Information Infrastructure Transition:

Challenges with implementing standardised checklists

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Abstract

Implementing an information infrastructure is challenging due to the installed-base of various information systems and technologies embedded in a social and organisational context. In overcoming these challenges organisations are often planning to implement uniform information infrastructures: common standards, common databases, common work-processes, and common applications. However, in order to align the uniform design with a heterogeneous environment, the uniform design is pragmatically adjusted and changed. This is illustrated by a case study of a maritime classification society in Norway. According to the uniform design, standardised versions of checklists were planned to be included in a new information infrastructure called NAUTICUS.A temporary solution with non-standardised checklists was implemented due to the installed-base of paper-based checklists, local work-practices, and difficulties with adapting the uniform design.

Keywords: information infrastructures, work-practice, social and organisational issues in information systems.

Introduction

The purpose of this article is threefold. First, the intention is to illuminate some of the challenges concerned with information infrastructures, focusing especially on the socio-technical aspects. Second, the purpose is to suggest some perspectives for analysing and understanding this phenomenon. Third, the aim is to point at some issues for further research and design.

The term *information infrastructure* has been used to describe large-scale networked information systems that often cut across work-practices, departments, functions, and organisational borders (Hanseth et al., 1996; Monteiro & Hanseth, 1995; Star & Ruhleder, 1994). In practice, this phenomenon spans from tailor-made large-scale distributed systems to the standardised Enterprise Resource Planning (ERP) systems as for instance the SAP R/3 package. It has been emphasised that an information infrastructure cannot be understood as pure technology, but that an information infrastructure is always embedded in a larger social structure (e.g. Hanseth et al., 1996; Star & Ruhleder, 1994). Consequently, the SAP R/3 package in itself is not an information infrastructure, but it can become one if it is implemented in an organisational context. Thus, an information infrastructure can be understood as a term for describing the heterogeneous, dispersed, complex and interdependent components, which our "work" rely on to collaborate and co-ordinate activities through sharing and interchange of information in a given context.

In order to conceptualise information infrastructures as a part of a wider social and organisational context, theories and perspectives that would help us understand the complex interplay between the technical and the social/organisational issues are relevant. Hence, this paper suggests web models (Kling, 1987), structuration theory (Giddens, 1984) and actor-network theory (Callon, 1991; Latour, 1991) as relevant choices for conceptualising this phenomena. These theories have also been used extensively by other researchers within the field of Information Systems[1].

A preliminary study of an in-house development project in a large maritime classification society called DNV has been conducted. DNV is a global organisation with over 4700 employees in over 300 offices, located in over 100 countries all over the world. DNV is currently implementing a new information infrastructure consisting of common applications and a common IT architecture to support their surveyors in planning, executing and reporting a survey of a vessel. One important part of the infrastructure is the NAUTICUS system, where all users will communicate through a shared database. The vision is that all surveyors around the world will exchange experience, share knowledge and collaborate through the shared database. The focus of the preliminary study has been to investigate the challenges in implementing this information infrastructure. The study indicates problems with aligning the standardised design for the new information infrastructure with the installed-base. Until now, when executing a survey on a vessel the DNV surveyors have used paper-based checklists for guidance. These checklists were planned to be included in NAUTICUS in a standardised form, and the surveyors were supposed to use them in order to generate reports, statistics and 'survey jobs' to be shared by other surveyors. The design including the standardised checklists was abandoned – and non-standardised and less detailed checklists were implemented. This indicate that uniform ICT solutions are pragmatically *adjusted* to overcome organisational complexity and an installed-base of existing systems, paper-based documents and information.

The paper is structured in the following way: In the next section some relevant theories and perspectives for conceptualising the phenomenon of information infrastructures are briefly outlined. The International Classification of Diseases (ICD) is suggested as a good illustration of the challenges with designing and implementing large-scale infrastructures. Next, the interpretative research method that was used is outlined. The research site and some aspects of the NAUTICUS project and history are summarised, and the process around the checklists is described in details. In the discussion part of the paper the challenges around implementing standardised checklists are discussed in light of actor-network theory.

[1] Web models: Kling (1987), Walsham (1993); Structuration theory: Damsgaard & Scheepers (1997), Orlikowski (1991), Orlikowski (1992), Walsham (1993), Walsham & Han (1991); Actor-network theory: Berg (1997), Hanseth & Monteiro (1995).

Conceptualising the Phenomenon

Theoretical perspectives

Researchers within the information systems field have started to use the term *information infrastructure* (e.g. Hanseth et al., 1996; Star & Ruhleder, 1994). Star & Ruhleder (1994) emphasise the socio-technical nature of an information infