (general). Gamma benefits from the DTI when it is originally published ("as-is") and then benefits from manually reusing the DTI. Despite the unstructured DTI are Gamma gaining from reused DTI, due to co-workers' manual work of synthesizing the DTI across product lines. The main part of the recognized benefits categorizes as emerging, adding to the product's operation and maintenance phases as well as the product's development phase. Recognized benefits are categorized as gaining Gamma's strategic goals, as well as operational goals.

4.3.9 Measuring benefits at Gamma

At Gamma, the benefits are viewed as intangible and the respondents are ambivalent on how hard it is to measure them. Gamma's research and development manager introduced some ways on how to measure and commented on why there is a need to measure all benefits:

"…it is much easier to argue if you have numbers to show. Because it is easier if you look at the management level to try to get resources for something. It gets very flimsy if you come and say that now we have so much to do because These and these customers come and demand this. The DTI will help us in freeing up designers. It will reduce support times. Yes, they say, but it sounds good. But how much? But if you can say that the support time will be reduced by 20% and we will reduce the designers' workload by 30% and this corresponds to this in money. It is much easier to argue." (Research and Development Manager, Gamma)

Another way to approach measuring is to understand the efficiency gained while assembling the product. Respondents comment that it should be possible to measure the time for assembling the product without using any assembly instructions and compare it with the time it takes to assemble a product using the DTI. Obviously, there are some biased errors in this kind of measurement since the assembler has gained knowledge on how to assemble the product. Nevertheless, it is seen as a viable way to measure the benefits based on the organization's gained efficiency.

Further discussed are also practicalities associated with how to measure the DTI. The research and development manager commented that it should be easy to measure and convenient to find the measurements:

> *"The hard thing about measuring is finding a way to measure. First of all, get the right data to look at and then also that you can practically measure it directly. For the risk is, if it becomes too complicated, if it is to be logged manually, then it will not. Alternatively, that you write in something you believe they want." (Research and Development Manager, Gamma)*

Also discussed was the necessity of detailed measurements. The argumentation related to the intended target group and what the measurements would be used for. If the measurements were aimed for internal use, the measurements could be less accurate, while for external use, the precision should be higher.

4.4 Organization Omega

Omega is a technology company, based in the American Midwest. It has existed for three decades, and the business idea has slowly moved from offering consulting services to being based on their software products and services. Omega was founded by some IT consultants and several respondents describe the entrepreneurial spirit as alive within the organization, where the co-workers can experiment with new technology, such as new software. The organization is rapidly growing in terms of the number of employees and customers. The number of co-workers is now close to 300, and Omega has customers in 180 countries. Omega is working with partners around the world to provide their customers with sales and support.

Omega's products are software for visual communication, with functions including recording, capturing, and editing videos. Included in Omega's software suite are three programs, where two can be categorized as mature and one new. The software development is primarily done in-house at the organization and up until recently by teams focusing on the specific software. The software could, therefore, have different interface functionality and management of similar functionality. These differences have been something that led to questions from customers. To prevent silo thinking, Omega has begun to use mixed resources with various product backgrounds, thus creating similar development for all its products. Another aspect of the new development process is that the resources will be used more evenly.

Management at Omega think this will create higher efficiency and in the future increased revenue. Initiated by the new development process are the charters, which are the DTI studied in Omega.

Omega's software is specified towards small-scale media production, such as education. The respondents describe the IT sector as a highly competitive one, especially with the newly introduced competition of new video recording functions in social media which makes it easy to record for free. They also refer to another competitor group which offers free software with more expanded functionality than those in social media. The respondents compare their software with the free software and conclude that theirs includes more sophisticated functionality. What they also include in the competition is that of the IT-educated co-workers. Omega needs more skilled co-workers, as they intend to grow and they are facing slight difficulties, as the demand is higher than growth. Part of that competition is a geographical one, that from other parts of the U.S., such as the Bay area in Silicon Valley.

"And we want to compete with some of the bigger technology companies that are located in the heart of Silicon Valley which is quite a contrast to where we are located, and that is where we lose staff to. There are more possibilities there and we have lost some of our employees to them. We are still coming to terms with losing them. That was a real blow to us several years ago before we started doing everything this way." (Program Manager, Omega)

4.4.1 Omega's DTI

Omega calls its DTI charters and it is located within the development process. Co-workers at the development department elaborated on the DTI's design and structure, and the management group established it. One of the respondents framed the idea behind the DTI:

"The reason we created the charters was so that we could have an easy, common, popular place where everyone could go to. And that was our foundation. And then on top of that, is that we have the initiative leads out there which were to be the sort of the revealers of the knowledge and make sure that they fully understood it and they make sure that everyone else understood it. And then the teams are there to be practical and build upon that." (Technical Manager, Omega)

The respondents show that the required content in the DTI are development requirements, the business or technical problem it is supposed to solve, a tentative solution, delivery date, required resources, success criterion, milestones and stakeholders. The content of the DTI is intended to be a brief overview, not limited by any rules, but in total not exceeding three-four pages with limited numbers of pictures.

"The charters serve as a kind of light in here. Some of them are in progress, some of them haven´t started yet. […] So, we have a summary of business needs, summary of deliverables, we've got our objectives for the project, success criteria, stakeholders, and in this one, yes, we actually have identified people. So, it starts off with like. There is not a name there, but we say that we need one back-end developer, two mac-developers, two windows-developers, Q&A resource, design resource, and then it will be our executive and engineering that goes through it and basically fills it out. You know, who you are going to get in the team." (Technical Manager, Omega)

4.4.2 Digitization of Omega's DTI

The digitization of Omega's DTI is viewed as relating to the first grade, see Figure 1. The co-workers working with DTI are gathering information from other co-workers either in an analogue or digital way. The first digital version of the DTI is handled by the owner of the DTI and accessible for all co-workers within Omega when ready for public viewing. The reuse is therefore fully accessible, although handled manually due to the unstructured format of the DTI. As such, the synthesizing and formatting for other stakeholders is done manually.

4.4.3 Product's life cycle phases related to Omega's DTI

The DTI is initially produced for usage during the product's development phase. The respondents describe it as being used for purposes other than merely the product's various life cycle phases. Some say it can be used for a general introduction for newcomers, where they can learn more about the latest product development. This, and other ways to relate to the DTI are viewed as natural ways of being more efficient and are not discussed as using the DTI in ways other than originally intended. In the development phase, the DTI is synthesized in various forms for presentation to other internal users, such as the approval board, or external stakeholders.

For Omega, the connection between the product's life cycle phases is evident as the charter is published in one life cycle phase. Nevertheless, the connection is mixed between the product's life cycle phases, a general approach for the DTI, and what can be viewed as DTI for a project. The latter is, in this case, related to the fact that the DTI is created as a foundation for development of the project, which is done in the form of small projects. One such connection is that resources are mentioned in the DTI, which are not related to the product, merely as a way to perform resource allocation. Therefore, the overall impression is that the respondents in Omega view the DTI as related to the product for product development, as well as specific project information. In the longer run, Omega intends to add actions such as retro-perspectives based on the DTI, which can take the form of quality retro perspectives for the product development as well as project retro-perspectives. Though, the DTI are a foundation for information, which earlier was taken care of by various co-workers.

4.4.4 Structure of Omega's DTI

The DTI consists of unstructured information related to new functionality, including headings such as development goals, resources and success factors. The headings are predetermined and are part of the DTI, which is discussed in document format. The maximum number of pages is limited to three or four and it is mixed in its structure. One intention with the DTI was to explain the goal with the development, which was frequently asked for by the developers. For this, and other purposes, a synthesized version of the DTI is created, showing the requirements for the design and relating it to one or several organizational goals. The synthesized version, called the map, aims to create efficient communication with various stakeholders, such as executive management and specific external stakeholders, like major IT vendors.

4.4.5 Information Systems of Omega's DTI

The DTI owners can choose any software to compose and store the DTI while formulating and explaining the new development. Most of them choose between Google Docs, Microsoft Word or OneDrive and their choice is mostly dependent on their personal preferences. Some prefer Google Docs because of its collaborative functionalities, some Microsoft Word because of its broader range of features, and some OneDrive based on its collaborative and traceability functionalities. The examples are characterized as ways to test new software as well as the personal freedom to test new features. In all cases, the first draft of the DTI represents a range of opinions and information and is accessible to a limited number of co-workers. Revising the DTI entails discussing different ideas and collaborating on its content.

The DTI is transferred to a standardized Microsoft SharePoint setup after approval and when development is to start. The DTI owner does this transfer manually from previously chosen software. The DTI is then accessible for all co-workers at Omega, who can use it for reading and printing. The DTI owner has full access to the DTI. It is worth noting that the compulsory usage of Microsoft SharePoint is not questioned, merely viewed as a way to make Omega more efficient.

" …and then we had this wiki and it became a massive thing. We had tens of thousands of things we had to search for. I didn't remember what folder it was put in; I couldn't find it. So, we decided we wanted a new SharePoint and to keep it basic and simple."

"…publish those on SharePoint or what I have been using it for most is these initiatives that you mentioned. They have a charter; it is like a mission state; what are we trying to accomplish; it kind of lays that out. And so, we post those upon SharePoint where everyone can see them. And you can update them as initiatives and progressives so everyone can go there and get updates and see where you are at in your initiatives. (Both quotes from the Program Manager, Omega)

4.4.6 Production process for Omega's DTI

The process of creating and using the DTI in Omega includes the following overall activities, shown in Figure 9: (1) the starting point, where the overall requirements are formulated, (2) the idea phase where the requirements are discussed and information is assembled digitally, (3) the approval phase involves a management decision concerning the development based on the requirements, (4) the development phase implies functionality development, and (5) the archival phase timeline starts at the development's conclusion. The DTI follows the development phase of the product.

Figure 9 DTI production process for Omega's DTI

The respondents describe the *starting point* as varying and add some examples: it can be an idea, a business requirement from the sales department, or a competitive feature to keep up with competitors. The owner of the DTI is the co-worker who starts the discussion and is the one who will manage the production of the DTI until the approval board approves the content.

How to manage the *idea phase* varied among the respondents and is one part of the co-worker's freedom of choice. Some gather colleagues in the same room to discuss the idea, using a whiteboard to take notes. Others start by writing down the most important points digitally. They choose these based on personal preferences; some respondents like the visualization possibilities of a whiteboard and some prefer to start thinking individually. All respondents describe discussions as a way to gather knowledge, test, challenge, listen, provide feedback and collaborate concerning requirements. The whiteboard notes are digitally stored for further collaboration. The document with the most important points can either be spread digitally throughout the organization or used in a formal meeting.

"Let´s see here. This is basically something that came back. I then went through and added comments and we would go back and forth via this mechanism to a considerable extent. And these are also some of the ideas that we are trying to create "(Project Development Manager, Omega)

The DTI owner sends the DTI to the executive management group for *approval* when it is recognized as a comprehensive representation of the tentative development. At this point, DTI storage is on Omega´s SharePoint installation with a standardized template. This marks one end of the co-worker's freedom of choice and is surprisingly not questioned by any of the respondents. Then the executive management reviews the DTI to grant or deny approval and informs the DTI owner of available resources. One respondent describes the required DTI content as varying, depending on who has described it and who is going to approve the DTI:

"That is one of those things where there is kind of a gut feeling because every manager is going to be different, every person who has approved initiatives is going to be slightly different. I tend to go on the slightly more liberal side so I make decisions and then sort of fill people in later rather than going and asking people first and then doing it." (Client Program Manager, Omega)

During the *development phase*, the DTI owner is required to update it and keep track of development status and use it as the foundation for discussions with the team or with stakeholders. The DTI owner decides whether or not to inform executive management when the functionality requires significant modifications. One example is if the actual DTI demands new visualization functionality and the team finds out that there is an audio feature which can be easily added as well. There is no official guideline when to approach the executive management for revisions and that decision is up to the DTI owners and their mindset.

As the initiative is finalized, the status will change and the DTI will be archived. The Quality Assurance approves the DTI's status as a result of their tests, and the DTI owner changes it. From this point on, the DTI is actively used for the coming months and after that occasionally. Some of the respondents use the DTI for a retro perspective and as a knowledge base. There are different opinions about the archived DTI. Some respondents believe that the rapid rate of development in the IT industry renders the archived DTI outdated after a short time period.

"It is funny because things move so fast in the software world that I am not sure that it is a ton of value to keep this around. I do not know that I would go back and say: "Why did we do (...)?" You know what I mean and go and read through all of this." (Program Manager Clients, Omega)

Those respondents refer to the code as of interest and argue that no developer would use the charters to understand the developed software. Some respondents see the archived DTI as the foundation for future knowledge use, especially for newcomers.

4.4.7 Omega's benefits

The DTI owner see it as a focal point for collaboration and searches for colleagues' domain knowledge. Their ability to collaborate and use their comprehensive knowledge is the only way to move forward while producing the initial draft of the DTI.

Pictured by the respondents are the unintended advantages gained from the collaboration: personal knowledge, a similar perception about the development, common language usage, and same interpretations. Another usage for the DTI is as a communication tool. The project managers use the DTI for spreading information, both in discussions and as the foundation for the approval board's decisions. The recipients are the project owners and the approval board. One frequently raised query from the approval board is whether the development aligns with Omega´s strategic goals or if a customer requires it. There is now a digital overview based on the DTI, called the map, to make this communication efficient. In this map, each row is marked with a colour and related to one or several organizational goals. This map is also of interest to the developers as they often ask for the goal of the development. The opinion among the project managers is that motivation increases if they know why they are coding the new functionality.

After the approval board's decision, the developers are gathered to start the new development project and the project manager usually initiates the development by discussing the DTI. The DTI is then used for communication and in discussion with the development team, shown by this quote from one of the project managers:

"It is a very good way to talk about what you are going to do because one thing that I have learned is that for any team you want to have a solid objective; what are you shooting for; what are we coming together as a team member and pushing for." (Project Manager, Omega)

The discussion includes using the DTI for knowledge sharing about the overall development goals, the new functionality and the subsequent development work among the project managers and the development team. The discussion moves back and forth, where it is usual to change details in the DTI as the discussion moves on.

"In that first week when I start to describe things to the development team, they are going to ask me tons of questions, and they are going to challenge me. 'Why would we do that?' Things like that and some are great questions, and some would be like: 'I don´t know; that is a great question. I need to think about that.'" (Project Manager, Omega)

An emerging advantage, unexpected when Omega introduced the DTI, were the benefits for the project managers and autonomy for the team members during the development. The team members use the DTI to make lower-level decisions and save time for project managers. As the DTI did not exist earlier as digital information, the hunt for specific information was a hunt for a specific co-worker and their specific knowledge. An example of increased autonomy is that the co-workers are more comfortable now can work remotely, which is an advantage for both them and the organization. Discussed in conjunction with this was the need to attract a skilled workforce; Omega has to face competition from organizations in Silicon Valley, and some skilled co-workers have left to join organizations there. Their departures were a brain drain that Omega still suffers from.

When the development is finalized, the DTI is archived. The archived volume of the DTI is low as the DTI was only recently introduced at Omega. Some respondents claimed that since Omega operates in the fast-moving IT industry, archived information is of no use. They declare the content of the DTI as too old and the knowledge viewed as out of date.

Respondents insist that Omega gains benefits because they archive this DTI digitally, not thought of ahead of the digitization. One gain is faster on-board process for newcomers, as they can access and read about on-going and past development projects. The gain is that newcomers hopefully develop domain knowledge faster and they can contribute to Omega's business faster. Another benefit is traceability of decisions. As the organization increases in size, time spent on searching for and finding this kind of information also increases and, along with this, co-worker's frustration. A planned activity, still not used by all respondents is the retrospective, whereby the DTI is used as the foundation to review success criteria and outcomes from the development project. Omega views it as a part of their review process and how they can improve.

4.4.8 Omega's analysed benefits

Omega's benefits are analysed according to the product's life cycle phases, the product, the structure, predetermined/emerging, and strategic/operational. The analysed benefits are shown in Table 7.

The benefits primarily relate to the *product life cycle phases* while developing the product. Omega is also gaining benefits from the DTI during production and maintenance, mainly as various foundations for knowledge requirements. One of the benefits is supporting all of the product's life cycle phases, that of 'Semantic Interoperability'. The result of this is that the majority of the benefits are gained in the product's life cycle phase when the DTI is published, however it is still offering support in other life cycle phases of the product.

The DTI created in Omega is based on having a general *relation to the product*. The general relation was the starting point for the strategic decision when introducing its DTI. Changing the general relation to an individual one can mean some difficulties as the more detailed information for specific individuals is not available.

The structure of Omega's DTI is loose and offers some benefits based on the headlines in the document. One such is the 'Collaboration tool with important suppliers" where synthesized DTI is sent to the suppliers. The respondents are happy about the digitization and see this as a step forward and do not discuss structuring it in any other terms.

There is only one *predetermined* benefit for Omega, namely focusing on strategic goals to unify product development. The introduction of the DTI was one step on the path to unification based on collaboration. Despite only one predetermined benefit there are several others where management used their impact on operational goals or use, such as 'Basis for retro-perspective' and 'Faster on-boarding process for newcomers'. The predetermined benefit is adjusted to Omega's context and the DTI is used as it is.

Omega's *emerging* benefits, #2 - #14, are further categorized as operational. The co-workers have all been involved in the process of digitizing the DTI and are interested in gaining as much as possible from the digitization. They want to make their work more efficient or use the DTI for communication to various stakeholders, such as the co-workers or important suppliers. The operational benefits also include 'Semantic Interoperability' and various ways of knowledge transfer. The emerging benefits consist of both the DTI as is or synthesized DTI. The benefits present in two tables for layout and readability reasons (Omega's recognized and analysed benefits cover several pages); one list of the benefits (Table 6) and one analysed benefits (Table 7). The tables relate to each other with a number for each benefit.

Number	Benefit
#1	Collaboration tool with important suppliers
#2	Easier to trace decisions
#3	Basis for retro-perspective
#4	Develop the organisation's language
#5	The owner of the DTI doesn't need to be around all the time
#6	Empower team members to make lower-level decisions
#7	Faster on-boarding process for newcomers
#8	Co-workers can work remotely
#9	Knowledge collaboration during idea phase
#10	Alignment between development and organisation's strategic goals
#11	Basis for discussions with project owners
#12	Basis for discussion with team members
#13	Inform team members
#14	Inform stakeholders

Table 6 Omega's benefits

Benefit	DTI characteristic Used product life cycle phase(s)	DTI characteristic DTI's relation to the product	DTI characteristic DTI's structure	Benefit category Predetermined / Emerging	Benefit category Strategic / Operational
#1	Development	General	As-is	Predetermined	Strategic
#2	Development	General	As-is	Emerging	Operational
#3	Development	General	Reused	Emerging	Operational
#4	Development	General	As-is	Emerging	Operational
#5	Development	General	As-is	Emerging	Operational
#6	Development	General	As-is	Emerging	Operational
#7	Development	General	As-is	Emerging	Operational
#8	Development	General	As-is	Emerging	Operational
#9	Development	General	Reused	Emerging	Operational
#10	Development	General	Reused	Emerging	Operational
#11	Development, operation, and maintenance	General	Reused	Emerging	Operational
#12	Development, operation, and maintenance	General	As-is	Emerging	Operational
#13	Development, operation, and maintenance	General	Reused	Emerging	Operational
#14	Development, operation, and maintenance	General	Reused	Emerging	Operational

Table 7 Omega's analysed benefits

Table 7 describes Omega's recognized benefits of DTI. The benefits occur in the product's life cycle phase development, but other life cycle phases are also recognized as benefiting from the DTI. The benefits can be viewed as relating to Omega's specific context or be more general, such as 'Develop the organization's language'. The DTI is published during the development phase of the product's life cycle phase, and the table shows that Omega recognizes the main benefits of DTI as occurring in that phase. Omega perceives additional benefits occurring in operation and maintenance phases. For Omega, the recognized benefits all focus on all products, related to one of the underlying functions of the DTI, which is to make the development process general for all Omega's products (general). Omega benefits from the DTI when it is published initially ("as-is") and then benefits from reusing the DTI. Gamma benefits from the DTI when it is published initially ("as-is") and then benefits from manually reusing the DTI. Although the unstructured DTI is Omega gaining from reused DTI, due to co-workers' manual work of synthesizing the DTI. Although Gamma's development of DTI to provide predetermined benefits for the product's life cycle phase development, the main part of their perceived benefits is categorized as emerging. Recognized benefits are mainly categorized as supporting Omega's operation goals, with some benefits adding to the strategic goals.

4.4.9 Measuring benefits at Omega

The respondents discussed how to measure the benefits of the DTI and emphasized it as difficult, since DTI's benefits were viewed intangible.

"It is definitively more candid towards intangible benefits, the things we are gaining; onboarding easily, easy communication" (Head of Program Managers, Omega)

The respondents elaborate on the dilemma with intangible benefits and how they seem to be immeasurable in financial terms. The respondents declare it difficult to get management's attention by solely showing intangible benefits since they want financial outcomes. The respondents have rarely heard about or used any benefit model for measuring digital information with financial outcome. Some respondents discuss how to measure the intangible benefits and solve it by suggesting to measure lost efficiency.

" You could certainly, if I was forced to go back and come back with a calculation that would say that this saves me x amount of time, and the entire group x amount of time because of those are valuable to us. And instead of taking us three weeks to do it, we can finish it in three days." (Program Manager Clients, Omega)

The program manager is on the same path, declaring how to measure efficiency with the newly implemented DTI. He described it the following way:

"Look, before we started to collaborate, we would see that staff would waiting two –three weeks for a decision. They were only working on bugs and we were consistently missing our project deadline by three months, because that is what

happened multiple times in a project. But look, since we started to communicating and collaborating better now our projects are completing on time, and we are not seeing those times overruns and cost overruns. (…) And it is because we communicated the decisions more efficiently, and it is because we are more collaborative." (Program Manager, Omega)

Regardless that the program manager thinks that it is feasible to measure intangible benefits, he declares that other co-workers at Omega might see it as a problem:

"Respondent (R): That is not national hard dollar benefits, you can´t actually show me, so I don´t know."

Interviewer (I): But if you have the hours you can see, use your salary and see the surrounding aspects. This is what we are paying our co-worker by hour here.

R: Even then.

I: I can understand the even then, because of the logic. Is this depending on that?

R: Exactly. You are starting from some individuals might see it as completely an assumption, and sure you can extend that assumption to real dollars. But it is still an assumption versus something that is literally hard measurable. 500 a day, 700 a day." (R: Program Manager, Omega)

An additional way to measure the intangible benefits were by giving operational issues, such as velocity, and referring to how it would increase due to the gained efficiency.

"But other people are tracking velocity. And we do have numbers from before we switched over. So, I think it would be very interesting to look at those two numbers and see which one is higher. As long as you can correct for that there is some learning, you know. You can definitively see the, see how it would be beneficial. (…) So that would be a really good measuring stick too. If we can hit that I would say that this (the implementation of the DTI) has definitively had a financial benefit." (Program Manager Clients, Omega)

The IT manager gives other steps for measuring intangible benefits based on using a software for a specific work task. The initial step included to understand the functional requirements for a specific work task and align those requirements with all the preferred software. The result is the benefits for each software. The next step is to add the cost for the software's license. The combination of the highest rank for functional requirements, added by the cost, results in measurements for each software, which can be used for prioritisation. These steps give another way of measuring intangible benefits with non-financial outputs.

One respondent focuses on the time when the DTI is accessed and refers to the issue of value: that the DTI is solely valuable when it is accessed. That is, DTI has value to the company when it is accessed and hence protecting its accessibility from other companies is also valuable.

"And then there is actual the value of the information that sits out there. It's proprietary information, if it got out, it can be detrimental to the company if our competitors would learn some of the things that we are doing or trying to do. So that sort of value I can´t even put a number on. It is hard to say. [...] It is just invaluable really. You could certainly, if I was forced to go back and come back with a calculation that would say that this saves me x amount of time, and the entire group x amount of time because of those are valuable to us. And instead of taking us three weeks to do it, we can finish it in three days. Three or four days because we can collaborate real-time, and off-line." (Program Manager Clients & Partnership, Omega)

Synthesized from this study is that tangible benefits are viewed as rare, at least the ones where the outputs are in financial terms. The organization articulated ways to measure intangible benefits based on efficiency. Another finding is that there is no straightforward way to use a benefit model since they mainly derive financial outputs. These findings can be of interest for the management level, approaching ways to communicate and compare the benefits. In Omega, the main perception is that measurement is viewed as not doable resulting in financial output.

4.5 Field study

One of the basic purposes of this mixed method study was to create a larger empirical basis compared to the previously few respondents, expressed in the method chapter. The starting point for this study is a qualitative part, forming the foundation findings related to the DTI's relation to the product. Not all DTI characteristics are presented due to logical reasons based on the variation among the respondents. One example is, e.g., the structure of each individual organization's DTI.

The organization for the qualitative part is a trade association for technical information in Sweden, Rho. Rho consists of 23 member organizations, mainly larger manufacturing and consultancy organizations. The manufacturing organizations are all Swedish private businesses and have a DTI department. The consultancy organizations' focus is primarily on DTI, adding areas such as construction and design of Information Systems. Rho is one of the results from the TIC II research project held at Mid Sweden University 2007 – 2014. The organizations are located throughout Sweden, primarily in the metropolitan regions.

Rho is a lively organization which has a board meeting every month, sends out a webinar with the same regularity, and holds an annual public conference. Their vision is to develop the Swedish technical information domain by creating a meeting place for businesses and organizations as well as to improve the status of the sector. They intend to offer meeting places for the sharing of competence and experiences. Rho is divided into several working groups, which focus on, e.g., their annual conference, a research group, education, legal improvements and standards, and a domain group.

Rho's board consists of six members, who all hold middle management roles in various Swedish organizations with either an internal or consultant perspective on DTI in organizations. Of the six members, two represent consultancy organizations and four private businesses, whereas three private businesses are included in the empirical material. A representative from a private organization chose to refrain from being interviewed due to lack of time.

The *first consultancy* organization has 350 employees mainly based in the southern parts of Sweden, but also outside of Sweden. They focus on DTI, software and embedded design, information management, and outsourcing of web development. They view the DTI production process as universal and has therefore a broad approach to the market. Their customers are often focused in the domains of vehicles, drugs, and software. They consider that specific knowledge is needed to create DTI within more technical industries, even though they emphasize a universal production process.

The *second consultancy* organization is based in the southern part of Sweden, has 400 employees, with a 100 located in Sweden. Their customers are global organizations based in Sweden, with focus on the energy- and plant industry. They focus on the production and maintenance of DTI, as well as outsourcing contracts for DTI. In practice this involves understanding the customers' approach to DTI, and where their views differ depending on the products' complexity and the DTI's end users.

The *first private business* is a global manufacturing organization with 44 000 employees with headquarters in Sweden. The global concern is located worldwide and their customers are located within 180 countries. Their main areas are technology, such as compressors, vacuum, mining and quarrying, industrial, and construction engineering. In one of these five business areas 45 out of 7000 co-workers' main work assignments include DTI. They produce DTI, which contains information for all the products' life cycle phases and this is intended for both internal and external customers. The DTI is produced for the products' pilot installation, to prepare for the products' launch by producing safety information and technical market information, operation, maintenance, and recycling.

The *second private business* is a Swedish manufacturing organization with approx. 15 000 co-workers. Their headquarters is based in Sweden and their customers are located around the world. They concentrate on high technology areas in the defence industry, with business areas like defence and security solutions, systems and products as well as aeronautics. The DTI co-workers are located in departments and in supportive roles within various departments. The organization emphasizes the centralized and decentralized ways of organizing the DTI work as an efficient approach to produce DTI systematically for technical complex defence products as well as sustain knowledge related to the products. One central DTI department enrols 85 co-workers, with access to additional 400 co-workers within the organization. The DTI contains information about maintenance, and spare products.

The *third private organization* operates in the transport sector and sells their transport solutions to other businesses. They manufacture transport solutions, such as lorries and buses, and provide service- and maintenance solutions for sold transport units. Their headquarters is located in Sweden and they have approx. 40 000 employees worldwide. The DTI departments follow two of the organizations' business areas, divided by technical specializations. The 90 co-workers at one DTI department produce DTI for maintenance and troubleshooting, which results in maintenance manuals, spare part catalogues, and repair methods. Other work assignments are to set maintenance requirements for product development.

The board members are all based in the southern part of Sweden and work to fulfil Rho's vision. Rho frames DTI as one way for organizations to compete in a multi-national market situation and display how DTI can be presented via new features. In relation to the multi-national market situations new laws and regulations are mentioned, such as the Maskindirektivet (2016) and the importance of adding more values to the products. New information technology is discussed primarily hardware, such as smartphones and 3D CAD models. The respondents' views on the market differs. Some of them see the DTI as being totally dependent on the product. Their view is that the DTI is more attractive when the product is more complicated, and the product's customers are other organizations, the B2B situation. The view on DTI is affected when it is related to cheap products sold to private consumers. The production space is then used for the product and DTI must take the smallest space available, exemplified in this respondent discussion:

"R2 (Respondent 2): I think that, regarding cost, one looks at another set of consumer products. The documentation of consumer products cannot cost anything. They are quite price-sensitive.

Interviewer: Why must they not spend anything?

R2: Yes, it is clear that if you buy a product that costs $ 500 or a thousand dollars, then the documentation may not cost more than the product. Quality gets limited, etc. There is much more focus on security when talking about consumer products. It's like anyone who can buy this.

R1 (Respondent 1): We can say that it's a lot about series production versus non-serial production there.

R2: It can be about serial production as well, but there is not the same price sensitivity if you pay $ 10,000 for a product instead of a thousand. Then you may be able to work on a more in-depth DTI and they may also need it, more information, and so on. And it is susceptible to competition when it comes to products." (R1 is Manager DTI and R2 is Team Manager DTI at a consultancy organization)

The respondents at Rho also show a variation in their internal view of DTI, for a variety of reasons. The consultancy organizations, where DTI is the main product, are naturally favourably disposed towards DTI and discuss the benefits gained. In the private organizations, the internal view of DTI varies. In one of them, DTI is seen as an unnecessary cost, which can be reflected by the fact that low-skilled co-workers in other areas have been moved to the one DTI department. Another private organization increased the status of DTI in recent years by focusing on their internal information architecture. A result of this work is that they have acquired more and more important internal information sources, such as the creation and maintenance of internal and external web publishing. Nowadays, the third private organization has included the aftermarket in its sales role and the result is that DTI is viewed as more and more important.

4.5.1 DTI

Rho is wider in their definition of technical information and does not limit it to DTI, even though the respondents describe it as mostly being digital:

"And I'm convinced, and we also see that the requirements are changing and the market is changing, the support for producing information changes, the equipment for reading information changes and becomes cheaper. Apparently, we are opposed to a much, much more digital management of information than we have had historically." (DTI manager consultancy organization)

Their overall perspective on the DTI is that it is any information related to products, based on the products' life cycle phases. Examples are instructions, educational material related to products, service instructions, and safety information. They clearly and strictly distinguish product-marketing material from DTI, as the latter contains more than strictly factual information about the product. In this case, the DTI can be part of the products' marketing material, which would lead to a less strict explanation of what DTI is. Their view is that DTI can be presented in the form of text, pictures, or film clips.

All organizations emphasize that they have both internal and external users of their DTI. Despite the various user groups, the DTI is intentionally produced for usage by one group, such as a maintenance manual for external users. These manuals are used internally for understanding how to improve product development by focusing on easier maintenance.

The organization's view on DTI varies, where the smallest sub-unit includes manuals, documentation of spare parts, and legal documents to the biggest sub-unit, which is any documentation connected to the product besides marketing material. Some organizations use the word product information and refer to product life management for further explanation of the term. Another view is that DTI is defined by the market situation and how consultancy services can be sold. Interestingly enough is that added to this view is the opinion that it is important to offer consultants interesting work assignments and therefore the view of what is DTI expands. One respondent admits that DTI is defined differently within the organization:

"No, [name of the organization] is a very decentralized company and all business areas, the five business areas, work according to their own set-ups, meaning we have no coordination. We exchange experiences, but we have no common guiding principles. So, what I am talking about now is very much about the department of [department name]. And how it is named and categorized, depends on the persons working in the various departments. "(Board member, Rho besides Manager Product Information at a private organization)

4.5.2 Structure of DTI

The DTI's structure varies across the spectrum of organizations. The consultancy organizations market their way to structure the DTI by using XML, thereby creating efficiency for production, maintenance, and presentation of the DTI. The customers who implement these XML systems are always larger organizations as the investments, both in form of financial and personnel resources, are intensive. The DTI structure varies among the private businesses. Two of the private organizations mainly produce semi-structured DTI, consisting of text, CAD drawings, and other pictures. They differ in the way that the unstructured DTI, the text, is more important to one of them, while the other one focuses on the drawings and facts related to them. The third private organization advocate video films as an important way to structure and present their DTI, and these are mainly used for repairing the products. It is interesting, however, that all respondents paint the potential of future presentations as a way for DTI to get out of its low-status role of today, without using it. They mention augmented reality, virtual reality, and Internet-Of-Things as ways to become attractive, described by one respondent:

"I think we need to make the information more easily accessible and easier to consume. And with the technology available now, it will be much cooler. And then I think it may be much more noticeable that this will happen. Because you think that our mechanics, they need to go training and if you have a digitized delivery to the workshop where they can wear a pair of 3D glasses or watch a movie." (Board member Rho besides Department Manager DTI)

4.5.3 Benefits of DTI

The benefits from the field study are firstly analysed from the qualitative part of the mixed method study and secondly from the quantitative part of the study.

Several respondents give examples of how the service desk or sales situations use the DTI, besides DTI's support for the manufacturing process. The results from the use often decrease the time for individual work assignments, where one example is that the service desk can refer customers to published DTI and by this avoid repetitive work assignments. In general, DTI is adding a knowledge perspective and thereby creating a positive gain for the service desk. There is less need to use co-worker's knowledge as the DTI exists. The sales associates can also use the DTI as an essential knowledge foundation when discussing with possible customers or in sales pitch situations.

"By using the DTI available later in the product life cycle, we have shown that if the sales associates use this DTI performance is increased. We can answer questions such as: What does spare parts sales look like, what accessories do we have if it is sold out. We are perceived as a more competent partner to our customers, and I are getting less wrong." (Manager Product Information, Board member Rho)

One respondent describes how their DTI can be beneficial to the repairmen, especially for the service of more complex machines. They have conducted studies to reduce service time and could cut it by a quarter as they have changed the sequence of service activities and also descriptions of the needed tools. Another respondent focuses on the level of detail and what is best for the user, illustrated by this statement:

"We need to describe a repair method so clearly that the customer doesn't need to return and redo the repair a few days later." (Middle manager DTI department, Board member Rho)

The first question about benefits of the DTI in the quantitative part of the study was whether DTI provides benefits. Initially shown is that only a few of the respondents view DTI as not adding any benefits to their organization. One way of indicating an answer to this question is Figure 10, showing the answer to the question if they think that DTI was merely a cost. The result show that DTI is viewed solely as a cost (77.0 %) followed by partially only a cost by 22.0 %, and 1.0 % DTI only as a cost. This question indicates that DTI is viewed as adding benefits to manufacturing.

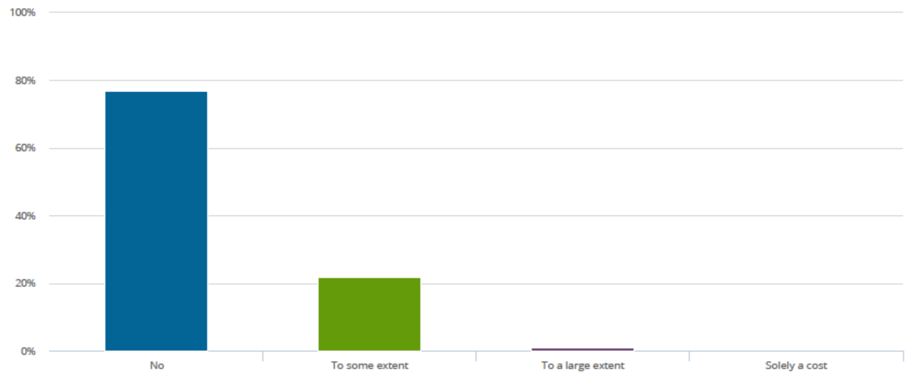


Figure 10 Answers to the question if DTI is only seen as a cost

Presented next is an overall picture of the benefits, based on fixed benefits and a possibility for the respondents to add their own benefits. Figure 11 illustrates that the highest ranked benefit is that of 'Improving the manufacturing process' (73 %), indicating that the strategic view on DTI is fulfilled by using it for internal work in the context of manufacturing organizations. In second place (71 %) is the benefit that 'DTI improves the support situation'. The DTI is used for purposes related to the manufacturing process and by this the DTI can add benefits as a result of the digitization as the information can be can be used by other parts of the organization than simply the manufacturing process.

The third ranked benefit is 'Knowledge transfer' (63 %), expressing that DTI is viewed as a knowledge mediator. Few of the respondents describe DTI as beneficial as their only product information source (14 %). Added benefits are: marketing requirements, time efficiency, finding new components, and legal requirements.

Figure 11 Benefits from survey

Figure 12 emphasizes the importance of DTI for the manufacturing process by showing that 56.7 % declare that they cannot manufacture their products without the DTI, 28.9 % respond partly to the question, 10 % to large parts, and 4.4 % completely. Many organizations' manufacturing processes rely on the DTI, implying its relevance for them. Other organizations rely partially on the DTI; using none or other information for their process.

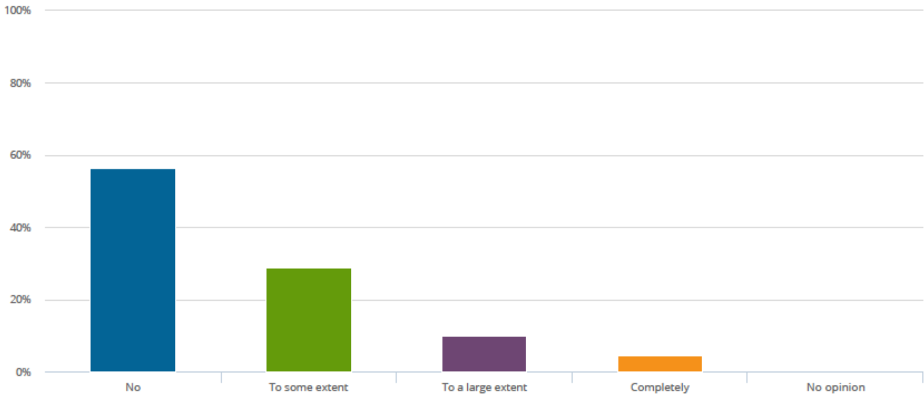


Figure 12 Answers to the question whether the organization can produce their products without the DTI

4.5.4 Relation to product

Several of the interview respondents emphasized the importance of the relation to the product while describing its benefits. Initially, this was brought up by the consultancy organizations, as being one foundation for more interesting and better paid assignments. They emphasized DTI as more beneficial when the relation to the product is based on complex products and sold to other organizations.

"My understanding is that it is related to the same things as I was talking about previously; these (organizations) with complex products and when the products' customers are supposed to be external organizations". (Vice President Product Information, Board member Rho)

The rationale behind this is that a complex product is usually costlier than a less complex one and thereby viewed as more beneficial to the customers and that an organization relies more on their products. These claims were interesting enough to investigate further in the survey and therefore the relation to the product is associated with two questions. Initially investigated was the organization's view on DTI in comparison to the manufactured products, see Figure 13, where the results show that the product is viewed as more beneficial to the organization than the DTI. Secondly investigated was the complexity of the organization's main manufactured products or product groups, see Figure 14.

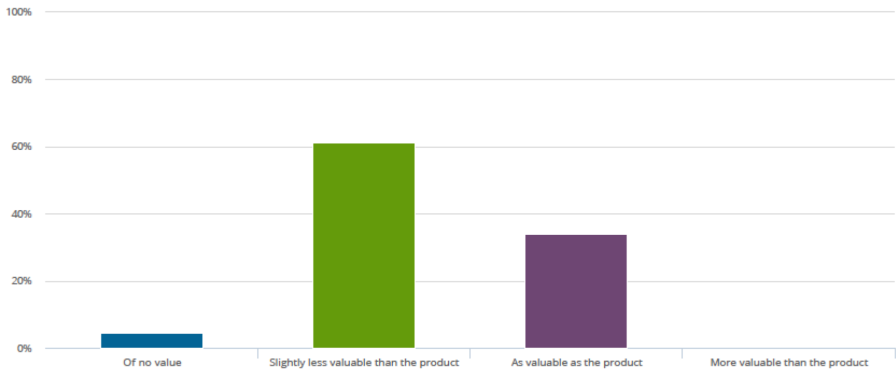


Figure 13 The organization's view on DTI in comparison to the manufactured products

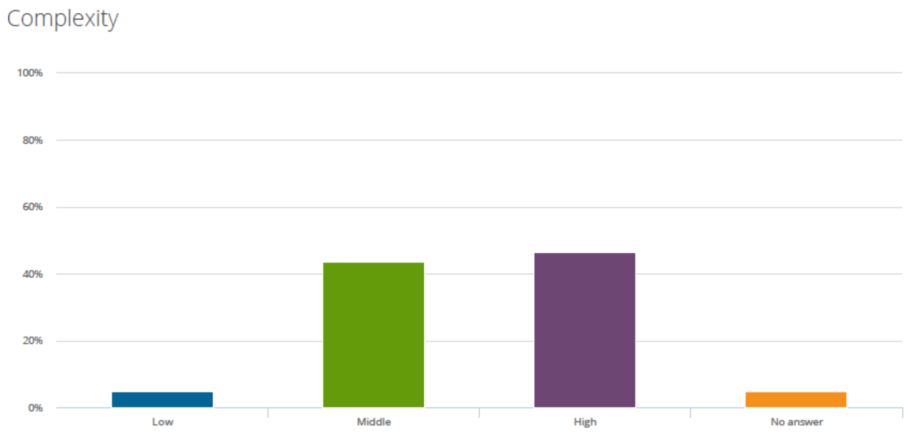


Figure 14 The complexity of the organization's main manufactured products or product groups

Therefore, the hypothesis was tested if the complexity of the product affects the organization's view on DTI. The result shows that there is no such statistical significance despite the perception that there should be. The perception that the complexity of the product influences the view seemed logical at first glance, but could not be verified statistically. The underlying causes may be that this view is incorrect, that the complexity of the product is estimated in the survey, and that there may be a more general positive view of the DTI as stated in the survey.

4.5.5 Measuring benefits at Rho

Discussed with respondents from Rho were general questions about how to measure the benefits of DTI. They view measuring as a problem and comment that the benefits are viewed as intangible and thereby perceived as hard to measure. One explanation for the perception is that the knowledge on how to measure is fundamental but still there is an increased interest in measuring the benefits of DTI. The interest is emphasized as deriving from the increased cost of managing the DTI. One respondent pictures the growing interest as well as the difficulties like this:

"Then, historically, the value of information has not been met. In recent years, these companies have begun to see that information is a vital part of our business. And, you see, we have discussed with CEOs who you ask what is the most important thing for your success? Yes, but there is information. Then it's not just product information, but it's information in general. At the same time, it is seen that there are very few companies that today actually put a true value on the information. That's why the chair and the tables we have in the conference room have greater

value in the company's figures than the information. And there I think there is something that will have to happen as well. You need to put a value on the information to invest in it and put it high on the agenda." (Business Area Manager for Technical Documentation, Board member Rho)

Several respondents emphasize the interest in the DTI as they view DTI as being a part of their brand, especially for business areas where competition is high. Those organizations experience problems with competition and are looking at other ways to earn market shares, despite the difficulties with measuring these intangible benefits.

" I know organizations who are starting to look at the intangible soft values. Obviously, they want their customers to be satisfied, as well as the retailers and their own customer centre selling their products. They need to find information about the products and can serve their customers and so. It's like an intangible benefit." (Business Area Manager for Technical Documentation, Board member Rho)

Another respondent explores their organization's way of dealing with benefits and whether they are measurable or not in a very pragmatic way. The organization does not view measuring the intangible benefits as a path forward since they view it as including ways to distort reality.

"(Benefit) Model? We have an approach, so to speak, that everyone uses. You describe the problem and then the target image and then you need to be pretty hands-on, you must not be too high-flying and just speak empty rhetoric; our bosses do not like that – they want to see reality. They emphasize that everyone can make a PowerPoint, then the next level is to put something in Excel, but the really hard thing is to make a mock-up and show its benefits. They like hands-on!" (Manager Product Information, Board member Rho)

Although the respondents describe DTI's benefits as intangible, they do mention ways of how to measure them. The most common way to measure benefits is by understanding how DTI creates efficiency advantages for the user. Often mentioned is faster ways to maintain or repair a product, searching for DTI, or by improved collaboration ways, depending on the aim for the DTI. In both these ways DTI is viewed as improving efficiency and how to measure is based on that efficiency perspective. One respondent declares some fundamentals for how to measure:

"And indeed, there's actually, it's easy to see which support cases have been received and if you can find the answer in the documentation? Then, you can actually see

how many fewer support cases you get in and take an average value. That piece is pretty simple to count on." (Vice President Product Information, Board member Rho)

Another respondent is on the same path, using almost the same narratives on how to measure. He explains the counting procedure by using efficiency as the foundation for customer support:

"It is all about estimating what the information brings to the organization. E.g. how much time is saved at the service desk? It is actually easy to count solved service cases and to see if the answer to them was found in the documentation. And by this you can compare the number of service cases and find out the differences between various years. The differences are then multiplied by the salaries at the service desk, which is a pretty straightforward way to count on." (Consultant Manager, Board member Rho)

An additional operational way to measure intangible benefits is by looking at the legal aspects; that is, by examining the cost of penalties for the organization when DTI is not delivered on time. Another way to measure is by efficient information architecture. The described information perspective is by structuring the DTI and in this way creating a single-source architecture.

"Where in this process you can reuse the same information. Not only the user documentation, and service documentation and so on without production as presale material, as aftermarket material, as educational material. All this is basically the same information. And then you keep on writing it over and over again. But, in fact, the same information is used, you have to look upon this on a higher level." (Business Area Manager Technical Documentation, Board member at Rho)

The synthesized findings imply that the benefits are viewed as intangible and that there is a somewhat ongoing movement to try to understand how to measure these benefits. The basis for the movement is the picture that the benefits need to be communicated and compared for management purposes. The DTI is viewed as an asset in the organization, but it is troublesome since it has problems to fit into the pattern of being a physical asset creating tangible benefits. The view on measuring the intangible benefits are declared in two ways. Some respondents view measuring as not doable, whereas some view it as doable. The respondents who view measuring as not doable, declare that there are no ways forward to communicate or compare the intangible benefits, whereas the doable path shows ways to communicate and compare. The foundation for measuring is related to efficiency in one or another way and there are limited suggestions on how to measure the benefits in other ways.

4.6 Synthesizing findings from studies

Synthesized in the following sections are the findings from the studies, presented in the following order: the identified benefits; the analysed benefits in relation to DTI's characteristics and benefit categories; and the measurements.

4.6.1 Identifying benefits

Previous research on identifying benefits has focused on the change involving an information system (e.g. by researchers Ward and Daniel (2012) or Brynjolfsson and Hitt (2003)). Identifying the benefits of any category of digital information differs to the identification of the benefits of an information system. One such is the physical identity of any software or hardware and the related cost of implementing it. DTI or any category of digital information is rarely related to any implementation cost. Despite this, the initial attempts to understand the benefits of any category of digital information are related to cost-benefit analysis (Flowerdew & Whitehead, 1975).

Since digital information rarely is associated with a cost, the common way to evaluate DTI shows another focus, namely the reuse of digital information (Vickery, 2011; Wixom, 2014). Vickery (2011) and Wixom (2014) focus on the benefits of the reuse of digital information, both based on a specific category of digital information and any category of digital information. The reuse is either based on what the user can earn by selling services based on digital information or how much an organization can gain from selling digital information. Synthesizing these attempts on identifying the benefits of any category of digital information are that they either use a cost-benefit analysis or the reuse of digital information, neither relating to the internal perspective or DTI.

Koski (2015) elaborates on time as one of the current efforts on understanding benefits of digital information in comparison to the benefits of any information system. She claims it as problematic as using *before* and *after* a change while investigating benefits of any category of digital information. Her argument is that there rarely are any changes related to digital information, such as implementation or adding new functionality. I would argue that there are such points of change, even for digital information. Shown here is that there are production processes attached to the DTI. These DTI production processes can be changed, e.g. in how digitized they are while producing the DTI.

There are several points of interest while looking at the synthesized benefits of DTI. The first is that there are benefits that are common from all studies, such as 'Semantic interoperability' (Ahlin & Saarikko, 2012) and DTI as knowledge foundation (Ahlin & Saarikko, 2013). For the benefit 'Semantic Interoperability' the DTI creates a common language, crossing borders in an organization. The benefit of DTI as a knowledge foundation is expressed in various grades of details, such as Alpha's 'Knowledge base for after-market' or field study's internal knowledge transfer.

Another point of interest is the benefits related context, which focus on an individual organization's business processes. Each study includes gained benefits, which relate to the individual organization's business process. The business process is likely to be the process where the product is either manufactured or produced. One example is Alpha's benefit 'Control and order while manufacturing', relating to the configuration management process or 'The basis for discussion with team members' relating to the initial steps in the development process in Omega. These benefits are both recognized to a contextual business process as well as the product's manufacturing or production process. The DTI co-worker's knowledge is mainly focused on the benefits related to the context, diminishing the path forward for general benefits related to the DTI.

Despite that DTI is part of a manufacturing process, the collaboration around it is low, e.g. compared with the view on internal-external value chains including external customers (Khuntia, Kathuria, Andrade Rojas, & Saldanha, 2017). Their taken stand is that benefits increase when a business process's stakeholders collaborate. Even though there are signs of such collaboration within this thesis's studies, the DTI is often viewed as stand-alone and not included in collaboration. The supporting perspective of DTI is the given and taken role within the manufacturing process. One possible outcome of the low collaboration grade for DTI, could be fewer gained benefits in the business process.

Several researchers claim that benefits are solely derived from immediate use (Balic et al., 2002; Jansen & Rieh, 2010; Moody & Walsh, 1999; Ottersten & Balic, 2010). Focused on in this thesis, are the advantages of DTI not necessarily related to the immediate usage of the DTI. One example of when usage yields direct benefits, is 'Assembling for production'. This benefit derives from reading the assembly instructions and offers instant help for the assembler. Other benefits, such as 'Semantic interoperability' and 'The owner of the DTI does not need to be around all the time' are not necessarily derived from using the DTI. They are identified as benefits and are not necessarily directly related to the usage of the DTI. Hence, I argue that benefits do not solely occur in usage and that there are various ways to understand the relation between use and benefits. One could claim that these benefits, here exemplified by 'Semantic interoperability', occur in discussions between colleagues and are indirect benefits. I would claim that they are direct benefits and do not occur in usage. There is usage involved since there has to be an understanding or knowledge of the DTI, but there is no direct usage involved. A result of this discussion is the importance of time and use, elaborated by e.g. Koski (2015), where one of her claims is that digital information is solely of interest while in use and that the passage of time impacts on the benefits. These calls deepen the request for a deeper understanding of the importance of time while strategizing for the use of benefits.

4.7 Benefits analysed in relation to DTI's characteristics

The identified benefits are first analysed in relation to the declared characteristics of the DTI.

Here, I argue for the importance of aligning the benefits to *the product's lifecycle phases*. The importance of this is based on the finding that the product's life cycle phase where it is published is of importance, while not neglecting the other life cycle phases. One way of using this knowledge is, e.g., while taking any steps towards changing the DTI and involving co-workers from other department(s) than the ones using the published DTI. I argue that the benefits of DTI with respect to the *product* change over time. DTI's relation to the product can start as the relation to an individual product and then move on to general products or product groups by, e.g., summarizing the DTI into statistics for various purposes.

There are several benefits to be derived from the *structure* of the DTI, both from the structured, semi-structured, and unstructured DTI. The structured and semi-structured DTI renders benefits such as statistics, where manual work is needed to gain such benefits from the semi-structured DTI.

4.7.1 Benefits in relation to Product's Life Cycle Phases

DTI's relation with a product's life cycle phases shows the subgroup of one particular activity across one, several, or all of the product's life cycle phases. As an overview, the product's life cycle phases include development, production, maintenance, or destruction (Essamlali et al., 2017; Li et al., 2015; Penciuc et al., 2016). The development phase includes development and ends with delivery to the customer and is viewed as the most resource-intensive of the product's life cycle phases (Li et al., 2015). Production and maintenance include the implementation and use of the product, including elements such as troubleshooting and upgrades. Lastly, the destruction comprises remanufacturing or disassembly of the product into parts and the reuse, refurbishing, or recycling of the parts.

Development

At Alpha, Gamma, and Omega, the DTI is published during the development. One finding is that several of the benefits emerge in this life cycle phase of the product. One example is Gamma where the co-workers gain benefits while using the DTI for assembling purposes. The entire organization at Gamma gains the benefit 'Standardized product development' that should result in uniform products. One example of gained benefits for Omega is that they are described as obtaining benefits in their competence competition for skilled developers, as co-workers can rely on the DTI and work remotely. Even though Beta's DTI is published in a later life cycle phase, there is at least one benefit during this life cycle phase, that of standardized products. Some of the benefits solely refer to this product life cycle phase. Examples of benefits only in the development phase are creating the foundations for collaboration by Omega's project managers while developing the DTI or Gamma's 'Quality assurance', where they found parts of their quality protocol in the DTI. Another benefit is the strengthened collaboration between Omega and their key stakeholders, based on their sharing and discussion of on-going and future product development.

There are several examples where the benefit is hard to be aware of from one of the product's life cycle phases. One example, there are DTI benefits in the product's development phase that act as a knowledge foundation of how to perform certain work assignments in development, manufacturing, and production of the product. In Gamma, the assemblers gain a knowledge foundation based on the DTI and benefit as their need for trial-and-error is reduced while assembling. This knowledge is also valuable while maintaining the product. The benefit 'Semantic interoperability' is derived at Omega as their project managers and developers start discussing how to develop the new functionality and this is useful during other parts of the product's life.

Production, maintenance, and destruction

Beta's DTI is published for the operation and maintenance and they gain the benefit of 'Knowledge base for operations'. Despite the fact that Beta's main benefits are recognized in these product life cycle phases, there are others gained in the development, such as 'Standardized products'. Alpha gain benefit while using the DTI as 'Knowledge base for after-market decisions'. In Gamma, the benefits occur as the customers gain lead-time by ordering spare components themselves. This creates more free time for Gamma's customer support. For Omega, the production and maintenance, is represented by benefits such as 'Easier to trace decisions' and 'Faster on-boarding process for newcomers'. The destruction is rarely represented in this material, mainly due to the focus on the DTI published for development and rarely mentioned by the respondents.

Studies	Development	Production, maintenance, and destruction
All studies	Standardized product production, Semantic interoperability, knowledge foundation	Semantic interoperability, knowledge foundation
Alpha	Control and order while manufacturing	Knowledge base for after-market decisions
Beta	Standardized products	Knowledge base for operations
Gamma	Assembling for production, Knowledge foundation for Quality assurance	Customer gains lead-time
Omega	Knowledge collaboration during idea phase Inform team members	Basis for retro-perspective

Table 8 Illustrations of benefits in the product's life cycle phases

The benefits show a sliding scale related to the product's life cycle phases, where the finding is that the relation between a product's life cycle phases and the gained benefits is not a one-to-one relation. This is shown by differences in what the included DTI covers, e.g. several of the product's life cycle phases or a particular activity within one life cycle phase. This finding contrasts with the strict granularity of the product's life cycle phases in relation to the DTI (Essamlali et al., 2017; Li et al., 2015; Penciuc et al., 2016). These studies show no discussion on a sliding scale for the DTI, merely focusing on the product's life cycle phases.

Table 8 show illustrations of recognized benefits, occurring in the product's life cycle phase where the DTI is published as well as in other of the product's life cycle phases. Previously shown are that the benefits are more numerous in the product's life cycle phase where it is published and the recognition of less benefits in others. It could be obvious that the purpose with the DTI is in the product's life cycle phase where it is published and that the benefits should be more numerous. Interesting are the benefits recognized in other of the product's life cycle phases. The DTI can cover several of the product's life cycle phases and therefore could benefits naturally be recognized in other of the product’s life cycle phases. Co-workers could also use the DTI in other of the product’s life cycle phases, adding to recognized benefits.

The finding that potential benefits from DTI can derive from across the product’s life cycle phases can support organizations in strategically planning revisions across phases to optimize the benefits of DTI. DTI is published at an early stage, and often revised for multiple phases and the lack of overt awareness of life cycle phases can prevent an organization from planning revisions to optimize benefits across the multiple phases. One understanding that can emerge while revising is that deriving benefits across the product’s life cycle phases can be of higher interest than the typical focus on which of the product’s life cycle phases the DTI is published for.

Another point is whether it is essential to include the product’s lifecycle phases as part of the definition of the DTI. From a benefit perspective, these may be unnecessary for analysing the benefits, as they appear to occur regardless of the lifecycle phase for which the DTI is published. One reservation for the removal of the product’s life cycle phases is that most of the benefits arise when the DTI is published, which may facilitate the analysis. A more precise way of expressing this would be to indicate the time of the publishing, supporting one of DTI’s characteristics, instead of explaining these as the product’s life cycle phases and nothing more. I argue for this renewal, thus contributing to a diversified view on the aim for publishing, integrating another time perspective and supporting the gained benefits.

One example of such a focus on a life cycle phase is, therefore, to specify the goals and intentions of the DTI’s publishing process and the time publishing occurs. Related benefits to the organization include a deepened clarity of the DTI’s connection to the product, especially what DTI *can* cover compared to what DTI is *expected* to cover. The focus on the goals of DTI's publishing creates several opportunities for discussion. One opportunity provides clarity about the product’s life cycle phases, which is not questioned in the empirical material of this thesis. Even though the aim for publishing is clear to the respondents, the total use is often broader, including hidden expectations, and making life cycle phases not that distinct.

4.7.2 Benefits in relation to product

The benefits in relation to the product is discussed earlier in research by Schönberg et al. (2011); Wellsandt et al. (2015a), Oevermann and Ziegler (2016), and Bulavsky et al. (2017). They all frame the relation between DTI and its product from different perspectives, e.g. by content, a product's life cycle phase, processes related to the product, or quality. All framings focus on a short part of the DTI's life cycle without elaborating on the changes to the product. Viewed here are several examples of differences in the described relation, both related to *how* and *by whom* the DTI is used.

The benefits' individual relation to the product is transformed into a more general relation that includes more than solely one product; instead, it becomes a relation to a product line or to all products of an organization. The benefits of the DTI are transformed from a singular perspective to a multi-product perspective from the time it is first published to later product life cycle phases, which may exclude some parts of the DTI. Despite that the product's life cycle phases are involved in this transformation, the benefits' individual relation to the product evolves gradually into a multi-product relation.

Synthesized DTI supports the overall product group by including statistics and a knowledge foundation across products in the same product group. Although general relations differ, such as including statistics or a foundation for customer offers, the DTI in each case has changed its relation to the product over time. Because the relation evolves over time, it is of interest to consider DTI's immediate relation to the product along with its long-term relation. The path for discussion within an organization could include multiple areas of focus: such as strategies for use of the changing relation, time aspects for the change, and further relational impact

The transformation from benefits covering a single product to product line or all products, does not occur at one specific point. Because of this variability, the product's life cycle phase can be considered as of low interest concerning the DTI's benefits to the product; the focus can remain fixed on the gain of DTI's benefits. It is essential to discuss the organization's perspectives on DTI's relation to its product while designing and developing the DTI, and not solely when it is initially published by the first user groups. Further, the synthesized DTI is of interest, because there can be information that is excluded from the synthesized version of the DTI. It could be right to exclude certain information at specific points in the process however at a later stage it could be important or even be of interest in future synthesized versions of the DTI to create other benefits.

Several respondents emphasize DTI as more beneficial to the organization when the product is complex and sold to other organizations. The reason for this conclusion was that a more complex product was supposed to be more expensive and add more functionality possibilities to the organization. As the statement is not verified statistically, it is of interest to investigate it further. Other statements in relation to the product could also be of interest to investigate further, such as a competitive market for new products, emphasized by respondents at Gamma. It is of interest to investigate what can affect the benefits of the DTI and then compare factors such as complexity, competitive vulnerability, and what the product is used for (e.g. life-supporting).

4.7.3 Benefits in relation to DTI's structure

The studied DTI cover structured, semi-structured, and unstructured digital information. Several of the respondents emphasized the future structure as being more structured, e.g., for parsing via XML (Bosschaart et al., 2015) of for Machine Learning based on structured information from the Web (Ringsquandl, Lamparter, Lepratti, & Kröger, 2017). What the structured information also provides is the possibility of reuse thus it should be marked with metadata (Tyrvainen & Päivärinta, 1999; Wallace, 2011).

The semi-structured and unstructured DTI could serve as foundation for more benefits due to its broader content. The semi-structured and unstructured DTI can include visualizations and other ways to explain various activities related to the product. Thereby, the user could gain more direct knowledge and the pre-knowledge is lower than for the structured DTI, e.g. described in (Ahlin & Saarikko, 2013). Adding the possibility of visualizations and free text gives greater freedom to create the opportunity for additional benefits compared to structured DTI. However, structured DTI can be used more explicitly and, for example, create a basis for statistics. Here, Alpha is gaining benefits that the other organizations are not getting. Alpha can automatically reuse their DTI for statistics, but the other organizations will have a rougher path to use their DTI for new products, including more manual work and imposition of hands such as searching and clarifying interesting product components. Despite the manual work needed, Beta, for example use their DTI for new products, however the undifferentiated text includes manual work to create statistics.

The structured DTI has more limited content as it rarely involves figures or video clips and is therefore less useful for other purposes than strict implementation. Despite this, there are several studies discussing structured information as the best way forward, along with presentation possibilities via unstructured information. Hence, the work that needs to be done includes the transformation from unstructured to structured, along with associated metadata, adding a cost that has not been considered by management and may be considered as demanding too much resources.
To act on this development is also to act on what has been described as the reuse of DTI by researchers such as Hart-Davidson (2013) or for information in general by Bollacker (2010). The structure could be viewed as important while automatically reusing DTI.

4.8 Analysing categorized benefits

In relation to the digitization, the benefits are categorized as either predetermined or emerging. This distinction refers to the decision of digitizing the DTI, and then delimiting the benefits to either predetermined or emerging after digitization. Ward et al. (1996) emphasize a delimitation between the predetermined and emerging benefits, and suggests they should be found in two different steps, before the pre- and then post-identification. Later, identifying the benefits is viewed as an iterative path by Ward and Daniel (2012). The usefulness of categorizing the benefits into predetermined or emerging could, therefore, be questioned. I would argue that this categorization is of importance for highlighting the benefits of DTI since the knowledge about them is low within organizations. Deciding which benefits should be the predetermined sets a focus for the change, while understanding the emerging benefits provides further development possibilities within the organization. With increased knowledge, the emerging benefits can later be added as predetermined while making other changes.

The predetermination is made on any management level in the organization and before the change. The predetermined benefits are perceived as focusing on the strategic view of the DTI in the various organizations. Besides being strategic, they also follow the manufacturing process where the DTI plays a supportive role. One implication of following the manufacturing process is that the benefits are related to the organization's context. One example is in Alpha, where the 'Tracing of product deliveries' is a fundamental point for the DTI and in Gamma where the 'Standardized product development' and 'Standardized customer product' are fundamental points.

The predetermined benefits relate to a specified change and can be determined (see e.g. Ward and Daniel (2012)), e.g., via a Benefit Dependency Network (Ward & Elvin, 1999). Evident here is that the predetermined benefits are based on strategic reasons. Ward et al. (1996) are on the same path, addressing strategic benefits as being aligned to business goals. Detailing the analysis of predetermined benefits, they are shown as being related to the DTI's supporting role in the organization's specific business sector. This perspective on a strategic benefit is in alignment with studies like Attaran (2001), which claims that strategic benefits are benefits occurring in strategic areas for the specific organization based on the specified resource. Piotrowicz and Irani (2010) address strategic benefits as being immeasurable and the empirical material shows that the benefits are perceived as intangible, while there are described efforts on how to measure them.

The predetermined benefits are recognized as solely based on the DTI as is, not covering any synthesized or aggregated DTI. The decision for changing the DTI could be viewed as squared, and solely discussed in terms of the DTI as is. Understanding and covering other aspects than the DTI as is, could open doors for other opportunities. Here, those opportunities are discovered while working with the DTI or by co-workers' gained knowledge of what the DTI is covering and can be used for in their operational roles. Further digitization of the DTI, such as moving to AR, VR or Industry 4.0 requires a deepened understanding of what benefits can be achieved. This could be achieved by workshops where the design is discussed by a bigger group than solely the co-workers who are relying on the purpose for publishing the DTI. One such example is the design perspective for benefits, investigated by, e.g., Frisk (2011) and Hart-Davidson (2013).

There are several aspects of the emerging benefits. One is that they can fulfil *operational causes*, such as 'Knowledge foundation for quality assurance' in Gamma or the 'Semantic interoperability' or *strategic causes*, e.g. 'Standardized product development' at Beta. Looking at the operational goals, the benefits can be viewed as a result of co-workers' knowledge about the existence of the DTI. They can see how it fills gaps or can see the support possibilities that using it will offer it. Therefore, the DTI is creating benefits that were emerging from the change based on the digitization and based on its place and visibility in the organization. Besides the operational perspective on the emerging benefits, the benefits are recognized as fulfilling strategic goals. There are several examples of this: 'The standardized product development' at Alpha or 'Standardized products' at Beta. All these examples include a management perspective, where the DTI is viewed as adding knowledge to the organization that can be used to achieve other strategic goals than those that were predetermined and can further develop the organization.

Other aspects on the emerging benefits are that DTI is progressing from as is to being developed by the organization. Examples of benefits that just exist are 'Sharing knowledge within the development team', 'Semantic interoperability' in the organization, 'The owner of the DTI doesn't need to be around', and 'Co-workers can work remotely'. There is no one who has made any change to the existing DTI in order for these benefits to be reached and therefore they are seen as if they simply exist. Then, there are the benefits that DTI has developed, which can mean aggregation of the existing DTI or merger with other sources of information. Examples of such benefits are the 'Knowledge base for after-market decisions' within Alpha, 'Education material' in both Beta and Gamma, or 'Basis for retro-perspective' in Omega. As development can take time, the benefit can occur after a while and therefore the DTI should not be viewed as static even though it is published.

The number of emerging benefits is more significant than the predetermined ones and this finding can give a reason to increase knowledge about these benefits. Increased knowledge can give rise to better utilization of the DTI and thus also its benefits. The emerging benefits can be viewed as mainly operational and are creating efficiency for co-workers (Cho & Shaw, 2009; Piotrowicz & Irani, 2010). In contrast to Cho and Shaw (2009); Piotrowicz and Irani (2010) suggest that operational benefits are short-time, for example Gamma's 'Knowledge base for operations', apparently not short-term. The operational benefits can be long-term and linked to that they are developed as services by aggregated DTI. The time perspective then becomes long-term, both in terms of the development of the benefit and its emergence. Another comparison of the studies' operational benefits are that they are not viewed as tangible, in contrast to the opinion of Cho and Shaw (2009) and Piotrowicz and Irani (2010).

Synthesized in Table 9 are approaches to predetermined and emerging benefits. The table's content shows that there are similarities and differences between the predetermined benefits and the emerging benefits. The similarities relate to the perspective on the predetermined benefits, where they are referring to the organization's strategic goals with the DTI and based on existing DTI. The emerging benefits are adding aspects such as operational goals, related to any business process in the organization, and are also used as a service in accordance with other information or in a synthesized way.

Predetermined benefits	Emerging benefits
Related to the organization's strategic goals, and	Related to the organization's strategic or operational goals, and
related to the manufacturing process, and	not specifically related to the manufacturing process, and
based on the DTI as-is	based on the DTI as-is or reused DTI

Table 9 Predetermined and emerging benefits of DTI

4.9 Synthesizing findings of what are the benefits

Here, I address the first research question, which is: ***What are the benefits of the DTI?*** In response to this research question, I describe the benefits as related to the digitization of DTI and the benefits' relation to DTI's characteristics: (a) the product's life cycle phases, (b) the product DTI, and (c) the structure of the DTI.

In this section, I focus on the identification of benefits concerning digitization of the DTI, which can be seen in various grades referring to Figure 1. Simply put, digitization of the DTI refers to any change from handwritten or printed DTI to DTI stored as data from hard copy, including virtual copy moving on to the use of sensors to create the DTI. One finding is that the benefits are derived both through direct and indirect usage of the DTI. A direct benefit is 'Assembling for production' and an example of indirect benefits is 'Semantic interoperability', which is described as beneficial at other occasions than the use of the DTI. These two examples show that it is possible for benefits of DTI to emerge outside of the moment of DTI usage.

Synthesizing the benefits from the studies show that there are commonly recognized benefits of DTI, such as foundations for knowledge, 'Semantic Interoperability', and knowledge transfers in the organizations. In these studies, additional benefits are shown related to the context for the studies, like 'Knowledge base for operations'. Related to the digitization of the DTI, the recognition is that benefits can be predetermined or emergent. Predetermined benefits refer to an organization's understanding of potential benefits and the strategic decisions made by management on any level in the organization. The management's decisions are mainly related to a business process that the DTI is supposed to support. One example of strategic decision-making is when the digitization of DTI directly supports the manufacturing process, such as in Gamma. Emergent benefits can occur at any point during the product's life cycle phases. The emerging benefits mainly relate to fulfilling operational goals, such as 'Quality assurance' at Gamma, and occasionally strategic goals, like 'Standardized product development' at Alpha. The emerging benefits are not solely recognized in the manufacturing or development processes; they can be gained anywhere in the organization. Emerging benefits may result from the existing DTI or from DTI that has been further developed, e.g. by aggregating, synthesizing, or adding information.

Furthermore, the benefits are analysed in relation to the previously found characteristics of DTI. The characteristics are: DTI's relation to the product's life cycle phases, DTI's relation to the product, and the structure of the DTI.
The DTI characteristic product's life cycle phases hold the subgroup of one particular activity, one, several, or all of the life cycle phases. The findings show that most benefits appear in the product life cycle phase where they are published, however benefits continue to emerge in other of the product's life cycle phases. In the studies, the DTI may be published in the development phase and then used in other life cycle phases, such as maintenance. Even though the organization may publish the DTI for one life cycle phase, they continue recognizing benefits by using the DTI in multiple phases. The co-workers in the organization do not care about the original purpose of the published DTI and the related product's life cycle phases: they will use the DTI as long as they can and can gain something from doing so. One example

of this is that Beta's DTI is published for maintenance and operations but used in development as well. Omega is on the same path as Beta, but starts DTI from development and adds the product's life cycle phase of maintenance. The finding emerged that the organizations seem unaware of the life cycle phases, so the DTI yields most benefits in the product's life cycle phase when it is published. The organizations still use DTI in other of the product's life cycle phases, but because it is not published strategically for those phases, it may be less useful than it could be. That is, if organizations were aware of the phases and the different ways that DTI can benefit them differently in different phases, they might publish more strategically and revise DTI for particular activities and life cycle phases. They should include people working in other of the product's life cycle phases when developing DTI so it can be more useful across phases (because, after all, it is already being used across phases!).

The benefits that result from DTI's relation to the product, here declared as either an individual product or a general product group, are mostly directly associated with the product. Some benefits are indirectly related to the product, however, through associated DTI production processes. One example of a direct benefit is Alpha's 'Control and order while manufacturing' and an indirect benefit is Omega's 'The owner of the DTI does not need to be around'.

Several respondents emphasize that the DTI is more beneficial to the manufacturing organization when the product is complex and the external user is an organization, rather than a simple product or one with private users. This statement was not verified statistically based on the organization's data but occurred solely as statements in interviews as informal observations from knowledgeable participants. For the organizations starting with DTI that supports an individual product, this may later transfer to a general group of products, so the benefits also transfer from individual to general, like a product line or several products. That is, in later life cycle phases, the benefits are based on synthesized or aggregated DTI supporting more than solely one product.

The structure of the DTI is described as either structured, semi-structured, or unstructured. Here, the studies include two organizations' DTI as unstructured, one semi-structured, and one structured. Regardless of structure, DTI is linked to activities related to the product, where the structured DTI can require more of its user than the unstructured or the semi-structured, described in Ahlin and Saarikko (2013). The higher requirements are related to the structured and contain logic that the user needs to interpret himself as opposed to the semi-structured or the unstructured, which contains more easily interpreted visualizations. Another way of looking at this is by saying that by not including any visualizations, due to the product's complexity, the structured way is adopted and by its semantics interchangeable with visualizations. The visualizations are one of the main ways forward, efficiently representing the activities to be conducted.

4.10 Synthesising findings related to measuring benefits

Here, I address the second research question, which is: ***What are the perceptions of how to measure benefits of DTI?*** The benefits are perceived as intangible by the respondents, based on their knowledge of how to measure benefits. Some of them mention the lack of a measurement method as a problem and refer to problems with communicating and comparing. These two activities are mainly of concern for management, on any level. The respondents' knowledge of how to measure is limited, and they describe it as few benefit models associated with DTI. The respondents perceive measuring intangible benefits as either not doable or doable. The respondents who describe measurements as not doable are mainly focusing on financial output, reflecting on standard ways to measure benefits. They also reflect upon the DTI as information, not yielding any cost or adding financial incomes. Still, they do reflect on the problematic situation that would arise if the DTI was not accessible and how they could move on without it. These reflections include several scenarios on how to solve the problems, mainly relating to finding knowledgeable co-workers and the cost of not finding them. The respondents who view measuring as doable also discuss problems with the measurement process, such as deciding the goals with measuring, interpreting the input to the measurement process, or how to interpret parts in the measurement process. They describe measuring the benefits of DTI as based on efficiency. They frame measuring as the time they are saving by using the DTI and multiply that with increased income or co-worker's hourly salary. This pragmatic perspective refers to a cost-benefit perspective and does not consider the DTI as a resource that might require other ways of measuring its benefits. Their standpoint is that DTI should be measurable in the same ways as measuring information systems. Looking at the measurement process, they view it as including input, which are the benefits.

The input is measured, here by efficiency, which gives the output in saved hours or cost.

The empirical material shows several findings on how to prepare measurements, where agreeing is the overall part. The findings show that the stakeholders need to agree upon common interpretations, which include a shared understanding of what is viewed as a benefit and what the benefits are. Another interpretation is the purpose of measuring and refers to why the measurement should be conducted. The stakeholders also need to establish common interpretations on how to measure. The measurement process can be hard to conduct if the common interpretations are not in place before starting the process and the whole process becomes more or less worthless, as described in Beta. Added to these details are the requirements for standardized historical measurements to offer historical comparability.

The synthesized findings related to the perception on how to measure the benefits of DTI are:

- The starting point for how to measure is that the benefits of DTI are mainly viewed as intangible, namely they are hard to measure
- The common interpretations on how to measure can include: the goal of the measurement process, what to measure, how to measure, and the benefits should be described in an agreed and comparable manner, in addition that there is a need for historical data to measure and that the historical data is comparable
- The ways to understand how to measure is divided among the respondents as doable or not doable
- The doable perspective on measuring is based on efficiency as the main operational basis for describing how to measure, limiting the view on DTI
- The not doable perspective refers to the lack of financial output

The conclusions from these findings are that the respondents are well aware of the strict division in tangible and intangible benefits, where tangible benefits seem to be the ones in favour of using benefit models. The respondents emphasizing DTI's benefits as not measurable argue for their answers by referring to benefit models. The benefit models available today have given rise to the strict division that exists in tangible and intangible benefits. In order to achieve measurability, the respondents minimize the view of benefit and see it only as efficiency. This is done without any thought that benefit is a multifaceted concept or that it is then merely a type of benefit that is measured. That the discussion that it is merely a view of benefit is used again shows that benefit is a concept that needs to be discussed. It becomes relatively clear here that it will have consequences. The knowledge shown in Ahlin (2019) that there are several ways to measure measurable benefits is not widely known, although the KPIs, for example, is a well-known concept in practice. The view is that it is the financial output that is important, which may have been created by the benefit models.

Previous research has shown that it is vital to agree on the measurement process, and the addition made here is the importance of describing the benefits in the same way. This means that the identification of the benefits is essential as well as how to make comparisons between benefit descriptions, not emphasized earlier. Previous research has shown that the knowledge of identifying benefits is low; the addition here is that granularity is essential. In order to handle comparisons years from now, granularity needs to be an essential part of the agreement from its inception.

5 Discussion

The discussion includes sections related to this thesis's research questions: "*What are the benefits of the DTI?*" and "*What are the perceptions of how to measure benefits of DTI?*" For each research question, the discussion includes synthesized findings and contribution claims describing the specific increase in knowledge in relation to the research questions. I base the arguments on previous research compared to the findings of this study, discussing the implications of each highlighted contribution claim. Further sections describe the implications for academia and practitioners and methodological reflections.

5.1 DTI's benefits

The analysed findings show several benefits of DTI. The analysis revealed that organizations gain most benefits from DTI in the product's life cycle phase when it is published however there are additional benefits in other life cycle phases. Product-related benefits evolve from a focus on individual products to encompassing entire product lines and DTI's structure adds benefits (e.g., while reusing DTI across products) with or without manual work to support the evolution. Another finding is that pre-defined benefits, planned for as part of the change of the DTI, are fewer than emerging benefits. As a result of these findings, I argue for the need of a more systematic benefit management and realization process to ensure that DTI is exploited to its optimal extent , e.g., discussed in Braun et al. (2009) or Ward and Daniel (2012). One important step for a more systematic benefit management is the identification of benefits, initially discussed.

I argue for the importance of the identification of benefits in this thesis' introduction. Braun et al. (2009)'s literature review focuses on research from various parts of steps in the Cranfield Process Model. Their findings show few studies focused on the identification of benefits, which overall attract little interest from researchers. The identification of benefits is the initial step and the one that builds the foundation for the others. To show little interest in this step is therefore surprising and could set traps for coming steps.

Interpretations is one way to identify benefits and it is the way Janssen et al. (2012) conducted their study on the benefits of Open Government Data, and is comparable to this study for DTI. The initiative of understanding and comparing the benefits requires similar granularity for the benefits, meaning that the foundation for the interpretations has to be on the same level of richness. Omega's list of benefits is clearly longer than, for example, Alpha's, indicating that granularity can be problematic when comparing these two lists. By using predetermined benefits, as in this thesis survey, the benefits are just predetermined and reflecting the knowledge by those deciding on the listed benefits.

The interpretation of the word benefit is of importance when identifying benefits. Previous research has shown that the word is imprecise (Breese et al., 2015; Wowor & Karouw, 2012). They explain the meaning as creating satisfaction for the stakeholders, whereas the empirical material here shows that the meaning is changing due to practical matters. The positive advantage is clarified while identifying the benefits of the DTI, while for measurements efficiency is in focus for practical reasons.

Gomes and Romão (2016) suggest one way of identifying the benefits as successful is by either interviewing or organizing workshops with invited stakeholders. For this thesis, the identification was either done via individual or group interviews. The steps are taken in a path to initially get a detailed knowledge of the benefits and to a stepwise overview of what is viewed as the benefits of DTI by the manufacturing industry. There are several pros and cons with the three steps and they are all in accordance with the collecting and analysing of empirical material. One example is that the individual interviews give a rich material for analysing and finding the benefits and is helpful while exploring a new area such as the benefits of DTI, even if it is time-consuming. Gomes and Romão (2016) emphasize that group interviews are helpful when one wants a consensus of which the benefits are of importance, however one loses the individual perspective. For the surveys, the identification of benefits is done before the survey and can add statistical material to previous identified benefits. From now on, the discussion will focus on the recognized benefits of DTI.

An organization decides to publish the DTI in one particular life cycle phase of the product. Although the benefits of DTI are more clearly concentrated in the product's life cycle phase in which the DTI is published, the organization also gains benefits from the DTI in other of the product's life cycle phases. The product's life cycle phases are explicitly described in previous research, e.g. in Product Lifecycle Management (PLM) (Ameri & Deba, 2005; Främling et al., 2014; Penciuc et al., 2016). PLM focuses on the product's *development* phase, relating that focus to a higher demand on resources, such as DTI. The finding here adds to knowledge about the product's life cycle phases and DTI: benefits are not limited solely to the product's life cycle phase where it is published but also are recognized during other of the product's life cycle phases. It is true that co-workers mainly use the DTI when it is published, but they use the DTI in any of the product's lifecycle phases in which it will benefit them. Therefore, in identifying benefits of DTI, it is essential to examine the use and benefits of DTI in all product life cycle phases, not just the product's life cycle phase in which DTI is published.

Benefits from DTI evolve from an individual product to synthesized and aggregated to support products more generally, such as across product lines or all an organization's products. When this change occurs varies. The change may occur based on changing life cycle phases of the product, but may also be prompted by the changing requirements of users of the product. For example, at Alpha, this change occurs somewhat in response to the changing life cycle phases of the product but also due to a request from co-workers to support internal needs. At Gamma, previously, the decisionmaker used the DTI as is (see e.g. Huang and Tsai (2011)) or relating to a specific activity, such as logistics (see e.g. Bougdira et al. (2016)). Evolution occurs as the result of a request from both internal and external users. The pattern to focus initially on individual products, followed by change into a more general relation with additional products or product lines gives knowledge into the organization's use of the DTI. This is in contrast to the static view on DTI's benefits and the relation to the product, described in Persson Slumpi et al. (2012) and Ahlin (2014). As a result of the evolvement in the relation to the product, planning for synthesizing or aggregating the DTI can add benefits during the product's life-time and serve as a foundation for decision-making, such as described in Alpha.

There are more emerging benefits than predefined ones in the findings, which can imply that DTI has a somewhat hidden, unexploited potential for management. The emerging benefits can be found via post-evaluations (Ward and Daniel, 2012). There is no self-fulfilment that the benefits should be predetermined, but the predetermined could get more attention from management since they mainly relate to strategic goals in the organization. Gaining knowledge about the emerging benefits could open up for other predefined benefits than initially intended. Koski (2015) believes post-evaluations of any category of digital information to be problematic, whereas there seem to be possibilities to conduct such evaluations. She argues for the lack of change related to digital information, opposite to the argument in this thesis. Those evaluation add the chance to find both predetermined and emerging benefits. The empirical material shows no evidence of conducting evaluations, neither before nor after the change. Solely implementing systematic evaluations procedure with informed co-workers could increase existing and future benefits and develop the DTI.

The emerging benefits can compromise of synthesized or aggregated DTI, opening up for the possibilities of reuse of the DTI. The emerging benefits fulfil operational goals based on co-worker knowledge. The co-workers know the content of the DTI as well as how they can use it to gain operational goals. The reuse of the DTI sheds light on DTI's structure, where, e.g., the structured DTI in Alpha can result in reused DTI. This reuse is conducted automatically and is easier to handle than reusing the DTI than for example in Beta and Omega. Nevertheless, co-workers at Beta and Omega take on the burdensome assignment and reuse the DTI manually. The findings show focus on the content reuse (Hart-Davidson, 2013; Priestley, 2001), despite wishes to change this by adding the information architecture perspective, using XML. The freedom of including other data to build more complex DTI could increase by using XML structures, responding to additional knowledge requirements and adding benefits.

5.2 How to measure the benefits

The analysis of how to measure the benefits revealed the importance of common interpretations when initiating the measurement process. The analysis shows DTI's benefits perceived as intangible, however one way mentioned to measure those benefits was limited to those showing efficiency. As a result of these findings, I argue for the possibilities to implement more efficient measurement processes as one way of evaluating DTI's benefits.

The initiation of the measurement process highlights common interpretations as important, both when it comes to the empirical material and previous research (Ljungberg & Larsson, 2012; Lycett & Giaglis, 2000). There are some slight differences in the interpretations that refer to the specific context. One added interpretation in this context is the common understanding of the word benefit.

The respondents refer to DTI's benefits as intangible and hard to measure. The analysis shows two paths for how to measure the intangible benefits. One path concentrates on DTI's benefits as not measurable, when reflecting financial output. Ward and Daniel (2012) suggest several steps for the output. Their scale ranges from observable to financial and includes explained explicitness as adding value and the degree of future improvement. The respondents' scale from not measurable to financial includes no other steps, limiting the view on the output.

The other path focuses on the benefits that add efficiency which can be measured. The respondent understands efficiency as saving costs, such as co-worker's time. This path limits the benefits that can be measured and does not include the benefits interpreted as not creating efficiency. The change from understanding a benefit as, e.g., creating a positive advantage to creating efficiency is done without any reflection by the respondents. They want to fulfil the goal of measuring the benefits in financial terms without reflecting on this change. Wowor and Karouw (2012) discuss the blurry approach to the term benefit, and the failure to reflect on it while measuring benefits. They relate the blurriness to the stakeholders involved. Here, the blurriness refers to pragmatism while finding ways to conduct an action. Synthesizing the perception of DTI's benefits as intangible with the pragmatic path forward as measuring it as efficiency shows contradiction. Not only does it limit the included benefits; it also limits the ways to measure benefits.

Both Wixom (2014) and Ahlin (2019) show ways of measuring intangible benefits. The first approaches data as a commodity with a price, and the second investigates ways to measure intangible benefits. Ahlin (2019) shows different ways to measure the intangible benefits. My research base on the benefits that we describe as immeasurable proves them to be measurable, not particularly reflecting benefits of DTI or digital information Wixom (2014)'s path of selling the DTI, could be a path forward, used by organizations providing DTI for external users. The respondents' show a narrow scope, not recognizing those ways of measuring DTI's benefits. There could be several reasons for that, such as that there are few voices for understanding DTI's benefits, the proven low knowledge on ways to measure DTI's benefits or low interest in adding another administrative process in the organization (Hu et al., 2006). The argument for how to measure DTI's benefits shows a discrepancy between the varying perceptions among the respondents on how to measure and the present knowledge within academia (Ahlin, 2019). The discrepancy indicates a knowledge gap and also a variation in the view on how measurement should be conducted.

5.3 Thesis contribution

This thesis contributes to the sparse research about DTI's benefits by identifying them and investigating the perceptions of how they can be measured. The work is a continuation of the licentiate thesis (Ahlin, 2014), which provided some glimpses of the benefits. Here, the licentiate thesis is built upon and broadened analysing the recognized benefits through multiple DTI characteristics and benefit categories. To make benefits more visible throughout an organization, co-workers need to be able to systematically evaluate the benefits of DTI to communicate them to other departments or administration. Hence, perceptions of how to measure are described here. The contributions are divided into practice and academia.

Initially, this thesis contributes to *practice* by demonstrating simply that DTI does indeed bring benefits, based on positive advantages that impact the work roles of employees of an organization as well as for the organization itself. That there are benefits from DTI should not be a surprising finding, as it is frequently used in organizations for a variety of reasons. Nevertheless, this argument has not been articulated previously based on empirical material from several studies. Further, this thesis contributes to practice by emphasizing DTI's benefits as either related to an organization's context, such as its specific manufacturing process, or general benefits, such as knowledge transfer or semantic interoperability.

The identified benefits reveal the possibility for a more systematic evaluation process, requiring knowledge from informed co-workers, e.g., the ones using DTI, or information architects. One contribution shows the concentration of benefits which occurs when the DTI is published, as well as the ongoing benefits present throughout a product's life cycle phases. This contribution implies that requirements for new or changed DTI should not solely be provided by co-workers directed related to its publishing; other co-workers also gain from the DTI and have an interest in its design. Another observation is the realisation that the benefits evolve: first benefitting individual products but progressing to general product lines or all products. This implies that organizations can design the structure of the DTI to more readily evolve from fulfilling the immediate need to providing data that supports future organizational endeavours. The DTI is often reused, even though such attempts are modest. Nevertheless, the move to reuse is rapid. It takes place as soon as the digitization has started, implying that co-workers can see immediate benefits of sharing the DTI within, and sometimes even outside, the organization. The emerging benefits are perceived as numerous, mainly relating to operational goals as well as strategic ones, and can be either the DTI in itself or the way it is used as a service. Other parts of the organization can use benefits that emerge as a result of the DTI, meaning benefits have come about due to the particular structure of procedures within an organization or commonly found across multiple organizations. Adding the knowledge about the identified DTI in organizations implies broadening the scope for informed co-workers to participate when evaluating and developing the DTI.

Included in the evaluation process is measuring the benefits (Ward & Daniel, 2012). Previous research and this thesis emphasize the importance of common interpretations, such as what to measure, how to measure, and access to sufficient resources, like historical measurements for comparison (Ljungberg & Larsson, 2012). This thesis showed that the perception of how to measure differed among the respondents. They perceive measuring DTI's benefits as not doable or doable. The not doable attitude is the belief that benefits are intangible, do not focus on financial outputs and that there are no ways to measure them. The doable perception is described as measuring the intangible benefits solely in terms of increased efficiency, thus limiting our perception of them, while at the same time academia shows various ways of measuring intangible benefits (Ahlin, 2019). These contributions add to the need for a systematic evaluation process of DTI's benefits and mean that the organization can make more informed decisions, e.g. while designing or developing the organization's DTI.

In academia, the evaluation process of DTI has not been in focus. One reason could be the view on the change of DTI, which is one fundamental factor for the evaluation process, see e.g. Ward and Daniel (2012). Researchers, such as Koski (2011) and Remenyi et al. (2007), describe the change as hard to find and thereby evaluate. Here, I contribute by showing that DTI can relate to various grades of digitalization and the possibility to recognize benefits rapidly.

The identification of benefits has not been in focus in research, see, e.g., Braun et al. (2009) and especially not in the identification of DTI. The identification here is done either via interviews or surveys. In contrast to, e.g., Balic et al. (2002) Ottersten and Balic (2010), the studies in this thesis, such as that at Alpha, show that benefits do not solely occur in usage and that there are various ways to understand the relation between DTI's use and its benefits. One such way is shown here, which distinguishes between direct and indirect usage of the DTI. That is, there is usage involved since there has to be at minimum an understanding or knowledge of the DTI, but benefits can still occur when no direct usage is involved.

Several of DTI's recognized benefits cover more than one of the product's life cycle phases, described in studies such as Gamma. Previous research describes a strict granularity of the product's life cycle phases in relation to the DTI (Essamlali et al., 2017; Li et al., 2015; Penciuc et al., 2016). The contrast in this thesis adds to an understanding of the product's life cycle phases, at least in relation to DTI's benefits. This contribution increases the perspective on the product's life cycle phases, reflecting on how to improve it for DTI's benefits, by, e.g., using a gliding scale.

Previous research discusses DTI's benefits as intangible, e.g. Dicks (2003), meaning that they are hard to measure. Ward and Daniel (2012) use a scale for measuring benefits and Ahlin (2019) shows that there are in fact ways to measure intangible benefits. Therefore, this thesis contributes by challenging the very concept of intangible benefits, and suggests that intangible is not the same as immeasurable. For academia, this adds to the understanding of the concept and induces further understanding of it.

The perceptions of how to measure benefits show the importance of common definitions as to the characteristics or results make something a benefit. The knowledge of how to measure differs between practice and academia: practice views measuring DTI's benefits as either doable or not doable; academia views measurement as merely difficult. The first limits focus on increased efficiency due to the benefit and the second requires evidence of financial outcome from a measurement process. Academia describes measurement processes with both financial and non-financial outcomes (Ahlin, 2019). This broader focus contradicts previous research and the perception in the studies. It is therefore of interest for academia to further investigate how to measure DTI's benefits, e.g. in various contexts.

5.4 Implications

My findings have implications for both practice and academia. In practice, managers responsible for DTI can more strategically manage and design the DTI, and implement an evaluation process by identifying benefits and deciding how best to measure them. For the evaluation process, there are possibilities for change, such as the gradual digitalization of the DTI.

The identification of the benefits provides several ways to understand them, such as the impact of DTI's benefits for achieving operational goals. This and other findings imply several formal ways of managing the DTI and thereby making more informed decisions. Another implication is the emerging benefits, which could be found in iteratively conducting post-evaluations with informed co-workers knowledgeable about operational goals. Besides this, is that the DTI is changing time-wise concerning the product as well as the gain of benefits in other of the product's life cycle phases than the published one. Both of these findings imply that the design of the DTI and the evaluation of DTI's benefits should involve a broad spectrum of co-workers, not solely those with the most frequent use of the DTI. The structure is of specific interest while looking at the design of the DTI, since the co-workers put effort into reusing the DTI, even when it is unstructured.

The investigated measurement process provides a variety of implications for practice, such as managing and developing the DTI. The contribution to the first part of the measurement process helps to avoid several problematic situations by describing how to handle necessary common interpretations, such as the understanding of the term benefit and how to measure. Further, the lack of knowledge of ways to measure DTI's benefits implies a need to increase knowledge on how to measure, especially the view on defining the term benefit while measuring. The contributions entail that practice can test and elaborate on various ways to measure DTI's benefits for further comparison possibilities. Another implication is the ways described to measure the so-called intangible benefits. The foundation for this knowledge is not simply the DTI, and an adjustment to DTI should, therefore, be of interest to investigate.

For *academia*, the contributions with measurement show that the category *intangible*, referring to immeasurable, can be questioned. The respondents' narrow perspective on measuring intangible benefits is supplemented by a systematic finding that there is a broader spectrum possible, such as a scale. The implication of this finding could be the fade away from the category of intangible and approaching a less distinct concept. The basis on which we describe intangibility is, therefore, a topic to investigate further.

The view on DTI as relating to a product and its life cycle phases is questioned here when it comes to DTI's benefits and the product's life cycle phases. For academia, this implies that our perspective on the product's life cycle phases can differ, like here, for a specific activity such as identifying benefits. The concept of the product's life cycle phases can, therefore, be further analysed concerning activities, where one suggestion is to refer to the specific activity instead of using the previous strict granularity.

5.5 Method

The Information System field rarely covers the area of concern in this thesis: DTI's benefits. As such, overall methodological choices could vary as there is no existing paradigm within this specific area. Looking at research into benefits, both qualitative and quantitative approaches are suitable, depending on the specific area. The overall focus is on interpretation of empirical material to start building a knowledge foundation, putting aside, e.g. a critical approach. The downside with interpretations is the problematic nature of making generalizations claimed by Klein and Myers (1999). One general idea with research is to create knowledge; there are minor doubts that even interpretative research follows the idea of abstraction and generalization. This thesis follows Polit and Beck (2010), who focus on adding understanding from descriptions of specific contexts. For this thesis, the descriptions about DTI, as well as their benefits, are in focus as the thesis covers a broad field like DTI in manufacturing organizations and thereby creating few generalizations or abstractions.

Qualitative assumptions have affordances and constraints. That is, some constraints include that only a few voices can be heard, comparing benefits based on those few voices, and being constrained in using follow up questions for a broader understanding (Alvesson, 2011; Patton, 2002). Of interest, therefore, was to gather additional perspectives, allowing for more voices, through a quantitative approach. I found mixed methods to be a good choice for this part of the thesis. The first part meant qualitatively creating a basis for the quantitative section and using this basis for designing questions for the survey. Unfortunately, web surveys usually do gather low response rates nowadays, mainly due to resource problems and fatigue and lack of interest in answering web surveys (Wagner et al., 2017). The authors discuss how to increase the response rate by adding telephone answers to increase the final response rate. This step was taken in the quantitative part of the mixed method to increase the response rate.

The selection of respondents included a focus on both variety of organizations and the respondent group of co-workers from each organization. When looking for organizations, all organizations chosen were to include manufacturing or the broader production of various types of products. The number of manufacturing organizations is significant, even if one is only looking within Sweden. Another perspective of the organizations was their contribution to the context, assumed to be described by their individual emergence (Klein & Myers, 1999). Here, there is a plain description of each context based on the respondents' views. These views solely describe the individual study's context as a background and have few critical notes. For the synthesized picture of DTI in manufacturing, this thesis consists of a foundation of DTI's role in manufacturing organizations as both DTI and manufacturing are of a broad variety. A complementary view could have been to conduct longitudinal studies for a broader and deeper understanding of a particular context, such as a specific manufacturing domain.

The homogeneity among the organizations is several. One, previously described, is their focus on the manufacturing process. Added to this can be that they are traditional in their organizational foundations using various organizational levels and departments. Thereby, they rely on DTI for internal purposes, such as manufacturing or selling services for maintaining the products. The business process for manufacturing is therefore of importance while recognizing DTI's benefits, and as such, the business processes and its activities are varying among the organizations. Another homogenous part is that the organizations are large in their individual business' segment. That could affect what is recognized as 'Semantic Interoperability' since the distance between all co-workers is more extensive than in small organizations. The organizations have to be small to reach to all co-workers, affecting their language in a standard way instead of the DTI. The new homogenous part is that all of the organizations' DTI intentionally is published for one of the product's life cycle phases, affecting the perspective on the DTI and who can affect it. The perspective on the DTI is that it belongs to a specific part of the manufacturing process and that the co-workers related to the manufacturing process are those that should affect it, despite the findings showing other results.

The organizations are all private businesses, which could have impacted the outcome when it comes to what is viewed as a benefit and the perception of how to measure. In an official authority could benefits, adding positive advantages, been viewed differently. Having the same precondition, like the manufacturing industry, could mean that the DTI in an official authority had another origin than fulfilling customer requirements. One such could be to fulfil a law or citizen requirements. Another aspect of the choice of organizations is that the respondents all claimed that efficiency was the way to measure financial outputs, affecting the view on benefits. Again, using official authorities manufacturing products could impact, e.g., the view on how to measure, including the perspective of gaining citizens.

The geographical location of the organizations could impact the result. The perspective on DTI in Omega is slightly different compared to the other organizations. Omega does include project estimations in their DTI, adding organizational resource allocation to it. One could say that it connected to the product's development, still adding a detail which mainly is viewed as belonging to other parts of the organization, such as human resource planning. The stricter view on what could be viewed as DTI in the other organizations could origin from perspectives from the trade association for DTI or the Maskindirektivet (2016).

For the second selection, that of the respondent group from each organization, it includes mainly middle managers. The rationale for this selection is their knowledge of different parts of the organization, such as the higher level or operational level, referring to a traditional organizational structure. Besides being middle managers, they are DTI users, or working closely with DTI users. Therefore, the middle managers are viewed as having the knowledge of what benefits the DTI users recognizing from the DTI. Focusing on the manufacturing organization they represent; their individual and synthesized answers give voices to the organization's perspective. It is important to remember however that their voices are voices of individuals within organizations and not the total representation of the organization's perspectives as a whole.

Klein and Myers (1999) stress one part of qualitative research as that of multiple interpretations. For interpretative research, this is discussed regarding understanding conflicts related to values by examining influences from the social context. The norms and values in organizations and departments vary, depending on e.g. organizational culture. On an overall thesis level, the goal with multiple interpretations is attached to the usage of various organizations for the included studies, and even by using respondents from various organizations in the last study. Despite this, there is a dilemma in the choice of responding organizations for research, as they tend to be positively interested in the research problems, especially as participants in a research project. The multiple interpretations can, therefore, be hard to get hold of. Here, one included study, #2, gives the opposite view of DTI's role in organizations.

Klein and Myers (1999) describe the interview situation as social interaction, which could be described by the respondent's and interviewee's changed opinion. For this thesis, there are some glimpses of the critical reflection, based on the description of the researcher's increased knowledge about both the domain area of DTI as well as how to conduct research. The critical reflection on the interview situation, rarely described in the Information Systems field, is occasionally mentioned here. One situation is for example at Beta, where the three initial interviews had a few interesting stories to tell about the DTI and its benefits. Therefore, two interviews were added to this study. Another problem in this thesis is the individual work of the researcher and thereby the problem to get feedback on the social interaction and the interviewer's impact.

The analysis was mainly conducted by the researcher working alone, thus creating continuity throughout the thesis but adding a few additional interpretations. The studies have all been analysed in a circling back and forth to add interpretations by the researcher, based on the human understanding regularly moving from the small parts to the overall picture (Klein & Myers, 1999). Built into this process of analysing material for a thesis are several quality checkpoints which added those additional perspectives. Such input came from supervisors, knowledgeable external auditors within the field, and other knowledgeable researchers. One part covered in the analysis is the DTI and its characteristics. Despite covering a broad range of digital information, the coverage here has its limitations. The limitations are, for example, product's life cycle phases, whereas the broad range could be pointed out as including the broader scope of manufacturing organizations. Despite these limitations and the broad range, the chosen DTI does fall within the frame of what is viewed as DTI.

6 Conclusions

This thesis aimed at describing the benefits of Digital Technical Information (DTI), in the context of manufacturing organizations. The problem related to this aim was founded in DTI as commonly used information firmly attached to a product and the organization's internal focus on the product. Understanding the benefits could, therefore, be one way forward to develop and manage the DTI further. The following research questions govern this thesis:

What are the benefits of the DTI?

and

What are the perceptions of how to measure benefits of DTI?

The identified benefits show that there is need for a systematic identification process, including knowledge relating to when the DTI is published and beyond as well the aim for publishing the organization's strategic and operational goals with the manufacturing process. Primarily shown is that there are benefits from DTI, both shared benefits, such as knowledge transfers within the organization and benefits related to the context of the organization's manufacturing process. The benefits are further analysed in the context of the product's life cycle phases, the product, the DTI's structure, predetermined/emerging, and strategic/operational goals. The product's life cycle phases show that most benefits are recognized in the product's life cycle phase when the DTI is published, however it continues to offer benefits in other of the product's life cycle phases. The benefits' relation to the product does evolve during time, initiated as supporting an individual product and evolving to support a product line or all products in the organization. The structured DTI adds benefits, such as synthesized DTI used for reaching the organization's strategic goals. The emerging benefits are often made use of by the organization's informed co-workers, who use DTI for supporting work tasks from a knowledge perspective.

The perceptions of how to measure the benefits of DTI show that there is a knowledge gap between academia and the findings. There is a common understanding on the initial phase, highlighting common interpretations. These include, e.g., how to interpret what counts as a benefit, what is considered for measurement, and what is the goal of measuring. Furthermore, DTI's benefits are perceived as intangible, however research shows various ways to measure them. The findings show two views on measuring: the doable and not doable. The doable path is that benefits can be measured while they show efficiency, limiting the benefits that can be measured. The not doable path is based on the view that intangible benefits cannot be shown in financial terms.

The thesis contributes to research about DTI where practitioners can gain by managing, developing, and formally evaluating the benefits. The formality of understanding the benefits and measurements could imply that the DTI can be compared and communicated. The research gives foundation for a systematic evaluation by showing how to identify DTI's benefits, where, e.g., the contribution of all co-workers using DTI is of importance. In addition, it is shown that there is a knowledge gap with regard to the measurement process, which can be remedied by research showing that there are ways to measure DTI's benefits. For academia, the thesis contributes by the discussion on the perspective of intangible benefits, which can be questioned by research showing that intangible benefits can be included in a measurement process.

6.1 Future research

This thesis provides several implications for future research. One such proposal is to continue to work to understand how to identify benefits. This thesis describes several successful ways to identify DTI's benefits such as via interviews or surveys. The problem with granularity is also discussed, e.g., when comparing benefits across organizations or for evaluation purposes. The level of granularity differs, e.g., based on the conducted interviews and the following analyses. One example is the number of found benefits as well as the level of details. Understanding how to approach granularity could open up for studies collecting more empirical data than, e.g., in this thesis.

Another proposal for future research is to further investigate DTI's benefits in terms of its characteristics. Here, the findings show that there are variations in the benefits related to the characteristics, such as the relation to the product and the product's life cycle phases. The DTI characteristics are not well investigated in previous research, and therefore a deepened investigation could add to our understanding of the complexity by giving more interesting details to the development of the DTI. Further understanding of the relation to the product and the product's life cycle phases and adding the perspective of reuse could give rise to interesting benefits as well as developing new services based on the DTI.

The third proposal for future research is the understanding of intangible benefits. Emphasized in previous research, e.g. in Kim et al. (2010), is the problems of measuring intangible benefits. In Ahlin (2019), I show several ways of measuring intangible benefits by desktop research. For example, Ward and Daniel (2012) use a scale from observable to financial for describing how a benefit can be measured. Therefore, is it of interest to further investigate intangible benefits. Examples of interesting research focus are if there are any intangible benefits or if a scale approach, such as Ward and Daniel (2012)'s, is the appropriate way forward.

A fourth proposal for future research is to continue the work with measuring the DTI's benefits, described both in this thesis and in Ahlin (2019). The conclusions from these two sources do not offer any support in the choice of a particular organization or context. What is revealed is a profound knowledge among the respondents on how to measure DTI's benefits, which suggests that there could be possible ways forward. Of interest could, therefore, be to design measurement methods for DTI benefits based on requirements from organizations in various contexts and test the designed measurement methods. The measurement methods could thereby be evaluated, and knowledge increased in organizations. Ways to conduct such studies could be by using Design Science Research (DSR) (Hevner, March, Park, & Ram, 2004) and designing measurement methods based on organizations' requirements. Another approach is using a mixed method research design. Therefore, I call on further research for understanding how to measure DTI's benefits, such as the impact of the context when it comes to choosing measurement process.

References

Addo-Tenkorang, R., Helo, P. T., & Kantola, J. (2017). Concurrent enterprise: a conceptual framework for enterprise supply-chain network activities. *Enterprise Information Systems, 11*(4), 474 - 511. doi:DOI: 10.1080/17517575.2016.1212274

Aerts, G., Smits, T., & Verlegh, P. (2017). How online consumer reviews are influenced by the language and valence of prior reviews: A construal level perspective. *Computers in Human Behavior, 75*, 855-864. doi:https://doi.org/10.1016/j.chb.2017.06.023

Ahlemann, F., Hesselmann, F., Braun, J., & Mohan, K. (2013). *Exploiting IS/IT Projects' Potential - Towards A Design Theory For Benefits Management.* Paper presented at the ECIS 2013, Utrecht.

Ahlin, K. (2013). *Värdeadderande aktiviteter i produktionsprocessen av TI och tillhörande effektivitetsmätningar*. Retrieved from Mid Sweden University Östersund: http://www.diva-portal.org/smash/get/diva2:667757/FULLTEXT01.pdf

Ahlin, K. (2014). *Approaching the Intangible Benefits of a Boundary Object.* (Licentiate thesis). Mid Sweden University, Östersund.

Ahlin, K. (2018). *Design and test of a measurement method for the benefits of technical information.* Paper presented at the IRIS/SCIS Conference 2018, Denmark, 5-8 August 2018.

Ahlin, K. (2019). *Measuring the immeasurable? The intangible benefits of digital information.* Paper presented at the 52nd Hawaii International Conference on System Science, Grand Wailea, Mahui.

Ahlin, K., & Ingelsson, P. (2013). *Information management, Lean and efficiency – are we focusing on the customer?* Paper presented at the Proceedings 16th Qmod conference on Quality and Service on Sciences ICQSS 2013, Portoroz, Slovenia.

Ahlin, K., & Saarikko, T. (2012). *A semiotic pespective on semantic interoperability*. Paper presented at the The 35th Information Systems Research Seminar in Scandinavia – IRIS 2012, Sigtuna, Sweden.

Ahlin, K., & Saarikko, T. (2013). *Exploiting Information: Seeking Long-term Preservation of organisational knowledge.* Paper presented at the 22nd Nordic Academy of Management Conference, 21-23 August, 2013.

Ahlin, K., & Slumpi, T. P. (2015). *A Communication-model for Intangible Benefits of Digital Information*. Paper presented at the American Information Systems Conference 2015, Puerto Rico.

Ahlin, K., Slumpi, T. P., & Öberg, L.-M. (2013). Nyttan med CM. In M. Eriksson & L.-M. Öberg (Eds.), *Configuration Management i teknikinformationens tjänst:-en antologi*. Sundsvall: Mittuniversitetet.

Ahlin, K., & Åslund, A. (2014). *Rapport KATI Utveckling och test av arbetsmetod för identifiering av nytta och värde i produktionsprocessen i framtagande av teknikinformation* (KATI - 2). Retrieved from Mittuniversitetet Östersund: urn:nbn:se:miun:diva-23813

Alvesson, M. (2011). *Intervjuer - genomförande, tolkning och reflexitivitet*. Malmö: Liber.

Alvesson, M., & Sköldberg, K. (2008). *Tolkning och reflektion - Vetenskapsfilosofi och kvalitativ metod*. Lund: Studentlitteratur.

Ameri, F., & Deba, D. (2005). Product lifecycle management: closing the knowledge loops. *Computer-Aided Design and Applications, 2*(5), 577 - 590. doi:10.1080/16864360.2005.10738322

Arduin, P.-E., Le Duigou, J., Abel, M.-H., & Eynard, B. (2015). Knowledge Sharing in Design Based on Product Lifecycle Management System. In *ICoRD'15–Research into Design Across Boundaries Volume 2* (pp. 507-517). New Dehli: Springer.

Attaran, M. (2001). The coming age of online procurement. *Industrial Management & Data Systems, 101*(4), 177-181. doi:https://doi.org/10.1108/02635570110390080

Bader, S., & Oevermann, J. (2017). *Semantic Annotation of Heterogeneous Data Sources: Towards an Integrated Information Framework for Service Technicians.* Paper presented at the 13th International Conference on Semantic Systems September 11–14, 2017, Amsterdam, Netherlands.

Bailey, S. (2011). Measuring the impact of records management; Data and discussion from the UK higher education sector. *Records Management Journal, 21*(1), 46-68. doi:https://doi.org/10.1108/09565691111125107

Balic, M., Berndtsson, J., Ottersten, I., & Aldman, M. (2002). *From Business to buttons.* Paper presented at the DS 30: Proceedings of DESIGN 2002, the 7th International Design Conference, Dubrovnik.

Bannister, F., & Connolly, R. (2014). ICT, public values and transformative government: A framework and programme for research. *Government*

Information Quarterly, 31, 119 - 128. doi:https://doi.org/10.1016/j.giq.2013.06.002

Barthelmey, A., Lenkenhoff, K., Schallow, J., Lemmerz, K., Deuse, J., & Kuhlenkötter, B. (2016). Technical documentation as a service–An approach for integrating editorial and engineering processes of machinery and plant engineers. *Procedia CIRP, 52*(1), 167-172. doi:10.1016/j.procir.2016.07.070

Basahel, A., & Irani, Z. (2010). *Examining the strategic benefits of information systems: A global case study*. Paper presented at the European, Mediterranean & Middle Eastern Conference on Information Systems 2010 (EMCIS2010) April 12-13 2010, Abu Dhabi, UAE. http://bura.brunel.ac.uk/handle/2438/4306

Batini, C., Cappiello, C., Francalanci, C., & Maurino, A. (2009). Methodologies for data quality assessment and improvement. *ACM computing surveys (CSUR), 41*(3), 16. doi:https://doi.org/10.1145/1541880.1541883

Baysal, M. M., & Roy, U. (2014). *Consistency of Assembly Related Product Information: Part 1—Representation.* Paper presented at the ASME 2014 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, August 17–20, 2014 Buffalo, New York, USA.

Bengtsson, M. (2016). How to plan and perform a qualitative study using content analysis. *NursingPlus Open, 2*(2016), 8-14. doi:https://doi.org/10.1016/j.npls.2016.01.001

Berg, B. L. (2009). *Qualitative Research Methods for the Social Sciences* (7th ed.). Boston: Pearson Education.

Bernabei, G., Sassanelli, C., Corallo, A., & Lazoi, M. (2014). A PLM-Based Approach for Un-manned Air System Design: A Proposal. In *International Workshop on Modelling and Simulation for Autonomous Systems* (pp. 1-11): Springer.

Best, D. P. (2010). The future of information management. *Records Management Journal, 20*(1), 61-71. doi:https://doi.org/10.1108/09565691011039834

Bhattacharya, P. J., Seddon, P. B., & Scheepers, R. (2010). *Enabling Strategic Transformations with Enterprise Systems: Beyond Operational Efficiency.* Paper presented at the Thirty First International Conference on Information Systems, St. Louis 2010.

Bhimani, A., & Willcocks, L. (2014). Digitisation,'Big Data'and the transformation of accounting information. *Accounting and Business*

Research, 44(4), 469-490. doi:https://doi.org/10.1080/00014788.2014.910051

Boland, R. J., & Tenkasi, R. V. (1995). Perspective Making and Perspective Taking in Communities of Knowing. *Organization Science, 6*(4), 350-372. doi:https://doi.org/10.1287/orsc.6.4.350

Bollacker, K. D. (2010). Avoiding a Digital Dark Age. *American Scientist, 98*(2), 106 -110.

Bosschaart, M., Quaglietta, E., Janssen, B., & Goverde, R. M. (2015). Efficient formalization of railway interlocking data in RailML. *Information Systems, 49*(April 2015), 126 - 141. doi:https://doi.org/10.1016/j.is.2014.11.007

Bossen, H., & Ingemansson, J. (2016). *Digitalisering av svensk industri - Kartläggning av svenska styrkor och utmaningar*. Retrieved from Vinnova: https://www.vinnova.se/publikationer/digitalisering-av-svensk-industri/

Bougdira, A., Ahaitouf, A., & Akharraz, I. (2016). *Cloud of things-based decision-making process using product's traceability*. Paper presented at the 2016 2nd International Conference on Cloud Computing Technologies and Applications (CloudTech), London.

Bowker, G. C., & Star, S. L. (1999). *Sorting Things Out - Classification and its consequences*. Cambridge, USA: MIT Press.

Braun, J., Ahlemann, F., & Riempp, G. (2009). Benefits Management - a literature review and elements of a research agenda In H. R. Hansen, D. Karagiannis, & H.-G. Fill (Eds.), *9. Internationale Tagung Wirtschaftsinformatik* Vienna, Austria.

Breese, R., Jenner, S., Serra, C. E. M., & Thorp, J. (2015). Benefits management: Lost or found in translation. *International Journal of Project Management, 33*(7), 1438–1451. doi:https://doi.org/10.1016/j.ijproman.2015.06.004

Brynjolfsson, E. (1993). The Productivity Paradox of Information Technology. *Communications of the ACM, 36*(12), 67-77.

Brynjolfsson, E., & Hitt, L. M. (2003). Computing productivity: Firm-level evidence. *Review of economics and statistics, 85*(4), 793-808. doi:https://doi.org/10.1162/003465303772815736

Bryson, J. M., Crosby, B. C., & Bloomberg, L. (2014). Public Value Governance: Moving Beyond Traditional Public Administration and the New Public Management. *Public Administration Review, 74*(4), 445–456. doi: https://doi.org/10.1111/puar.12238

Buckland, M. K. (1991). Information as Thing. *Journal of the American Society for Information Science (1986-1998); Jun 1991; 42, 5; ABI/INFORM Global, Jun* (42), 351. doi:https://doi.org/10.1002/(SICI)1097-4571(199106)42:5<351::AID-ASI5>3.0.CO;2-3

Bulavsky, P., Belozerov, V., Groshev, G., Vasilenko, M., Yefimenko, Y., & Gordon, M. (2017). *Estimation of time parameters of electronic document management.* Paper presented at the East-West Design & Test Symposium (EWDTS), 2017 IEEE, Novi Sad.

Bytheway, A. (2014). *Investing in Information - The Information Management Body of Knowledge*. Switzerland: Springer.

Carmi, E., Oestreicher-Singer, G., Libai, B., & Yassin, O. (2011). *Assessing value in product networks*. Paper presented at the International Conference on Information Systems, Orlando Florida.

Carter, M., Petter, S., & Randolph, A. B. (2015). *Desperately Seeking Information in Information Systems Research* Paper presented at the Thirty Sixth International Conference on Information Systems, Fort Worth.

Changchit, C., Joshi, K. D., & Lederer, A. L. (1998). Process and reality in information systems benefit analysis. *Information Systems Journal, 8*(2), 145 - 162. doi:https://doi.org/10.1046/j.1365-2575.1998.00031.x

Chircu, A. M., & Kauffman, R. J. (2000). *Limits to Value in Electronic Commerce-Related IT Investments.* Paper presented at the 33rd Hawaii International Conference on System Sciences, Hawaii.

Cho, W., & Shaw, M. J. (2009). *Balancing the strategic value and the operational value in it portfolio selection.* Paper presented at the AMCIS 2009 Proceedings.

CODEX. (2016). CODEX - rules and guidelines for research. Retrieved from http://codex.vr.se/en/index.shtml

Creswell, J. (2007). *Qualitative Inquiry & Research Design - Choosing Among Five Approaches* (Second ed.). Thousand Oaks: Sage.

Creswell, J. (2014). *Research Design Qualitative, Quantitative and Mixed Methods Approaches Fourth Edition* (Fourth ed.). Los Angeles: Sage.

Creswell, J., & Clark, V. P. (2011). *Designing and Conducting Mixed Methods Research* (2nd ed.). Thousand Oaks, CA: SAGE.

Cui, A. S., & Xiao, Y. (2019). The role of market and technical information generation in new product development. *Journal of Product Innovation Management, 36*(3), 305-330. doi:https://doi.org/10.1111/jpim.12479

Dahlbom, B., & Mathiassen, L. (2017). A Scandinavian View on ACM's Code of Ethics. Retrieved from http://courses.cs.vt.edu/professionalism/WorldCodes/ACM.Commentary.html

Dameri, R. P. (2012). *Defining an evaluation framework for digital cities implementation.* Paper presented at the International Conference on Information Society (i-Society 2012), London, UK.

Davison, G., Murphy, S., & Wong, R. (2005). *The use of eBooks and interactive multimedia as alternative forms of technical documentation. I.* Paper presented at the In Proceedings of the 23rd annual international conference on Design of communication: documenting & designing for pervasive information Coventry, United Kingdom.

DeLone, W. H., & McLean, E. R. (1992). Information Systems Success: The Quest for the Dependent Variable. *Information Systems Research, 3*(1), 60-95. doi:https://doi.org/10.1287/isre.3.1.60

Dicks, R. S. (2003). *Management Principles and Practices for Technical Communicators* Boston, MA: Pearson Longman.

Digital, I. X. (2015). IEEE/IET Electronic Library (IEL). Retrieved from http://innovate.ieee.org/documents/11249/68852/IEL+2015+sale+sheet.pdf/fc0108db-2fab-4fdb-bc84-068d0ec7857b

Durão, L. F. C., Haag, S., Anderl, R., Schützer, K., & Zancul, E. (2018). *Digital twin requirements in the context of industry 4.0.* Paper presented at the IFIP International Conference on Product Lifecycle Management.

El-Chaar, J., Boer, C., Pedrazzoli, P., Mazzola, S., & Dal Maso, G. (2011). *Interactive 3D virtual environments for industrial operation training and maintenance.* Paper presented at the Reliability, Maintainability and Safety (ICRMS), 2011 9th International Conference.

Elberse, A. (2008). Should you invest in the long tail? *Harvard Business Review, 86*(7/8), 88.

Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of advanced nursing, 62*(1), 107-115. doi:https://doi.org/10.1111/j.1365-2648.2007.04569.x

Erlingsson, C., & Brysiewicz, P. (2017). A hands-on guide to doing content analysis. *African Journal of Emergency Medicine, 7*(3), 93-99. doi:https://doi.org/10.1016/j.afjem.2017.08.001

Essamlali, E., Taha, M., Sekhari, A., & Bouras, A. (2017). Product lifecycle management solution for collaborative development of Wearable

Meta-Products using set-based concurrent engineering. *Concurrent Engineering, 25*(1), 41-52. doi:https://doi.org/10.1177/1063293X16671386

Evans, G. E., & Riha, J. R. (1989). Assessing DSS effectiveness using evaluation research methods. *Information & Management, 16*(4), 197-206. doi:https://doi.org/10.1016/0378-7206(89)90037-2

Federici, T. (2007). *ERPs in SMEs: Ex-Post Evaluation of Success Factors.* Paper presented at the ECIS, St. Gallen, Switzerland.

Fitterer, R., Rohner, P., Mettler, T., & Winter, R. (2010). *A taxonomy for multi-perspective ex ante evaluation of the value of complementary health information systems-applying the unified theory of acceptance and use of technology.* Paper presented at the 2010 43rd Hawaii International Conference on System Sciences.

Flowerdew, A., & Whitehead, C. (1975). Measuring the benefits of scientific and technical information. *Economics of Informatics, Amsterdam: Elsevier/North-Holland*.

Frisk, E. (2007). *Categorization and overview of IT evaluation perspectives - A literature review*. Paper presented at the ECIME 2007: The European Conference on Information Management and Evaluation, University Montpellier 1.

Frisk, E. (2011). *Evaluating as a Design – Towards a Balanced IT Investment Approach.* (Doctor Thesis). IT-university, Gothenburg.

Frisk, E., Bannister, F., & Lindgren, R. (2015). Evaluation of information system investments: a value dials approach to closing the theory-practice gap. *Journal of Information Technology, 30*(3), 276-292. doi:https://doi.org/10.1057/jit.2014.9

Främling, K., Kubler, S., & Buda, A. (2014). Universal messaging standards for the IoT from a lifecycle management perspective. *IEEE Internet of things journal, 1*(4), 319-327. doi:10.1109/JIOT.2014.2332005

Gattullo, M., Uva, A. E., Fiorentino, M., Scurati, G. W., & Ferrise, F. (2017). From paper manual to AR manual: do we still need text? *Procedia Manufacturing, 11*, 1303-1310. doi:https://doi.org/10.1016/j.promfg.2017.07.258

Giaglis, G., Mylonopoulos, N., & Doukidis, G. (1999). The ISSUE methodology for quantifying benefits. *Logistics Information Management, 12*(1/2), 55-62. doi:https://doi.org/10.1108/09576059910256259

Giaglis, G., Paul, R., & O'Keefe, R. (1999). *Combining Business and Network Simulation Models for IT Investment Evaluation.* Paper presented at the 32nd Hawaii International Conference on System Sciences, Hawaii.

Gomes, J., & Romão, M. (2016). Improving project success: A case study using benefits and project management. *Procedia Computer Science, 100*, 489-497. doi:https://doi.org/10.1016/j.procs.2016.09.187

Gregor, S. (2006). The nature of theory in information systems. *MIS Quarterly, 30*(3), 611-642. doi:10.2307/25148742

Gupta, M. P., & Jana, D. (2003). E-government evaluation: A framework and case study *Government Information Quarterly, 20*(4), 365 - 387. doi:https://doi.org/10.1016/j.giq.2003.08.002

Hallikainen, P., Kivijärvi, H., & Nurmimäki, K. (2002). *Evaluating Strategic IT Investments: An Assessment of Investment Alternatives for a Web Content Management System.* Paper presented at the 35th Hawaii International Conference on System Sciences, Hawaii.

Hart-Davidson, W. (2013). What are work patterns of technical communication? . In J. Johnson-Eilola & S. A. Selber (Eds.), *Solving problems in technical communcation*. Chicago: The University of Chicago Press.

Helms, R. W. (2002). *Product data management as enabler for concurrent engineering.* (Doctor thesis). Research School for Operations Management and Logistics, Eindhoven Technical University, Eindhoven.,

Hendricks, K. B., Singhal, V. R., & Stratman, J. K. (2007). The impact of enterprise systems on corporate performance: A study of ERP, SCM, and CRM system implementations. *Journal of operations management, 25*(1), 65-82. doi:https://doi.org/10.1016/j.jom.2006.02.002

Hennink, M. M. (2014). *Focus Group Discussions - Understanding Qualitative Research*. Oxford: Oxford University Press.

Hermann, M., Pentek, T., & Otto, B. (2016). *Design principles for industrie 4.0 scenarios.* Paper presented at the 2016 49th Hawaii international conference on system sciences (HICSS).

Hevner, A. R., March, S. T., Park, J., & Ram, S. (2004). Design Science in Information Systems Research. *MIS Quarterly, 28*(1), 75-105. doi:10.2307/25148625

Hitt, L. M., & Brynjolfsson, E. (1996). Productivity, business profitability, and consumer surplus: three different measures of information technology value. *MIS Quarterly*(2), 121-142. doi:10.2307/249475

Hsieh, H.-F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative health research, 15*(9), 1277 - 1288. doi:https://doi.org/10.1177/1049732305276687

Hu, Q., Frisk, E., Eikebrokk, T. R., Hallikainen, P., Päivärinta, T., & Nurmi, A. (2006). *IT Investment evaluation: Why hasn´t it beecome an organizational routine?* Paper presented at the 14th European Conference on Information Systems, Gothenburg Sweden.

Huang, S.-L., & Tsai, Y.-H. (2011). Designing a cross-language comparison-shopping agent. *Decision Support Systems, 50*(2), 428-438. doi:https://doi.org/10.1016/j.dss.2010.10.004

Huang, X. (2012). *Function-Based Categorization of Online Product Information Types.* Paper presented at the Americas Conference on Information Systems 2012, Seattle.

Ilshammar, L., Bjurström, A., & Grönlund, Å. (2005). Public E-Services in Sweden Old Wine in New Bottles? . *Scandinavian Journal of Information Systems, 17*(2), 11-40.

Ingelsson, P., Löfstedt, U., Bäckström, I., & Öberg, L.-M. (2015). Taking a Holistic Perspective on Technical Communication and Lean. Quality Innovation Prosperity, vol. 19: 2, pp. 103-122. . *Quality Innovation Prosperity, 19*(2), 103 - 122. doi:http://dx.doi.org/10.12776/qip.v19i2.608

Jacks, T., Palvia, P., & Schilhavy, R. (2011). A framework for the impact of IT on organizational performance. *Business Process Management Journal, 17*(5), 846-870. doi:https://doi.org/10.1108/14637151111166213

Jamous, N., Bosse, S., Görling, C., Hintsch, J., Khan, A., Kramer, F., . . . Turowski, K. (2016). *Towards an IT Service Lifecycle Management (ITSLM) Concept.* Paper presented at the Enterprise Systems (ES), 2016 4th International Conference.

Jansen, B. J., & Rieh, S. (2010). The Seventeen Theoretical Constructs of Information Searching and Information Retrieval. *Journal of the American Society for Information Science and Technology, 61*(8), 1517–1534. doi:https://doi.org/10.1002/asi.21358

Janssen, M., Charalabidis, Y., & Zuiderwijk, A. (2012). Benefits, Adoption Barriers and Myths of Open Data and Open Government. *Information*

Systems Management, 29(4), 258 - 268. doi:https://doi.org/10.1080/10580530.2012.716740

Johnson-Eilola, J., & Selber, S. A. (Eds.). (2013). *Solving problems in technical communication*. Chicago: The University of Chicago Press.

Kagermann, H. (2015). Change through digitization—Value creation in the age of Industry 4.0. In *Management of permanent change* (pp. 23-45): Springer.

Kaner, C., & Bond, W. P. (2004). *Software Engineering Metrics: What Do They Measure and How Do We Know?* Paper presented at the 10th International Software Metrics Symposium, METRICS 2004.

Karjalainen, A., Päivärinta, T., Tyrvainen, P., & Rajala, J. (2000). *Genre-based metadata for enterprise document management.* Paper presented at the 33rd Annual Hawaii International Conference on System Sciences.

Kawalek, J. P., & Jayaratna, N. (2003). Benchmarking the process of "interpretative" research in information systems *Benchmarking: An International Journal, 10*(4), 400 - 413. doi:https://doi.org/10.1108/14635770310485006

Khallaf, A. (2012). Information technology investments and nonfinancial measures: A research framework. *Accounting Forum, 36*, 109 - 121. doi:https://doi.org/10.1016/j.accfor.2011.07.001

Khuntia, J., Kathuria, A., Andrade Rojas, M. G., & Saldanha, T. (2017). *Supply Chain Information Integration and Firm Performance: Evidence from India.* Paper presented at the AMCIS, Boston, Massachusetts, USA.

Kim, K., Kim, K., & Kang, K. (2010). Valuation on the Intangible Benefits of EVMS using CVM. *Journal of Asian Architecture and Building Engineering, 9*(1), 221-228. doi:https://doi.org/10.3130/jaabe.9.221

Klein, H. K., & Myers, M. D. (1999). A set of principles for conducting and evaluating interpretive field studies in Information Systems. *MIS Quarterly, 23*(1), 67 - 94. doi:10.2307/249410

Koski, H. (2011). *Does Marginal Cost Pricing of Public Sector Information Spur Firm Growth?* Retrieved from http://www.etla.fi/wp-content/uploads/2012/09/dp1260.pdf:

Koski, H. (2015). *The Impact of open data – a preliminary study*. Ministry of Finance publications 15b/2015

Krauth, E., Moonen, H., Popova, V., & Schut, M. C. (2005). *Performance Measurement and Control in Logistics Service Providing*. Paper presented at the ICEIS, Florida, USA.

Kvale, S., & Brinkmann, S. (2014). *Den kvalitativa forskningsintervjun*. Lund: Studentlitteratur.

Langefors, B. (1995). *Essays on Infology*. Lund: Studentlitteratur.

Lee, A. S., & Baskerville, R. L. (2003). Generalizing Generalizability in Information Systems Research. *Information Systems Research, 14*(3), 221-243. doi:https://doi.org/10.1287/isre.14.3.221.16560

Lee, S., Ma, Y., Thimm, G., & Verstraeten, J. (2008). Product lifecycle management in aviation maintenance, repair and overhaul. *Computers in Industry, 59*(2-3), 296 - 303. doi:https://doi.org/10.1016/j.compind.2007.06.022

Legner, C., Urbach, N., & Nolte, C. (2016). Mobile business application for service and maintenance processes: Using ex post evaluation by end-users as input for iterative design. *Information & Management, 53*(6), 817-831. doi:https://doi.org/10.1016/j.im.2016.03.001

Li, J., Tao, F., Cheng, Y., & Zhao, L. (2015). Big data in product lifecycle management. *The International Journal of Advanced Manufacturing Technology, 81*(1-4), 667-684. doi:https://doi.org/10.1007/s00170-015-7151-x

Li, Y., Huang, J., & Song, T. (2019). Examining business value of customer relationship management systems: IT usage and two-stage model perspectives. *Information & Management, 56*(3), 392-402. doi:https://doi.org/10.1016/j.im.2018.07.012

Liebenau, J., & Backhouse, J. (1990). *Understanding Information - An Introduction*. London: Macmillan Information Systems.

Lieu, D. K. (2009). Techniques for creating animations for technical presentation. *Engineering Design Graphics Journal, 68*(1).

Livian, Y.-F., & Burgoyne, J. G. (2005). *Middle Managers In Europe*. London and New York: Routledge.

Ljungberg, A., & Larsson, E. (2012). *Processbaserad verksamhetsutveckling Varför - Vad - Hur?* Lund: Studentlitteratur.

Longo, B., Fountain, T. K., Johnson-Eilola, J., & Selber, S. (2013). What can history teach us about technical communication. In (pp. 165-186): Chicago: University of Chicago Press.

Love, P. E., Irani, Z., & Edwards, D. J. (2004). Industry-centric benchmarking of information technology benefits, costs and risks for small-to-medium sized enterprises in construction. *Automation in Construction, 13*(4), 507-524. doi:https://doi.org/10.1016/j.autcon.2004.02.002

Love, P. E., Matthews, J., Simpson, I., Hill, A., & Olatunji, O. A. (2014). A benefits realization management building information modeling framework for asset owners. *Automation in Construction, 37*, 1-10. doi:https://doi.org/10.1016/j.autcon.2013.09.007

Lubell, J., Peak, R. S., Srinivasan, V., & Waterbury, S. C. (2004). *STEP, XML, and UML: complementary technologies.* Paper presented at the ASME 2004 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference, Salt Lake City, Utah, USA.

Lucky, M., Pasini, D., & Spagnolo, S. L. (2019). *Product Data Management for Sustainability: An Interoperable Approach for Sharing Product Data in a BIM Environment.* Paper presented at the IOP Conference Series: Earth and Environmental Science, Milan, Italy.

Luftman, J. (2000). Assessing Business-IT Alignment Maturity. *Communications of the AIS, 4*(14), 99-128. doi:10.4018/978-1-59140-140-7.ch004

Lundegård, R. (1998). *Information Management in Construction Projects: Current Practices and Guidelines.* (Doctor Thesis). Chalmers University of Technology, Göteborg.

Lundin, J. (2015). *Designing technical information: Challenges regarding service engineers' information-seeking behaviour.* (Licentiate thesis). Mälardalens högskola, Västerås.

Lundin, J. (2020). *Shaping thought through action: A study of the use and design of technical information.* (Doctoral Thesis). Mälardalen University,

Lycett, M., & Giaglis, G. (2000). *Component-Based Information Systems: Toward a Framework for Evaluation.* Paper presented at the 33rd Hawaii International Conference on System Sciences, Hawaii.

Magoulas, T., & Pessi, K. (1998). *Strategisk IT-management.* (Doctor Thesis). Göteborgs Universitet, Göteborg.

Marnewick, C. (2016). Benefits of information system projects: The tale of two countries. *International Journal of Project Management, 34*(4), 748-760. doi:https://doi.org/10.1016/j.ijproman.2015.03.016

Marotta, V., Zhang, K., & Acquisti, A. (2015). *The Welfare and Allocative Impact of Targeted Advertising.* Paper presented at the Thirty Sixth International Conference on Information Systems, Fort Worth.

Marra, M., Di Biccari, C., Lazoi, M., & Corallo, A. (2018). A Gap Analysis Methodology for Product Lifecycle Management Assessment. *IEEE*

Transactions on Engineering Management, 65(1), 155-167. doi:10.1109/TEM.2017.2762401

Maskindirektivet. (2016). Maskindirektivet. Retrieved from http://www.sis.se/en/theme/maskinsakerhet/Maskindirektivet/

Maxwell, J. A. (2012). *Qualitative research design: An interactive approach* (3rd ed.). Thousand Oaks, CA: Sage publications.

Mcloughlin, S., Scheepers, H., & Wijesinghe, R. (2014). *Benefit Planning Management for ITSM: Evaluating Benefit Realization Frameworks.* Paper presented at the 25th Australian Conference on Information Systems ITSM 8th -10th Dec 2014, Auckland, New Zealand.

Meißner, A., & Schnepp, W. (2014). Staff experiences within the implementation of computer-based nursing records in residential aged care facilities: a systematic review and synthesis of qualitative research. *BMC medical informatics and decision making, 14*(1), 54. doi:https://doi.org/10.1186/1472-6947-14-54

Moody, D. L., & Walsh, P. (1999). *Measuring the Value Of Information-An Asset Valuation Approach.* Paper presented at the European Conference on Information Systems, Copenhagen, Denmark.

Murphy, K. E., & Simon, S. J. (2001). *Using Cost Benefit Analysis for Enterprise Resource Planning Project Evaluation: A Case for Including Intangibles.* Paper presented at the 34th Hawaii International Conference on System Sciences - 2001, Hawaii.

Müller, S. D., & Skau, S. (2014). Success Factors Influencing Implementa--tion of E---government at Different Stages of Maturity: A Literature Review *International Journal of Electronic Governance, 7*(2), 136 - 170. doi:10.1504/ijeg.2015.069495

Nelson, H. J., & Nelson, K. M. (2003). *IT: What's It Good For?* Paper presented at the 36th Hawaii International Conference on System Sciences, Hawaii.

Niknam, M., & Ovtcharova, J. (2013). *Towards Higher Configuration Management Maturity.* Paper presented at the IFIP International Conference on Product Lifecycle Management.

Noffsinger, R., & Chin, S. (2000). Improving the delivery of care and reducing healthcare costs with the digitization of information. *Journal of Healthcare Information Management, 14*(2), 23-30.

Norzaidi, M. D., Chong, S. C., Salwani, M. I., & Lin, B. (2011). The indirect effects of intranet functionalities on middle managers' performance:

Evidence from the maritime industry. *Kybernetes, 40*(1), 166 - 181. doi:10.1108/03684921111117988

Oevermann, J., & Ziegler, W. (2016). *Automated intrinsic text classification for component content management applications in technical communication.* Paper presented at the ACM Symposium on Document Engineering, Vienna, Austria.

Ottersten, I., & Balic, M. (2010). *Effektstyrning av IT : nyttan uppstår i användningen*. Solna: Liber.

Otto, B. (2012). Managing the business benefits of product data management: the case of Festo. *Journal of Enterprise Information Management, 25*(3), 272 - 297. doi: https://doi.org/10.1108/17410391211224426

Papadopoulos, T., & Kanellis, P. (2007). eGovernment initiatives and ex-ante IT investment evaluation. *AMCIS 2007 Proceedings*, 99.

Parker, M. M., Benson, R. J., & Trainor, H. E. (1988). *Information Economics Linking Business Performance to Information Technology*. Englewood Cliffs: Prentice-Hall.

Patton, Q. M. (2002). *Qualitative Research & Evaluation Methods* (3rd ed.). Thousand Oaks: Sage Publications.

Penciuc, D., Le Duigou, J., Daaboul, J., Vallet, F., & Eynard, B. (2016). Product life cycle management approach for integration of engineering design and life cycle engineering. *AI EDAM, 30*(4), 379-389. doi:https://doi.org/10.1017/S0890060416000366

Peppard, J., Ward, J., & Daniel, E. (2007). Managing the Realization of Business Benefits from IT Investments. *MIS Quarterly, 6*(1), 1 - 11.

Persson Slumpi, T., Ahlin, K., & Öberg, L.-M. (2012). *Intraorganizational benefits from product configuration information–a complementary model.* Paper presented at the DS 70: Proceedings of DESIGN 2012, the 12th International Design Conference, Dubrovnik, Croatia.

Piotrowicz, W., & Irani, Z. (2010). Analysing B2B electronic procurement benefits: information systems perspective. *Journal of Enterprise Information Management, 23*(4), 559-579. doi:https://doi.org/10.1108/17410391011061816

Polit, D. F., & Beck, C. T. (2010). Generalization in quantitative and qualitative research: Myths and strategies. *International journal of nursing studies, 47*(11), 1451-1458. doi:https://doi.org/10.1016/j.ijnurstu.2010.06.004

Porter, M. E. (2008). *On competition*: Harvard Business Press.

Praditya, D., & Janssen, M. (2015). *Benefits and challenges in information sharing between the public and private sectors.* Paper presented at the Academic Conferences Limited.

Priestley, M. (2001). *DITA XML: A reuse by reference architecture for technical documentation.* Paper presented at the Proceedings of the 19th annual international conference on Computer documentation.

Program, H. R. P. (2016). Human Research Protection Program. Retrieved from https://hrpp.msu.edu

Päivärinta, T., Tyrvainen, P., & Ylimaki, T. (2002). Defining organizational document metadata: A case beyond standards. *ECIS 2002 Proceedings*, 114.

Remenyi, D., Bannister, F., & Money, A. (2007). *The effective measurement and Management of ICT costs & benefits* (Third ed.). Oxford: Elsevier.

Renkemaa, T. J. W., & Berghout, E. W. (1997). Methodologies for information systems investment evaluation at the proposal stage: a comparative review. *Information and Software Technology, 39*(1), 1-13. doi:https://doi.org/10.1016/0950-5849(96)85006-3

Ringsquandl, M., Lamparter, S., Lepratti, R., & Kröger, P. (2017). *Knowledge Fusion of Manufacturing Operations Data Using Representation Learning*, Cham.

Ríos, J., Hernández, J. C., Oliva, M., & Mas, F. (2015). *Product Avatar as Digital Counterpart of a Physical Individual Product: Literature Review and Implications in an Aircraft.* Paper presented at the ISPE CE.

Rowley, J. (2007). The wisdom hierarchy: Representations of the DIKW hierarchy. *Journal of Information Science, 33*(2), 163-180. doi:https://doi.org/10.1177/0165551506070706

Schultze, U., & Avital, M. (2011). Designing interviews to generate rich data for information systems research. *Information and Organization, 21*(1), 1 - 16. doi:https://doi.org/10.1016/j.infoandorg.2010.11.001

Schönberg, C., Weitl, F., & Freitag, B. (2011). Verifying the consistency of web-based technical documentations. *Journal of Symbolic Computation, 46*(2), 183-206. doi:https://doi.org/10.1016/j.jsc.2010.08.007

Scopus. (2015). Scopus home page. Retrieved from http://www.scopus.com/home.url?zone=header&origin=searchbasic

Shang, S., & Seddon, P. B. (2002). Assessing and managing the benefits of enterprise systems: the business manager's perspective. *Information*

Systems Journal, 12(4), 271 - 299. doi: https://doi.org/10.1046/j.1365-2575.2002.00132.x

Siikala, T. (2018). *Value and benefits of technical documentation services: an analysis of corporate websites.* (Master Thesis). University of Tampere,

SIS. (2004). Quality management systems – Guidelines for configuration management (ISO 10007:2003, IDT). In. Stockholm: SIS Förlag AB.

Stockdale, R., & Standing, C. (2006). An interpretive approach to evaluating information systems: A content, context, process framework. *European Journal of Operational Research, 173*(3), 1090–1102. doi:https://doi.org/10.1016/j.ejor.2005.07.006

Svensson, A. (2010). *Professional Knowledge Sharing in Aircraft Maintenance.* Paper presented at the IRIS, Trondheim.

Tekom. (2017). Defining Technical Communication. Retrieved from https://www.stc.org/about-stc/defining-technical-communication/

Thompson, J. D. (1988). *Hur organisationer fungerar* (A. Grip, Trans.). Stockholm: Prisma/Norstedts.

Thomson, R., & Lynn, J. (2008). *Digital technical documentation development: Migration of paper based support systems within submarine periscope engineering.* Paper presented at the 2008 IEEE International Conference on Industrial Engineering and Engineering Management.

Thun, S., Kamsvåg, P. F., Kløve, B., Seim, E. A., & Torvatn, H. Y. (2019). Industry 4.0: Whose Revolution? The Digitalization of Manufacturing Work Processes. *Nordic Journal of Working Life Studies, 9*(4). doi:https://doi.org/10.18291/njwls.v9i4.117777

Tuomi, J. (1999). *Data is more than knowledge: Implications of the reversed knowledge hierarchy for knowledge hierarchy for knowledge management and organizational memory.* Paper presented at the International Conference on System Sciences (HICSS 32), Wailea Maui, USA.

Tyrvainen, P., & Päivärinta, T. (1999). *On rethinking organizational document genres for electronic document management.* Paper presented at the 32nd Annual Hawaii International Conference on Systems Sciences.

Vannoy, S. A., & Salam, A. F. (2010). Managerial Interpretations of the Role of Information Systems in Competitive Actions and Firm Performance: A Grounded Theory Investigation. *Information Systems Research, 21*(3), 496 - 515. doi:https://doi.org/10.1287/isre.1100.0301

Velmourougan, S., Dhavachelvan, P., Baskaran, R., & Ravikumar, B. (2014). *Software development Life cycle model to build software applications with* *usability.* Paper presented at the International Conference on Advances in Computing, Communications and Informatics, ICACCI 2014.

Vezzetti, E., Violante, M. G., & Marcolin, F. (2014). A benchmarking framework for product lifecycle management (PLM) maturity models. *The International Journal of Advanced Manufacturing Technology, 71*(5-8), 899-918. doi:https://doi.org/10.1007/s00170-013-5529-1

Vickery, G. (2011). *Review of recent studies on PSI re-use and related market developments*. Retrieved from European Union: https://ec.europa.eu/digital-single-market/en/news/review-recent-studies-psi-reuse-and-related-market-developments

Väyrynen, K., & Iivari, J. (2015). *The Competitive Potential of IT Applications-An Analytical-argumentative Evaluation.* Paper presented at the Thirty Sixth International Conference on Information Systems, Fort Worth 2015.

Wagner, J., Schroeder, H. M., Piskorowski, A., Ursano, R. J., Stein, M. B., Heeringa, S. G., & Colpe, L. J. (2017). Timing the Mode Switch in a Sequential Mixed-Mode Survey: An experimental evaluation of the impact on final response rates, key estimates, and costs. *Social Science Computer Review, 35*(2), 262 - 276. doi:https://doi.org/10.1177/0894439316654611

Wallace, P. (2011). *Information Systems In Organizations*. New Jersey: Pearson College Div.

Ward, J., & Daniel, E. (2012). *Benefits Management : How to Increase the Business Value of Your IT Projects (2nd Edition)*. Somerset, NJ, USA: John Wiley & Sons.

Ward, J., & Elvin, R. (1999). A new framework for managing IT-enabled business change. *Information Systems Journal, 9*, 197 - 221.

Ward, J., Taylor, P., & Bond, P. (1996). Evaluation and realisation of IS/IT benefits: an empirical study of current practice. *European Journal of Information System, 4*(4), 214 - 225. doi:https://doi.org/10.1057/ejis.1996.3

Wellsandt, S., Hribernik, K., & Thoben, K.-D. (2015a). *Content analysis of product usage information from embedded sensors and web 2.0 sources: A first analysis of practical examples.* Paper presented at the Engineering, Technology and Innovation/International Technology Management Conference (ICE/ITMC), 2015 IEEE International Conference.

Wellsandt, S., Hribernik, K., & Thoben, K.-D. (2015b). Sources and characteristics of information about product use. *Procedia CIRP, 36*(2015), 242-247. doi:https://doi.org/10.1016/j.procir.2015.01.060

Wiener, N. (1948). *Cybernetics, or Communication and Control in the Animal and the Machine*. Cambridge: MIT Press.

Wingkvist, A., Ericsson, M., & Löwe, W. (2011). A visualization-based approach to present and assess technical documentation quality. *Electronic Journal of Information Systems Evaluation, 14*(1), 150.

Wixom, B. (2014). Cashing in on your Data. *Center for Information Systems Research, Sloan School of Management, Cambridge, MA: Massachusetts Institute of Technology. Research Briefing, 14*(8).

Womack, J. P., & Jones, D. T. (2003). *Lean thinking: Banish Waste and Create Wealth in your Corporation.* (2nd ed.). London: Simon & Schuster.

Wowak, K. D., Craighead, C. W., & Ketchen Jr, D. J. (2016). Tracing bad products in supply chains: the roles of temporality, supply chain permeation, and product information ambiguity. *Journal of Business Logistics, 37*(2), 132-151. doi:https://doi.org/10.1111/jbl.12125

Wowor, H., & Karouw, S. (2012). *Quantifying IT Business Value: Case Study of North Sulawesi Province, Indonesia*. Paper presented at the ICACSIS, Indonesia.

Wysocki, A. F. (2013). What Do Technical Communicators Need to Know about New Media? In J. Johnson-Eilola & S. A. Selber (Eds.), *Solving Problems in Technical Communication* (pp. 428 - 453). Chicago: The University of Chicago Press.

Yoo, Y., Henfridsson, O., & Lyytinen, K. (2010). Research commentary—the new organizing logic of digital innovation: an agenda for information systems research. *Information Systems Research, 21*(4), 724 - 735. doi:https://doi.org/10.1287/isre.1100.0322

Zangiacomi, A., Pessot, E., Fornasiero, R., Bertetti, M., & Sacco, M. (2020). Moving towards digitalization: A multiple case study in manufacturing. *Production Planning & Control, 31*(2-3), 143-157. doi:https://doi.org/10.1080/09537287.2019.1631468

Zheng, L., III, R. N., Sandborn, P., & Terpenny, J. P. (2013). Ontology-based knowledge representation for obsolescence forecasting. *Journal of computing and information science in engineering, 13*(1). doi: https://doi.org/10.1115/1.4023003

Zhi, J., Garousi-Yusifoğlu, V., Sun, B., Garousi, G., Shahnewaz, S., & Ruhe, G. (2015). Cost, benefits and quality of software development documentation: A systematic mapping. *Journal of Systems and Software, 99*(2015), 175-198. doi:https://doi.org/10.1016/j.jss.2014.09.042

Zins, C. (2007). Conceptual approaches for defining data, information and knowledge. *Journal of the American Society for Information Science and Technology, 58* (4), 479-493. doi: https://doi.org/10.1002/asi.20508

Öberg, L.-M. (2007). *Forskning och utveckling kring teknisk information*. Retrieved from DIVA: urn:nbn:se:miun:diva-7288

Appendices

Included in the appendices are the interview guides from all studies, mentioned as Appendix 1 etc.

Appendix 1

These are the interview questions from the study at Alpha, focusing on the research question:

"Which are the benefits of the Configuration Management (CM) process in a manufacturing organization?"

Question set	Interview questions
General questions	What is your organizational role?
	For how long time have you been working in the organization?
Configuration Management	What is the connection between your organizational role and Configuration Management?
	What does Configuration Management mean to you?
	Describe the Configuration Management Process. In your opinion, is it well documented?
	What is the organizational structure for configuration management?
	How well do the information systems support your work tasks?
Configuration Management benefits	How is configuration management contributing to your team?

	In order to fulfill organizational goal or be more efficient; what is the contribution from configuration management?
	Do you measure configuration management in any ways?
Organisational aspects on Configuration Management	Other organizations refer to your configuration process as best practice; do you know why?
	How is the configuration process evaluated?
	Is it any communication from management about the configuration process and if; how is it done?
	How does the organization look upon configuration management?
	Has the organization changed view on configuration management now or in the past?
	What improvements can be done in the configuration management process?

Appendix 2

These are the interview questions from the study at Beta, focusing on the research questions:

"What are the added activities adding benefits in a DTI production process?" and *"How can efficiency be measured in a DTI production process?"*

Question set	Interview questions
General questions	What is your organizational role?
	For how long time have you been working in the organization?
	What is your previous experience of DTI?
The DTI production process and its development	What is the connection between your working role and the production process?
	What is your view on DTI? Both what it consists of and the reputation of it.
	Do you think that the DTI production process is well documented? Is it correct documented?
	In your opinion – what should the production process look like? Who decides about the process?
	How do you, or the organization, find the customer's requirements (both outsourcing and end customer)?
	How is the development of the process done?

	How is knowledge exchanged between the two parts in the process?
DTI production process	What are the benefits of DTI?
	In which activity/activities are customer benefits generated?
	In which activity/activities are waste generated?
DTI production process effectiveness/efficiency	Do you think that the right things are done in the DTI production process?
	Do you think that things are done right in the DTI production process?
DTI production process measurements	On what base is the process measured?
	Which are the measurements?
	How do you think that the measurements should be to develop more customer benefits?

Appendix 3

These are the interview questions from the study at Gamma, focusing on the research question:

"Which are the benefits DTI creates throughout the manufacturing process?"

The study is four-fold, containing interview questions during a tour of the DTI production process, the group interview, the individual interviews at C-level, and the follow-up interview. Presented first are the interview questions for the tour at the DTI production process and group interview, held immediately after the tour.

Question set	Interview questions
DTI production process	What is the purpose with your work activity?
	Why do you start your work activity?
	What input is required when you start your work activity?
	What do you do at your work activity, chronologically?
	What do you need to accomplish your work activity?
	What is the output of your work activity?
	What benefits are created in your work activity?
	If you did not do your work activity, what would be the result of that?
Group interview questions	Which are the overall benefits that are created from the process?

	To whom are those benefits created?
	How can we rank those benefits?
	How can those benefits be communicated?
	How can we show that those benefits are created

A third part for the empirical part in this study was semi-structured interviews with persons on the C-level, like CFO, who are members of the organization's management group.

Question set	Interview questions
General questions	What is your organizational role?
	For how long have you been working in the organization?
	What changes has happened, related to DTI, since our last interview?
Confirmation of benefits	Which benefit and stakeholders are related to the DTI?
	Have you been working with measurements related to the benefits?
	Which are the ideas about future work with DTI?
	Who needs to give the notifications?
Requirements on notifications	How precize must the notifications be?

	What can a qualitative notification look like?
	What can a quantitative notification look like?
	How often does the receiver of the notifications need it?

The *fourth part* of this study included a follow-up interview to confirm found benefits.

Question set	Interview questions
General questions	What is your organizational role?
	For how long have you been working in the organization?
	What changes has happened, related to DTI, since our last interview?
Confirmation of benefits	Which benefit and stakeholders are related to the DTI?
	Have you been working with measurements related to the benefits?
	Which are the ideas about future work with DTI?

Appendix 4

These are the interview questions from the study at Omega, focusing on the research question:

"How can benefits of DTI be measured? "

This study is two-fold including a ***first part with individual interviews*** forming the basis for the second part, the group interview.

Question set	Interview questions
Intro questions	What is your organizational role?
	What is your project role?
	How long time have you been working in the organization?
Artefacts and tools that you use during your daily work tasks	In what way do you use the DTI?
	How often do you use the DTI?
	What would you do without the DTI?
	How do you use the DTI in collaboration with your project members?
	Your experience of pros and cons from other project using the same kind of DTI?
Opinion on the actual intangible benefits of the DTI	What benefits does the DTI create for you?
	Why and when do you experience them as benefits?

	How much do you value the DTI in financial terms?
	Does the organization use any method to associate value to digital information?
	The pros and cons with the DTI in perspective project collaboration?
Opinion of what you would want as an intangible benefit of the DTI	What are your future requirements for DTI?
	Why do you need these requirements?
	To whom are they beneficial?
	How can they be implemented?
Closing Question	What is your formal background? (Level of education, years they have worked in this role or a similar role)

The *second part* of this study included the group interview.

Question set	Interview questions
Confirmation of benefits	From the described benefits of DTI, which of them do you agree upon?
	Do you miss any benefit of the DTI?

Relating the benefits to Boundary Object Theory	For each benefit – how do they relate to the syntactic, semantic, and pragmatic view?
Evaluation of findings and test	How do you view our findings?
	How useful is this test for the organisation?

Appendix 5

This appendix includes the mixed method study based on the research question:

"What is management's view on DTI as an internal resource? "

and

"Do managers view DTI as less valuable in comparison to its products?

The ***first part*** was conducted at Rho, including individual interview questions.

Question set	Interview questions
Intro questions	What is your work role?
	In which industry is your organization located or in which industries are you working as a DTI consultant?
	How many employees are working at your organization?
The organisational perspective on DTI	What does your organization perceive as DTI? What does organizations in general perceive as DTI?
	Is the DTI mainly digital or analogue?
	How is the DTI connected to a product or a service?
	How is DTI produced and by whom?
Managers' views on a valuable resource	Does management talk about DTI?
	Is DTI connected or mentioned in any kind of organizational strategy?

	Is DTI viewed as adding efficiency and/or effectiveness to the organisation?
	Is DTI owned by the organisation?
Managers' perspective on benefits of DTI	Are benefits of DTI mentioned, communicated, described or visualized in your organisation?
	In what perspectives do the organization view benefits? (Anything positive, efficiency, effectiveness etc).
	Are the benefits of DTI valued in financial terms?
	What happens when DTI is not produced on time?
	What happens when DTI is lacking?
Managers' perspective on DTI in comparison to the product/service	In your opinion, what is your management's view on DTI?
	Is DTI valued more, equal, or less than the product/service it is connected to?

The *second part* of this mixed method's study includes the questions from the survey and alternatives for answers.

Survey questions	Alternatives for answers
Who are your main customers?	One choice: (1) Other businesses, (2) Private customers
How would you describe the complexity of your main products/product groups?	Scale ranging from "low complexity" to "high complexity" (the steps are low, middle, and "high complexity" or "no answer")
Is the DTI mentioned in any of your business strategies?	One choice: (1) Yes, (2) No, or (3) I do not know
Is the DTI produced at its own department?	One choice: (1) Yes, (2) No, or (3) I do not know
Do you use DTI in the organization for efficiency?	Scale ranging from no to "to a large extent "(the steps are no, "to some extent", largely, "to a large extent ", or "no perception"
Do you think the DTI only is costly to the organization?	Scale ranging from no to "solely a cost" (the steps are no, "to some extent", largely, or "solely a cost"
Do you use the DTI to manufacture your products?	One choice: (1) Yes, (2) No, (3), I do not know, or (4) The DTI is not produced for our manufacturing process
Do you think you are able to produce your products without DTI?	Scale ranging from no to completely (the steps are no, "to some extent", largely, and completely

Do you think that it is possible to sell your products without DTI?	Scale ranging from no to completely (steps from no, "to some extent", largely, and completely)
Which are the benefits of DTI?	Multiple choices: (1) DTI improves our support, (2) DTI is required for legal reasons, (3) We use DTI internally as knowledge carrier, (4) DTI is our only source of information for the product, (5) DTI improves our manufacturing process, (6) DTI is not beneficial at all, and (7) other benefits (free choice)
How do you consider DTI the organization's view of DTI in comparison to the products you manufacture?	Scale ranging from "of no value" to "more valuable than the product" (steps from " of no value", "slightly less valuable than the product", "as valuable as the product", or "more valuable than the product"
Do you have the same term on technical information within the organization?	One choice: (1) Yes, (2) No, or (3) I do not know
Do you own all your DTI?	One choice: (1) Yes, (2) No, or (3) I do not know

Paper I

INTERNATIONAL DESIGN CONFERENCE - DESIGN 2012
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INTRAORGANIZATIONAL BENEFITS FROM PRODUCT CONFIGURATION INFORMATION – A COMPLEMENTARY MODEL

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Keywords: Benefit, intraorganizational, configuration management

1. Introduction

The configuration management (CM) of products has a long tradition and includes management of the way hardware, software, and information are configurated internally as well as in relation to one another (e.g. Larmour and MacLean, 1995). Despite the long tradition, there are indications among practitioners that the benefits CM contributes with still are not clearly expressed. For example CM practitioners we are cooperating with identifies the identification of benefits of CM as particularly critical in order to strengthen CM's position in the organization and increase its impact. This communicates that within a Swedish context CM has a rather weak position. To some extent this can be related to CM being a complementary process which are needed in order to make other processes work effectively [Sörqvist, 2004], hence CM becomes more or less invisible. Another potential reason could be that CM to a large extent concerns management of information which can be difficult to put a price tag on. The information that is managed could for example be engineering information (EI) that has a focus on the design process and can, according to Storga, Marianovic and Savsek, [2011] be sketches, drawings, notes, and meeting minutes. Some of this information are later formally recorded in technical reports and other engineering documentation such as CAD-models, production drawings, calculations, installation instructions, user guides etc. [Storga, Marianovic and Savsek, 2011]. The formalization of EI can roughly be translated to the definition of technology information (TI) provided by Öberg [2007]. A concept that to some extent includes both EI and TI is product configuration information (PCI). PCI is defined by the Swedish Standards Institute (SIS) as "requirements for product design, realization, verification, operation and support" [SIS, 2004, p. 6]. More specifically, PCI includes requirements, specifications, design drawings, parts lists, software documents and listings, models, test specifications, maintenance, and operating hand books, and should also be relevant and traceable according to SIS [2004].

A additional potential reason for the weak position of CM is that there is limited research on CM, and a lack of academic engagement according to Huang and Mak [1998] and Burgess et al. [2005]. Searching in the topic field in the databases of Science Citation Index Expanded with the search string: "configuration management" AND benefit* generates 63 hits. However, few of them are explicitly discussing the benefits of CM and none is discussing the benefits of PCI. This supports the claims of Huang and Mak, and Burgess et al.

Even though there is limited research on benefits of CM, potential benefits can be identified in for example different definitions of CM. For example in Leblang's [1994] definition of CM a benefit like control, mainly over the configuration of the product and potential change activities related to the product, can be identified. Also in the most progressive part of CM research, in the area of software and software development [se, for example, Conradi & Westfechtel, 1998, Sarma et al., 2003], benefits can be identified. For example in the definition of CM found in IEEE's Standard Glossary of

Software Engineering Terminology [1990], benefits like control, not only in relation to the configuration and change, but also in relation to functional and physical characteristics, can be found. Also that the designed product is in compliance with the requirements specified can be argued to be a benefit. Drawing benefits from more general definitions of CM is one thing, but there are more focused discussions concerning benefits of CM in for example Krikhaar et al. [2009] and in the report produced by the Aberdeen Group [2007]. We will discuss the above identified benefits further on in this article. What however struck us was that so far we have not been able to find a model that takes a more holistic approach to benefits related to CM, and especially that recognizes the potential benefits the information related to CM like PCI can generate. Hence, the aim of this article is to develop a model that takes into account previous identified benefits as well as adding benefits identified in a study specifically targeted on this matter, with a certain focus on the information aspect.

2. Towards the development of a model – the method

The basic steps of the development of a model have been as follows:

- Investigate identified benefits in a literature review of scientifically articles and reports
- Investigate identified benefits by practitioners, in an interview study, in one company with complex products, containing hardware and software
- Compare identified benefits
- Discuss similarities and discrepancies
- Develop a model

The literature review

The collecting of articles and reports for the literature review was done by using Google Scholar [Google, 2011] and Science Citation Index Expanded (SCIE)[Web of Knowledge, 2012].The keywords used and combined in this search were *´Product configuration management´, ´Software configuration management´ and ´Product configuration information ´* in combination with *´benefit´*. As was discussed in the Introduction very few articles and reports were identified in this process. The ones that seemed relevant have been analyzed and the expressed benefits of CM have been extracted. The result from this analysis was a set of benefits that became the base for the coming benefit-model.

The interview study

The next step was to identify benefits identified by state of the art CM practitioners, at least according to other Swedish CM practitioners. The study was conducted as an activity in a work package (WP) within the EU funded project Technical Information Centre II (TIC II). TIC II engages practitioners within the TI industry as well as researchers with an interest in the production of TI. The particular WP where the study took part focused on CM in relation to TI. Prior to the study reported on here, the participants within the WP had been engaged in a problem identifying sessions concerning CM. The key result of this session, as was discussed in the Introduction, was that the participants identified arguments related to the benefits of CM to be crucial to identify. An interview study was launched with the participants in the WP in order to make an inventory of possible benefits as well as testing different questions to be included. The result of these activities was a set of areas to be investigated with adhering questions. The areas were: (1) general questions about the respondent´s organization role, (2) the respondents' definition of CM, (3) benefits of CM, and (4) organizational views of CM.

Research setting

The company, in which the interview study was conducted in, hereafter called Alfa, belongs to a global concern which employs around 12.500 people. The concern is divided into five business areas; aeronautics, dynamics, electronic defence systems, security and defence solutions, and support and services. Alfa works with production and maintenance of electronic defence systems, mostly radar systems and employs 2.000 people.

At Alfa product development almost always has its base in existing products, and the development is rather to customize each delivery in correspondence with the wants and needs of a

customer. In near future different base products will be used in the production and customers offered different product options.
Alfa started to use CM fifty years ago due to the fact of a huge spectrum of different products. Today information needed for the configuration process is digitalized in different systems, several only used by one department, and one central system. The central system is updated when the design process starts and also when any product changes are made. External stakeholders interested in prepared documents are often subcontractors, auditors or users.

Research design

The interviewees, seven altogether, were selected in accordance to their working role´s contact with CM. Other affecting factors were that they upheld a middle manager role and were representing different departments at company Alfa. Besides being middle managers the interviewees had different roles like development project manager, team manager software development, team manager customer support, team manager customer documentation, team manager mechanics construction, process coordinator configuration.
The interviews conducted with these middle managers were recorded and transcribed. As supporting analyze software, Nvivo9 was used. The empirical material was analyzed by importing the transcribed material into the database of Nvivo9. In the analysis different categories were used like Benefits or CM process. The coded material based the foundation for the empirical presentation. The material was also analyzed by the researchers reading through it repeatedly looking for any benefits the interviewees mentioned that could be related to CM or PCI. One overarching assumption was that all benefits were seen as benefits; no matter how many of the interviewees it was identified by and during what circumstances. However the analysis process actually started much earlier, already in the interview sessions, and it was here the topic of this article first was identified.

3. CM and benefits – review of related research

Benefits that add value to the individual work also are of benefit for the organization as such [O´Shea, 2009]. Ward and Daniel [2006] mean that benefits are reached by increasing the performance of individuals or groups in the organization in their work role, or increasing the performance of the whole organization. One way of increasing benefits are by fulfiling requirements of the most important stakeholders and thereby satisfy the great mass. The most pragmatic challenge with benefits is however to measure them, because without any measures it is difficult to argue any benefits. According to Ward and Daniel [2006] benefits can either be measured in economical values or in more subjective values. Lagsten [2009] gives the intangible evaluation methods more pragmatic advantage due to organizational education situations and openness towards stakeholders.

The benefits identified in the Introduction, "control", "change management", and "design in compliance with the requirements specified", can also be found in the articles we have identified. Starting with "change", this benefit is further emphasized by for example Burgess, et al. [2005] when they argue that the importance of managing change with CM is due to meet the needs of changes across a product life cycle. These changes are implemented in an increasingly higher pace, and it is also the case that the products are becoming increasingly complex and are produced in an increasing higher pace [Stock, Weber and Steinmeier, 2005; Storga, 2004]. The importance of managing change is also visible in Estublier et al., [2005] discussion concerning the importance of CM for software, as software of today is more complex, has a longer lifespan and more often is life critical. This points towards that CM at least in relation to change can generate some benefits. However, to be able to manage change is it important to know what the product will look like (design), is looking like (production), and will continue to look like (support) [Burgess et al., 2005]. Dart [1991] puts it in another way and argues that CM contributes with visualizing the structure of a product where components are identified and where it is possible to find out what makes a product unique. This discussion can be related to one of the other benefits of CM, namely control. Control is explicitly stated as a benefit by Krikhaar et al. [2009] as well, however, as control is the benefit that often is highlighted CM has got a "bureaucratic" stamp according to them.

Dart [1991] also points towards one of the benefits identified in the Introduction namely that the design should be in compliance with the requirements specified. She phrases it as the configuration being a hierarchy of components and this makes it possible to control all deliveries against the configuration schema

A majority of the discussions related to benefits of CM are centred on the above identified benefits. However, there are an additional number of benefits that have been identified. Krikhaar et al [2009] for example argue that through supporting of efficient building and testing of correct configuration which is done by for example reduced rework and efficient problem solving - CM is an enabler for system evolution. They also, with examples from medical device industry, illustrate an example of CM being important when it comes to being able to demonstrate how a product been produced (quality assurance). This is also a requirement of the European Machinery directive. Bershoff [1984] further argues that one important benefit with CM is that it supports project management. Finally the Aberdeen research group published a benchmarking report in 2007 where they argue that *"quality, time to market, and costs are top pressures driving companies to improve configuration management "[*Aberdeen Group 2007 p. 1]. The identified benefits can so far be summarized as in Table 1 below.

Table 1: Summary of benefits identified in related research

Order and control	Krikhaar [2009], Leblang [1994], IEEE [1990], Burgess et al., [2005], Dart [1991]
Change management	Leblang [1994], IEEE [1990], Burgess, et al. [2005]
Design according to specified requirements	Dart [1991], IEEE [1990]
Enabler for system evolution	Krikhaar [2009]
Supporting management	Bershoff [1984]
Supporting product assurance	Bershoff [1984]
Product quality improvement	Aberdeen Group [2007], Ikeda and Akamatsu [2004]
Time to market improvement	Aberdeen Group [2007]
Development cost reduction	Aberdeen Group [2007]
Supporting efficient building and testing of correct configuration	Krikhaar [2009]
Quality assurance	Krikhaar [2009]
Sharing information within a team during the product life-cycle	Krikhaar [2009]

The benefits summarized in Table 1 overlaps to some extent even though they are labelled differently. For example order and control and CM's potential to support management are similar and could hence be discussed in relation to one another. Other examples are product assurance, design according to specified requirements, product quality improvement, and quality assurance could be related to one another; as well as change management, PCI and CM as enabler of system evolution; and development cost reduction and supporting efficient building and testing of correct configuration. These groups of benefits are difficult to clearly separate from one another and can therefore be discussed as groups instead of single benefits.

A reflection related to the literature review is that a majority of the benefits have been identified within the context of the software industry. Only Burgess et al. [2005] are not departing from the software industry. There are arguments that CM for software and hardware has evolved kind of isolated from one another [Krikhaar et al. 2009, Persson Dahlqvist et al. 2004]. Krikhaar et al. [2009] argues though that there are some differences between hardware and software CM. The most important difference is that software is more manageable which means that it is easier to make changes within software than in hardware. A lot of research and practical work is though going on when it comes to solutions and methods that are applicable in both software and hardware [Kirkhaar et al. 2009; Asklund 2001].

4. PCI, CM and benefits – the interview study

In the interviews conducted we could identify several different benefits that, to some extent overlap, with the benefits identified in the literature but also diverge from it. In this section we compare the benefits identified in the literature study with the ones identified in the empirical study to be able to identify benefits that are not overlapping. However, we start this comparison by identifying the benefits that overlap.

Benefits that overlap

Order, control, and supporting management

One benefit that seems to permeate any discussion concerning CM is order and control. Upon asking the interviewees about what benefits CM contributed with, everybody ascribed CM to contribute with order and control over what product that had been delivered and the configuration of that product, etc. To emphasize this follows some quotes:

"For me it is how we manage the products that we have today. Why do they look like this, and also what can respectively part in a product do. And how do we know what is going on. That's what configuration management is for me". (Team manager customer support)

"That we have control on which revision the customer has and when we are about to update them we have control what new revision it should be updated to; we have control on the status of the product, the documentation" (Team manager customer documentation)

"They feel that they have something to back them up when responding to the customer and when they send stuff. They know that they do the right thing." (Team manager customer support)

In the above quotes the importance of generating and managing information through CM is to achieve control and order, becomes evident. As it is indicated in the quotes the information serves as evidence on what has been delivered to a particular customer. It also generates a description on why the delivered product has a particular configuration and what the different parts contribute with. This is further emphasized in the following quote concerning traceability:

"I think it is obvious. Everything has a label that is traceable to what it is and how matters stand. It is a unique system, but very powerful." (Team manager software development)

Change management and enabler for system evolution

As it is indicated earlier in this article the design process at Alfa almost solely departs from an existing product that either are improved and/or adapted to the requirements of a customer. Rarely, it is the case that something completely new is designed. This is emphasized in the following quote:

"Rarely do we produce something completely new. What we do in nine cases out of ten is that we depart from something existing. And then we do a new version from that." (Team manager software development)

Hence, managing change and how the systems evolve are crucial. This is emphasized in the following quote:

"Some customers demand that we must report any changes after a certain point. For example if you have a customer who has ordered radar systems to ten boats, and then they are not supposed to be delivered all at once. You will deliver one or two and another one a year later or two. It is a very long deliverance plan. And then you become sensitive to changes in the configuration. They want all ten systems to look the same, something they will never do because things disappear or must be replaced. They want us to report any changes and explain why. And then we explain our system." (Project manager)

The above is further discussed related to the guarantee of a product:

"Often you have a guarantee phase that lasts a number of years. Then you have a direct connection to the customer and then you have to take it in the product. Then you have a version that is delivered to the customer and the development is a couple of versions further away. Then it's partly about solving the problem at the customer and then to implement it in the product in a controlled fashion for the future". (Project manager)

Product quality improvement, quality assurance, design according to specified requirements and supporting product assurance

In the empirical material there are indications that CM is used in order to assure and improve the quality of the products. One example is the following quote:

"But it gives us control on what we have done, and it also gives us that we can return to something that was good, we also know what wasn't good." (Coordinator configuration process)

The importance of CM for assuring the quality of the product is further emphasized in the following quote:

"Then CM is a big part, we must deliver the right things, we cannot build something with the wrong configuration, containing the wrong code and stuff. These things we get back and affect our results negatively. We must know what has been sent to the customer, we have CLS-agreement. We have agreements concerning spare parts and service and stuff, for a long period of time. We must know what parts to bring along when we travel across half the world." (Project manager)

The persons that have been interviewed also express some frustration when it comes to how the company succeeds in using the potential that they believe CM has. They think that a more active organization could use the information in a more proactive way to be able to improve the products even more, hence assure its quality.

Development cost reduction and supporting efficient building and testing of correct configuration

That CM has a favourable impact on reducing development costs is expressed by several of the interviewees. The empirical material shows a number of examples where CM reduces cost when it comes to development of products.

"Can we reuse instead of constructing new all the time, and then we make money." (Coordinator configuration process)

"We can benefit from it during manufacturing; we can see what editions there are; we can see what different parts the product is constituted of that we can replace with parts that are new developed containing new functions, etc." (Team manager mechanic´s construction)

"We don't want to do that. Because we have our version managing system we have the possibility to have a product developed just for this. If you can further develop to more functions, more opportunities, to create a broader customer base, we can put it into several different projects, but it is still the same product. This is what really the big gain is. And everything is connected to our version managing system that we have. We can further develop and add new functions without removing anything old. This makes that even though we sold it as the first version we can resell it as a spare part in the twentieth version and it still manage to do the same thing." (Coordinator configuration process)

Sharing information within a team

The benefit of CM for sharing information within a team was expressed in the interviewees, but not as clearly as the cost reduction. One of the interviewees, however, described this in the following manner:

"Yes, of course it does. If everyone gets, within the assignment one has, if you know where to find the information, so of course. Then you're not dependent on one person, you don't have to talk to the neighbour. If the neighbour isn't there you still know where to find the information. This could of course be achieved by storing all the documents in one place. That's a bonus. However, I think that we create a person independency with our order. That is probably one of the big things." (Coordinator configuration process)

Benefits that do not overlap

Time to market improvement

Only one benefit identified in the literature could not be found in the empirical material namely, time to market improvement (Aberdeen Group, 2007). The reason for this is probably due to the products the company is manufacturing and the market they are competing on, rather than on the relevance of the benefit as such. There is very little competition on this market hence time to market becomes of more or less no importance at all.

Base for aftermarket design

When it comes to the benefits of base for aftermarket design discussed in this section and common language for design discussed in the next section these benefits were by the interviewees closely related to what we in this article labels PCI and not CM in general.

Alfa is offering the customers the service of delivering spare part within three days at the latest. Living up to the agreement requires that Alfa has spare parts in storage but also information of what version a customer has and if it could be replaced with some other version. But it is not just about the service of delivering spare parts to new systems. Alfa also offers long service agreements spanning over many decades as is indicated in the following quote:

"When we still today can repair or manufacture parts for a forty-year-old system, and still knows exactly what to do it is a good system." (Coordinator configuration process)

Again the information is crucial to be able to deliver according to this agreement. The information also gives Alfa a potential opportunity to do new business with the customers by knowing the customer's systems and being able to argue that the systems need to be replaced as is indicated in the following quote:

"[…] this customer has really old systems and product management can go to the market department and say:"Here, they have really old systems; we could sell something new to them. Why don't we do it?"(Team manager customer support)

This potential is however under exploited for the moment.

Common language for design

Within the company Alfa, CM has been used for a long period of time this has made that the chosen ontology's and how the structure been designed is well known. A positive side effect of this is that the communication is more effective, both when it comes to communication between different actors and within groups. The following quotes visualize this:

"Yes I do. Because I can go to a construction instantiation and say what I need. We're talk about […], and yeah everyone knows that it is that cable. That I would say. Otherwise I had been forced to bring a picture to show all the time, or accessing the system and show in the computer what the cable looks

like or in a catalogue. It is a language I would say. To me, going into the ELFA-catalogue it is a number instead. But they have also had logic in their numbering instead. There are those who buy from ELFA and they know the numbers as well. But the language makes it easier." (Team manager customer support)

"Yes, definitely. If I say that I need a [..] on this product, do you have it and can you send it to me? Then they know exactly what type of information I want as well." (Team manager customer documentation)

PCI was identified as a benefit that earlier more or less has been overlooked in research on CM. At least there is little research to be found related to PCI in general and PCI and benefits in particular. The contribution of this work is to identify information as a crucial part and generator of benefits in relation to a product.

The differences and similarities between the empirical result and the benefits identified within literature are summarized in Table 2 below.

Table 2: Benefits of CM in theory and practice

Benefit	
Order and control + Supporting management	Confirmed
Change management + Enabler for system evolution	Confirmed
Design according to specified requirements+ Product quality improvement + Quality assurance+ supporting product assurance	Confirmed
Time to market improvement	Not confirmed
Development cost reduction+ Supporting efficient building and testing of correct configuration	Confirmed
Sharing information within a team during the product life-cycle	Confirmed
Base for after-market design	Identified within the empirical data
Common language for design	Identified within the empirical data

As Table 2 suggests many of the benefits identified in earlier studies also are confirmed by the practitioners in our study as well. However, as was mentioned earlier in this article, previous research has not discussed the role the information related to the CM process might play. In our study it became clear that PCI can contribute with benefits earlier not recognized related to aftermarket design but also as a language that can be used during design. Hence we suggest that a model of benefits related to CM really should be a model of benefits related to CM and PCI. In Table 3 below we outline a model which distinguish between the benefits of CM (process) and PCI (information).

Table 3: Benefits of CM and PCI

Benefit	
Order and control + Supporting management	Confirmed
Change management + Enabler for system evolution	Confirmed
Design according to specified requirements+ Product quality improvement + Quality assurance+ supporting product assurance	Confirmed
Time to market improvement	Not confirmed
Development cost reduction+ Supporting efficient building and testing of correct configuration	Confirmed
Sharing information within a team during the product life-cycle	Confirmed
Product Configuration Information	Identified within the empirical data

Base for after-market design	Identified within the empirical data
Common language for design	Identified within the empirical data

Discussion and conclusions

The research reported on in this article departed from a call for identifying benefits of CM by practitioners in CM. The aim of this article was to develop a model that takes into account previous identified benefits as well as adding benefits identified in a study specifically targeted on this matter, with a certain focus on the information aspect. In Table 3 above we summarized the benefits identified both in earlier research and in state of the art practice, and distinguished between benefits related to CM in general and to PCI in particular. Hence, this model does not just contribute with a set of benefits that practitioners can use in order to strengthen CM's position in the organization and increase its impact. It also provides research with an analytical lens through which CM practice can be analyzed through. Important to remark is that the results still should be seen as explorative in its nature. The benefits identified in earlier research must be scrutinized through the provided lens of the suggested model in order to more thoroughly position them as belonging to CM or PCI. This because the earlier identified benefits was not used when the questions for the study were developed. The model could therefore serve as a base for further studies where the benefits could be used for more explicit questions about benefits.

Further on the model could be developed to become useful to managers at different levels to describe the benefits of PCI. The model then has to be further elaborated when it comes to how those benefits are related to each other. Another area of interesting research would be to compare this result with empirical data from small and medium companies since this data set is collected from a large group of companies. Finally, we think that through this explorative model of CM and PCI it can be concluded that PCI is seen as a valuable resource at the management level.

References

Aberdeen Research Group, "The Configuration Management Benchmark Report: Formalizing and extending CM to drive quality, Technical Report, Aberdeen Group, Boston, MA, 2007.

Asklund, U.,"Configuration management for open source software",1st Workshop on Open Source Software 2001,2001.

Bersoff E.,"Elements of Software Configuration Management", IEEE transactions on software engineering, vol. se-10, 1984, no. 1, January .

Burgess, T. F., McKee, D., Kidd, C.,"Configuration management in the aerospace industry: a review of industry practice", International Journal of Operations & Production Management. Vol. 25, 2005, 3, 290-301

Conradi, R., Westfechtel, B,. "Version Models for Software Configuration Management". ACM Computing Surveys, Vol. 30,1998, No. 2, June.

Dart,"Concepts in configuration management systems", Proceeding of SCM '91 Proceedings of the 3rd international workshop on Software configuration management, 1991.

Estublier J, Clemm G., Leblang, D., Tichy W., Hoek A., Wiborg-Weber I., Conradi R., "Impact of Software Engineering Research on the Practice of Software Configuration Management", ACM Transactions on Software Engineering and Methodology, Vol. 14, 2005, No. 4, October .

Google , url www.scholar.google.com, 2011.

Huang, G. Q.,Mak, K. L.,"Computer aids for engineering change control", Journal of Materials Processing Technology,Vol 76,1998, 187-191.

IEEE, "IEEE Standard Glossary of Software Engineering Terminology", 1990.

Krikhaar R., Mosterman W., Veerman N., Verhoef C.," Enabling System Evolution Through Congifuration Management on the Hardware/Software Boundary", Systems Engineering Vol 12, 2009,No.3

Kunihiko. I., Yasuyuki, A. "Starting SPI from Software Configuration Management: A Fast Approach for an Organization to Realize the Benefits of SPI." in Bomarius, F., Iida, H. (Eds.): PROFES 2004, LNCS 3009, pp. 92–104, 2004.

Lagsten, J.," Verksamhetsutvecklande utvärdering i informationssystemprojekt", Licentiat Thesis, Linköping: Linköpings Universitet, Institutionen för Datavetenskap, 2005

Leblang, D. B.,"The CM Challenge: Configuration management that works" in Tichy, W. F. (ed.)Configuration Management. John Wiley & Sons Ltd. Chichester, England, 1994

O'Shea, D.,"Sustaining key stakeholders' vital values within ethical enterprise architecture". PhD thesis, University of Technology, Sydney, Australia, 2009.

Persson Dahlvist A., Crnkovic I, Asklund U. ,"Quality Improvements by Integrating Development Processes",2004.

Sarma, A., Noroozi, Z., Hoek, A.v.d. Palantír, "Raising awareness among configuration managementworkspaces" in International Conference on Software Engineering. 2003. Portland, Oregon

Stock, I., Weber, M., Steinmeier.E, "Metadata based Authoring for Technical Documentation," Paper presented at the SIGDOC´05, Coventry United Kingdom, 2005.

Storga, M., Marjanovic, D., Savsek, T, "Reference model for traceability records implementation in engineering design environment", 18th International Conference on Engineering Design ICED11 , 2011

Storga, M., "Traceability in Product Development", In the proceedings of International Design Conference – DESIGN 2004, Dubrovnik, May, 1-8, 2004.

Swedish Standards Institute, "Quality management systems – Guidelines for configuration management (ISO 10007:2003, IDT)",SIS Förlag AB, Stockholm, 2004.

Sörqvist, L. Ständiga förbättringar.Lund: Studentlitteratur, 2004.

Ward, J. ,Daniel, E.," Benefits management – Delivering Value from IS&IT Investments",Hoboken: John Wiley & Sons, 2006

Öberg, L-M., "Forskning och utveckling kring Teknisk Information", 2007, retrieved 2011 8th of Dec 2011 at www.miun.se/ticprojektet/

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Paper II

A Semiotic Perspective on Semantic Interoperability

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Abstract

While information technology enables us to access more material than ever before, we need to come to grips with the disagreeable fact that data is not information. Sharing data without safeguarding comprehension may lead to confusion at best and disaster at worst. The issue at hand is one of ensuring semantic interoperability between actors from disparate contexts. Research into this problem is plentiful, but typically focused around specific subject matters, limiting its appeal to a limited range of scholars and practitioners. Based upon a literary study, we identify two extreme approaches to managing semantic interoperability. These are denoted top-down and bottom-up. We illustrate real world instances of these approaches using the TFI-model based on a case study encompassing two organizations. Our theoretical model is found to be a viable lens through which to generalize and interpret issues pertaining to semantic interoperability between human actors. We therefore see a need for further research into human-based on semantic interoperability.

Keywords: Semantic interoperability, top-down, bottom-up, TFI-model, semiotics

1 Introduction

As our ability to share and process data increases, we fancy ourselves on the cusp of realizing the vision of the ubiquitous information society. However, we must face the disagreeable fact that data is not information and sharing does not guarantee understanding. We must learn to distinguish between quantity (data) and quality (information) if we are ever to resolve this dilemma. Overconfidence in our ability to transfer data can lead to serious consequences – perhaps the most spectacular of which being the Mars Climate Orbiter that suffered catastrophic failure due to application of English units rather than metric units in one of its data files (NASA, 1999).

The issue of conveying information rather than data has already received significant attention under the guise of semantic interoperability. Unfortunately, research into semantic interoperability tends to suffer from one of two conditions. It is either rather technically biased (Backhouse & Halperin, 2009), or it is based in a specific context which is imbued with a nomenclature that is often quite esoteric. A search for "semantic interoperability" in research database such as Science Citation Index Expanded yield a large number of hits pertaining to eGovernment, eHealth, semantic web and Geographic Information Systems. Each of these areas approaches the difficulties of semantics from their own perspective and using their own ontology. The current trend of imbuing semantic interoperability with a technical language puts it closer to technical knowledge than scientific knowledge, thus

limiting its potential for verification or falsification to a limited community (Boisot, 1995, p.72-73; Popper, 1974, p.81).
From a management perspective, the lack of accessibility means that more precious time has to be spent absorbing data (Rockart, 1979), not to mention the risk of finding oneself at the mercy of technical experts (Ackoff, 1967; Ross & Weill, 2002). Hence, we see that there are advantages to approaching semantic interoperability from a general perspective to the scholar as well as the practitioner.

Our intent is to approach semantic interoperability from an informatics perspective by studying how it may be discussed from a semiotic perspective. Therefore, we treat semantic interoperability not as a state of technical compatibility, but rather the ability of individuals to derive the same meaning from a set of data. Based on our starting point, literature suggests two diametrically opposed views on this topic; we refer to these as top-down and bottom-up. In addition to semiotics, we describe these approaches utilizing the TFI-model which distinguishes between technical, formal and informal aspects of the organization. An empirical study is then undertaken in an effort to demonstrate what form our theoretical posits may assume in practice. This is not intended to validate the premise presented, but rather to provide an illustration much in the same manner as Hirschheim & Klein (1989).

2 Semiotics

Advances into information technology have taken us from a situation where data was effectively tied to a limited geographical area, to one where data may be transmitted in vast quantities to anyone or everyone (Orman, 1983). However, the increase in distance (physical as well as cognitive) between transmitter and receiver has highlighted the inherent difficulties in correctly interpreting data out of context (Langefors, 1973, p.242-249; Liebenau & Backhouse, 1990, p. 25-27; Boisot, 1995, p. 93-115; Harvey, Kuhn, Pundt, Bishr & Riedemann, 1999).

While computers and digitized data exacerbated this issue through sheer volume, it is by no means a novel topic. The same basic issue has been extensively studied under the guise of semiotics for the better part of a century (Liebenau & Backhouse, 1990, p. 15).
Semiotics, of which semantics are a subset, is the study of signs and how they facilitate communication. Semiotics may be divided into four components: Empirics, syntactics, semantics and pragmatics (Liebenau & Backhouse, 1990, p.11-79). Empirics and pragmatics may be further subdivided (Stamper, Liu, Hafkamp & Ades, 2000) if needed, but that level of detail may be considered redundant for the discussion at hand.
Empirics form the basic physical components of transferring data – the medium that facilitates transmission from sender to receiver. Syntactics provides us with rules that enable us to impose some manner of structure upon the data which we transmit or receive. It is only with an appropriate structure that we may process and refine data regardless of whether we are compiling financial data or digitizing a painting. Semantics pertain to the transfer of intended meaning. The meaning of data is often tightly linked with a particular context (Magoulas & Pessi, 1998, p. 366-369; Harvey et al, 1999). Thus, the focus of semantics is the relationship between what is being transmitted and what is being understood. One of the basic tools with which to accomplish this is a common terminology (Liebenau & Backhouse, 1990; Holsapple & Joshi, 2002).

Pragmatics represent the manner in which understanding prompts action. Even with mutual understanding assured, we cannot unconditionally assume that a piece of information will prompt similar action in two different individuals (Star & Bowker, 2002).

Overcoming the semantic barrier, such as by common ontology, enables organizations to bring disparate skill-sets to bear on complicated tasks such as development projects (Boland & Tenkasi, 1995). Ontologies may be created in several fashions, ranging from being the brain-child of one person to extensive collaborative efforts (Holsapple & Joshi, 2002). However, establishing a shared ontology is a delicate and lengthy process which often runs counter to the rational desire to economize on information processing (Boisot, 1995, p. 39-82). Indeed, existing organizational channels of communication may prove detrimental to establishing a new ontology or new ways of perceiving one's surroundings (Boland & Tenkasi, 1995; Miller, 1993).

3 The TFI-model

In order to frame our discourse, we find it imperative to draw upon a plethora of sources in order to do the subject justice. In addition to semiotics, we intend to utilize the TFI-model (Liebenau & Backhouse, 1990, p. 109-112; Stamper et al., 2000) which in broad terms outlines the interplay between organizational layers and systems without constricting our discussion.

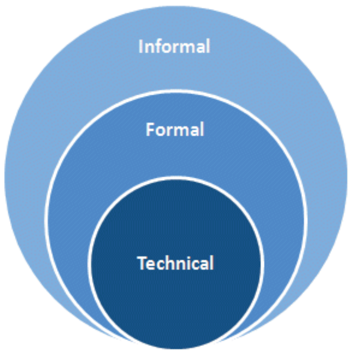

Figure 1: TFI-model adapted from Stamper et al. (2000)

The constituent parts of the TFI-model are technical systems, formal organization and informal organization. Technical systems are, in a word, artefacts. While hardware and software might be the most common artefact in conjunction with information systems, they are not the only inhabitants of this domain. In essence, anything that contains or conveys information may be considered an artefact. Formal organizations are specified patterns of action – usually by design. While these patterns may be distributed by means of an artefact (such as a manual), essence of formal systems are the codified and preordained nature of the actions that are carried out. Lastly, informal organizations are structures that are more happenstance than designed. That being said, they may of course to some degree be anticipated based on our individual qualities such as skill-set, experience and disposition.

Furthermore, an informal status does not preclude these actions from being considered common or natural in a particular context.

The TFI-model posits that these three domains are layered in a manner that technical systems are subsumed under formal organizations – which in turn are subsumed under informal organizations. Hence, a technical system requires one (or more) formal organizations (such as rules or standards) in order to serve any functional purpose. In much the same manner, a formal organization has to be accepted by the informal organization (such as norms and values) in order to gain any footing.

4 Managing semantic interoperability

Based on our literature study we have identified two extreme approaches to semantic interoperability. We refer to these as top-down and bottom-up.

4.1 Top-down

The expression *top-down* in itself is widely used in conjunction with change management where senior management drives changes based primarily on a strategic view of the organization (Kirkbride, 1993; Nadler & Tushman, 1997, p.52-54). The decision to adopt the term top-down in our discussion on semantic interoperability is based on the locus of this logic – not the mechanics itself. One must make the important distinction between change management and semantic interoperability in that the former deals with action, the latter comprehension. It is of course quite possible that there may be a temporal or even causal relationship between the two areas – such as insufficient comprehension prompting change efforts – but such a discussion is beyond the scope of this paper. Furthermore, we must distinguish between the ownership of the underlying logic for structuring data and the data itself. A unit or subdivision may control data regarding its operations, customers and personnel in that local staff has the right to add, edit or delete what is stored in local/regional information systems. This does not mean that the unit or division is allowed to alter the *way* in which data is structured (Ross, Weill & Robertson, 2006, p. 28-38). Authority to amend the data structure may reside far removed from the unit(s) in which it is implemented.

A top-down approach to semantic interoperability expresses an implementation of formal standards that are intended to promote communal action throughout the organization. Standards are disseminated or even enforced by means of artefacts of some kind – such computerized information systems. The standards in question range from management policies to regulatory imperatives (DiMaggio & Powell, 1983).

The logic underlying the top-down approach is to a large extent rooted in Simon's (1962) notion of the organization as a goal-seeking entity. The organization seeks to achieve a highly complicated objective that must be broken down into manageable steps in order to be managed by an organizational unit. Thus, the manager – being the designer of the organization – is concerned with not just what is to be done, but also *how* things are to be done in order to optimize the organization as a whole (Simon, 1996, p. 4-5, 110-120; Simon, 1997, p. 186-197). In semiotic parlance, the designer is primarily concerned with pragmatics as he/she alone possesses an understanding of the system as a whole. The most common expression of this is how expertise and know-how is assigned to tasks; a common expression of this being hierarchies such as a bureaucracy or a multi-departmental form (Tompkins, 1987; Chandler, 1962, p. 325).

Davenport & Prusak (1997, p. 74-75) expresses the top-down perspective as a "monarchy" where one person or unit in the organization determines the shape and form of information processing. There are certain benefits associated with centralization, such as efficiency (Boland & Tenkasi, 1995) and standardized terminology (Holsapple & Joshi, 2002). However, the limited world view of a handful of individuals may also bring about detrimental effects, including poor information quality (Ackoff, 1967), arbitrary decision making (Ciborra, 2000, p. 39) and insufficient understanding of ends and means (Peppard, 2007).

4.2 Bottom-up

The bottom-up perspective may be thought of as a task-oriented approach to governance where the term "management" implies coordination rather than control. While there are several nuances in how people perceive the concept of bottom-up (Sabatier, 1986; Kirkbride, 1993), we intend to look upon this as a state where each organizational unit has their own taxonomy which is suited for their needs. Davenport & Prusak (1997, p.72-74) approximates this concept in their decentralized notion of "feudalism" where cooperation between departments is atypical. Thus while information structures corresponds to each organizational unit, top-level management may perceive information redundancy as high and have trouble accessing specific pieces of information without the aid of localized staff.

Organizations strive towards certainty in their decision-making despite the insurmountable complexities of the real world (Galbraith, 1973, p. 4-6). Failing to complete this Sisyphean task, organizations adapt by isolating their core technologies from uncertainty or ambivalence (Thompson, 1967, p.10-13). In doing so, one may formulate an operational logic that focuses on the task itself and perceives the surroundings only in the simplest of terms. It is then up to various supporting functions – such as management – to ensure that the core processes may operate under this premise.
The logic underpinning this perspective is described by Churchman (1971, p. 53-68) as the principle of non-separability. According to this view, the constituent parts of a system may not be designed or analyzed in isolation. Doing so would omit relativistic properties that may only be ascertained in a given context. Consequently, the designer – who has a great understanding of the core technology – must effectively translate external demands (e.g. by executives) so that they harmonize with local conditions rather than cause disruptions. In order to accomplish this, he/she must be familiar with the terminologies (or syntaxes) of both worlds in order to conceptualize the current state as well as the desired future state. This is also true of information which adjusted to the actual department and individual work tasks gives individual advantages as well as rich interoperational flow (Fagerström, 2003, p.189). It is entirely possible that the core processes over time achieve a level of distinctiveness that is difficult to emulate or replace (McKiernan, 1997). Should this distinctiveness be considered valuable, it stands to reason that the organization would seek to preserve it – even if this prohibits closely knit organizational design.

To some extent, the bottom-up paradigm precludes strict objectivity. Where one individual may see a problem, another sees business as usual. This difference in perspective is a result of the intricate ways in which system, organization and context influence one another. Following this logic, defining the problem is no longer a technical issue, but a social one (Magoulas & Pessi, 1998, p. 130-132; Checkland, 2000). As technical and non-technical aspects of the organization continue to influence one another, unpredictable – *emergent* – properties appear over time.

A complementary view of the bottom-up perspective is given by Ciborra (2000, p. 26-27 who argues that separability of design and management is a misconception by management that holds no bearing on reality. Designers and operational staff exert a sense of care and cultivation in their work which enriches the core technologies. It is only then that alignment between human and artefact can be achieved (Monteiro, 2000, p.72-75).

Davenport & Prusak (1997, p. 177) argue that top-down approach is problematic where critical know-how is located at the operational level. Highly normative change efforts championed by top-level management are typically met with lukewarm enthusiasm and limited success. In these milieus, it is therefore wiser that management concern itself with coordination; for instance by identifying competencies, assigning responsibilities and clarifying the organization´s strategy and objectives. Davenport & Prusak (1997) sees this as the way to achieve real information interoperability rather than leave it at platitudes and ambitions. This strategy necessitates dealing with individuals in the organization who want to keep information to themselves for political, emotional or technological reasons. The information architecture therefore needs an appropriate level of inscription which will lead to behaviour that is beneficial to all parties (Monteiro, 2000, p.76-79).

5 Method

The aim of this study is to approach semantic interoperability from an informatics perspective by studying how it may be discussed in terms of human understanding. This is done by employing a qualitative research method; multiple case study (Yin, 2009, p.60-62). Since the study is undertaken in order to understand the efficacy of the framework, the study may be categorized as an explorative study. Our theoretical framework is tested against two organizations where primary data is collected via employee interviews. The analysis is conducted via a hermeneutical research process, which basically involves collecting and interpreting empirical data (Patton, 2002, p.113). As our analysis is intended to test theory, we therefore view this as a deductive analysis.

Theoretical framework was implicitly known to us before this study and further reading provided us with several frameworks and models relevant to our research. Since it was our intention to rely on extent literature in the field of Informatics we therefore selected theoretical models that easily could be augmented.

The hermeneutical process of interpreting case Beta started in an earlier study, where semantic interoperability was one of the benefits from structured information (Slumpi Persson, Ahlin & Öberg, 2011). Interest arose to understand general aspects of semantics and therefore empirical material from one other company was needed. As the study was to be held on a general level and used to illustrate theoretical material, two companies, with different views, seemed appropriate. For the study at hand, one interview was held in each organization with personnel from middle management level – altogether two interviews. Sample size is in accordance with the fact that the empirical material will be used as illustrations and individual chosen due to their knowledge and experience. The interviews were held at the offices of the respective informants. We dedicated 45 minutes for company Alfa and 85 minutes for company Beta. The interviews were semi-structured, encompassing prepared- and unprepared questions based on informant responses (Creswell, 2007, p.352). The interviews were recorded and subsequently transcribed and categorized in different themes according to TFI-model. Some secondary data was also collected via the public websites of said organizations. Analysis was undertaken in an iterative fashion, where authors compare and discuss empirical material.

6 Case studies

In this section we present our case study and our results.

6.1 Case Alpha

Our first case is the branch office of a corporate group active in the financial sector. Altogether, the group encompasses approximately 15000 employees divided over 500 branch offices. Alpha offers a plethora of financial services to a wide range of customers. In order to provide customer service, the financial data of each client has to be accessible for every branch office. Given the nature of the information handled by the financial group, securing information from unauthorized access as while concurrently ensuring customer service are both primary concerns.

6.2 Case Beta

Our second case belongs to a global industrial group with approximately 12500 employees of which 2000 are working at Beta. Beta works with production and maintenance of electronic defence systems, mostly radar systems. Product development is usually based upon existing products, focusing on customization in correspondence with the wants and needs of the customer. Due to the nature of the products, large development projects involving several departments are standard operating procedure. In combination with product life-time service contracts, inter-departmental information is a necessity. External stakeholders such as subcontractors, auditors or users often require access to product documentation as a means to ensure quality.

6.3 Empirical pictures from cases

The centralized management style of case Alpha promotes semantic interoperability by means of uniformity – rules and regulations are formulated by top-level management and subsequently distributed through an intranet to national or global branches as relevant. It is the explicit duty of each employee to ensure that he/she keeps up with any and all changes in services and proper procedure. As for the comprehensibility of the information provided, our empirical data suggests the implicit assumption that education and on-the job training is intended to ensure uniformity of interpretation. However, alterations in formal procedure are often absorbed via informal division of labour. Certain events considered to be of particular significance are sometimes brought up and discussed at local office meetings, thus providing an opportunity for further exposition.

Informal organizations consisting of different persons are set in place to keep us updated on changes in rules and regulations. Sometimes news is even brought up on office meetings. (Senior manager, Alpha)

Alpha is characterized by strong centralization which also extends to the governance of information. Should a branch office wish to have something posted anywhere on the intranet, this would have to be communicated to the regional manager – and possibly further on up the hierarchy – for approval. In contrast to the management of the information structure, the actual information may in practical terms be considered the property of each office. Private customers as well as small businesses typically frequent the same branch office over a long period of time and it is not uncommon for business-owners to handle private- and business finances at the same office. This serves as an impetus for inter-divisional work processes as the financial situation of an individual may depend just as much on how well his/her business is doing as the shape of his/her private finances. As the line between private- and business finances sometimes blur, the branch office staff must sometimes handle this complexity in an informal manner.

Case Beta provides a sharp contrast as top management of the corporate group adopts a more hands-off approach to the identities of its constituent companies. Each company has its own name, logo and product catalogue. Customer relations are also handled on a strictly individual basis - there is no shared customer registry. Hence, each company is left to manage its own information – limiting "global" information to the essentials such as financial data. However, within Beta, semantic interoperability is managed by means of a product revision standard. Originally implemented some 50 years ago, it was not primarily intended as a means to disseminate information, but rather safeguard documentation of complex artefacts. Beyond complexity, the lengthy life-span of the artefacts (in excess of 40 years) places high demands on the logic underlying documentation in order to trace variations in components and configuration over time, devoid of ambiguity. As this product revision standard has been at the core of the company's product development for a long time, it is no longer a mere formalism. The codes and expressions stated in the standard are often used by employees in daily conversation. To some degree, this furthers the understanding of the artefact as a whole as the product revision standard is based on the type of product, its model, configuration et cetera.
The logic underlying the product revision standard is managed by a small team within the company. Operating in an informal, democratic fashion, they maintain the standard, instruct new employees in its use and modify the standard when necessary.

No, I am the group leader, but we go by a democratic model. If three people [out of four] say OK, then it is OK. If two people say it is OK, then we have not achieved [the goal]. (System owner, Beta)

Inputting data is left to the individual employees who are tasked with modifying the design of the artefact in question. While mistakes do occasionally occur in applying the correct code to a revised design, this is rarely a problem as employees usually work within a limited range of possible variations to an artefact. The project manager is then ultimately responsible for ensuring that the artefact corresponds to customer specifications as well as documentation.

In comparing the two cases, there are obvious contextual dissimilarities – most noticeably the products and services that they provide. Yet they are similar in so far as they both depict organizations that have been in existence for over half a century – less than a decade of which spent under current ownership. It is also interesting to note that employees in both cases prefer to "ask a colleague" rather than utilize designated support functions.

7 Analysis/discussion

The discussion will follow the structure of the TFI-model with emphasis on relationships between the layers, as it is here that semantics, i.e. understanding, plays a significant role (Liebenau & Backhouse, 1990, p. 109-112).

7.1 Juxtaposition, Alpha and Beta

Illustrating the cases using the TFI-model, we may observe two distinct ways in which technology and informal organization may influence the formal aspects of the organization.

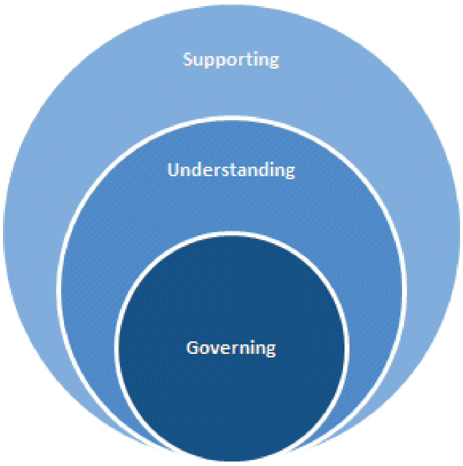

Figure 2: Alpha interpreted via TFI-model

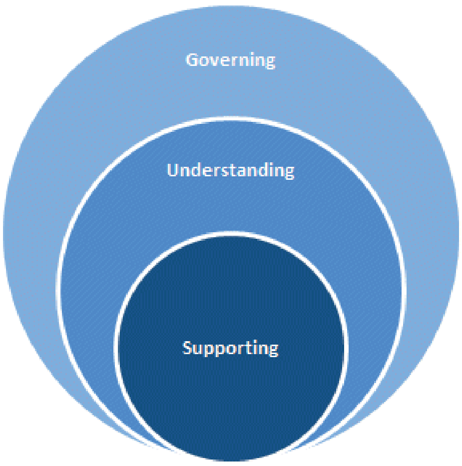

Figure 3: Beta interpreted via TFI-model

The centralized information management at Alpha is motivated by a need for similarity despite serving customers nationwide. In the terminology of the semiotic framework, uniformity in pragmatics is sought by means of instructions and updates distributed via the intranet. A sense of shared semantics is attained on a local level when new instructions are contextualized by means of formal meetings or informal conversations. From a TFI perspective, we may describe case Alpha as being governed by formal directives distributed via technical (IT) systems and supported by means of informal structures that have formed in order to improve contextualization.

The specialized information management at Beta stems from its need to trace variations in complex products over a very long time-frame. The elaborate syntax set in place to facilitate this necessity has over several decades become ingrained in the organization to the point where it is practically a part of local culture. Although initially confronted with a steep learning curve, employees are able to use the highly codified syntax to share information in a very efficient manner; supported by a computerized catalogue-system if it is needed. Hence, we view the information infrastructure at Beta as being governed from cultural, informal structures present in the organization with technical systems merely serving a supporting role.

7.2 Technical systems and formal organization

In reviewing the two cases, we can discern two distinct ways of managing technical systems. Alpha resembles what Davenport & Prusak (1997, p. 74-75) describe as a monarchy; the ability to alter technical systems is highly centralized. This enables uniformity in data quality and the ability to handle customers the same way despite serving a vast geographical area and heterogeneity in customer requirements. Beta corresponds to feudalism where cooperation, integration and technical conformity between group companies is limited. This allows great disparity in products, services and customer base.

In terms of syntax, it is readily apparent that new employees face different levels of complexity in the two cases. Workers at Alpha undergo on-the-job training that is usually completed within the space of one day. Employees at Beta face a more drawn out period of intermittent training that covers several months. Based on the disparity in time-frames, we may infer that the level of generality between syntaxes differ significantly, Beta being far more idiosyncratic.

Furthermore, we may discern different levels of inscription in the technical systems. At Alpha, employees are to a large extent instructed to act based upon information that is stored in the technical systems. In effect, the technical systems act as a means to impact the actions and understanding of employees from a single point in the organization. Beta provides a sharp contrast in that information stored in the system provides a distinct logic for arranging information, yet does not specify behaviour in any explicit form. This is most acutely felt through the lack of regulatory functions despite the complicated syntax. Employees are in other words “free” to make mistakes.

7.3 Formal and informal organization

As previously mentioned, the levels of complexity facing new employees differ significantly between the two cases. Alpha sees new employees able to learn to utilize the technical systems within days whereas the product configuration system at Beta takes months to learn. This difference is noteworthy seeing as both companies typically hire college/university graduates with relatively homogeneous backgrounds. The semantic structure (Langefors, 1973, p. 242-249) of employees should therefore be somewhat similar with respect to skill-set. Even so, Beta accepts a lengthy process of adaption whereas Alpha has apparently taken steps to ensure that pre-existing skills (attained at university) to a large degree suffice. The apparent acceptance of this lengthy time frame suggests a high level of integration into corporate culture (Monteiro, 2000, p.72-75).

Moving beyond the lengthy period of adaptation, the common language provided by the product revision system at Beta allows the organization to economize on information (Boisot, 1995, p.39-86) by simply using product codes as short-hand. Also, employees are rewarded for their efforts by having a large extent of freedom to work as they see fit. The situation at Alpha is quite the opposite as information is made available in greater volumes than employees are able to process; effectively bringing about scanning or informal division of functional areas.

8 Conclusion

The aim of this study was to approach the topic of semantic interoperability from an informatics perspective, i.e. in terms of human understanding rather than technical compatibility. A literary study suggested two extreme viewpoints in managing semantic interoperability: Top-down and bottom-up. Utilizing a deductive approach, a case study has been undertaken in order to illustrate what form these viewpoints may assume in real life.

Our real-world cases have been analysed based upon a view of semantic interoperability based upon semiotics, the study of signs. Furthermore, our view of the cases is based upon the TFI-model which expresses three organizational layers: Informal organization, formal organization and technical systems. Combined, the human focus of semiotics and the explicit consideration of formal as well as informal factors of TFI provide us with a novel perspective on semantic interoperability. We believe this perspective is pertinent to academia as well as practice due to its generality. However, we do not claim this to be a useful tool as it stands, but merely a suggested starting point for future endeavours.

Approaching the concept of semantic interoperability by means of a common body of research would enable a wider research community than each individual context can produce. We therefore call on a unified approach so that we may all learn from one another rather than suffer from a lack of semantic interoperability ourselves.

9 References

Ackoff, R. (1967). “Management Misinformation Systems”, *Management Science*, Vol. 14, No. 4, 147-156.

Backhouse, J. & Halperin, R. (2009).” Approaching Interoperability for Identity Management Systems.,” in Rannenberg, K., Royker, D. & Deuker, A. (Eds.) *The Future of Identity in the Information Society,* Heidelberg, Springer Verlag.

Boisot, M. H. (1995). *Information Space,* Routledge, London.

Boland, R. J. & Tenkasi, R.V. (1995). “Perspective Making and Perspective Taking in Communities of Knowing,”. *Organization Science*, Vol. 6, No. 4, 350-372.

Chandler, A. D. (1962). *Strategy and Structure: Chapters in the History of the American Industrial Revolution,* Cambridge, Mass, MIT Press.

Checkland, P. (2000). “Soft Systems Methodology: A Thirty Year Retrospective,” *Systems Research and Behavioural Science*, Vol.17, 11-58.

Churchman, C.W.(1971). *The Design of Inquiring Systems: Basic Concepts of Systems and Organization,* New York, Basic Books Inc. Publishers

Ciborra, C.U. (2000). “A Critical Review of the Literature on the Management of Corporate Information Infrastructure,” in Ciborra, C.U. (Ed.) *From Control to drift – the dynamics of corporate information infrastructures,* Oxford, University Press.

Davenport, T.H.& Prusak, L. (1997). *Information Ecology,* New York, Oxford University Press.

DiMaggio, P.J. & Powell, W.W. (1983). “The iron cage revisited: Institutional isomorphism and collective rationality in organizational fields,” *American sociological review*, Vol.48, No. 2, 147-160.

Fagerström, B. (2003). “ IT-användning – en analysmodell för IT-nytta,” Doctoral Thesis Luleå, Luleå Technology University, Department of Business Administration and Social Science.

Galbraith, J. (1973). *Designing Complex Organizations,* Reading, Mass,Addison-Wesley Publishing.

Harvey, F., Kuhn, W., Pundt, H., Bishr, Y., & Riedemann, C. (1999). “Semantic Interoperability: A Central Issue for Sharing Geographic Information,” *The Annals of Regional Science,* Vol. 33, 213-232.

Hirschheim, R. & Klein, H.K. (1989).” Four Paradigms of Information Systems Development,” *Communications of the ACM*, Vol. 32, No. 10, 1199-1216.

Holsapple, C.W & Joshi, K.D. (2002). “A Collaborative Approach to Ontology Design,” *Communications of the ACM,* Vol. 45, No. 2, 42-47.

Kirkbride, P. (1993).” Managing Change,” in Stacey, P. (Ed.) *Strategic Thinking and the Management of Change,* London, Kogan Page.

Langefors, B. (1973). *Theoretical Analysis of Information Systems,* 4th Edition, Lund, Studentlitteratur.

Liebenau, J. & Backhouse, J. (1990). *Understanding Information – An Introduction,* Palgrave Macmillan, London.

Magoulas, T. & Pessi, K. (1998). “*Strategic IT-management,”* Doctoral Thesis Gothenburg, Gothenburg University, Department of Informatics.

McKiernan, P. (1997). “Strategy past; Strategy futures,” *Long Range Planning,* Vol. 30, No. 5, 790-798.

Miller, D. (1993). “The Architecture of Simplicity,” *The Academy of Management Review*, Vol. 18, No. 1, 116-138.

Monteiro E. (2001). “Actor Network Theory and Information Structure,” in Ciborra, K.U. (Ed.) *From Control to drift – the dynamics of corporate information infrastructures*. Oxford, University press.

Nadler, D. & Tushman, M. (1997). *Competing by Design: The Power of organizational Architecture*. New York, Oxford University Press.

National Aeronautics and Space Administration (NASA). (1999), *Mars Climate Orbiter Mishap Investigation Board Phase I Report, r*etrieved from ftp://ftp.hq.nasa.gov/pub/pao/reports/1999/MCO_report.pdf.

Orman, L. (1983). "Information Independent Evaluation of Systems," *Information & Management,* Vol. 6, 309-316.

Patton, Q. M. (2002). *Qualitative Research & Evaluation Methods.* 3rd Edition*.* Thousand Oaks, Sage Publications.

Peppard J. (2007). "The conundrum of IT management," *European Journal of Information Systems,* Vol. 16, 336-345.

Popper, K.R. (1974). *Objective Knowledge: An Evolutionary Approach*. Revised reprint. London, Oxford University Press.

Rockart, J.F. (1979). "Chief Executives Define their own Data Needs," *Harvard Business Review*, Vol. 57, No.2, 81-93.

Ross, J.W. & Weill, P. (2002)."Six IT decisions your IT people shouldn't make," *Harvard Business Review* 80(11), 85–91.

Ross, J., Weill, P. & Robertson, D. (2006). Enterprise Architecture as Strategy. Boston, Harvard University Press.

Sabatier, P.A. (1986). "Top-Down and Bottom-Up Approaches to Implementation Research: A Critical Analysis and Suggested Synthesis," *Journal of Public Policy*, Vol. 6, No. 1, 21-48.

Simon, H. (1962)." The Architecture of Complexity," *Proceedings of the American Philosophical Society.* Vol. 106, No. 6, 467-482.

Simon, H. (1996). *Sciences of the Artificial*. Third edition. Cambridge, Mass, MIT Press.

Simon, H. (1997). *Administrative Behavior*. Fourth edition. New York, The Free Press.

Slumpi Persson, T., Ahlin, K. & Öberg, L-M.(2012). "Intraorganizational benefits from product configuration information – a complementary model," conference paper International Design Conference – Design 2012 Dubrovnik - Croatia, May 21 - 24.

Stamper, R., Liu, K. , Hafkamp, M. & Ades, Y. (2000)." Understanding the roles of signs and norms in organisations – A semiotic approach to information systems design," *Journal of Behaviour & Information Technology*, Vol. 19, No. 1, 15–27.

Star, S. L., & Bowker, G. (2002). "How to Infrastructure," in Lievrouw, L. & Livingstone, S. (Eds.) *Handbook of new media.* London, Sage.

Thompson, J. D. (1967). *Organizations in Action*. New York, McGraw-Hill.

Tompkins, P. K. (1987). “Translating Organizational Theory: Symbolism over Substance,” in Jablin, F., Putnam, L., Roberts, .K. & Porter, L. (Eds.) *Handbook of Organizational Communication*. Newbury Park, Sage Publications.

Yin, R.K.(2009). *Case Study Research – Design and Methods*. Thousand Oaks, Sage Publications, Inc.

Paper III

Exploiting Information: Seeking Long-term Preservation of organisational knowledge

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Abstract

Long-term preservation of organisational knowledge gives the business opportunities to reuse stored knowledge. This preservation of knowledge is present both in the organisation as such, found explicitly in the organisational stock, and also in the individual workers, implicit in their flow of action. Theoretically have the reuse of knowledge been named organisational memory and also been addressed in knowledge management. In a single case-study of a manufacturing company, the authors study the utilisation of product configuration information (PCI) and its role in meeting requirements on long-time preservation of product-related knowledge. This structured and standardised information is used throughout the organisation, serving as a base for both organisational and individual knowledge for the entire company. Since the information has been used in the same way for decades it is a part of the organisation´s culture and influences structures and procedures connected to the information base. The result of the study implies that usage of PCI grants the individual worker a high degree of task-related freedom as well as intra-organisational mobility. The downside for the individuals is the long time period it takes to get familiar with PCI due to its complexity. For the organisation as such, PCI provides a stable stock of knowledge which is available over extended periods of time, drastically reducing dependence upon individual workers.

Keywords: organisational memory, knowledge management, long-term preservation of knowledge, product configuration information

Introduction

Product development is an essential process to companies in wide variety of market segments. It is a constant source of concern as each year sees more complex products and increasingly compressed development cycles (Sawy, Malhotra et al. 1999; Hicks, Culley et al. 2002; Storga 2004). Concomitant to increased complexity of physical products is a more heterogeneous set of intangible resources in order to support development as well as logistics (Porter & Millar, 1985). As gathering and creating immaterial resources – such as information and knowledge – can be every bit as costly as acquiring physical materials, there are obvious incentives to reuse both where possible. Historically, the reuse of knowledge has been largely implicit in that know-how has shaped processes, structures and culture – tangible remnants of past experience sometimes referred to as *organisational memory* (March & Simon, 1958; Walsh & Ungson, 1991). As enterprises have shifted towards competing via application of inimitable resources (Barney, 1991), there have emerged an increasing awareness that greater care should be taken to explicate and safeguard immaterial resources – such as experience and knowledge – as they are difficult to replicate (Grant, 1996). This issue, in turn, has been extensively addressed under the guise of *knowledge management* (KM) – the purpose of which is to explicate and disseminate knowledge present within the organisation (M. Broadbent, 1998; Inkpen, 2000; O'Dell & Grayson, 1998).

However, knowledge is a nebulous concept that invites a wide range of interpretations. In practical terms, we may perceive knowledge as either explicit organisational stock or implicit in an individual worker's flow of action (Bontis, Crossan, & Hulland, 2002; Styhre & Gluch, 2010). Neither perspective is in its own right satisfactory in terms of reliably preserving knowledge. Individual workers are able to deftly adapt and apply their experience in a wide range of situations, but may leave the organisation at any time – taking their knowledge with them (DeLong, 2004; Drucker, 2001). Conversely, treating knowledge as stock assures possession within the organisation, but does not guarantee proper application (Chowdhury, 2010). Nor does if assure accessibility as knowledge management systems (KMS) are subject to creative destruction like any other technology (Hicks, Culley et al. 2002; Bollacker 2010). Differences between the two perspectives aside, it would seem that longevity is a source of concern in the preservation of knowledge within an organisation – regardless of whether we entrust it to the minds of workers or the storage facilities of a system. How then may we overcome this temporal barrier and ensure knowledge preservation over extended periods of time?

The purpose of this paper is to illustrate how individual knowledge and organisational knowledge may be combined – and in this act promote long-term preservation and management of knowledge within an enterprise. We approach this via case study of a defence contractor where product configuration information (PCI) serves as a persistent base of knowledge. PCI contains requirements for product design, realisation, verification, operation and support, and is expressed in artefacts such as specifications, design drawings and operating manuals (SIS, 2004). As the enterprise in question typically accepts responsibility to serve and maintain their products for several decades after delivery, they have had to develop a means to safeguard long-term access to product knowledge. We describe this case and analyse their approach to establishing a common base of organisational knowledge that remains stable over time.
It is our aim to contribute to KM literature by addressing the issue of long-term preservation of knowledge and how this is affected by factors more commonly attributed to organisational memory.

Knowledge management

The resource-based view of the firm (Barney, 1991) as well as the derivative knowledge-based view of the firm (Grant, 1996) suggests that intellectual resources are a significant source of sustainable competitive advantage. Following this line of reasoning, knowledge management (KM) as a field of research and practice commonly extends to mapping skills and know-how present within the organisation as well as means to disseminate and exploit knowledge resources (Alavi & Leidner, 2001; M. Broadbent, 1998). This can be directly motivated in terms of efficiency as recycling and reusing existing knowledge saves time and resources (Hicks, Culley, Allen, & Mullineux, 2002). Another, less direct, use for readily available knowledge is the potential for innovation by means of either co-development between different actors or combining separate areas of expertise (Yoo, Henfridsson, & Lyytinen, 2010). The former expresses a situation where knowledge resources that would otherwise be markedly heterogeneous are rendered sufficiently accessible so as to promote meaningful report, e.g. via a task force or project group (Boland & Tenkasi, 1995), whereas the latter involves bringing extant formalised knowledge resources to bear on a single task in order to create novelty or utility – such as by adding digital properties to physical artefacts (Yoo, Boland, Lyytinen, & Majchrzak, 2012).

Both of these points, the resource-based and the knowledge-based view, highlight the need of the organisation to *manage* knowledge much like other resources – decision makers need the ability to assess what knowledge resources are present so that they are able to assess competitive ability and address any noticeable gaps (Aldrich & Herker, 1977; O'Dell & Grayson, 1998).

Knowledge and Information

Knowledge in itself is a somewhat nebulous concept that tends to invite different interpretations depending on the interests and perspectives of the observer (Zins, 2007). In terms of evaluation, knowledge is often envisioned as part of a hierarchy where wisdom forms the apex, followed by knowledge, information and data in that order (Rowley, 2007). Following this perspective, knowledge may signify the ability to translate input into action (Ackoff, 1989) or, in an inverse manner, how to shape output based on past actions (Tuomi, 1999). While this hierarchy has gained some traction in literature, traversing it is not to be taken lightly as the conceptualisations of the constituent layers are by no means homogeneous. Information, for instance, may be regarded as structured or unstructured – the former being regarded as factual, descriptive statements whereas the latter is not (Wallace, 2011). Hicks et al. (Hicks et al., 2002) discuss a different distinction – that of formal and informal information. They describe formal information as being relatively stable and intended to communicate something with little or no difference between recipients. Conversely, informal information provides different meanings to different individuals. While the aforementioned conceptualisations of information differ in certain areas, a crude contrast can be discerned between the subjectivity of unstructured, informal information, and the objectivity – or at least inter-subjectivity – of structured, formal information.

Formalised knowledge management efforts are dependent upon explication of knowledge as they are typically operationalised via some manner of computerised knowledge management system (KMS) that facilitates rapid access to material (Alavi & Leidner, 2001). Once digitised, IT can facilitate distribution of explicit knowledge with great efficiency. However, distribution of explicit knowledge does not guarantee understanding as explicating knowledge is a subjective process, dependent upon one's theoretical perspective and area of concern (Boisot, 1995).

Perspectives on knowledge

An exhaustive discourse on the nature of knowledge is well beyond the scope of this paper. From a pragmatic standpoint, it is however relevant to briefly discuss the dichotomous relationship between perceiving knowledge as *stock* or as *flow of action* (Bontis et al., 2002; Styhre & Gluch, 2010). The latter perspective, knowledge as flow of action, highlights the subjective quality of knowledge. Knowledge is to a large extent tied to individual experience and the context from which this experience is derived (Hippel, 1994). Drucker (Drucker, 2001) elaborates on the practicalities of this individual perspective when he describes knowledge workers and their role in complex tasks and collective efforts. First and foremost, knowledge in and of itself is not a source of value or advantage unless it is put to good use. The ability to capitalise on knowledge is therefore dependent upon the ability to either find suitable tasks for existing knowledge resources or find knowledge resources to solve existing tasks (Drucker, 1992). Secondly, knowledge workers tend to possess greater expertise (in their respective fields) than their superiors. It is no great exaggeration to suggest that the activities of knowledge workers are black-boxed and only discernible in terms of input and output. This puts the organisation is an awkward position as it stands to lose vital skills and know-how should an employee resign or retire (Baskerville & Dulipovici, 2006).

One way of limiting the risk of knowledge walking out the door is by entrusting its custodianship to the organisation itself rather than the individual workers. However, for knowledge to be viable as stock, it must first be rendered in a form that is viable for codification, storage and dissemination with any degree of efficiency (Alavi & Leidner, 2001; Boisot, 1995). Given the individualistic nature of knowledge, this process of explicating knowledge is by no means simplistic. Nonaka (Nonaka, 1994) refers to this transition from tacit to explicit knowledge as externalisation and underscores the complexity involved compared to the more profoundly researched mechanisms such as personally transferring tacit knowledge through practical demonstration. Furthermore, externalisation is dependent on contingent factors such as the complexity of the knowledge in question and the motivation of actors to share knowledge (Sun, 2009; Wang & Noe, 2010).

One pervasive issue with perceiving knowledge as stock is that capturing it entails some form of de-contextualisation, either through abstraction or codification (Boisot, 1995). The relative effort in reintroducing lessons learned as formalised knowledge is evident in the limited efficacy of written rules and similar measures (Cohen & Bacdayan, 1994). Hence, a more traditional approach is to capitalise on knowledge through embedding it in routines and processes (Darr, Argote, & Epple, 1995a). Hence, we must take into account that a stream of past events and experiences are now implicitly felt in current organisational procedures or tangible artefacts that go beyond what can be described as knowledge. Rather, they may be described as part of an organisational memory.

Organisational memory

The notion of organisational memory was popularised by March and Simon (March & Simon, 1958) in their assertion that organisational procedures are the persistent outcome of a given set of circumstances, and as such may be regarded as a "memory" of the decision process. While not as diverse as knowledge, the conceptualisations of organisational memory range from that of a mere metaphor to a more literal interpretation that sees organisations as entities capable of cognition (Walsh & Ungson, 1991). While there are those who equate organisational knowledge and organisational memory (Alavi & Leidner, 2001), there are differences in how the two concepts are approached. The most obvious difference is that of nomenclature – organisational memory has been defined as "stored information from an organisation's history that can be brought to bear on present decisions" (Walsh & Ungson, 1991). The difference between information and memory is perceived as one of time – information being current and memory past. Looking beyond differences in nomenclature, there are similarities in the apparent desire to separate that which is personal and that which is shared. El Sawy et al (Sawy, Malhotra, Gosain, & Young, 1999) makes this distinction in their notion of episodic memory which is linked to personal experiences, and semantic memory which is shared within the organisation.

In an attempt to provide the concept with more structure, Walsh and Ungson (Walsh & Ungson, 1991) outline six "bins" that may possess organisational memory: Individuals, culture, transformations, structure ecology and external archives.

Individuals are of course in possession of their own cognitive faculties, belief systems and preferences that they utilise in the performance of their tasks. Worth noting is that Walsh and Ungson (ibid) perceive information technologies as part of this bin as it is individuals – not the organisations – that directly utilise these tools. Organisational culture colours the way employees view their environment as well as how they communicate. It may take the form of formalised languages or frameworks or less formal stories and gossip. Transformations entail all aspects of input being transformed to output – be it manufacturing or education. The logic underpinning these transformation processes provides a link back to past experiences and in effect provides a tangible expression of past knowledge and decisions. Structures express the roles that employees possess and how these roles assert influence on how we act (division of labour) as well as interact (attitude towards environment). Ecology describes the physical workplace and how this reflects organisational attitudes and professional status. Lastly, external archives are made up of any source of memory that rests outside of the organisation. This encompasses a rather diverse mixture of sources, ranging from past employees to government agencies and business partners.

A seventh "bin", information space, has been suggested by Karsten (Karsten, 1999) in an attempt to highlight the interconnected nature of the aforementioned repositories of organisational memory. The information space is limited to current, short-term information, the meaning and significance of which is negotiated by workers and managers. The relationship between information and organisational memory is also discussed by Stein and Zwass (Stein & Zwass, 1995) in their outline of an IT-enabled organisational memory information system (OMIS). As the scope of OMIS is purported to match Walsh and Ungson's conception of organisational memory, explicit attention must be paid to matters pertaining to the degree of shared ontology, epistemology, semantics et cetera. Only after availing ourselves to these meta-requirements are we able to ascertain the suitable level of temporal as well as spatial integration of information describing organisational events.

Despite the tremendous advantages offered via technology, we must not allow ourselves to lose sight of the fact that a neat separation of tacit knowledge (experience) and explicit knowledge (information) is only clear when presented as such in literature (Fahey & Prusak, 1998; Rowley, 2007). In reality, tacit knowledge without any degree of formalisation renders even the most rudimentary management or transfer of knowledge cumbersome as we have no framework upon which to build any form of coordination. Conversely, explicit knowledge is entirely useless unless it is presented to us in a format that we are able to comprehend and apply (Levina & Vaast, 2006). In other words, the levies between tacit and explicit rapidly give way to emergence as tools, people and contingencies interact over weeks, months and years. The temporal perspective is a source of concern as it is difficult to know *what* warrants saving and *how* to best capture knowledge since we cannot positively predict future needs and preferences (Fahey & Prusak, 1998).

Challenges in preservation of knowledge

There are several operational challenges in preserving knowledge. First and foremost, explicated knowledge – in the form of data – requires a medium for storage. This in and of itself can create problems as digital media have nowhere near the longevity of non-digital media, e.g. paper (Bollacker, 2010). Furthermore, utilising digital data creates the need for intermediate components, such as software, that renders digital data comprehensible to our senses. Should these intermediate components become unavailable through obsolescence or physical breakdown, we would then be unable to access data despite having it in our possession (Carraway, 2011; Hicks et al., 2002).

Looking beyond physical accessibility, there are also cognitive issues to consider when accessing explicated knowledge. The most obvious issue may be described as *spatial* in the basic sense that our different experiences, perspectives and training brings about heterogeneity of interpretation (Langefors, 1995). It is possible – or perhaps even likely – that two individuals will look at the same data and draw different conclusions. Interpretations may diverge further if one considers a *temporal* dimension. Specifically, intended meaning and received meaning may differ substantially if the originator does not provide a sense of conviviality and legitimacy for the recipient (Carraway, 2011; Chowdhury, 2010). In practical terms, a description of an item or occurrence may not be sufficient for future comprehension unless it is imbued with a sense of shared context (Nonaka, Toyama, & Konno, 2000).

In summary, it would seem that attention to temporal as well as spatial integration is required in preserving knowledge over time. The individual worker can mitigate these issues through our innate ability to weigh inputs, adapt to the world around us and make informed judgments; yet we are held back by our imperfect memory and limited range of comprehension. The aggregate organisation on the other hand can, with the aid of IT, sport perfect recall regardless of knowledge domain. Entrusting the preservation of knowledge to an organisation assumes that qualities such as judgment can be formalised and institutionalised – a lofty goal if ever there was one. The issue, it would seem, is one of deriving the best of both workers and the organisation – tacit and explicit knowledge –rather than risking being inhibited by their limitations.

Method

As discussed above, the aim of this study is to discuss the challenges in managing knowledge for individuals and organisations of complex products development and maintenance over a long period of time. In this study we have pursued this using a qualitative research method; single case study (Yin, 2009). The study´s theoretical framework consists of an overview from two related areas, knowledge management and organisational memory, which are combined in an effort to pursue the research question. Given this premise, the study can be categorised as an explorative study. The theoretical framework is tested against one organisation where primary data is collected via employee interviews. The analysis is conducted via a interpretative research process, which basically involves collecting and interpreting empirical data (Walsham, 2006). This study uses an inductive analysis, which is derived from performing a comparison from the interpreted empirical base and the combined theoretical framework during the research process (Krippendorff, 2012).

Parts of the theoretical framework, knowledge management, was implicitly known to us before this study and was further bolstered by additional reading where this was deemed relevant to our research. Since it was our intention to rely on extant literature in the field of informatics/information systems, we therefore selected theoretical concepts that could easily be augmented. Originating in our prior knowledge of knowledge management, the issue of knowledge preservation led us to organisational memory, i.e. via Alavi and Leidner´s work (Alavi & Leidner, 2001). The theoretical field of organisational memory was largely unknown to us prior to this study – necessitating active search for literature using different databases. In broad terms, we here see knowledge management as largely focussed on explicit knowledge whereas organisational memory is more multifaceted.

Since the study was to be limited to a general and exploratory level and used to illustrate theoretical concepts, one case was deemed sufficient by the authors. For the study at hand, seven interviews were held with personnel from middle management level within a single organisation, which will be referred to as Alpha. Alpha delivers electronic defence systems. Roles held by respondents were development project manager, team manager software development, team manager customer support, team manager customer documentation, team manager mechanics construction, process coordinator configuration. Our choice of middle management is due to their knowledge of the company´s operational processes as well as the strategic priorities of upper management (Davenport & Prusak, 1997). Although the engineers at Alpha are skilled knowledge workers, we only concern ourselves with *one* of their tasks – product revision and its accessibility over time. The interviews were held at the offices of the respective informants. At least one of the authors attended each interview, which ranged from 60 to 100 minutes in length. The interviews were semi-structured, encompassing prepared- and unprepared questions based on informant responses (Creswell, 2007). The interviews were recorded and subsequently transcribed and categorised in different themes according to theoretical concepts. Some secondary data was also collected via the public website of Alpha. The content in the empirical material was divided into the two broad categories of knowledge – the organisational view and the individual view. These are regarded as units of analysis with categorical distinctions (Krippendorff, 2012). Analysis was undertaken in an iterative fashion, where authors compared and discussed empirical material.

Case study

The object of our study, which we will refer to as "Alpha", may be described as a defence contractor involved in the production and maintenance of electronic defence systems. It is part of a global industrial group with approximately 12500 employees – 2000 of which are working at Alpha. Alpha is a late addition to the industrial group, having been acquired in the mid-2000s. Product development is usually based upon existing products with added customisation based upon customer specifications. The complexity of the products, combined with life-time product maintenance contracts, necessitates frequent exchange of information across departmental boundaries as well as reliable records on products and constituent components. External stakeholders, such as subcontractors, auditors or customers, often demand access to product documentation as a means to ensure quality.

Empirical findings

First implemented some 50 years ago, Alpha´s approach to product configuration information (PCI) was originally motivated by a joint venture between three large organisations that needed to keep track of products comprised of huge amounts of disparate components. Furthermore, the end product was expected to have a long life-span, making reliable records a priority. As the joint venture became a thing of the past, the standard used to structure information continued to be unilaterally developed by Alpha where it existed independent of any explicit departmental allegiance. As the original scope spanned the eclectic product libraries of three large organisations, PCI allows considerably more diversity than Alpha actually needs – creating considerable redundancy.

In addition to complexity, the lengthy life-span of Alpha's products (in excess of 40 years) places high demand on documentation in order to trace variations in components and configuration over time, – devoid of ambiguity:

"When we can still to this day repair or manufacture parts for a forty-year-old system, and still know exactly what to do, we have a good system." (Coordinator configuration process)

As PCI has been a part of Alpha's product development for a long time, it is no longer a mere formalism. The codes and expressions stated in the standard underlying PCI are sometimes used as short-hand by employees in daily conversation. To some extent, this furthers the understanding of the artefact as a whole as the logic underlying the standard used for product revision is based on the type of component, its model, configuration et cetera. The most visible aspect of PCI is the unique identifier used for each component. The identifiers are formed by a span of approximately a dozen characters that are arranged in a specific fashion. While this highly specific structure may suggest a purpose, its meaning is far from self-explanatory to the unenlightened.

Knowledge of PCI differs from domain knowledge (i.e. mechanics, hydraulics, electronics etc.) as it signifies its place in a context rather than elucidate its internal structure or architecture. It is not a specification in itself, but rather a pointer to the correct specification among several that may differ significantly or merely in minor detail (e.g. colour). This indirect nature of PCI presents a form of meta-knowledge that can be considerably more stable over time compared to domain knowledge where conditions may vary wildly. In extreme cases, whole domains of knowledge may appear and gain prominence. For example, when Alpha first started using PCI, there was no such thing as software. Yet today it is an integral part of most – if not all – of their products.

As a means of support, Alpha utilises two software tools where one manages input and the other retrieval. The adoption of the current (new) scheme to interact with the PCI was prompted by the change in ownership as continued use of the old tool, where input and retrieval were integrated, would have incurred significant licensing fees. While less suited to the task, the introduction of the new tool was championed by management and gained acceptance from users following organisation-wide training. This separation of functionality into two separate tools is an ever present potential for error as users are often prone to ask one's colleague rather than accessing the formal knowledge base using the secondary tool. The continued use of two separate tools is motivated by internal budgeting as no department wants to shoulder the cost of integrating the tools.

Scrapping the peculiar logic of PCI and switching to a different standard (for which the new software tool offers better support) was not considered an option. The commitment to the old standard seems to run deep, and several informants described PCI as "imbued in the very walls" at Alpha. Its usage and history serves to promote the transfer of knowledge from each worker to the organisation, facilitating an environment where no single worker is irreplaceable.

The logic and structure underlying the PCI is managed by a small team within the company. Operating in an informal, democratic fashion, they maintain the standard, instruct new employees in its use and modify the standard when necessary. Individual employees add content in the course of their work, i.e. designing or modifying components needed to construct the finished product. While mistakes do occasionally occur, e.g. in applying a correctly revised identifier to a modified component, this is rarely a problem as employees usually work within a limited range of systems and components. The content of PCI is usually taken at face value, making the individual workers themselves responsible for its veracity. Hence, PCI in many ways serves as a direct extension of a person's working context and standing in the company.

The knowledge base is built upon input from past and present employees. New employees are required to participate in training sessions where the fundamentals of the standard are explained, and typically acclimatise to practice by learning one functional area at a time. Even though new employees tend to be highly educated to begin with, it usually takes them at least six months to learn PCI and associated procedures. Learning (internalising) the standard is not a formal requirement, but exceedingly common among workers. Consequently, new employees who are unwilling to adapt tend to leave the company.

PCI appears to strike a balance between individual knowledge and organisational knowledge. One informant made the following comment in response to a hypothetical scenario where the PCI is excised from Alpha:

”We have a lot of individual knowledge, so we can perhaps manage without documentation. There are people who can construct a product structure on different levels. The knowledge still exists, due to that we have very competent individuals in different areas. […] A simultaneous change of personnel would make for a catastrophe. So a first step would be a reconstruction in some way, with the existing personnel and their knowledge.” (Team manager software development)

Discussion

Following the statements made by informants, the use of product configuration information (PCI) at Alpha appears to bring about several positive effects for the company. Keen insight into the structure of products provided via PCI enables purposeful supervision and economies of scale with regards to product development as well as post-delivery logistics. Hence, we may surmise that PCI in a very real sense functions as an organisational memory that not only follows the products from cradle to grave, but also permeates the structures and processes at Alpha – providing advantages in terms of efficiency and profitability. Not only that, but in light of the intricate nature of the products, a cumulative, adaptive and stable manner of gathering and structuring explicit knowledge is essential to the operations of Alpha. These bottom-line effects would however not come to pass without the ability to capture, preserve and reuse engineering designs over significant periods of time – equal to or exceeding the life-cycle of the products themselves. Given that this life-cycle may in fact exceed the span of any single worker’s professional career, safeguarding relevant information and know-how often falls to the organisation.

From the perspective of an individual worker, the impact of PCI is initially a matter of amending one’s pre-existing knowledge with this new nomenclature that is largely unique to Alpha. This requires a certain deviation from the individualistic mind-set on the part of the engineers that make up the bulk of the workforce. The individual initially finds him/herself in the somewhat submissive position of learning something that is not task-oriented and as such does not offer a readily visible payoff. This can deter those with an entrepreneurial mind-set as they may perceive this as a push to conformity rather than individuality – a quality that rests at the heart of skilled knowledge workers (Drucker, 2001). At Alpha, informants repeatedly stated that PCI is a part of the company and at times even used as short-hand in conversations, suggesting that culture is a potent force in promoting acceptance of the standard. It is therefore no exaggeration to consider the internalisation of PCI as a significant checkpoint for actually entering into the organisation as opposed to merely being an employee. While the task of internalising PCI may seem daunting to the uninitiated, it offers profound insight to those who have grown accustomed to its underlying structure. It is only after passing this hurdle that the reciprocity of knowledge between organisation and worker become apparent. In essence, the use of PCI can be regarded as automatic retrieval (Walsh & Ungson, 1991) or knowledge embeddedness (Darr, Argote, & Epple, 1995b) as its use is integrated into organisational processes, facilitating the ability of structures to serve as repositories for organisational memory. Having mastered the “language” of PCI, the engineer is then in a better position to pursue his/her task with a greater degree of freedom. Hence, the need to coordinate with any centralised management is significantly reduced to a matter of requesting assistance if needed rather than doing so as a matter of procedure.

The idiosyncratic nature of PCI offers indirect advantages to the organisation as well as workers in that it facilitates internal transfer of staff as opposed to outside recruitment as employees are already familiar with PCI. The value of understanding PCI is cumulative as it facilitates internal transfer and makes the individual increasingly valuable to the company as he/she learns more about processes and how they interrelate. In other words, the knowledge worker forms closer ties with the organisation rather than any given task or area of expertise, thus aiding in the retention of staff (DeLong, 2004) and strengthening the role of individuals as a source of organisational memory. Utilising PCI may be considered a shared structure by which designers capture tacit knowledge and render it as explicit knowledge. This particular transformation process is not pivotal to any unit, but peripheral in all core activities.

The relative invisibility of PCI to the organisation as well as individuals appears to be reflected in the uneven support it has received from top-level management despite being the carrier of decades of experience. On the one hand, the decision was made to keep the existing PCI structure despite the fact that the constituent companies of the corporate group to which Alpha now belong all utilise a different methodology for managing their product catalogue. On the other hand, using two separate non-integrated tools to manage complex products over extended periods of time does seem conducive to long-term preservation of knowledge. If anything, it appears motivated by aversion to short-term cost rather than commitment to long-term preservation of knowledge. The contradiction becomes apparent when one considers that Alpha relies extensively on the PCI in all aspects of its operations – from product development to customer support and warehousing of spare parts. The disconnect between promoting long-term preservation of knowledge and shirking short-term costs for software tools does seem to offer anecdotal support for Karsten's (Karsten, 1999) argument that information space needs to become an integral aspect of organisational memory.

Conclusions

The challenge of preserving knowledge over extended periods of time is a complicated issue, comprising future accessibility as well as relevance and comprehensibility. We have conducted a case study of company "Alpha" that is involved in the manufacturing of products that typically require spare parts and essential maintenance for several decades – extending the life-cycle of a product well beyond its completion and delivery. Alpha approaches its long-term knowledge management via product configuration information (PCI) – a complex structure whereby the nomenclature of systems and components reflect their place in the product hierarchy. Although requiring extensive training, PCI extends the individual worker considerable freedom as well as an environment amicable to intra-organisational mobility. The organisation, in turn, has access to a stock of knowledge that is stable over time and independent of any single employee. Despite the necessity and advantages of PCI, management at Alpha appears reluctant to develop specialised tools that support its use. While anecdotal at best, this suggests that the value of long-term preservation of knowledge is difficult to evaluate – especially set against tangible short-term costs of new investments. This study suggests that long-term preservation of knowledge is aided by a close link between the stock of knowledge and the organisational memory. In this case, continued utility of the organisational stock of knowledge despite the lack of explicit tool-support was largely enabled by PCI's pervasive presence in organisational processes as well as corporate culture.

References

Ackoff, R.L. (1989). From data to wisdom. *Journal of Applied Systems Analysis, 16*, 3-9.

Alavi, Maryam, & Leidner, Dorothy E. (2001). Review: Knowledge Management and knowledge management systems: Conceptual foundations and research issues. *MIS Quarterly, 25*(1), 107-136.

Aldrich, H.E., & Herker, D. (1977). Boundary Spanning Roles and Organization Structure *Academy of Management Review, 2*(2), 217-230.

Barney, J. . (1991). Firm resources and sustained competitive advantage. *Journal of Management, 17*(1), 99-120.

Baskerville, R., & Dulipovici, A. (2006). The theoretical foundations of knowledge management. *Knowledge Management Research & Practice, 4*(2), 83-105.

Boisot, M. H. (1995). *Information Space*. London: Routledge.

Boland, R. J., & Tenkasi, R.V. . (1995). Perspective Making and Perspective Taking in Communities of Knowing. *Organization Science, 6*(4), 350-372.

Bollacker, Kurt D. (2010). Avoiding a Digital Dark Age. *American Scientist, 98*, 106 -110.

Bontis, N., Crossan, M. M., & Hulland, J. (2002). Managing An Organizational Learning System By Aligning Stocks and Flows. *Journal of Management Studies, 39*(4), 437-469.

Broadbent, M. (1998). The phenomenon of knowledge management: What does it mean to the information profession? *Information Outlook, 2*(5), 23 - 35.

Broadbent, M. . (1998). The phenomenon of knowledge management: What does it mean to the information profession? . *Information Outlook, 2*(5), 23–35.

Carraway, Leslie N. (2011). On Preserving Knowledge. *The American Midland Naturalist, 166*(1), 1-13.

Chowdhury, G. (2010). From Digital Libraries to Digital Preservation Research: The Importance of Users and Context. . *Journal of Documentation, 66*(2), 207-223.

Cohen, M. D., & Bacdayan, P. (1994). Organizational routines are stored as procedural memory: Evidence from a laboratory study. . *Organization Science, 5*(4), 554-568.

Creswell, John W. (2007). *Qualitative Inquiry & Research Design - Choosing Among Five Approaches* (Second ed.). Thousand Oaks: Sage.

Darr, Eric D., Argote, Linda, & Epple, Dennis. (1995a). The acquisition, transfer and depreciation of knowledge in service organiazations: Productivity in franchises. *Management Science, 41*(11), 1750 - 1762.

Darr, Eric D., Argote, Linda, & Epple, Dennis. (1995b). The Acquisition, Transfer and Depreciation of Knowledge in Service Organisations: Productivity in Franchises. *Management Science, 41*(11), 1750 - 1762.

Davenport, T.H., & Prusak, L. (1997). *Information Ecology*. New York: Oxford University Press.

DeLong, D.W. (2004). *Lost knowledge: Confronting the threat of an aging workforce.* . USA: Oxford University Press.

Drucker, Peter F. (1992). The New Society of Organizations. *Harvard Business Review, September - October*.

Drucker, Peter F. (2001). *The essential Drucker: selections from the management works of Peter F. Drucker*. New York, NY: HarperBusiness.

Fahey, L., & Prusak, L. . (1998). The eleven deadliest sins of knowledge management. *California management review, 40*(2), 265.

Grant, R. M. . (1996). Toward a Knowledge-Based Theory of the Firm. . *Strategic Management Journal*, 109-122.

Hicks, B. J., Culley, S. J., Allen, R. D., & Mullineux, G. (2002). A framework for the requirements of capturing, storing and reusing information and knowledge in engineering design. *International Journal of Information Management, 22*, 263 - 280.

Hippel, E. von. (1994). "Sticky information" and the locus of problem solving: implications for innovation. *Management science, 40*(4), 429 - 434.

Inkpen, A. C. . (2000). Learning through joint ventures: a framework of knowledge acquisition. *Journal of Management Studies, 37*(7), 1019-1044.

Karsten, Helena. (1999). Relationship Between Organizational Form and Organizational Memory: An Investigation in a Professional Service Organization. *Journal of Organizational Computing and Electronic Commerce, 9*(2), 129-150.

Krippendorff, Klaus. (2012). *Content Analysis* (Third Edition ed.). Thousand Oaks: SAGE Publications Ltd.

Langefors, Börje. (1995). *Essays on Infology*. Lund: Studentlitteratur.

Levina, N., & Vaast, E. . (2006). Turning a Community into a market: A practice perspective on information technology use in boundary spanning. . *Journal of Management Information Systems, 22*(4), 13-37.

March, J.G., & Simon, H.A. (1958). *Organizations*. New York: John Wiley & Sons.

Nonaka, Ikujiro. (1994). A dynamic theory of organizational knowledge creation. *Organization Science, 5*(1), 14-37.

Nonaka, Ikujiro, Toyama, Ryoko, & Konno, Noboru. (2000). SECI, Ba and Leadership: a Unifed Model of Dynamic Knowledge Creation. *Long Range Planning, 33*, 5-34.

O'Dell, C., & Grayson, C. J. . (1998). If only we knew what we know: Identification and transfer of best practices. . *California Management Review 40*(3), 154-174.

Porter, Michael E., & Millar, Victor E. (1985). How information gives you competitive advantage. *Harvard Business Review, July - August, 1985*, 149-174.

Rowley, J. (2007). The wisdom hierarchy: Representations of the DIKW hierarchy. *Journal of Information Science, 33*(2), 163-180.

Sawy, Omar A. El, Malhotra, Arvind, Gosain, Sanjay, & Young, Kerry M. (1999). IT-intensive value innovation in the electronic economy: Insights from Marshall industries. *MIS Quarterly, 23*(3), 305 - 335.

SIS. (2004). Quality management systems – Guidelines for configuration management (ISO 10007:2003, IDT). Stockholm: SIS Förlag AB.

Stein, Erie W., & Zwass, Vladimir. (1995). Actualizing Organizational Memory with Information Systems. *Information Systems Research, 6*(2), 85 - 117.

Styhre, A., & Gluch, P. (2010). Managing knowledge in platforms: boundary objects and stocks and flows of knowledge. *Construction Management and Economics, 28*(6), 589-599.

Sun, P. Y. T. . (2009). Managing asymmetries in transferring tacit knowledge. *Knowledge Management and Organizational Learning, 4*, 95-109.

Tuomi, J. (1999). *Data is more than knowledge: Implications of the reversed knowledge hierarchy for knowledge hierarchy for knowledge management and organizational memory.* Paper presented at the International Conference on System Sciences (HICSS 32), Wailea Maui, USA.

Wallace, P. (2011). *Information Systems In Organizations*. New Jersey: Pearson College Div.

Walsh, J. P., & Ungson, G. R. (1991). Organizational memory. *Academy of management review*, 57-91.

Walsham, G. (2006). Doing Interpretative Research. *European Journal of Information Systems, 15*(3), 320-330.

Wang, S., & Noe, R. A. . (2010). Knowledge sharing: A review and directions for future research. *Human Resource Management Review, 20*(2), 115-131.

Yin, R.K. (2009). *Case Study Research – Design and Methods*. Thousands Oaks: Sage Publications.

Yoo, Y., Boland, R.J., Lyytinen, K., & Majchrzak, A. (2012). Organizing for Innovation in the Digitized World. . *Organization Science, 23*(5), 1398 - 1408.

Yoo, Y., Henfridsson, O., & Lyytinen, K. (2010). Research commentary—the new organizing logic of digital innovation: an agenda for information systems research. *Information Systems Research, 21*(4), 724 - 735.

Zins, C. (2007). Conceptual approaches for defining data, information and knowledge. *Journal of the American Society for Information Science and Technology,, 58* (4), 479-493.

Paper IV

Information Management, Lean and Efficiency: Are We Focusing on the Customer?

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Abstract

Purpose: The purpose of this paper is to examine what happens with the internal view an organisation has on information management when a holistic view is diminished into a blinkered view and the consequences it conveys for the customer. The customer consequences are divided into two parts – creation of external customers' values and creation of value for the internal customer explored in terms of efficiency.

Methodology/Approach: Interviews with both outsourced co-workers and project leaders still in the organization.

Findings: The organisations lack of listening to the external customer affects all three areas lifted in the analysis. The studied organisations have great opportunities for developing their process for producing TI, both regarding their mutual relationship as well as in regards to the external customer with the help of Lean and by applying a more holistic view on the production of Technical Information.

Keywords: Information management, Lean, Customer value, Technical Information, Efficiency

Paper type: Case study

Introduction

In the manufacturing process, the production of various products is the base (Storga 2004). The product consists of different parts as does the information connected to it (Porter and Millar 1985). The classic value chain contains product and information within closed boundary organizational walls. However the information that belongs to the organization also has an impact on the customers as well and therefore creates its own boundaries. The former organisational boundaries change due to information´s impact and give rise to information boundaries (Sawy, Malhotra et al., 1999). As a result, in this extended value chain, customers, in combination with products´ information, have more impact on the internal organizations, an impact which has developed and increased due to improved information technology during the last decades (Wallace 2011). The rise of technology has improved our access to the information and for the manufacturing process, this means easier and better access to the technical information, in pragmatic ways categorized as the structured information (Wallace 2011). Technical Information (TI) is characterized by information that enables a safe and environmentally-friendly introduction, usage, maintenance and destruction of products and services (Asproth, 2011).In other words TI is connected to its product life cycle and due to its tight connection has a high impact on the quality of it.

Focusing on quality and thereby creating value for the customer is the foundation of most initiatives within Quality Management. One initiative that is gaining more and more attention and is being applied in many different organizations is Lean. Within Lean long-term thinking, a system view, and customer focus are fundamental alongside the notion of eliminating waste in the organization's value flows. Liker (2004) describes Lean by means of 14 principles divided into four parts of a pyramid, the '4 P' model. The bottom of this pyramid and the most important factor for success is the value 'Long term thinking'(ibid). According to Bicheno & Holweg (2009), a system approach is very essential for Lean. They define a system approach as focusing on the organization as a whole before paying attention to the parts (ibid). Emiliani (2010) states that the reason for applying Lean has to be for the benefit of the customer, not for internal company reasons since understanding what the customer really needs and what builds customer value in an organization is essential for business success.

The context for this study is a manufacturing company which uses Lean, with technical information as an outsourced sub-process. In general, the view on TI and its contribution to businesses in different business sectors is seldom clearly expressed (Slumpi, Ahlin et al. 2012). If it is expressed, it is more in terms of softer valued benefits and rarely in terms of financial incomes. To look upon the product, containing a physical and information part (Porter and Millar 1985) is to look at and develop only a single part of it and not take a holistic view. This blinkered view flows through this study´s whole organization and also occurs in discussions with the customers. The purpose of this paper is therefore to examine what happens with the internal view an organization has on information management when a holistic view is diminished into a blinkered view and the consequences it conveys for the customer. The customer consequences are divided into two parts – creation of external customer values and creation of value for the internal customer explored in terms of efficiency.

Theoretical pictures

To discuss this paper´s purpose we have made a theoretical framework containing pictures from both the field of Information systems and Quality Management. The starter is the holistic system view from both fields continuing with management of information and completing with the two customer perspective, external in eyes of value and internal in eyes of efficiency.

System view

Overall distinctions of system views or an epistemological way to describe system are to divide them into hard system and soft system thinking (Checkland, 1985). The hard system thinking describes an efficient way of seeking solutions to problems and thereby reaching the goal. The engineers who design the systems are, in this sense, providing the users with rational ways to reach the organization´s goals. The soft system is oriented towards learning and acknowledges that there are human ingredients in problem-solving, which makes the world problematic, but understandable by using different models. These aspects of hard and soft system thinking can be seen as being represented by the values continuous improvement and focus on people within Lean (see, for instance, Liker, 2004 and Emiliani, 2007). Furthermore, the system approach is defined as focusing on the organization as a whole before paying attention to the parts (Binero & Holweg 2009). Lean emphasizes the supply chain, where the production within the organization is a part of a value stream from the sub-suppliers to the ultimate customer (Womack & Jones, 2003). Seddon (2005) claims that managing the organization as a system is, among other things, to have an outside-in perspective and has a design based on customer demand, value and flow. Deming (1994) defines the system as a network of independent components that work together to try to accomplish the aim of the system. There has to be an awareness and understanding that functions and activities are held together in processes (ibid).

Information Management

One part of the product system is the information which from an internal perspective in an organisation can be viewed from different angles. The operational view and its connection to the process is one angle (Davenport and Prusak 1997). From an information management (IM) view, information is looked upon as a resource which has to be governed in a lifecycle perspective and where different questions are raised during different lifecycle parts (Best, 2010). Managers have to face responsibility for planning, deciding and focusing on governance of the whole lifecycle of operational and organizational information (ibid; Reponen, 1993). Best (2010) argues that the purpose for implementing yet another management structure is to increase the internal organizational performance. In close relation to Best´s declaration is Detlor´s (2010), which states that IM´s goal is to help both individuals and organizations to access, process and use information efficiently and effectively. The expected result will hereby be that the organization operates better and more in alignment with their strategic goals.

The strategic view of IM is a holistic one, operationally given by guidelines for lifecycle perspectives on digitalized information (Reponen, 1993). As a result of the planning phase, a strategy profile is produced and the organization’s attitudes towards the specified topic are also included (ibid). Inside organizations, information can be managed operationally on a scale from solo monarchy to the other end point of the scale, in an anarchistic way (Davenport, Eccles & Prusak, 1993).

A practical way to discuss information as such is achieved by describing its formalization (Yeo, 2002). Usually categorization for information is done in structured- or unstructured information (Ferruci & Lally, 2004; Wallace, 2001) and data (Rodrigues, 2002). The structured information has metadata connected to it and is therefore easy to obtain an overall view of big quantities. These quantities can be used as a foundation for different kinds of decisions and thereby create new information (Langefors, 1996). Commonly viewed extract from structured information is seen as knowledge (Rowley, 2007), in a pyramid metaphor, where the individual or/and organization has impact on the creation and maintenance of knowledge.

External customer satisfaction – value

The word quality raises a lot of different associations and expectations and according to Dale (2003), the fact that the customer makes the quality judgment seems to be something present in most definitions of quality. The definition that forms the basis for this article is the one given by Bergman & Klefsjö (2010); "The quality of a product or service is its ability to satisfy, or preferably exceed, the needs and expectations of the customers". Customer value is often described as the difference between the total customer value and the total customer cost (monetary and sacrifice) of a product (goods or services) (Kotler, 2000). Delivering customer value requires a clear understanding of exactly what kind of value is desired by customers. Importantly, customer value is not inherent in the product or services themselves; rather it is experienced by customers as a consequence of using the supplier's product and services for their own purposes (Woodruff & Gardial, 1996). Value can only be defined by the ultimate customer according to Liker (2004).

In this paper the customer is seen as the person or persons using the TI. The external customers are viewed as the end customer or user and the internal customers as users within the organization that has outsourced TI. From a product or service point of view value can be seen as the sum that the customer is willing to pay for it (Barber & Tietje, 2008).

Information as such is valuable for the entire organization and more valuable when it contains certain qualities (Wallace, 2011). Although the customer satisfaction given by information quality is hard to predict and changeable between different customers given characteristics are overall predictable. The design will also be affected by the different customer requirements (Löwgren & Stolterman, 2008). As designers tend to use templates to produce systems, the more user and customer requirements, the greater the number of templates. Quality, and as a result of this customer´s input, can therefore also be seen in the number of templates used to modularize and design a system.

Internal customer satisfaction – efficiency

Ljungberg and Larsson (2012) states that all processes are part of a network of processes, that information is exchanged between different parts throughout the process and that resources need to be available. According to Egnell (1999), the advantages of focusing on processes are: decreased risk of sub-optimizing and discrepancy between different functions in the organization, fewer unnecessary activities, higher work satisfaction, reduced costs, clearer aims and a higher inclination to do the right thing from the beginning. Modig and Åhlström (2012) state that Lean is a change from resource focus to customer focus and that the processes are central for creating value for the customers. They believe that processes are the building blocks of an organization and that the processes need to be defined from the perspective of what flows through them not from the various functions within an organization (ibid). Both Womack and Jones (2003) and Liker (2004) are clear about the importance of defining value from a customer point of view, arranging the processes, or value streams, to create this value and then making the value flow through the processes. This value flow should also include the information flow since these are two sides of the same coin (Rother and Shook 2004). Waste reduction is something many people associates with Lean. According to Bicheno and Holweg (2009), value is the converse of waste and waste elimination is seen as a means to achieve Lean – not an end in itself. The elimination of waste is closely linked to creating flow in an organization's processes (Womack and Jones 2003 and Liker 2004). Bicheno and Holweg (2009) list the traditional seven types of waste defined by Taichii Ohno as: overproduction, waiting, unnecessary motions, transporting, over processing, unnecessary inventory and defects. Very often an eighth type of waste is added, that of untapped human potential (ibid)

To work with the things the customer requires, organizations have to confront two different questions – "Are we working with the right activities inside our organizations?" and "Are we doing appointed activities the right way?". The first concept is named effectiveness and the second efficiency (Luftman, 2000). In this study we will discuss efficiency that puts pressure on the organization to be curious and think in new directions (Ljungberg & Larsson, 2012). These authors claim that in order to create permanent new thinking, structural preserving components like norms, culture and structures need to be changed. Modig & Åhlström (2012) state that within Lean the focus for creating efficiency needs to be flow-oriented instead of resource-oriented. Measuring is the starting point for improving operational performance but the challenge lies in measuring the right things and using those measurements as the basis for managing performance improvement (Radnor and Barnes, 2007). Saad and Patel (2006) also stress that there have been few attempts to measure the performance at inter-organizational level and these have been essentially focused on tangible and financial factors.

Research approach

The aim of the paper was met by combining two different search fields within the academic world – Quality Management and Information Systems. The connecting bridge between these two fields is spelled Management, both included in the definitions of the academic fields. In Total Quality Management this is done by i.e. Hellsten and Klefsjö (2000):

"A continuously evolving management system consisting of values, methodologies and tools the aim of which is to increase external and internal customer satisfaction with a reduced amount of resources." (Hellsten & Klefsjö, 2000 p.241)

And in Information Systems by (Holmberg 2005):

"Structure and properties of information and communication as well as theory and methods for the transfer, organizing, storage, retrieval, evaluation, and distribution of information, and furthermore information systems, networks, functions, processes, activities that mediate knowledge from source to user and are based on general systems, cybernetics, automation, and technology for human work environments in timely and current praxis." (Holmberg 2005,p. 3)

Method

In practice we conducted this by using a qualitative research method to meet the study´s purpose. A single case study (Yin 2009) was used and looked upon as a single case even though two different organizations were included. The connecting part of these two organizations is the production process of TI and therefore they are viewed as an entirety. The two organisations cooperate in the same production process of TI due to an outsourcing project. Since the study was held on a general level and used to illustrate theoretical material one case was deemed sufficient by the authors. The theoretical pictures were built with earlier research from the area of Information Management and Quality Management. Since the study is undertaken in order to understand the theoretical pictures, the study may be categorized as an explorative study. The theoretical pictures are compared with the study´s organizations where primary data is collected via interviews of employees. Data, in smaller quantity, was collected through the website´s of respective company. A few documents were also available through Alpha´s management. The analysis was conducted via an interpretative research process, which basically involves collecting and interpreting theoretical and empirical data in an iterative way (Walsham, 2006). This study has an inductive analysis, which is seen as inferences made from particulars to generalizations (Krippendorff 2012).

Content to the empirical material was collected by five interviews held at the office of each respondent. In table 1 is the working role and organisational belonging to each respondent.

Person	Working role	Organisation
A	Team manager Technical Information location A	Alpha
B	Team manager Technical Information location B	Alpha
C	Responsible outsourcing location B	Beta
D	Project manager delivery location B	Beta
E	Project manager deliver location B	Beta

Table I: The study´s respondents

The interviews lasted between 70 and 90 minutes and one of the authors attended all the interviews. Afterwards the interviews were transcribed verbatim and content were categorized according to the four categories:

- Studied organisations
- Context description technical information
- External customer perspective - value
- Internal customer perspective - efficiency

The categories were constructed in coordination to the purpose of the paper – to analyse consequences for information management, internal and external customer in the study´s context.

Empirical pictures

In this chapter the two organizations Alpha and Beta are presented and also empirical pictures from the interviews. The empirical pictures are divided into: Context description technical information; External customer perspective – value; and Internal customer perspective – efficiency.

Studied organisations

Alpha is a consulting company specialized in management and operational development of TI and they have been working in the field of TI since the mid 1990s. The company operates in seven countries around the world, including Sweden, and the total number of employees is approximately 600. In Sweden there are seven different office locations and the company is part of a group organization. Discussed on their web-site is their strategic goal, which is to be a:"... leading, global supplier of information services. We will deliver best-in-class services, solutions, and quality to our customers."

Beta is a part of a worldwide group of technical companies in the process industry and they are in total more than 27 000 employees. The group has companies working with mining, construction, recycling, pulp and paper, power and oil and gas. Beta is specialized in manufacturing, maintenance of equipment and services for pulp and paper industry and has approx 700 employees.

Context description technical information

Beta outsourced the technical information department in 2010. The company which won the outsourcing contract was Alpha. Stipulated in the contract is that Alpha is responsible for producing and delivering customer documentation connected to the products both to the internal and external customer. The staff at the TI department are now employed by Alpha, but they are still working with the same tasks as before the outsourcing was done. Beta has implemented Lean in their organization and uses it when they, for example, develop new products in their projects. The TI department is not involved in this way of working and the Lean initiative has not been extended to include the sub-supplier of TI; they are working alone in their process without any influence from others.

The technical documentation that is produced consists of customer documentation that includes instructions for installation, operation, maintenance and quality documentation. The customer documentation is created by Alpha partly in collaboration with Beta and also partly in cooperation with sub-contractors providing the developed products.

From an organizational point of view, Beta´s construction department is responsible for the documentation and the documentation is seen as a part of the product, but not as a part of the core business. This is the underlying reason why the outsourcing has been done to Alpha. The purpose of the outsourcing was to get better competence in producing TI, better efficiency in the production process of TI and as a result of this a decrease in costs when making the TI. It also provides access to more convenient information systems. Since documentation is not viewed as a part of the core business and yet is still a part of the product delivery this makes its position ambiguous and dependent on what the paying customer demands. Some customers view TI as extremely important to be able to install and use delivered products and therefore have a clear demand picture whereas other customers just put the covers on the shelf. Internally, in Beta, TI has low status and for them it just is something of a necessary evil.

External customer perspective - value

Requirements on TI can be seen from different customer´s perspective. Beta´s overall requirement is that TI has to be produced in an efficient way and the internal installation assembler wants it to be correct and delivered on paper. TI is brought to the external customer in a standardized way and Alpha´s experience is that the external customer seldom imposes any requirements on TI, except translation. Neither Alpha nor Beta have done any surveys or investigations of the external customers' requirement of nor what could make their work more efficient by using TI. Both Alpha and Beta have thoughts and ideas about making external customer surveys in the future. New features or requirements of the content of TI are posted by the employees themselves and are almost always connected to the outsourcing contract where financial efficiency is estimated. New laws and regulations can put demand of new content, especially as regards the quality documentation. These new requirements occur little by little and Beta´s respondents think that there will be an increased number of quality documents in the future.

When discussing what kind of value TI brings to the internal and external customer, several of Beta´s respondents answers that we measure the value of TI in numerical values, like punctual delivery. If the delivery is not made in time, Beta's contracts with external customers stipulate a delayed payment penalty. In the outsourcing contract between Alpha and Beta all stipulated measurements refer to cost aspects and the internal customer aspects, such as number of hours of discussion with the Beta´s ordering part.

As regards TI's value, the overall value perspective is the external customer – like an assembler, montage company, user and Beta´s own support staff. Occasionally Beta views TI as valuable in form of marketing material or education material. The external customers often use the digitalized TI as a part of their own product management systems and the paper version is used as a moveable reference book.

The respondents refer to the independent and standardized production process and discuss its value result in terms of correct terminology, a uniform and user-friendly layout and good traceability for the documentation. The rest of the organization looks upon the process as stand-alone and do not want to be involved at all. This view has been the unspoken rule for a long-time and has not changed due to the outsourcing. When we asked the respondents whether it was possible to stop producing and publishing TI, the answer was no and reference was made to the external customers' knowledge process.

Internal customer perspective - efficiency

There is an overall intention in the outsourcing contract to make the production process of TI more effective during the contract period. To make it more efficient is symbolized by reducing cost and nothing else. Follow-ups of this overall intention are done yearly and in line with the agreed roadmap. The measurements are done by appreciations of percentage and seen in form of reductions in working hours or cost for a special activity. At the annual contracting meeting, the perceived percentage is negotiated and agreed upon.

Despite the fact that there are measurements for reprocessed working hours or costs, both parts experience difficulties in measuring efficiency. They discuss the difficulties in terms of not measuring on the needed detail level, not enough historical measurements and that both parts do not agree upon produced measurements. They have not agreed upon which source for time estimate to use – one respondent uses the financial Information system and one other respondent knowledge from a long work life at Beta.

Analyse and discussion

Information Management

The study´s information context is technical information in the form of structured information (Wallace 2011), where organisational management of the information is clear in its different roles. TI has a low priority from the organizational owner, the construction department. In the life cycle perspective information should be managed in all phases to obtain its full value (Best 2010). In this case production of information is outsourced and management is diversified between the two organizations. Since information is not seen as a full valued part of the product (Porter and Millar 1985) the conclusion is that a strong and one-handed management is not considered necessary. As a result, information is used neither to its full extent nor as a competing advantage. This is also emphasized by the low competence about customers' requirement for the information. This view should be seen in the context of one respondent's answer to the question about stopping production of all TI, where the answer is that this would decrease the customers´ knowledge about delivered products. Today´s information design is based on a hard systems thinking rather than a soft systems thinking (Checkland 1985) as rationale causes like strict process thinking is used when TI is produced. In contrast to soft systems thinking which is oriented to learn and also the Lean-perspective based on designing the organization to meet the customers´ demands (Seddon, 2005). There is no intention to use the knowledge of the staff within the TI production process or involve them in the organization´s main processes, which can be seen as the eight waste within Lean, that of untapped human potentials (Bicheno and Holweg 2009).

To further analyse the lack of interest in producing required information is also by extension to discuss the degree of freedom for the customer. The freedom is limited when decisions have to be taken (Langefors, 1996) and in long-term product knowledge. For Beta this is a failure to use its full business potential and the competitive advantage information can bring.

External customer perspective - value

In the extended definition of process the customer has a central role (Ljungberg and Larsson 2012). Womack and Jones (2003) use the customer and their requirements as a starting point for the processes, or the value streams. To Alpha the customer Beta is very concrete and they have a clear view about their relationship and what they require in the form of output. This knowledge is due to the close connections achieved by sitting in the same office locations and the knowledge gained from previous employment. What are missing are the requirements from the user of the information, foremost the external customer. As a result, produced information is created without any response from the customers. The design of such a production system could be used by using standardized templates (Löwgren and Stolterman 1998) and hereby produce more and more opportunities for the customer. From the customer requirements the information systems in use for producing TI could be upgraded and new features installed and used.

The value of a product or service is the sum that the customer is willing to pay for it (Barber and Tietje 2008). At Beta they only look at the cost part of TI and never on the income part. Due to this way of considering TI, as just rendering cost, it is hard to understand what the income could be.

The value creating activities that exists within a process will be defined as activities that the customers see as valuable (Ljungberg and Larsson 2012). For Beta and the overall process description there is a difficulty in describing what the external customer considers as important since this knowledge does not exist. The clarity towards the external customer is vague as regards new thinking and by this line of action the process as such is not developed, something which Ljungberg and Larsson (2012) discuss in terms of curiosity and change of culture. The internal customer, Beta, views quality as something important and believes that activities related to the quality aspect should be rewarded however today there is no such measurement value among the existing ones. In addition the definition given to quality is mainly based on internal company opinions on what the customer wants and not based on external customer requirements. This in turn can lead to a failure to meet the real needs and expectations in accordance to Bergman and Klefsjö (2010) definition of quality.

Internal customer perspective – efficiency

Efficiency can be described in terms of doing activities the right way (Luftman 2000). In this study, Alpha and Beta are doing this by follow an agreed roadmap where there is a mapped path for increasing the process efficiency. In other words, the producer and the internal customer are deciding the efficiency of the process. In order to define measurements for efficiency, there has to be agreement about what to measure and how (Ljungberg and Larsson 2012). As Radnor and Barnes (2007) point out, the challenge lies in measuring the right things and using those measurements as the basis for managing performance improvement. The studied organizations could benefit from gaining more information on what the customer values in order to agree upon what measurements that are right for them. An improved clarity will raise the joint effort for a more efficient process. Today´s measurements concern hours or money and appeal to a hard system thinking and not the softer values (Checkland 1985). The purpose of outsourcing was only partly to reduce cost and the aspects of gaining knowledge and more convenient technology are not being measured even though this was also part of the purpose and could represent the softer measurements. Broadening the selection of measurements and using softer values like perceived quality or knowledge will give another focus on the process and in combination with customer surveys, will probably mirror the customers' perception of quality in a better way. The quality measurements will be inherited from the customer and therefore the importance of the customer impact will be raised more and more.

In addition and in connection to Lean´s ideas of only delivering what creates value for the customer and eliminating waste (Bicheno and Holweg 2009) the effectiveness of the process for producing TI could also be measured since this focuses on doing the right activities in a process (Luftman 2000).

Conclusions

Not taking the starting point in what the external customer needs and expects can have consequences in a number of areas – i.e. missed business potentials that TI could give the company in the shape of TI as a way of increasing the value of the product if adapted to customer needs. It could also affect customer satisfaction negatively given the internal perspective on defining quality, which in turns could lead to the customer not getting what he or she really needs in the day-to-day operation (Woodruff and Gardial 1996). This also has an effect on what the organizations measure in form of efficiency and could influence the choice of measurements to better reflect the customer's perception of what is value and quality in TI.

As TI is not seen as valuable Beta, the owner of it, see no potential in developing it and in the long-term perspective no need for new technical implementations, like new information systems or new technical aids. Connected to the management of information the full customer value in terms of information as a base for knowledge is not supported (Reponen 1993).

In conclusion, it can be said that Alpha and Beta have great opportunities for developing their process for producing TI, both regarding their mutual relationship as well as in regards to the external customer. If Lean were to be used in the process for producing TI and to develop the sub-suppliers of TI, this could give new business opportunities, a greater internal understanding of the values of TI as well as better use of the TI personals competence; thus creating a fruitful bond between the internal and external customer perspective.

References

Asproth, V. (2011). Slutrapport för projektet Teknikinformationscentrum 2007-2011. *Projektet TIC*. V. Asproth. Östersund, Institutionen för Informationsteknologi och Media.

Barber, C. S. and B. C. Tietje (2008). "A Research Agenda for Value Stream Mapping the Sales Process." *Journal of Personal Selling & Sales Management,* Spring (2): 155 - 165.

Bergman, B. and B. Klefsjö (2010). *Quality: from Customer Needs to Customer Satisfaction*. Lund, Studentlitteratur.

Best, D. P. (2010). "The future of information management." *Records Management Journal,* 20 (1): 61-71.

Bicheno, J. and M. Holweg (2009). *The Lean toolbox : the essential guide to Lean transformation*. Buckingham, PICSIE Books.

Checkland, P. (1985). "From Optimizing to learning: A Development of Systems Thinking for the 1990s." *The Journal of the Operational Research Society,* **36** (9): 757 - 767.

Dale, B. G. (2003). *Managing Quality*. Malden, Blackwell Publishing.

Davenport, T. H., R. G. Eccles, et al. (1993). «Information Politics.» *Sloan Management Review* Fall.

Davenport, T. H. and L. Prusak (1997). *Information Ecology*. New York, Oxford University Press.

Deming, W. E. (1994). *The new economics for industry, government, education*. Cambridge, Mass., Massachusetts Institute of Technology Center for Advanced Engineering Study.

Detlor, B. (2010). "Information management." *International Journal of Information Manage-*

ment, **30**: 103-108.

Egnell, P.-O. (1999). *Processer och processorientering*. Luleå, Centrum för kvalitetsutveckling.

Emiliani, B. (2010). *Moving forward faster : the mental evolution from fake Lean to REAL Lean*. Wethersfield, Conn., The Center for Lean Business Management, LLC.

Ferrucci, D. and A. Lally (2004). "Building an example application with the Unstructured Information Management Architecture." *IBM Systems Journal,* **43**(3): 10.

Hellsten, U. and B. Klefsjö (2000). "TQM as a management system consisting of values, techniques and tools " *The TQM Magazine,* 12 (4): 238-244.

Holmberg, S. C. (2005). Systemisk Information vid Mituniversitetet. Mid Sweden University

Kotler, P. (2000). *Marketing management*. Upper Saddle River, N.J., Prentice Hall.

Krippendorff, K. (2012). *Content Analysis*. Thousand Oaks, SAGE Publications Ltd.

Langefors, B. (1995). *Essays on Infology*. Lund, Studentlitteratur.

Liker, J. K. (2004). *The Toyota way : 14 management principles from the world's greatest manufacturer*. New York, McGraw-Hill.

Ljungberg, A. and E. Larsson (2012). *Processbaserad verksamhetsutveckling Varför - Vad - Hur?* Lund, Studentlitteratur.

Luftman, J. (2000). "Assessing Business-IT Alignment Maturity." *Communications of the AIS,* **4**(14).

Löwgren, J. and E. Stolterman (1998). "Developing IT Design Ability Thorugh Repertoires and Contextual Product Semantics." *Digital Creativity*, **9** (4): 223-237.

Modig, N. and P. Åhlström (2012). *This is lean : resolving the efficiency paradox*. Stockholm, Rheologica publishing Bulls Graphics AB).

Porter, M. E. and V. E. Millar (1985). "How information gives you competitive advantage." *Harvard Business Review,* July - August, 1985: 149-174.

Radnor, Z., J. and D. Barnes (2007). "Historical analysis of performance measurement and management in operations management." *International Journal of Productivity and Performance Management,* **56**(5): 384-396.

Reponen, H. (1993). "Information Management Strategy - an evolutionary process." *Scandinavian Journal Management,* **9**(3): 189 - 209.

Rodrigues, L. C. (2002). "Business Intelligence: the management information system next step". *Third International Conference on Management Information Systems Incorporating GUS and Remote Sensing*, Southampton, WIT Press.

Rother, M. and J. Shook (2004). *Lära sig se. Att kartlägga och förbättra värdeflöden för att skapa mervärde och eliminera slöseri*. Stockholm, Edita Norstedts Trycker.

Rowley, J. (2007). "The wisdom hierarchy: Representations of the DIKW hierarchy." *Journal of Information Science,* 33(2): 163-180.

Saad, M. and B. Patel (2006). “An investigation of supply chain performance measurement in the Indian automotive sector.” *Benchmarking: An International Journal,* 13(1): 36-53.

Sawy, O. A. E., A. Malhotra, et al. (1999). “IT-intensive value innovation in the electronic economy: Insights from Marshall industries.” *MIS Quarterly,* **23**(3): 305 - 335.

Seddon, J. (2005). *Freedom from command & control : rethinking management for lean service*. New York, Productivity Press.

Slumpi, T. P., K. Ahlin, et al. (2012). “Intraorganizational benefits from product configuration information - a complementary model”. *International design conference - design 2012*. Dubrovnik, Croatia.

Storga, M. (2004). *Traceability in product development*. International Design Conference - Design 2004 Dubrovnik.

Walsham, G. (2006). “Doing Interpretative Research.” *European Journal of Information Systems*, 15(3): 320-330.

Wallace, P. (2011). *Information Systems In Organizations*. New Jersey, Pearson College Div.

Womack, J. P. and D. T. Jones (2003). *Lean thinking: Banish Waste and Create Wealth in your Corporation.* London, Simon & Schuster.

Woodruff, R. B. and S. F. Gardial (1996). *Know your customer - New approaches to understanding Customer Value and Satisfaction*. Blackwell Business.

Yeo, K. (2002). “Critical failure factors in information system projects.” *International Journal of Project Management,* 20: 241 - 246.

Yin, R. K. (2009). *Case Study Research – Design and Methods*. Thousands Oaks, Sage Publications.

Paper V

A Communication-model for Intangible Benefits of Digital Information

Full paper

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Abstract

The communication of the intangible benefits to different stakeholders is important at the development of organizational resources, in this study digital information, and could be described as a boundary-spanning activity. In this study we build on Ahlin's model (2014) and illustrates categorization of intangible benefits of digital information by using Carlile's (2002; 2004) efficient boundary objects, the syntactic, semantic and pragmatic. Qualitative empirical pictures from three cases are illustrated by questions, derived from the efficient boundary objects. The illustrations show that this is an accessible path forward and that the illustrations can be changed to further research with the goal to practical test the communication model.

Keywords

Intangible benefit, digital information, communication model, technical information.

Introduction

The communication of the benefits organizational resources generate includes internal as well as external stakeholders. Thusly it could be described as a boundary-spanning activity (Abbott et al. 2013; Leifer and Delbecq 1978). This activity is of specific importance when it comes to further developing the resources and increasing their benefits (Kotter 2012). Ward and Daniel (2012) emphasize communication as one of the important ways to influence success. They evolve the importance of communication by categorizing stakeholders, their power and how to communicate. Their examples range from keeping the stakeholders informed, get them on board, or an approach to change someone's mindset. A crucial part of the communication process related to the organization's benefits is to first identify and understand the resources, both tangible and intangible (Frisk 2007), and the potential to be further developed (Frisk and Ljungberg 2009; Ward and Daniel 2012) Identifying and communicating benefits is however a challenging task, especially when it comes to the intangible benefits (Ahlin 2014).

Thus organizations require some sort of support in order to complete this endeavour. However, so far we have not been able to identify such a support. Ward and Daniels (2012) do indeed investigate the necessity and provide insights into the construction of a model in the context of information technology that could serve as a support. Still, this model does not help the organization to identify and communicate the intangible benefits of, for example, digital information. A model that is better adapted to supporting organizations in the process has been developed by Ahlin (2014). This model was specifically targeted at identifying and communicating efficient collaboration as an organization's benefit and at the ways digital information could improve this collaboration. The development of the model was highlighted in the work of Ward and Daniel (2012) but the theoretical foundation of the model can primarily be found in the work of Star (Bowker and Star 1989; Star 2010) and Carlile (2002; 2004) and the theoretical discussions related to boundary object (BO). More specifically, the model was based on parts of Bowker and Star's (1989) definition – "local needs and how to maintain a common identity across sites", on Carlile's (2002) three approaches: syntactic, semantic, and pragmatic; and on a visualization of BO (Huang and Huang 2013). The choice of theoretical foundation is based on the close relation between BO and boundary spanning identified by, for example, Levina and Vaast (Levina and Vaast 2005), and on the fact that the process in focus in this research has been identified to be about boundary spanning.

The model developed by Ahlin (2014) was tested on a particular type of digital information, namely technical information (TI) and the ways TI could promote collaboration (Ahlin 2014). TI is information connected to a product or service (Nyström and Asproth 2013) and can be operationalized as sketches, drawings, and meeting minutes connected to the design process of a product or a service (Storga et al. 2011). The test of the model found that it had the potential to identify and communicate the intangible benefits of digital information but needed to be further developed. Ahlin (2014) does not explicitly state how the model should be used in order to support an organization in the process of identifying and communicate the intangible benefits of digital information. Therefore, the aim of this study is to further develop the model by making the way the model should be used more explicit. This would enhance the model's potential to function as a support for organizations' endeavours to identify and communicate the intangible benefits of digital information. An illustration is that the model is a chest of drawers were Ahlin (2014) outlined the furniture with drawers and this study aims to develop how put content in the different drawers.

Introducing the original model

The model that is the point of departure is illustrated in Figure 1 and can be found in Ahlin (2014). As was mentioned above, the model was influenced by the benefit management model suggested by Ward and Daniel (2012), who investigated the requirements for a benefit management model for IT investments. For a project delivery, this benefit management model focusing both on delivering specific project benefits, like an implementation plan and training in technology, and also on general requirements for such a model. The general descriptions of requirements for a benefit management model from Ward and Daniel can be turned into the following actions: identifying the benefits; communicating the benefits, managing the change of benefits; and reviewing the potential opportunities of the benefits. However, as was also mentioned above, the model has, theoretically speaking, primarily been influenced by the research on BO. In Ahlin(2014), as well as for this study, benefits are viewed as adding efficiency in the organization. This is done by using the resource for a specific work role or by the entire organization.

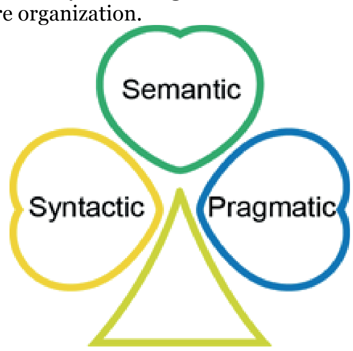

Figure 1 The normatively effective BO (Ahlin, 2014).

A BO can be described as something that facilitates collaboration, is positioned between collaborating parties, and does not require a complete mutual agreement between these collaborating parties (Star 2010). However, BO has been proven to facilitate not only collaboration but also knowledge processes over organizational boundaries such as sharing and assessing knowledge (Carlile 2002; Carlile 2004). In Carlile's (2002; 2004) research, three different knowledge boundaries have been identified: the syntactic, the semantic, and the pragmatic. We argue that digital information is one of the vehicles knowledge travels by, thus the boundaries identified by Carlile becomes valid to address. In our view, for digital information to become a BO, it must be able to deal with the boundaries identified by Carlile.

For a BO to address the *syntactic* boundary and create an ability to share and assess knowledge, it needs to provide the organization with a common language (Carlile 2002), which helps the organization to transfer knowledge over organizational boundaries (Carlile 2004). Operationally speaking, this is done in the form of representation (Carlile 2002), and is implemented through a shared dictionary (Carlile 2004). As both the internal and the external surroundings are in a constant flux, the organization needs to keep the dictionary updated in order for it to function as a BO.

At the *semantic* boundary, the challenge is that different stakeholders might have different interpretations of the knowledge at hand and that these interpretations might be based on implicit knowledge not yet externalized (Ahlin and Saarikko 2013). These differences in interpretation might hamper knowledge sharing and assessing. Thus, the BO *at the semantic boundary* needs to provide the organization with an ability to translate knowledge, an ability to learn about the different interpretations, and help the collaborating parties to achieve a common meaning (Carlile 2004). Part of this translation is to convert implicit knowledge into explicit knowledge (Ahlin and Saarikko 2013).

The foundation for the conversion of knowledge from implicit to explicit is the representation (Zins 2007). The stakeholders have to discuss the representation, and together form a shared meaning in order to create common knowledge. To prevent knowledge barriers, the discussions have to be based on equal inputs, and fair results.
Finally, at the *pragmatic boundary,* the main challenge is neither to transfer existing knowledge, nor to translate existing knowledge, even though these aspects are part of the challenge as well. Instead, it is to transform existing knowledge (Carlile 2002; Carlile 2004). The transformation becomes necessary when there are different interests present among the collaborating parties and the goal is to develop a common interest to share and assess knowledge (Carlile 2004). In practice, it is about parties agreeing on transforming their existing knowledge base to fit a new setting. This might be a painful process, as the change of knowledge base does not come without costs.
The relation between these three boundaries and the BO addressing them has changed over the years. From Carlile (2002), it was possible to infer that each boundary should have a BO of its own. In more recent research, such as in Carlile (2004) or Huang and Huang(Huang and Huang 2011), the strong relation between the different boundaries is emphasized, and thus it becomes relevant to argue that a BO should be able to address the different boundaries simultaneously.

Method

As was stated above, the aim of this study is to further develop Ahlin's (2014) model. The research approach adopted resembles the scientific research cycle described in Straub (1989) that consists of three steps: explore, confirm, and refine. Our cycle focuses however on model development. Thus the three main steps in our model develop cycle were:
1. build a model
2.test a model
3.identify improvement potential in the model

Figure 2 The model develop cycle

For this study the first step of the model develop cycle, the building of a model, is reported on. The building, or rather the rebuilding, of the model departs from the identified potential improvements found in an earlier validation of the model. It was conducted in two steps. Firstly a set of questions for each of the parts of the model was developed. This approach was influenced by the work of Huang and Huang (2013) that developed a measurement model to understand the knowledge boundaries between different stakeholders in system analysis. The building of the model was realized by identifying a set of questions that could be related to each part of the model, e.g. syntactic, semantic, and pragmatic (described in the next section of this article). Our base for formulating the set of questions was to use them as illustration tool. This tool was tacit in Ahlin (2014) and is seen as one of the development steps to build the model.
Secondly, it is illustrated in this study what kind of answers each of the questions might generate. For this three different data sets were used: Alpha, Beta and Gamma, e.g. multiple case studies (Yin 2009). Each data set was then subjected to an interpretative analysis (Walsham 2006) in search for answers to the questions in the model. More specifically, an inductive analysis was conducted, which is derived from performing a comparison between an empirical base and the theoretical framework, e.g. the model (Krippendorff 2012). The illustrations were chosen as a way forward to add details to the chest drawer before testing the model in practice.

Research cases

The first two data sets are the same as in Ahlin (2014) and are re-analyzed here. Supplementing the first two data sets with a third one is done to further develop and validate the model. Of importance is that the empirical material was not collected primarily for developing the model. The reason for using empirical material collected for other purposes is that the model is still immature and still does not motivate a specifically designed study. Walsham (2006) argues that theory can guide the whole research process or be identified rather late as a relevant tool for conducting analysis. Here, the latter approach is applied; Ahlin (2014) indicates that this type of test still generates important insights into a model's strengths as well as its weaknesses.

The first case, named "Alpha", is a defence contractor involved in the production and maintenance of electronic defence systems with approximately 12 500 employees. Product development is usually based upon existing products with added customization based upon customer specifications. In this case, the BO is the TI limited to the standardized product information. This product information is built on a hierarchical system and the organization has used it for several decades. The TI provides knowledge about the original and updated product components and their status. The TI is stored in a legacy system and can be modified by co-workers in the development department. The legacy system represents the master data and is not automatically integrated to other systems in real-time. The study comprises seven semi-structured interviews with middle managers from different departments, like project managers and team managers. The purpose of the study was to identify an organization's benefits of TI. The question categories were: description of TI; its benefits for work roles; and the organization's benefits.

The second case, named "Beta", is a worldwide construction company in the paper mill industry with 600 employees. The organization has outsourced the production of TI. Since Beta and the outsourcing company are working together in the TI production process, they are viewed as one case. The BO in Beta is the TI that is provided to the internal and external customers and consists of installation, operation, maintenance and quality manuals. The TI is stored on file servers and can be read by the organization's operative co-workers. Updates are only performed by the co-workers in the TI production process and are not integrated with any other information systems. The TI is mainly delivered in paper format to the customers. Five semi-structured interviews were held with middle managers from two different departments; the TI production and the customer project management. The purpose of the study was to identify quantitative ways of showing efficiency development in the production process of TI. The question categories were: the production process of TI, its benefits and production process; the efficiency and effectiveness in the production process; and actual and future measurements of the process.

The third case, named "Gamma", is a construction engineering company with 150 employees. The organization bases its manufacturing on a hydraulic invention used on excavators. The BO in Gamma is a TI that is a set of assembly instructions used by internal and external customers. The TI is stored in the legacy system as master data; accessible for reading and updating by all co-workers. The legacy system is automatically integrated with other information systems. The purpose of the study was to theoretically develop and test a working method for identifying the benefits of TI. The empirical material was collected at one focus group workshop and two semi-structured interviews. The participants were co-workers producing TI and the interview respondents were development managers. They discussed the production process activities; its input, output, benefits and stakeholders. The interview categories were: a description of TI; identification of its benefits; and model requirements for identifying these benefits.

Model development

To develop the model, we formed a set of questions related to each of the boundaries identified by Carlile (2002; 2004). The questions are as follows (Table 1):

Boundary	Question
Syntactic	In what ways is the organization using the representation as a common language?
	In what ways are the process connected to the representation?
	In what ways can the organization search digital information based on the stored representation?
Semantic	In what ways are the representation used for learning in the organization?
	In what ways are knowledge generated based on the representation?
Pragmatic	In what ways is knowledge cooperation in business processes implemented in the organization based on the representation?

Table 1: Illustration tool

The first three questions are based on a BO's ability to span the syntactic boundary by creating a common language based on the ability to transfer knowledge (Carlile 2002; Carlile 2004). The first question is directly connected to the language, the second question derives from the ability to transfer knowledge, which implies that a source for knowledge transfer is needed. We look upon this source as the process connected to the representation, i.e. having a production process - and documenting it - creates knowledge about the representation to all co-workers connected to the process. The third question is also connected to the knowledge transfer. As the representation is stored digitally in information system(s), co-workers need to reach the information. Therefore, the search functionality plays an important role in knowledge transfer, i.e. its accessibility, accuracy.

A BO's ability to span the semantic boundary gives the organization an opportunity to learn and a way to translate knowledge (Carlile 2002; Carlile 2004). The first question is directed to how the representation is used for learning. The second question asks in what ways knowledge is translated to the co-workers. This question is broad and open-ended, not limited to the tacit or explicit perspectives of knowledge, for example.

A BO's ability to span the pragmatic boundary derives from transforming the representation into learning. The learning is used to update the business processes with new functionality (Carlile 2002; Carlile 2004). One example of this could be to use statistics based on the representation to offer new customer agreements. This question is straightforward in its nature, summarizing this BO and looking for implemented operational changes.

Development of model

Below the result of developing the model by applying the questions developed on the empirical material is presented.

Syntactic

In What Ways Is the Organization Using the Representation as a Common Language?

In Alpha, the TI is used as a common language. Orally they use the TI as it is, and the receiver of the information understands it without disturbances.

"This language, if you can call it a language; everyone here knows it. You don't need to do it [i.e. showing illustrations], meaning that it simplifies and shortens our working hours, so to say." Group manager, Spares Department.

This quote shows that there is no need for further explanations or visualizations; the messages are clear and correctly understood. The co-workers see this as an efficient way to communicate.

In What Ways Are the Process Connected to the Representation?

Before outsourcing, Beta's TI production process was a tacit process; partly familiar to the co-workers acting in it. During the first year of outsourcing, the process was thoroughly investigated and documented regarding its activities, resources and responsibilities. To keep the process unified, all co-workers were located in one office area and learned new activities as a result.

"Then [after the outsourcing] it was decided that it was better if the group shared an office area. And when you share activities among all co-workers, you can adjust resources when needed. Often, in a group some people become specialized in certain activities; that is how it is." TI manager.

In What Ways Can the Organization Search Digital Information Based on the Stored Representation?

The legacy systems search functionality is available to all co-workers, and information is regularly updated in Gamma. Based on the semantics, searching is relatively easy and visualized with several options. When the search returned zero hits, the co-workers used their tacit product knowledge, and as a next step asked their colleagues to find information. The way to search is described by one of the engineers:

"*Yes [we search] on the structure or on the description; assembly instruction and EC or so*." Engineer.

Semantic

In What Ways Are the Representation Used for Learning in the Organization?

In Beta, the co-workers use TI to learn how to install their products. Beta offers this service to its customer, and based on commercial purposes, not all installation information is provided to the customers. Occasionally, based on their own initiatives, Beta's co-workers use TI for internal educational purposes.

"I have conducted some education, nothing standardized. You can do it the way you want to do it. But I usually go through certain education material for the first step, to build their knowledge base. And I usually want them to find the material in the manual." Project Manager.

Besides the financial gains from the outsourcing of the TI production, another result is that the representation of TI has changed. New ways for visualization used by the outsourcing company are added to textual descriptions. Worth mentioning is that the TI producers experience increased professional pride by adding this knowledge.

In What Ways Are Knowledge Generated Based on the Representation?

"Structure and order" is a phrase repeated by respondents in Alpha when they answer the question: "What does TI symbolize for you?". They further emphasize that "structure and order" is about

knowing what is produced, where, and to whom the products are delivered.
”But if you have many products that are different […] then you need order and structure. You need to know exactly what is delivered to the customer; how this specific product configuration is made.” Project manager.
The independence of separate co-workers is based on the representation. What earlier was individual co-workers knowledge is now part of a common organizational knowledge base and accessible to the organization. As a result, the co-workers have the possibilities to circulate among work tasks and also change departments.
TI provides knowledge to Gamma in a container, which can be used by anyone. The increasing number of customers raises delivery demand and the organization needs to rely less on co-workers and their tacit knowledge. Another perspective is that TI should increase knowledge among sales personnel:
“What we are expecting is that the sales force should have better information about the advantages of the product, and hence be able to convince and persuade the customers that our product is the best product; to elucidate the advantages of our product compared to our competitors’ products.” Product Development Manager.
Another product knowledge aspect based on TI is traceability. Depending on today’s TI representation, there are limited ways to trace products, and their inherent components. The organization has stand-alone representation for deviation. During our interview session, there seemed to be little or none knowledge about this representation and how it could be connected to traceability.

Pragmatic

In What Ways Is Knowledge Cooperation in Business Processes Implemented in the Organization Based on the Representation?

Knowledge cooperation in Alpha’s development projects is based on the role of the configuration manager (CM). This provides other production departments with opportunities to gain feedback and improve individual skills. The construction project manager describes the efficiency given by this role:
“ To give feedback on the construction. If we don’t do it, then we will have too many people giving feedback, for different reasons, too late. [….] And then the construction changes will be too big. And it takes too long to start all over and do it properly.“ Construction project manager.
One example of knowledge cooperation is the base product, brought about by knowledge sharing between different departments. Every product is based on customer preferences, yet they are alike in many ways. Alpha is therefore developing the base product to save construction, development, and maintenance time; resulting in raised efficiency and profit. The knowledge benefits of TI in Alpha are based on the product and start when the customer has signed the contract. Knowledge cooperation with other departments, such as the finance and marketing department rarely occurs.
Interest from other departments to gain knowledge from TI is low. On rare occasions, it is used by the sales department and on request by customers. During the product development process, knowledge sharing between the construction department and the TI production department is limited. Time constraints within the construction department appear to be a major factor preventing this knowledge sharing. The discussion disintegrated to the point that the construction department wanted to keep track of the time spent talking to their TI colleagues. Below is a quote from Beta’s TI manager:
“Because if there is something that the construction department wants from this outsourcing, it is fewer questions regarding the documentation than earlier. Now when we have a professional organization here, we don’t want to tell every technical informant how they are supposed to write and what the pictures should look like. We want to spend our hours developing instead.“ TI manager.
In Gamma´s business processes, cooperation is based on TI as well as the co-workers tacit product knowledge. TI is used to confirm the co-workers tacit knowledge, and also to have the last words. From the development departments perspective, the sales personnel’s knowledge cooperation is one-directional; from production to sales. There is no input from the sales personnel to production. Customer inputs to production are based on test customers in Gamma’s geographical surroundings.
“Yes, we do have some test pilots sending us inputs. For every new product, we will test a series of test documents. We will have spent time with them and seen how things are working out. Maybe seen what we need to change as well.” Mechanical engineer.

Discussion

This study’s aim was popular illustrated by a chest drawer where the starting point was sketched furniture in form of a model (Ahlin 2014). The sets of questions were used as illustrations and showed that we could find answers to all the questions in the model in the empirical material it was applied to. This implies that the model has potential for identifying and categorizing intangible benefits of digital information. What further strengthens our conviction of the model’s considerable potential is the fact

that the questions could often be answered by multiple empirical voices in the different cases.
Generally, the conversion from theory to an operational business, using BO theory, is difficult. The difficulty stems from the theory being on a descriptively higher level (Star 2010) and rarely applied to operational questions. Huang and Huang (2013), for example, use the BO theory to create questions that are used as an analytical base. Their questions are formulated and designed for a specific empirical context. The model suggested here is more generic in nature, thus the questions are more generic. We relate one to three questions to each boundary whereas Huang and Huang (2013) developed between three and five questions for each boundary and use them as a basis for their questionnaires. The respondents to the different questions vary between the two studies; in ours we use them as illustration whereas Huang and Huang (2013) practically examine certain hypotheses. The differences between the two studies are hard to describe, one part of it can be made between BO are different. Huang and Huang rely on existing BO theoretical basis and connect it to innovations while we are exploring the intangible benefits of a BO.
Since this study's model is based on the boundaries identified by Carlile (2002, 2004), we cannot argue that the model captures all possible intangible benefits. However it should be a solid base to depart from upon building a model for this purpose. Another aspect to take into account is the representation, in this case TI, and other factors that affect it. For example, in some cases it is the design of the technical artefact that affects the answer and in other cases it is the design of the information architecture that has the biggest impact. Predicting the cause and effect is hard for this specific case; the important thing is to understand that the intangible benefit exists or can be created.
As is illustrated by the model above, it is of great importance to not only build new models that will function as instruments but also carefully test and validate whether the instruments measure what they are supposed to measure (Straub 1989). To ensure this, Straub (1989) argues for several different techniques of validation, both qualitative and quantitative. Qualitative validations techniques are, according to Straub (1989), suitable in the early validation of the model while quantitative are better suited in the later and final validation of the model.

Further research

One way to move further with the model is to test it, both in theory and in practice. Another suggestion for further research is to investigate the recently added metaphoric boundary suggested by Huang and Huang (2013). A BO addressing this boundary refers to a tacit category which helps people expresses their thoughts and ideas: representing the motivational part of knowledge. One practical example is best practice or the strategic goal(s) of digital information.

References

Abbott, P., Zheng, Y., Du, R., and Willcocks, L. 2013. "From Boundary Spanning to Creolization: A Study of Chinese Software and Service Outsourcing Vendors.," *Journal of Strategic Information Systems* (22), pp. 121 - 136.

Ahlin, K. 2014. "Approaching the Intangible Benefits of a Boundary Object," in: *Computer and System Science*. Östersund: Mid Sweden University.

Ahlin, K., and Saarikko, T. 2013. "Exploiting Information: Seeking Long-Term Preservation of Organisational Knowledge," in: *NFF 2013*. Reykavik, Iceland.

Bowker, G. C., and Star, S. L. 1989. *Sorting Things out - Classification and Its Consequences*. Cambridge, USA: MIT Press.

Carlile, P. R. 2002. "A Pragmatic View of Knowledge and Boundaries: Boundary Objects in New Product Development. ," *Organization Science* (13:4), pp. 442-455.

Carlile, P. R. 2004. "Transferring,Translating, and Transforming:An Integrative Framework for Managing Knowledge across Boundaries," *Organization Science* (15:September-October), pp. 555-568.

Frisk, E. 2007. "Categorization and Overview of It Evaluation Perspectives - a Literature Review," in: *ECIME 2007: The European Conference on Information Management and Evaluation*. University Montpellier 1.

Frisk, E., and Ljungberg, J. 2009. "The (Missing?) Value of It in Public Organizations - the Case of the Swedish Rescue Services," *17th European Conference on Information Systems*, Barcelona.

Huang, E., and Huang, T. 2013. "Measuring Boundary Objects in an Attempt to Explain Innovativeness " in: *46th Hawaii International Conference on System Sciences*. Hawaii: pp. 3645 - 3653.

Huang, E. Y., and Huang, T. K. 2011. "Antecedents and Outcomes of Boundary Objects in Knowledge Interaction in the Context of Software Systems Analysis," *Hawaii International Conference on System Sciences*, Hawaii.

Kotter, J. P. 2012. *Leading Change*. Watertown, MA: Harvard Business Review Press.

Krippendorff, K. 2012. *Content Analysis*, (Third Edition ed.). Thousand Oaks: SAGE Publications Ltd.

Leifer, R., and Delbecq, A. 1978. "Organizational/Environmental Interchange: A Model of Boundary Spanning Activity. ," *The Academy of Management Review* (3:1), pp. 40-50.

Levina, N., and Vaast, E. 2005. "The Emergence of Boundary Spanning Competence in Practice: Implications for Implementation and Use of Information Systems " *MIS Quarterly* (29 2), pp. 335-363.

Nyström, C., and Asproth, V. 2013. "Virtual Teams - Support for Technical Communication " *Journal of Organizational Transformation and Social Change* (10:1), pp. 87 - 103.

Star, S. L. 2010. "This Is Not a Boundary Object: Reflections on the Origin of a Concept " *Science, Technology & Human Values* (35:5), pp. 601-617.

Storga, M., Marjanovic, D., and Savsek, T. 2011. "Reference Model for Traceability Records Implementation in Engineering Design Environment," in: *18th International Conference on Engineering Design ICED11* Copenhagen, Denmark.

Straub, D. 1989. "Validating Instruments in Mis Research," *MIS Quarterly* (13:2), pp. 147 - 169.

Walsham, G. 2006. "Doing Interpretative Research," *European Journal of Information Systems* (15:3), pp. 320-330.

Ward, J., and Daniel, E. 2012. *Benefits Management : How to Increase the Business Value of Your It Projects (2nd Edition)*. Somerset, NJ, USA: John Wiley & Sons.

Yin, R. K. 2009. *Case Study Research – Design and Methods*. Thousands Oaks: Sage Publications.

Zins, C. 2007. "Conceptual Approaches for Defining Data, Information and Knowledge.," *Journal of the American Society for Information Science and Technology,* (58 4), pp. 479-493.

Paper VI

Design and test of a measurement method for the benefits of technical information

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Abstract

Various measurement methods can be included in a benefit model in order to derive outputs from the benefits of a resource. In this study, the resource is technical information (TI). TI is a resource that some view as having a low status, which affects both the resource and the staff working with it by negatively influencing the work role and the management of the information. The purpose of this study is to design and test a measurement method with TI as the resource. Based on a general design for measurement methods, there are three steps in this method: the input, the rule and the output. The input consists of interviews; the rule is based on the categorization of the efficient boundary object; and the output is a summation of the categorization. This study is based on a case study at a US technology company in the Midwest with respondents on middle management level. The key findings are that the measurement method is useful, but not without flaws. Individual and group interviews used for input lead to a rich wealth of empircal data on the benefits of TI and categorizations of those benefits. However, the method is rather time-consuming. The design requires the researcher to perform several interviews, transcriptions, and analyses. The test implied a discussion on linguistics, both for the input and the rule. The study's serves to fill a knowledge gap of the benefits of TI in the field of Information Management, and thereby increase its status.

Key words: benefit model, benefits, measurement method, technical information

1. Introduction

An essential part in Information Management is to govern the resource information during its lifecycle (Bytheway 2014; Davenport and Prusak 1997). There are several ways to govern, one way is to describe the benefits of a resource using a benefit model (Ward and Daniel 2012). The description can be presented through visualizations such as the Dependency Network Diagram and/or measurements from a Return-On-Investment formula (Lundberg 2009). The usage of a benefit model is described by Ward and Daniel (2012) as the foundation for general management of the resource, via activities such as communication and decision-making. They express communication to stakeholders, who have a supporting or opposing interest in the resource. Without communicating to the stakeholders, their support or interest for the resource could be lost. The decision-making is mainly conducted on management level within an organization, and uses measurements as foundation (Remenyi et al. 2007). Without measurements decision-making could be stopped and thereby further development of the product. Researchers mention various reasons for including measurements of the benefits in a benefit model. The reasons range from showing the organization's total benefit of a resource (Hallikainen et al. 2002), to the view measurements that describe a resource for communication purposes (Lycett and Giaglis 2000).

In the Information Management field, a benefit model usually describes the benefits of an information system or the information technology, rarely information (Remenyi et al. 2007). As earlier mentioned, this can affect the development of the resource*. Therefore, the objective aim for this study is to design and test a viable measurement method.* The origin for this benefit model was created in Ahlin (2014), and the measurement method is to be viewed as an addition to the model. This measurement method serves to fill earlier mentioned knowledge gap for measuring the benefits of information. In the following paragraphs, the setting for this study will be described and its importance further established.

To contextualise information, an equivocal concept, technical information (TI) is the resource in focus for this study. This category of information is connected to products or services during their life cycle (Nyström and Asproth 2013). The life cycle of a product or a service includes phases like development, usage, maintenance and destruction. TI can be notes, installation instructions or product requirements. TI can be shared, which implies that the stakeholders can spread out among the departments in the organization. Depending on the specific TI of relevance, the TI can also be used externally. The interest of using TI is it closely relationship to products, and various relations to them. The term TI is broad in its concept, relating to the existing plethora of products. The broadness in operationalized TI can be viewed as its downside when it comes to comparison, and an upside as it comes to usage and importance.

The rationale for developing a benefit model for TI is connected to the low status of TI and the staff working with it. The low status can, in the long term, result in low quality of produced TI, and amplify problems for customers using the product. Löfstedt et al. (2014) consider the low status and attributes it to the co-workers' low influence on the process of creating TI. They claim that the co-workers' knowledge about the information is not taken into account by other parts of the organization. The co-workers knowledge could, for example, be used in the form of single sourcing of the information and re-use of it. Dicks (2003) states that TI can create benefits for the organization, and is convinced of the necessity to make this more apparent to raise TI's status. He declares that the appearance can be made in several ways, where one is to measure the benefits. As for other measurements in benefit models, they can be used for communication and decision-making. The connection between TI's low status, measurement of benefits connected to TI, communication, and decision-making is to make the effects of TI more apparent via communication to stakeholder, and thereby of interest to govern via decision-making. Summarizing this selection of arguments as to why it is of interest to measure the benefits of TI, the business arguments are often highlighted. Those arguments could be turned into scientific discussions, a line that few studies have taken. Few studies discuss TI and the usefulness of communicating its benefits, either via a benefit model or measurements, despite that the actual practitioners might not only improve their working situation with this kind of knowledge, but also the way TI is used.

Benefits cover a range of mainly positive outcomes. One example is the usefulness of a resource (Ottersten and Balic 2010), another produced efficiency (Bytheway 2014). As no general explanation is used in the IS field, this study clarifies its understanding to the later and will cover it by means of the individuals' opinions about what they experience as improved operational performance in their work role.

This article consists of approaches to the measurement of benefits, a description of Ahlin's benefit model, the design of the measurement method, the test of the measurement method, an analysis of the design and test, and conclusions from the study.

2. Approaches to measurements of benefits

To start with measurement methods in general, Kaner and Bond (2004) include input, rule and output as parts of the method. Usually, the rule is built on a theory and when operationalized it is characterized by the measured resource. The output from the measurement method depends on the rule. One way to categorize the output is in financial or non-financial terms, where the financial output can be used in a cost-benefit analysis, thus adding value to the existing measurable benefits (Ward and Daniel 2012). The non-financial approach can vary from specific words counted in presentation materials to the measurement of usage of the resource. These measurements can be used for comparison or as the foundation for decisions etc.

The combination of benefits and measurement methods, urge the categorization of benefits into tangible and intangible ones. The tangible benefits is described as easy to measure by Frisk (2007). Examples of measurement methods connected to them are Return-On-Investment (ROI), and Net Present Value (NPV). For the ROI, the input consists of financial measurements in form of cost of investment and gain of investment (Remenyi et al. 2007). The NPV uses the cash flow, investment time and net period cash flow to produce the output profitability.

The intangible benefits are sometimes referred to as qualitative benefits (Frisk 2007; Giaglis et al. 1999) or soft benefits (Khallaf 2012), which are perceived as hard to measure. Examples of intangible benefits from information or information systems are improvements in organizational quality (Chircu and Kauffman 2000), information quality, or information flexibility (Wallace 2011). In this study, the intangible benefits are viewed as hard to measure and consist largely of improving the organization's operational performance.

Despite the view that intangible benefits are hard to measure, there is a tendency towards measuring them (Ahlin forthcoming). For intangible benefits, the inputs to the rules mostly consist of interview material, surveys or simulations of processes. One example of input via interviews or surveys is this for the Balanced Score Card. In this case the questions can concern areas like customer orientation, business contribution or operational excellence and connect these to the actual resource and then generate the output organizational impact. The rule can vary, from being specified by the organization's strategy connected to the resource to definitions of theories. An example rule using the organizational strategy is the Analytical Hierarchy Process. This rule refines the organizational strategy to a detailed level. Key Performance Indicators, a theory that can be expressed in business performance or efficiency and user satisfaction (Kim et al. 2011)(Kim et al. 2011)(Kim et al. 2011) to express intangible benefits in measurements.

Kaner and Bond (2004) discuss topics that can affect how measurements, for example semantics in interviews. The same word can be understood in different ways and affect the result and by this its output. Another affecting topic is the knowledge about used theory and resource. As the rule is imposed by both of them, it implies good knowledge about the resource, how it is used in the organization and the theory.

Referring to Remenyi et al. (2007), who describe that information yields intangible benefit, and that subsequent intangible benefits contribute positively to the organization, there is of interest to discuss the contradiction of intangible benefits and measurement. Regardless of the fact that there are ways to measure the intangible benefits, one can view this as something of a contradiction. The contradiction is built into the striving to measure the intangible benefits that by their very nature can be viewed as hard to measure. One of the reasons for measuring them it is to show a total picture of the benefits of a resource, a picture that at the beginning of information systems era only included the tangible benefits (Brynjolfsson 1993). To add a measurement of the intangible benefits to the overall picture could be viewed as moving from solely showing the financial outputs of the benefits to adding an interpretative perspective. The position taken in this study is that the intangible benefits ought to be included in the total benefit picture and that they are hard to measure. The measurements that are the respondents' interpretations of, for example, interview questions and should be treated as interpretations. This means that they should be used with comparable measurements, such as equivalent results from the previous year or organizational goals that are viewed as equal. Along with Lycett and Giaglis (2000), these interpretative measurements are viewed as a practical way to increase the stakeholders' interest in a resource.

3. Ahlin's benefit model for the benefits of TI

In Ahlin (2014), boundary object (BO) was used as the theoretical foundation for a benefit model for the benefits of TI. Carlile (2002) and Star (2010) characterize the BO theory as transforming knowledge to deal effectively with differences and dependencies at the boundaries and view it as a central point for collaboration. Huang and Huang (2013) emphasize that organizations can consider reducing the influence of boundaries in two ways: either by breaking them down or finding ways to communicate across them. The argument for using BO is that TI can be viewed as an operationalization of the object in the BO theory. TI can be used across boundaries to increase knowledge, for example between departments in an organization. One argument for TI as knowledge transformer across boundaries is given by Hart-Davidson (2013), where he views the transformation of TI among departments as one of the key skills for the TI staff.

In the BO theory, Carlile (2002) describes three different boundaries, namely syntactic, semantic and pragmatic. The syntactic boundary is connected to an ability to provide the organization with a common knowledge, which is derived via a shared syntax across a boundary. The semantic boundary is described as adding the interpretation to the shared syntax. The interpretations at the semantic boundary are often different, which makes knowledge collaboration tougher. Ahlin and Saarikko (2013) argue that the interpretation might be based on the implicit knowledge that is not yet externalized. According to Carlile (2004), the semantic boundary needs to provide the organization with a capability to learn about the different interpretations. The third boundary, the pragmatic, highlights the importance of the ability to understand the consequences of how the syntax can be interpreted differently and that knowledge depends on collaboration (Carlile 2002). Within this boundary, knowledge is viewed as embedded in practice and the greater the distance between work roles that individuals have from each other, the harder it is to communicate the knowledge.

Based on the syntactic, semantic and pragmatic boundary, the first step of Ahlin's benefit model was realized, and included an illustration tool (Ahlin and Persson 2015). This tool, in the form of questions, can be used to find benefits of TI within an organization and classify them. For further development of the model, Ahlemann et al. (2013) was used. They describe design requirements for benefit models, and include measurements as one. Included in their description of measurement methods is that the measurement method should yield outputs in clear measurements, that the method should be easy to communicate and easy to refine. Other researchers, like Päivärinta et al. (2007), argue that a measurement method should be included in a benefit model, and easy to conduct.

4. Designing the measurement method

The detailed design of the measurement method in this study is based on a literature study, investigating measurement methods for intangible benefits (Ahlin forthcoming). The result from this study describes the overall step in such a method as (1) creating the input, (2) using the rule, and (3) forming the output. More detailed results from the literatures study shows that the first step can be based on interviews, surveys, or simulations and should give what is to be measured. If interviews are used, the benefits need to be interpreted from the material and if possible verified. One way to do this in a survey is to use a pre-selected list of benefits or possibilities to describe them. The second step is based on any suitable theory, and the third step, the summation, can be given in financial or non-financial values.

For this study, the first step is to collect the benefits of the resource, which gives a verified list of them. Here, interviews were chosen to collect the benefits of TI, and thereby a list of benefits. The reason for choosing interviews is that the benefits of TI are considered to be hard to grasp, and the interview situation with possibilities to discuss is a way to grasp them. The interviews include three sets of domain questions, where the first one is asked to understand how they use tools for TI in their daily work. The three sets covered: (1) artifacts and tools you use during your daily work tasks; (2) your opinion on the actual benefits of the TI; and (3) your opinion as to what you would want as the benefits of the TI. To find the benefits one direct question and one indirect question were constructed. The direct question asks for their view of derived benefits and the indirect what would happen if they could not use the TI.

The measurement method's second step is to use a rule, which for this study is based on the BO theory and its three boundaries for the efficient BO (Carlile 2002; Carlile 2004). In affiliation to the categorization, its foundation needs to be clearly expressed. How to measure the benefits varies depending on the existing view. Each benefit can be measured either as increasing the efficiency to only one boundary or to one or more boundaries. For the second step, the design for collection of data could follow the same path as for the first step. This could be done by conducting interviews, focus group meetings or surveys. Here, the choice was to use a focus group meeting, and refer it to the first test for a resource that can be hard to grasp and for an oral description of the underlying theory.

The third step is to sum the points given to the benefits.

Figure 1 – Design of a measurement method added to Ahlin's benefit model

5. The study's test and its results

The test in this study is based on a single case as test foundation (Yin 2009). This single case was deemed sufficient as a first test of the designed measurement method. Involving additional case seemed inappropriate without an overall understanding of the designed measurement method.

5.1 Collecting, categorizing, and summation of the benefits

For this design test, seven interviews with middle managers (six project managers and one development manager) were conducted. The seven interviews gave a rich empirical material to understand the TI, and the benefits connected to it. To follow the design of the measurement method, and measure the benefits, a focus group meeting was held. Hennink (2014) describes a focus group as a way to generate rich material in a new area, not to reach consensus. The rich material from the focus group was essential to create a useful first test of the measurement method, and understand it.

The argument for using middle managers and their perspective, is that they have knowledge about the operational part of the organization and they know what the executive level discusses and decides about (Davenport and Prusak 1997). Their organizational knowledge is of importance for this study, as the organization's perspective of the benefits is an essential factor. Apart from the middle management perspective, the respondents have all worked with the TI from its introduction in Omega. Their work role is connected to using the TI, and they have the authority to influence Omega's TI. The interviews lasted between 60 and 90 minutes, and the focus group meeting lasted for 90 minutes. All the interviews and the focus group were recorded and transcribed verbatim. Four of the interviews were done in collaboration with a research colleague.

5.2 Finding the benefits

Finding the benefits was based on the view that benefits create efficiency in the work role for the individuals or the organization, and that the source for the benefit was the TI. If one or more respondents mentioned a benefit it was put on the benefit list. Most benefits were found when the respondents answered the direct and indirect question of what benefits TI yielded.

For the first step in finding the benefits, all interviews were read twice. Finding them was based on two questions, where the first one was: "Is the respondent talking about increased efficiency for a work role?" followed by " Is it the actual TI causing it?" The outcome of this was transmitted to a composite list. The content of the list consisted of quotes from each interview, where a benefit from TI was mentioned. Subsequently, every quote was synthesized into a shorter description. All shorter descriptions were combined into similar categories such as tracing decisions or inform team members. These categories were then compiled into a new list, with one occurrence per category. This list was then used as the input to the categorization in the measurement method.

5.3 The test's context

The test took place at Omega, a technology company, based in the American Midwest. It has existed for three decades, and the business idea has slowly moved from offering consulting services to being based on their software products and services. The organization is rapidly increasing in terms of the number of employees and customers. The workforce is now close to 300, and they have customers in 180 countries. The choice of Omega was based in their interest in understanding the benefits of their recently implemented TI, and their interest in contributing in developing a benefit model for TI. An initial meeting was held to verify Omega's interest in TI in relation with the aim of this study. The meetings participants were the middle managers from Omega, the researcher, and a contact person from Omega. The participants at the meeting agreed to continue the study.

This test's TI takes the form of Omega´s charters, which contain overall software development information. This information is accessible to all of Omega´s co-workers and was recently introduced as the information part in their development process. The headings are, for example, development goals, requirements, resources and success factors. In the software development process, the project managers own the information, except when it is archived. There is no designated ownership, once it is archived. The TI is mainly for internal usage, and can be accessed for reading by external parties, like the IT vendors who have an impact on Omega's development. The interest of discussing and understanding the newly introduced charters was the reason for choosing them as foundation in this study.

5.4 The results from the test

This section of the article describes the study's test results step by step. In the first step are the benefits described, in the second the categorization of the benefits, and for the last step, the summation.

5.4.1 Step 1 - The input in form of benefits

The starting point for creation of the TI includes collaboration and a search for colleagues' domain knowledge. It is emphasized as the only way to move forward while producing the initial draft of the TI. One respondent expresses it like this while looking at the information:

"Let´s see here. This is basically something that came back. I then went through and added comments, and we would go back and forth via this mechanism to a considerable extent. And these are also some of the ideas that we are trying to create."

Pictured by the respondents are the positive results of the collaboration; individual knowledge, a similar perception about the development, common linguistic usage, and interpretation. Another usage for the information is as a communication tool. The project managers use the TI for spreading information, both in discussions and as the foundation for the approval board's decisions. The recipients are the project owners and the approval board. One frequently raised query from the approval board is whether the development can be categorized as being within Omega´s strategic goals or if a customer requires it. There is now a digital overview based on the TI, called the map, to make this communication efficient. In this map, each row is marked with a colour and is connected to one or several organizational goals. This map is also of interest to the developers.

As the project manager initiates the development, the information is used as a foundation for communication and in discussion with the development team, shown by this quote from one of the project managers:

"It is a very good way to talk about what you are going to do because one thing that I have learned is that for any team you want to have a solid objective; what are you shooting for; are we coming together as a team member and push for. "

The TI is used for knowledge sharing about the overall development goals, the new functionality and the coming development work with the project managers and the development team. The sharing is done in iterations, where the details in the information are changed as the discussion moves on.

"In that first week when I start to describe things to the development team, they are going to ask me tons of questions, and they are going to challenge me. 'Why would we do that?' Things like that and some are great questions, and some would be like: 'I don´t know; that is a great question. I need to think about that.'"

A gain, unexpected when Omega introduced the TI, was efficiency and autonomy; the team members can use the information to make lower-level decisions and thus save time for project managers. Another example of increased autonomy is that the co-workers can work remotely. Discussed in conjunction with this was the need to attract a skilled workforce; Omega has to face competition from organizations in Silicon Valley and some skilled co-workers have left to join organizations there. Their departure was described as a brain drain that Omega still suffers from.
When the development is finalized, the TI is archived. As this approach was recently introduced at Omega, the archived volume of information is low. Some respondents claimed that since Omega operates in the fast-moving IT industry, archived information is of no use. The information is looked upon as perishable and not of interest once archived.

"It is funny because things move so fast in the software world that I am not sure that it is a ton of value to keep this around. I do not know that I would go back and say: "Why did we do (...)?" You know what I mean and go and read through all of this."

Respondents insist that Omega is more efficient nowadays because they archive this TI digitally. One efficiency gain is a faster on-board process for newcomers, as they can access and read about on-going and past development projects. The efficiency gain is that newcomers develop domain knowledge faster and in this way they can contribute to Omega's business faster. Traceability of decisions is another aspect of this drive for efficiency. At Omega, this has been and still is troublesome since they have had to rely on co-workers' good memory. One respondent described finding facts about decisions by walking around Omega and chasing one co-worker after another and finally finding someone who remembered the decision and where it possibly could be stored digitally. As the organization increases in size, time spent on searching for and finding this kind of information also increases and, along with this, co-worker's frustration. A planned activity, still not used by all respondents is the retro-perspective, whereby the TI is used as the foundation to review success criteria and outcomes from the development project. Omega views it as a part of their review process and how they can improve. Shown in Table 1, is the list of the benefits derived from the interviews.

Benefits found in the interviews
Collaboration tool with important suppliers
Easier to trace decisions
Basis for retro-perspective
Develop the organization´s language
The owner of the TI doesn´t need to be around all the time
Empower team members to make lower-level decisions
Faster on-boarding process for newcomers
Co-workers can work remotely
Knowledge collaboration during idea phase
Alignment between development and organization´s strategic goals
Basis for discussions with stakeholders
Basis for discussions with project owners
Basis for discussions with team members
Inform team members
Inform stakeholders

Table 1: Step 1- the list of benefits from the interviews

The interview respondents, the seven middle managers, were all invited to the focus group; four of them attended. It was three project managers (initiative leads) and one development manager. Acting as moderator was the researcher. The initial part of the focus group included the verification of Table 1. The group confirmed all the found benefits and added one more. This step included a linguistic understanding of the mentioned benefits where the descriptions of the benefits could be changed. This was the case for two of them, as semantic differences of opinion arose. The result is shown in Table 2. One example of such a linguistic discussion is this conversation between two respondents at the focus group:

"#1: In my world I use stakeholders and project owners interchangeably.
#2: And I do not, because in my world I know, that originated the thing with the charters, is that the stakeholders are directly involved, but refining the charters is that we are giving further out and more developed."

Verified list of benefits
Define and fulfill staffing resources (resource planning)
Collaboration tool with important suppliers
Easier to trace decisions, record history
Base for retro-perspective
Develop the organization´s language
The owner of the TI doesn´t need to be around all the time
Empower team members to make lower-level decisions
Faster on-boarding process for newcomers
Co-workers can work remotely
Knowledge collaboration during idea phase
Alignment between development and organization´s strategic goals

Basis for discussions with stakeholders
Basis for discussions with project owners
Basis for discussions with team members
Inform team members
Inform stakeholders

Table 2: Step 1- the verified list of benefits

7.2 Step 2 - The rule

The second step was to categorize the list of the benefits, by using the syntactic, semantic and pragmatic boundaries. Each benefit on the list was discussed by the focus group jointly and scores could be given to all of the three boundaries. Due to the small number of participants, the moderator gave the oral description of the boundaries at the same time. All participants in the focus group took part in the categorization and discussed it. Initially, some semantic discussions took place, where they verified each other´s standpoint about how the TI is beneficial, when it is beneficial, and how to interpret the different boundaries. The importance of discussing these things are described by one respondent:

"...as the act of going through and categorizing them. And having those conversations and being deliverable about understanding sort out the balance of where we are at right now. "

Benefits	Syntactic	Semantic	Pragmatic
Define and fulfil staffing resources (resource planning)			1
Collaboration tool with important suppliers	1	1	1
Easier to trace decisions, record history		1	1
Base for retro-perspective		1	
Develop the organization´s language during the conceptual phase	1		1
The owner of the TI doesn´t need to be around all the time			1
Empower team members to make lower-level decisions			1
Faster on-boarding process for newcomers	1	1	1
Co-workers can work remotely			1
Knowledge collaboration during conceptual phase	1	1	1
Alignment between development and organization´s strategic goals	1	1	
Basis for discussions with stakeholders		1	
Basis for discussions with project owners		1	
Basis for discussions with team members		1	1
Inform team members	1	1	1
Inform stakeholders	1	1	

Summation	**7**	**11**	**9**

Table 3: Step 2 and 3 - The categorization of the benefits and the summation

7.3 Step 3 – the Output

The findings of the focus group are useful for Omega, on a general level. The TI creates greater efficiency and boosts learning see Table 3. The benefits are viewed as creating nearly half as much efficiency as common language, and in between is the pragmatic efficiency. All the benefits discovered were categorized as creating efficiency at one or more boundary. One of the participants commented that this was the underlying philosophy of the implemented information:

> *"The reason we did the charters was so that we could have an easy, common, preferable place where everyone could go to. And that was our foundation. And then on top of that is that we have the initiative leads out there which were to be the sort of the revealers of the knowledge and make sure that they fully understood it and they make sure that everyone else understood it. And then the teams are there to be practical and build upon that."*

8. Analysis of the design and test

This study's aim is to design and test a measurement method for the benefits of the TI and derive knowledge based on this information. The knowledge part of the study is discussed in lessons learned and divided into a design and a test section.

8.1 The design

The study is designed with a specific input and output. The inputs are the interviews and the outputs are the measurements from the categorization based upon the participants' responses. For the first step of this method a list was generated; a list that contained the benefits of Omega's TI. The utilized interview process was time-consuming because of the various steps involved: preparing, performing, transcribing and finally analysing them. To change to a survey instead, where the list is prewritten, would demand good knowledge about the resource and its context and could imply that some benefits were not found. The result of the input is therefore of interest. Is there a need to do the interviews or are surveys a way to adapt to Päivärinta et al. (2007)'s philosophy that a measurement method should be as easy as possible to conduct? One of the pros of doing interviews are that there is a far greater likelihood of getting much more detailed information than when doing a survey.

In the second step the categorization of BO theory was (Carlile 2002; Carlile 2004) as a rule for the measurement method. As there are three boundaries, the rule for scoring could be zero - three scores for each benefit on the list. This is based on my view that the benefits can increase efficiency at more than one boundary. An implication of this rule is that each of the boundaries is viewed equally since weighting is part of the method. For example, weighting the score could appear as a benefit scoring for both the syntactic and the semantic, where the semantic is allotted 0.3 and the syntactic 0.7 points. In an un-weighted scoring the syntactic and semantic would get one point each. For this study, un-weighted version was chosen because weighted scoring would complicate the measurement method and would potentially influence the respondents' answers.

The third step, the output, is fairly straightforward. It functions as a summation of the study's rule. In the longer run this could include an evaluation section with the implications of the result for the organization.

8.2 The test

On an overall level, the test was fruitful as the measurement method created sufficient input, used a rule based on the theory for the benefit model and produced output in the form of measurements. Following Lycett and Giaglis (2000) the measurements could be used for decision-making or communication.

During steps 1 and 2 in the test of the measurement method, linguistic clarity was crucial, in keeping with what Kaner and Bond (2004) mention. One example of linguistics is the moderator's verification of the list of benefits see Table 1. As the list is a result of the analysis of the interviews, the workshop participants could either agree or disagree with the statements. Another example of linguistic discussion was the efficient boundaries and how to approach them in the categorization. The respondents asked the moderator for more detailed information about how to understand the terminology. The moderator used outside examples to assist respondents in their understanding. To understand the boundaries more clearly, they could be exemplified from Omega. One disadvantage of exemplifying before the categorization is that it could set limits to the respondents' framing and their discussion by guiding them as to what is right or wrong. Hennink (2014) views the discussion, and subsequent generation of rich material, as of importance in a focus group meeting. Consider this option when performing a focus group study and a joint discussion. All respondents get the same information at the same time, hear the same questions and answers, but can impact each other in one way or another through discussion.

The test result from step 3 shows that the semantic boundary is most efficiently approached, followed by the pragmatic and the syntactic. The TI used in this test is newly implemented in Omega to make them more efficient while growing. A glimpse on evaluating the result shows that Omega could be on its way to achieving their goal to use this TI as a way to be more efficient by learning. In connection to the result a discussion about Omega as the case organization is of interest. Omega, a tech company, is by itself interested in technology, and one could therefore say that they are positively disposed to finding the benefits of the digital TI. The organization as such, could be more interested in detecting the efficiency and flow of TI, by using diverse information ways to colleagues. The fact that all of the respondents are at a middle management level, that they use and depend on the actual TI, can affect the result. They can be too positive towards the specific TI, its benefits and how it is used. Also they could provide a too coordinated view in their discussions due to the similarity of their work roles.

9. Conclusions

This study produced several insights into the area of measurement methods for TI. The aim of this study is to design and test a measurement method, based on indications of the low status for TI and the individuals working with it. A benefit model is a way to communicate the positive outcome a resource, in this case TI. By addressing the low status with a benefit model, the low designator can be lessened. The measurement method in this study is an addition to Ahlin's benefit model, which originates in communicating the benefits of TI (Ahlin 2014).

This study contributes to IM by adding knowledge of one way to design a measurement method to a benefit model for TI, as earlier research in the field aimed at measuring the benefits of either an IS or IT. The knowledge contribution to designing a measurement method consists of creating input by investigating benefits of TI, categorizing the benefits based on theory, and making a summation of the categorizations. Here, the foundation for the input was the interviews, as the perception is that the benefits are hard to grasp (Remenyi et al. 2007). For the categorization, the syntactic, semantic, and pragmatic approaches of the boundary object were used (Carlile 2004). In the last step, the summation, the scores were summed.

The findings in the test contribute to business aspects of TI. An organization can use the results of the test and improve the method's practical application. The test produced fruitful findings, although it was time-consuming to conduct and linguistics appeared to play an important role. The impactful part consists of a list of benefits, which include more than a dozen benefits derived from the case organization's TI. Examples of these benefits are empowering team members to make lower-level decisions, faster on-boarding for newcomers, and collaboration tool for important suppliers. The time-consuming part of the test was the interviews, which required conducting, transcribing, and analysing. Linguistics played an important role in the focus group agreeing on the benefit list and the categorization of the benefits. The meaning of the category words syntactic, semantic and pragmatic required clarification.

Both the design and test result in further growth of the minimalistic knowledge foundation about measurement methods to be added to benefit models for TI. Referring back to the low status, this study provides possibilities to communicate the internal benefits of TI. The result of the measurement method indicates how TI is used within an organisation to diminish boundaries.

As this is a first test, limited to one case, there are several interesting paths for further research. One of which is to change the way of collecting benefits to surveys, which is less time-consuming than interviews. This survey can be based on the interview questions, and play a role in i.e. developing a guide to find the benefits. Development of such a guide was not part of this study. Another path for further research is to alter the organization. This study's empirical material was collected at a software company in the Midwest USA. Changing of organization could either mean a change of trade or geographical location. All of these could produce interesting findings to add to the low knowledge foundation connected to benefits and measurement method of TI.

References

Ahlemann, F., Hesselmann, F., Braun, J., and Mohan, K. 2013. "Exploiting Is/It Projects' Potential - Towards a Design Theory for Benefits Management," *ECIS 2013*, Utrecht.

Ahlin, K. 2014. "Approaching the Intangible Benefits of a Boundary Object," in: *Computer and System Science*. Östersund: Mid Sweden University.

Ahlin, K. forthcoming. "Measuring the Immeasurable? The Intangible Benefit(S) of Digital Information."

Ahlin, K., and Persson, T. 2015. "A Communication-Model for Intangible Benefits of Digital Information," *American Information Systems Conference*, Puerto Rico.
Ahlin, K., and Saarikko, T. 2013. "Exploiting Information: Seeking Long-Term Preservation of Organisational Knowledge," in: *NFF 2013*. Reykavik, Iceland.
Brynjolfsson, E. 1993. "The Productivity Paradox of Information Technology," *Communications of the ACM* (36:12), pp. 67-77.
Bytheway, A. 2014. *Investing in Information - the Information Management Body of Knowledge*. Switzerland: Springer.
Carlile, P. R. 2002. "A Pragmatic View of Knowledge and Boundaries: Boundary Objects in New Product Development. ," *Organization Science* (13:4), pp. 442-455.
Carlile, P. R. 2004. "Transferring,Translating, and Transforming:An Integrative Framework for Managing Knowledge across Boundaries," *Organization Science* (15:September-October), pp. 555-568.
Chircu, A. M., and Kauffman, R. J. 2000. "Limits to Value in Electronic Commerce-Related It Investments," *33rd Hawaii International Conference on System Sciences*, Hawaii.
Davenport, T. H., and Prusak, L. 1997. *Information Ecology*. New York: Oxford University Press.
Dicks, R. S. 2003. *Management Principles and Practices for Technical Communicators (Part of the Allyn & Bacon Series in Technical Communication*.
Frisk, E. 2007. "Categorization and Overview of It Evaluation Perspectives - a Literature Review," in: *ECIME 2007: The European Conference on Information Management and Evaluation*. University Montpellier 1.
Giaglis, G. M., Paul, R. J., and O'Keefe, R. M. 1999. "Combining Business and Network Simulation Models for It Investment Evaluation," *32nd Hawaii International Conference on System Sciences*, Hawaii.
Hallikainen, P., Kivijärvi, H., and Nurmimäki, K. 2002. "Evaluating Strategic It Investments: An Assessment of Investment Alternatives for a Web Content Management System," *35th Hawaii International Conference on System Sciences*, Hawaii.
Hart-Davidson, W. 2013. "What Are Work Patterns of Technical Communication? ," in *Solving Problems in Technical Communcation,* J. Johnson-Eilola and S.A. Selber (eds.). Chicago: The University of Chicago Press.
Hennink, M. M. 2014. *Focus Group Discussions - Understanding Qualitative Research*. Oxford: Oxford University Press.
Huang, E., and Huang, T. 2013. "Measuring Boundary Objects in an Attempt to Explain Innovativeness " in: *46th Hawaii International Conference on System Sciences*. Hawaii: pp. 3645 - 3653.
Kaner, C., and Bond, W. P. 2004. "Software Engineering Metrics: What Do They Measure and How Do We Know?," in: *10th International Software Metrics Symposium, METRICS 2004*.
Khallaf, A. 2012. "Information Technology Investments and Nonfinancial Measures: A Research Framework," *Accounting Forum* (36), pp. 109 - 121.
Kim, H. H., Cho, K.-W., Kim, H. S., Kim, J.-S., Kim, J. H., Han, S. P., Park, C. B., Kim, S., and Chae, Y. M. 2011. "New Integrated Information System for Pusan National University Hospital," *Health Informatic Research* (17:1), pp. 67-75.
Lundberg, D. 2009. *It Och Affärsnytta : Konsten Att Lyckas Med Investeringar I It*. Lund: Studentlitteratur.

Lycett, M., and Giaglis, G. M. 2000. "Component-Based Information Systems: Toward a Framework for Evaluation," *33rd Hawaii International Conference on System Sciences*, Hawaii.
Löfstedt, U., Ingelsson, P., Bäckström, I., and Öberg, L.-M. 2014. "Can Lean Improve the Status of Technical Communication? : Taking a System Perspective.," in: *17th QMOD-ICQSS Conference, Prague, Czech Republic :* . Prague, Czech Republic.
Ottersten, I., and Balic, M. 2010. *Effektstyrning Av It : Nyttan Uppstår I Användningen*. Solna: Liber.
Patton, Q. M. 2002. *Qualitative Research & Evaluation Methods*, (3rd ed.). Thousand Oaks: Sage Publications.
Päivärinta, T., Dertz, W., and Flak, L. S. 2007. "Issues of Adopting Benefits Management Practices of It Investments in Municipalities: A Delphi Study in Norway," *Hawaii International Conference on System Sciences*, Hawaii.
Remenyi, D., Bannister, F., and Money, A. 2007. *The Effective Measurement and Management of Ict Costs & Benefits*, (Third ed.). Oxford: Elsevier.
Star, S. L. 2010. "This Is Not a Boundary Object: Reflections on the Origin of a Concept " *Science, Technology & Human Values* (35:5), pp. 601-617.
Wallace, P. 2011. *Information Systems in Organizations*. New Jersey: Pearson College Div.
Ward, J., and Daniel, E. 2012. *Benefits Management : How to Increase the Business Value of Your It Projects (2nd Edition)*. Somerset, NJ, USA: John Wiley & Sons.
Yin, R. K. 2009. *Case Study Research – Design and Methods*. Thousands Oaks: Sage Publications.

Paper VII

Measuring the Immeasurable? The Intangible Benefits of Digital Information

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Abstract

The benefits of digital information are mostly viewed as intangible, meaning that they can be hard to measure. This lack of measurements makes the benefits difficult to compare and communicate, creating problems for e.g. decision-making and the strategic development of specific digital information. Therefore, I conducted a literature review to find out how the combination of intangible benefits and measurements are dealt with in the information systems field. I found that we measure the intangible benefits of information systems or information technology. Here, the measurement method is divided into input, rule, and output. The input consists of pre-determined individual benefits, areas of pre-determined benefits, or interpreted benefits from respondents. The rule follows an accepted theory or contextual adjusted rules, and the output (benefit) can be seen as either financial or non-financial. The avenue for further research focuses on the digital information as the primary resource, not information systems or information technology.

1. Introduction

The benefits of digital information are difficult to measure, which has influenced its strategic use and development by preventing effective communication and by allowing detractors to minimize the potential impact of benefits. This paper presents a focused discussion of measurement strategies, showing that benefits can be (and are being) measured, aimed at supporting more effective communication of benefits. By utilizing measurement strategies, organizations can more efficiently choose aspects of digital information to emphasize, in order to maximize benefits.

The problem of determining the benefits of digital information is discussed by Remenyi et al. [39]. They claim that there are few benefits of digital information and that they are hard to measure, especially in financial terms. Emphasized by Wixom [47] is the problem of measuring. She sees it as one of the key challenges when organizations want to understand the benefits of digital information and frames the challenges as problematic when fixing a price on digital information or when using digital information for internal bartering. In Ward and Daniel [45], measurements are in focus and explained as a way to communicate the benefits of digital information. Their investigation shows that communication of benefits should be directed towards the stakeholder, implying that there is a need for a different kind of communication. Slumpi et al. [44] are on the same track, describing the communication of benefits as a way to increase the status of digital information. Another aspect of measuring intangible benefits is the importance of showing a complete picture of the generated benefits claimed by Brynjolfsson [3], Remenyi et al. [39], and Ward and Daniel [45]. This motivation is not specifically directed towards the benefits of digital information.

Communication is one way to motivate measurements of benefits, thereby creating interest in transforming the intangible benefits into tangible ones. Apart from communication, comparison and decision-making are in focus as regards the benefits of digital information, especially for management [39]. Measurements make it easier to compare interpretations of intangible benefits and in the long run provide a foundation for decision-making. Part of the decision-making is to keep track of the benefits; more easily done if they can be measured.

Digital technical information (DTI) is one category of digital information related to products. DTI includes such things as manuals or CAD-drawings. Several researchers, like Slumpi et al. [44] and Ingelsson et al. [18], discuss the profound knowledge about the benefits and their measurements resulting in low impact for the DTI in comparison to the product. They even discuss the problems this creates for co-workers dealing with DTI in the form of influence and status in the workplace. Another example and angle is Open Data (OD), which is digital information from governments that should be publicly provided in a machine-readable format [26]. OD is supposed to improve efficiency and be the foundation for digital innovations, merely formed as logical benefits and rarely shown by measurements. Therefore, several authorities are questioning the effort of publishing the data and creating barriers for work roles such as app developers [9].

Even though intangible benefits are hard to measure, the information systems community has developed several methods to do this, some based on Key Performance Indicators (KPI) or the Balanced Score Card (BSC). To create a broad understanding of the most recently developed measurement methods, this study aims to create a knowledge base for the measurement of the intangible benefits of digital information. The foundation for this is created by means of a literature summary. This paper covers: a deeper understanding of related concepts; a method description; the analysed results from the literature in the form of the categories of financial and non-financial measurement methods; and a discussion about how we measure intangible benefits.

2. Related concepts

The problem of determining the benefits of digital information can be equated with the fact that in most cases it creates *intangible benefits* [39]. The interpretation of what intangible benefits are can differ. Intangible benefits are often compared with tangible benefits, referring to measurable benefits from investments [3]. Ward and Daniel [45] use a scale for measuring benefits including the steps observable, measurable, quantifiable, or financial. In their classification, intangible benefits are viewed as observable, but they do describe the possibilities of measuring these benefits in the long run, e.g. by using surveys. Frisk [10] describes intangible benefits as soft benefits and Serafeimidis and Smithson [42] discuss them in terms of how they might improve something in the organization. The improvements will not be visible on the bottom line and are therefore viewed as hard to measure. Lycett and Giaglis [30] describe intangible benefits as indirect or strategic advantages, something that is still hard to describe in measurable terms. They explain that the indirect advantages are intertwined with other organizational resources and that the strategic advantages are beneficial for the entire organization from a long-term perspective. Murphy and Simon [32] follow the same track and declare that intangible benefits either improve the internal organization's operational performance or its output performance. Examples of output are higher product quality, improved product delivery or improved service combining an internal and external organizational perspective. A common perspective here is the general view of intangible benefits as hard to measure and relies on personal or group interpretation of gained benefits.

Commonly researched in the information systems field are information systems, reviewing the information stored in them [5]. The view of digital information is therefore somewhat limited and discussed only by a few researchers in the field. The digital aspect of digital information relates to electronic storage, using zeros and ones as representation, like in an ordinary information system of today [2]. Focusing on information, one main view is the relationship between data and information, where information mainly is viewed as interpreted data [28, 49].

The measurement process is fundamental when discussing measurements. Ljungberg and Larsson [29] describe the measurement methods as follows: collect the input to the method, do the measurement, and describe the output. Kaner and Bond [22] are more explicit about measurements and use the definition: "*measurement is the empirical, objective assignment of numbers, according to a rule derived from a theory, to attributes of objects or events with the intent of describing them*. "For this study, the input is related to the view of intangible benefits, namely the interpretation of what is a benefit by individuals or groups of individuals. Kaner and Bond [22] emphasize the rule as any consistent rule, whereas any random rule is not viewed as a rule. From here, I include the intangible benefits in the measurement and declare that the rule affects the input. One way to do this could be to create the input via interviews, use a rule implying various KPI and identify the benefits according to those KPI. One example of KPI is the digital information contribution to the organization according to a given scale. The output shows the contribution of used resources to the organization relating to the set-up of its KPI.

3. Method

To fulfil the aim of creating the knowledge base, a literature summary was initiated. To review existing literature, Machi and McEvoy [31] suggest the following steps: (1) find literature, (2) organize it, and (3) carry out a refining revision of the chosen literature. This is described by Pickard [38] as the skill of searching appropriately and scanning the literature to find appropriate material. Machi and McEvoy [31] describe the literature search as including searching, previewing and selecting material. Here, these findings are under the headings "Search the literature" and "Survey the literature".

3.1 Search the literature

Based on the purpose, the first exploratory search used the word combination “intangible benefits” AND measurement AND information in the SCOPUS database and then later in the IEEE. The decision to search in two databases was based on the fact that the number of hits in SCOPUS was as low as 6. To validate the result, IEEE was used, which gave 7 hits. To continue to look for measurement methods, previous knowledge about the concept of information economics was used. Information economics includes the measurement of the intangible as well as the tangible benefits of both information systems and digital information [39, 36]. The search used a combination of information economics and “intangible benefit”. Rendering 46 hits in IEEE, the abstracts were read to add material to the knowledge base. The articles in focus were those that included a method to measure the intangible benefits. This search rendered literature where researchers had based their research on the empirical foundation of information systems and in some cases information technology. The digital information was rarely used as an empirical foundation. As information economics is an explicit concept, the next step was an additional search to find more articles. This search was broadened by just using the words “intangible benefit” and rendered 581 hits in SCOPUS.

To reduce the number of hits, the included subject areas were social sciences, business administration, computer science, economics, and decision science. There were 268 new hits. The headings and abstracts were reviewed to find suitable material describing ways to measure intangible benefits. The same step was taken in the database IEEE; using the search words intangible benefit. This rendered 102 hits, which were reviewed by reading the headlines and abstracts of articles containing ways to measure intangible benefits. In total, 28 articles were selected to understand how we measure the intangible benefits of digital information. The search, which initially had a loose outline, was shaped by the increased knowledge of the researcher. Pickard [38] describe this evolution of increased knowledge as an iterative process, forming the knowledge base.

3.2. Survey the literature

The survey of the literature was done by finding themes [31]. Here, the themes are the various methods used to measure intangible benefits. The 28 articles were loaded into Nvivo software, and then scanned to look for the measurement method mentioned in the article. The results were synthesized in the description of the measurement method and are shown in Table 1. The foundation can be a specific measurement method, like Key Performance Indicators, or described in the article, as a framework created for a specific information systems area, like e-government, information system in the supply chain area or for a bank in a specific country. The themes, by measurement method, were devised to create order and structure; the initial step in the process of surveying the literature and understanding the way intangible benefits are transformed into tangible ones.

Table 1 Found measurement methods

Measurement method	**Author(s)**
BSC	Grembergen and Amelinckx [13], Royer and Wolfgang [40], Ogembo-Kachieng’a et al. [34]
Analytical Hierarchy Process (AHP)	Hallikainen et al. [16]
Key Performance Indicator	Giaglis et al. [11], Kim et al. [24], Wu et al. [48], Ordoobadi [35], Giaglis et al. [12]
Information Economics	Chircu and Kauffman [7]
Framework	Khallaf [23], Lycett and Giaglis [30], Carayannis and Watson [4], Sherer et al. [43], Chang et al. [6], Kumaralalita et al. [27], Kahraman et al. [21], Gupta and Jana [15], Gunasekarana et al. [14], Seddon et al. [41], Jacks et al. [19]
Context, Content, and Processes	Serafeimidis and Smithson [42]
Cost-Benefit Analyses	Murphy and Simon [32], Kim et al. [25], Crowder et al. [8], Jacobs and Rodgers [20]
Simulation	Mutschler et al. [33]
Organizational Benefits from an Enterprise Model	Ayal and Seidmann [1], Hong and Kim [17]

Using the above process does not find every single measurement method for intangible benefits. Webster, and Watson [46] declare that a literature review will be good enough if it has searched top information systems journals; here I argue that the material found is adequate for the purpose. Scopus contains six out of eight in the Senior Scholars' Basket of Journals, added by numerous other IS journals. In addition to the search in IEEE, which contains 26 journals within the information technology field, the search field is deemed to be sufficient.

4. Analysis

The analysis functions on the themes from the survey of the literature. Influential parts of the area of measuring benefits, such as the output in either financial or non-financial terms, are added to the themes. The latter provides an overall categorization for the themes. The analysis was conducted in two steps. The first step was to reread the articles and decide whether to include them in the final material or not. The second step was to categorize the material based on financial or non-financial output.

In the initial part of the analysis, each article was read through once again. The following aspects for searched for in this step: the articles' rule regarding the transformation of intangible benefits into tangible ones, how the rule was conducted or deemed to be conducted, and the input/output from the rule. These findings were reviewed to fulfil parts of this study's aim, see Table 2. In every measurement method group, the articles were chosen that provided different aspects of the actual measurement method and also included a specific rule. For the first reason, Ogembo-Kachieng'a et al. [34] was excluded from the BSC group and for the second reason, Wu et al. [48] and Ordoobadi [35] were excluded from the KPI group. The remaining articles were then uploaded in a new Nvivo project.

Table 2 Analysed measurement methods

Measurement method	Author (s)
BSC	Grembergen and Amelinckx [13], Royer and Wolfgang [40]
Analytical Hierarchy Process (AHP)	Hallikainen et al. [16]
Key Performance Indicator (KPI)	Giaglis et al. [11], Kim et al. [24]
Information Economics	Chircu and Kauffman [7]
Framework	Khallaf [23], Lycett and Giaglis [30], Seddon et al. [41], Jacks et al. [19]
Context, Content, and Process	Serafeimidis and Smithson [42]
Cost-Benefit Analyses	Murphy and Simon [32], Kim et al. [25]
Simulation	Mutschler et al. [33]

The second step included further analysis, where the remaining articles were categorized into two main categories: financial and non-financial output. Ward and Daniel [45] influenced this inductive analysis and their rough categorization of output, from observable to financial, is based on Patton's [37] description of inductive analysis. This description includes exploring and finding important patterns. With knowledge of the material and influenced by the aforementioned categorization, the decision was made to use two categories – non-financial and financial output. With the articles in Table 2, the financial output contains four articles and the non-financial contains ten articles. In order to have a better overview of the non-financial field, this category was further divided by using the previously found themes, such as the KPI, and BSC. The articles picked for these themes mentioned one of these methods. Two articles were picked for both themes, leaving six articles. The foundation of the measurement methods; found to be framework and organizational goal alignment, was searched for in the remaining six articles. Both of these two categories contain three articles each.

4.1 Measurement methods with financial output

The measurement methods with financial outputs are shown in Table 3. The group consists of four studies, all of them using measurement methods for a specific kind of information system, like e-commerce or enterprise resource planning (ERP). Mutschler et al. [33] propose a method based on the theory of system dynamics. This theory uses chains based on cause and effect to explain benefits. The method is not tested on empirical data, only explained theoretically. The explanation is given, using a specific kind of information systems (Workflow Management Systems). Mutschler et al. [33] views the method as cost driven, based on cost factors and impact factors in specific areas connected to the business process, where the information systems are used. The cost factors are direct and the indirect costs are connected to the investment in the information system. In this case, the impact factors are connected to the areas of technology, organization and project management.

Specific benefits, which are used as chains and causes in the dependency network, are derived from the factors.

Two of the other methods use surveys in their measurement methods to find the intangible benefits. Kim et al. [25] use a survey to find the willingness to pay for the information system, which is viewed as the total intangible benefit. Chircu and Kauffman [7] use a survey to understand the users' eagerness to adopt the system, implying that the intangible benefits are viewed as usage of an information system, and estimate a cost saving based on the usage. Murphy and Simon [32] believe that the major intangible benefit is user satisfaction and identify its increase in the context of a new information system's implementation. This increase is then measured in cost savings. The input data is compiled via identification of the benefits, and surveying inputs from users of the system. All of these studies' measurements of intangible benefits are then used in a cost-benefit analysis.

Table 3 Measurement methods with financial output

Article	Input/Output of measurement process
Mutschler et al. [33]	I = factors that influence benefits of the system, O = economic measurements
Kim et al. [25]	I = surveys with questions related to the resource, O = monetary value
Chircu and Kauffman [7]	I = surveys with questions about adoption and interviews to understand the barriers, O = percentages, connected to adoption of IS, which can be turned into financial values.
Murphy and Simon [32]	I = identified benefits, O = cash flow.

4.2 Measurement method with non-financial output

The second category is the measurement methods that generate non-financial output(s). The group consists of ten studies, three of which use information technology as a foundation and the remaining seven use information systems. The category is further divided into themes depending on their method or used foundation. The themes are methods based on goal alignments, frameworks or outputs such as KPI, or BSC. The two goal alignment methods use organizational goals as guiding principles for the implementation of information systems [16, 42], see Table 4. The first of these studies uses the Analytical Hierarchy Process, AHP, which, based on the organizational goals, refines them to a detailed level. The detailed level is measured by a survey, weighted against the organizational goals and, as a final step, prioritized. The second method compares the results from a questionnaire with other projects. The results are shown in form of a benefit profile with measurements.

Table 4 Measurement methods with non-financial output, goal alignment

Article	Input/Output of measurement process
Hallikainen et al. [16]	I = goals at different levels. O =measurements in form of weighted alternatives for the investment.
Serafeimidis and Smithson [42]	I = key benefit areas, O = measurements

Four of the studies use frameworks to dig deeper into the world of measurements, see Table 5. One of them is based on a literature review and describes the factors that affect organizational performance as a result of using information technology [19]. The factors are listed as resources, capabilities, and information technology/business alignment. In the second framework, a measurement method is proposed. This method includes a survey, which results in the information required by the project. The future aim for this framework is to add functionality like simulation and "what if" decision features in a CASE tool [30]. The third framework orientates its output towards the organization's increased value, by measuring processes and their impact on both the internal and external level [23]. The last framework describes benefits from information systems from both a short- and long-term perspective [41]. The tested factors for the short-term are functional fit and overcoming organizational inertia; whereas the long-term adds the factors integration, process optimization, improved access to information and on-going IS projects.

Table 5 Measurement methods with non-financial outputs, framework based

Article	Input/Output of measurement process
Jacks et al. [19]	The output is measurements about organizational performance, which are divided into profitability, productivity and intangible benefits.
Lycett and Giaglis [30]	I = questions aiming to find key information, O = measurements
Khallaf [23]	I = level of IT investment, process flexibility and quality, and customer satisfaction, O = Measurements for the organization's market value
Seddon et al. [41]	I = word count of identified factors, O = weighted factors from the specific implementation

Two examples using the BSC measurement methods were picked (see Table 6), one of which uses BSC for Enterprise Identity Management Systems [40]. The proposed measurement method synthesizes the four parts in the BSC to two. The first part consists of the business and the financial and the second of security/risk and supporting processes. In the second article, BSC is used for the e-business, which measures customer orientation, business contribution, operational excellence and future orientation [13]. The measurements are collected in various ways, for example via surveys or site visits.

Table 6 Measurement methods with non-financial outputs, BSC

Article	Input/Output of measurement process
Royer and Wolfgang [40]	I = intangible benefits in the financial, security/risk mgmt., supporting processes and business processes, O = measurements
Grembergen and Amelinckx [13]	I = survey(s) with questions in the area of customer orientation, business contribution, customer orientation, operational excellence, and future orientation O = measurements

KPI is used as one way of transforming the intangible benefits to tangible [12, 24], see Table 7. The starting point for both these articles is to understand the KPI for the desired output. Giaglis et al. [12] use business performance and [20] use efficiency and user satisfaction. Kim et al. [24] develop a simulation model from the as-is state, which they see as providing opportunities to improve the effects of the benefits.

Table 7 Measurement methods with non-financial outputs, Key Performance Indicator

Article	Input/Output of measurement process
Giaglis et al. [12]	I = qualitative costs and benefits, O = business performance measures in the form of KPIs
Kim et al. [24]	I = questions connected to the different KPIs. O = measurements for efficiency and user satisfaction.

5. Discussion

This study aims to create a knowledge base for how we measure the intangible benefits of digital information. In reviewing the literature, no such study was found. Most articles use some information system followed by information technology as a resource for the investigated measurement methods. At least information systems use digital information, implying that it is part of the resource. In the longer run, this could mean that digital information is seen as part of the output, and thus should not be investigated as a resource in isolation. One way to improve the findings in the aim's direction could be to change the search words. Examples of other search words could be to use the word value instead of benefit or specify the category of digital information of interest, in the same way as a specific information system is used in some of the articles. Another way to understand the few studies of digital information is to follow the claim by Carter et al. [5] and perceive the focus in the information systems field as rarely including the content of the information systems.

The articles were published between 1996 and 2012 with the median year being 2006. We can thereby ascertain that recent research activity on how to measure intangible benefits is low. The studies have been conducted sporadically, and the researchers have not used or found any traces of previously focused activity. There are few discussions in the articles on why the measurements are conducted. Some mention that managers require financial decisions to see the complete picture of the investment [32, 23]. There is no discussion about how to describe the measurement. Few studies mention measurements and even fewer talk about transformation, which could be a preferable description in comparison to measurement. Using the term transformation would indicate that there are interpretations included and help the users of the figures to understand the basis for them. Despite this, measurement is used here to adhere to the existing tradition within the information systems field.

More detailed results from the study handle the three components, input, rule and output [22]. Here, the structure emphasizes a more natural understanding of the included components and the steps included in the measurement method. The findings from each of the inherent components are covered in Figure 1.

The ***input*** is either handled as pre-decided, intangible benefits (c.f. [42]), used for confirmation or formed by the interpretations of answers from interviews, or surveys (c.f. [32]). Both the pre-determined way and the interpretations are direct ways to find the benefits, where the first is more direct than the other. One possible other way is to use auxiliary input by asking what would happen if the digital information was not accessible.

Here, one way of handling the inputs are pre-determined benefits, both in specific areas and as individual benefits. Often mentioned in relation to intangible benefits are to make them visible and thereby get a picture of all benefits. Using pre-determined benefits make this picture hard to reach. On the contrary can the finding of all intangible benefits be hard to reach and questioned from various stakeholders. Operationally, the pre-determined benefits are related to a specific area or individual benefits. Both these ways put emphasis on the creator of the questions having in-depth knowledge of e.g. the specified area or rule to be used. One example could be to miss benefits and thereby create a foundation for decision-making of low quality. The usefulness of pre-determination occurs as comparability; focusing on the same benefits in comparison to interpretation.

Few of the articles include an extended way of finding input or verification of the input although Chircu and Kauffman [7] is an exception. It claims to find precious material and bases the benefits on this material. The researcher's effort is therefore time-consuming although adding more value to the measurement method.

In the literature review, I found a variety of underlying ***rules*** used for the methods, like Contingent Valuation, goal alignment, framework, BSC, system dynamics and KPI. Despite this, my finding is that the methods used vary, and thereby the underlying theory. The variety in rules in this study can be explained by the choice of presenting a sample from each method. In some of the articles, the choice of the underlying rules is discussed as being suitable for both the resource and the organization that uses the measurement method. For the articles where there is no empirical investigation of the measurement method, the expectation is that the organization will make a choice. The rules are derived both from ordinary views on how to express tangible benefits. One example is the CVM that expresses the customers' willingness to pay for the resource [25] or the AHP [16]. The latter is a method for refining and structuring goals in an organization, where the intangible benefits are compared and prioritized concerning the organizational goals. Other rules are derived from particular perspectives in the organization, such as frameworks dealing with strategic goals [19], operational goals [30], or the rarer more occasional customer [23] or user satisfaction [24].

The ***output's*** structure of financial and non-financial relates to the area of benefits, emphasized by Ward and Daniel [45] in a slightly more detailed structure. For here, the measurement methods with financial outputs are less numerous than the non-financial ones, aligned with statements from Remenyi et al. [39] and Wixom [47]. This might be a sign of dealing with benefits that are seen as hard to measure and put a monetary value on. The financial output includes various ways, such as monetary value [42] or cash flow [32], both framed on the frequently used cost-benefit analysis. A cost-benefit analysis is derived solely from the measurable benefits, taking no account of the differences between measurable and non-measurable assets. This drawback can be offset by the fact that the non-measurable benefits are given a clearance compared to the cost and a better image is created, for example, by an implementation. Focusing on the digital information as a resource for deriving the benefits, the implementation cost is rarely estimated as its creation is mainly done via individuals [47]. The use of such an analysis can, therefore, be hard, not solely based on the intangible benefits.

The result of non-financial output is strongly linked to the various rules, such as the KPI or the BSC. The outputs applied relating to the unique context are synthesized. In these cases, the context can be attributed to the organization, the specific resource or the used benefits. Kaner and Bond [22] emphasize the output as the objective assignment of numbers. Here, the interpretations of the surveys or interviews should be reflected in the treatment of the numbers as the objectivity can be questioned. The possibility to interpret differently is high, depending on, e.g. the questions in a survey and the way they are formulated. Therefore, a comparison in the same context is a preferred activity, not considering the objectivity and usage in various contexts.

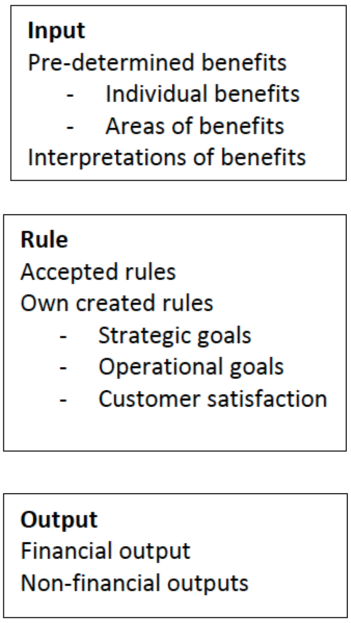

Figure 1 Findings from the inherent components in the measurement methods

6. Conclusion

The communication of benefits derived from digital information is viewed as difficult, as the benefits are experienced as intangible and can be viewed as hard to measure [39]. However, not measuring these benefits and thereby not communicating their importance or making decisions for their future can give low status to the digital information and the working roles connected to it [44]. It is therefore of interest to understand how we can measure the benefits of digital information, despite the fact that the intangible benefits are viewed as hard to measure. This study's literature summary shows that we do in fact measure them in various ways. The input to the measurement method varies from pre-determined benefits on various detail levels, such as areas or individual benefits. The input to the pre-determined benefits functions on surveys, whereas interviews create input to interpretations of benefits. The input to the method is mostly interviews and surveys with questions connected to the resource and the rule, implying that we need to understand them both.

The literature review shows the usage of various rules in the measurement methods. These rules can be founded in BSC, KPI or goal alignment for the organization, and there is always a rule connected to the measurement method. The rule follows two paths and is derived either from a specific theory, such as CVM, or from an organization's own created rules. The focus for these own created rules is mainly strategic or operational goals for the organization or business processes and more rarely customer satisfaction. The output follows the rule and in this study is categorized by its output into financial or non-financial, where most of the measurement methods are non-financial.

There are several interesting avenues for further research, and I would like to propose three. One is heading back to the initially discussed resource for this study, digital information. As mentioned earlier, this resource is not primarily investigated in the articles found in the literature summary. The first proposal for future research is to create a deeper understanding of how to design and evaluate measurement methods while using digital information as the resource. The first glimpses of this have been provided in this study's discussion, and from here our understanding can be deepened. The second avenue for further research is to build upon the knowledge base from this study, which gives a first glimpse of the measurement methods used. One way is to add measurement methods using statistics for further understanding in the area. A third avenue is to build a foundation for why we are transforming intangible benefits into tangible ones, focusing on digital information. The presented idea here is communication, decision-making, and tracing, whereas there might be other arguments or even ways to act upon the intangible benefits.

7. References

[1] M. Ayal, and A. Seidmann, "An Empirical Investigation of the Value of Integrating Enterprise Information Systems: The Case of Medical Imaging Informatics", Journal of Management Information Systems, 2009, pp. 43-68.

[2] K.D. Bollacker, "Avoiding a Digital Dark Age." American Scientist, 2010, *pp.* 106 -110.

[3] E. Brynjolfsson, "The Productivity Paradox of Information Technology", Communications of the ACM, 36, 1993, pp. 67-77.

[4] E.G. Carayannis and R. Watson, "Measuring Intangibles: Managing Intangibles for Tangible Outcomes", PICMET '01. Portland International Conference on Management of Engineering and Technology, Portland, Orlando, 2001.

[5] M. Carter, S. Petter, and A.B. Randolph, " Desperately Seeking Information in Information Systems Research", Thirty Sixth International Conference on Information Systems, Fort Worth, 2015.

[6] H-L. Chang, J. Chang and K. Wang, "Developing an IT Portfolio Approach to Justify IT Investments", Hawaii International Conference on System Sciences, Hawaii, 2011, pp. 1 - 10.

[7] A.M. Chircu and R.J. Kauffman, "Limits to Value in Electronic Commerce-Related IT Investments", 33rd Hawaii International Conference on System Sciences, Hawaii, 2000.

[8] R. Crowder, G. Wills and W. Hall, "Hypermedia maintenance support applications: Benefits and development costs", Computers in Industry, 2005, pp. 681-698.

[9] J. Crusoe and U. Melin, "Investigating Open Government Data Barriers.", International Conference on Electronic Government, Springer, 2018.

[10] E. Frisk, "Categorization and overview of IT evaluation perspectives - A literature review", ECIME 2007: The European Conference on Information Management and Evaluation, University Montpellier 1, 2007.

[11] G.M. Giaglis, N. Mylonopoulos and G.I. Doukidis, "The ISSUE methodology for quantifying benefits from information systems", Logistics Information Management, 12, Logistics Information Management, 1999, pp. 55-62.

[12] G.M. Giaglis, Paul, R. J., and O'Keefe, R. M. "Combining Business and Network Simulation Models for IT Investment Evaluation," 32nd Hawaii International Conference on System Sciences, Hawaii, 1999.

[13] W.V. Grembergen and I. Amelinckx, "Measuring and Managing E-business Projects through the Balanced Scorecard", 35th Hawaii International Conference on System Sciences Hawaii, 2002.

[14] A. Gunasekarana, P.E.D. Loveb, F. Rahimic and R. Mieled, "A model for investment justification in information technology projects", International Journal of Information Management, 21, 2001, pp. 349-364.

[15] M. P. Gupta and D. Jana, "E-government evaluation: A framework and case study", Government Information Quarterly, 20, 2003, pp. 365 - 387.

[16] P.H. Hallikainen, Kivijärvi and K. Nurmimäki, "Evaluating Strategic IT Investments: An Assessment of Investment Alternatives for a Web Content Management System", 35th Hawaii International Conference on System Sciences, Hawaii, 2002.

[17] K. -K. Hong, and Y.-G. Kim, "The critical success factors for ERP implementation: an organizational fit perspective", Information & Management, 2002.

[18] P. Ingelsson, , U. Löfstedt, I. Bäckström, I., and L.-M. Öberg, "Taking a Holistic Perspective on Technical Communication and Lean." Quality Innovation Prosperity, 2015, pp. 103-122.

[19] T.P. Jacks, Palvia and R. Schilhavy, "A framework for the impact of IT on organizational performance", Business Process Management Journal, 17, 2011, pp.846-870.

[20] G. Jacobs and C. Rodgers, "ISDN-based distance learning: tangible costs, intangible benefits", Computers & Education, 1998, pp. 41-53.

[21] C. Kahraman, N.f.Y. Ates, S.C. ¸evik, and M.G.˙Ilbay, S.A.a.E. an, "Hierarchical fuzzy TOPSIS model for selection among logistics information technologies", Journal of Enterprise Information Management, 2007, pp.143-168.

[22] C. Kaner and W.P. Bond, "Software Engineering Metrics: What Do They Measure and How Do We Know?" 10th International Software Metrics Symposium, METRICS 2004, 2004.

[23] A. Khallaf, "Information technology investments and nonfinancial measures: A research framework", Accounting Forum 36, 2012, pp.109 - 121.

[24] H.H. Kim, K.-W. Cho, H.S. Kim, J.-S. Kim, J.H. Kim, S.P. Han, C.B. Park, S. Kim and Y.M. Chae, "New Integrated Information System for Pusan National University Hospital", Health Informatic Research, 2011, pp. 67-75.

[25] K.J. Kim, K. Kim and K.Y. Kang, "Valuation on the Intangible Benefits of EVMS using CVM", Journal of Asian Architecture and Building Engineering, 2010.

[26] H. Koski, "The Impact of open data – a preliminary study." Ministry of Finance publications 15b/2015, 2015.

[27] L. Kumaralalita, A.N. Hidayanto and D. Chahyati, "Compliance Analysis of IT Investment Governance Practices to Val IT 2.0 Framework in Indonesian Commercial Bank": The XYZ Bank Case Study: ICACSIS, 2011, pp. 297-304.

[28] Langefors, B. Essays on Infology. Studentlitteratur. Lund, 1995

[29] Ljungberg, A. and E. Larsson, Processbaserad verksamhetsutveckling Varför - Vad - Hur? Studentlitteratur, Lund, 2012

[30] M. Lycett and G.M. Giaglis, "Component-Based Information Systems: Toward a Framework for Evaluation", 33rd Hawaii International Conference on System Sciences, Hawaii, 2000.

[31] Machi, L. and B. McEvoy, The literature review - six steps to success, 2nd ed., Corwin, Thousand Oaks, 2012.

[32] K.E. Murphy and S.J. Simon, "Using Cost Benefit Analysis for Enterprise Resource Planning Project Evaluation: A Case for Including Intangibles", 34th Hawaii International Conference on System Sciences, Hawaii, 2001.

[33] B.J. Mutschler, Bumiller and M. Reichert, "An Evaluation Approach for Analyzing Workflow Management Systems from a Value-based Perspective", 10th IEEE International Enterprise Distributed Object Computing Conference (EDOC'06), Hong Kong, 2006.

[34] M. Ogembo-Kachieng'a, M. Mothepu, and W. Omodho, "Business Evaluation of Information Communication Technology Projects in Southern Africa: The Case Study of Lesotho Revenue Authority", Technology Management for Emerging Technologies, 2013.
[35] S. Ordoobadi, "Evaluation of advanced manufacturing technologies using Taguchi's loss functions", Journal of Manufacturing Technology Management, 2009, pp. 367-384.
[36] Parker, M.M., R.J. Benson and H.E. Trainor, Information Economics Linking Business Performance to Information Technology, Prentice-Hall, Englewood Cliffs, 1988.
[37] Patton, Q.M. Qualitative Research & Evaluation Methods, 3rd ed., Sage Publications, Thousand Oaks, 2002.
[38] Pickard, A.J. Research Methods in Information 2nd Edition, Facet Publishing, London, 2013.
[39] Remenyi, D. ,F. Bannister, and A. Money, The effective measurement and Management of ICT costs & benefits, Third ed., Elsevier, Oxford, 2007
[40] D. Royer and J. Wolfgang, "Assessing the Value of Enterprise Identity Management (EIdM) – Towards a Generic Evaluation Approach", The Third International Conference on Availability, Reliability and Security, Barcelona, Spain, 2008.
[41] P.B. Seddon, C. Calvert and S. Yang, "A multi-project model of key factors affecting organizational benefits from enterprise systems", MIS Quarterly, 34, 2010, pp.305 - 328.
[42] V. Serafeimidis and S. Smithson, "The Management of Change for Information Systems Evaluation Practice: Experience from a Case Study", International Journal of Information Managemen, 16, 1996, pp. 205 - 217.
[43] S.A. Sherer, M.R. Ray and N.M. Chowdhury, "Assessing Information Technology Investments With An Integrative Process Framework", 35th Hawaii International Conference on System Sciences, Hawaii, 2002.
[44] T.P. Slumpi, K. Ahlin and L.-M. Öberg, "Intraorganizational benefits from product configuration information - a complementary model", International design conference - design 2012, Dubrovnik, Croatia, 2012.
[45] Ward, J. and E. Daniel, Benefits Management: How to Increase the Business Value of Your IT Projects, 2nd Edition, John Wiley & Sons, Somerset, NJ, USA, 2012.
[46] J. Webster, and R. Watson, "Analyzing the past to prepare for the future: Writing a literature review", MIS Quarterly, 2002, pp. xiii-xxiii.
[47] B.H. Wixom, "Cashing in on your data" in: Research Briefing, MIT Information for Systems Research, Cambridge MA, 2014.
[48] F. Wu, C.Liu, H.Z.Li, K.Gao and J.Tian, "The Benefits Evaluation of ERP Project Investment Based on Real Options", 2006 IEEE International Conference on Systems, Man, and Cybernetics, Taipei, Taiwan, 2006.
[49] C. Zins, "Conceptual approaches for defining data, information and knowledge." Journal of the American Society for Information Science and Technology, *2007, pp.* 479-493.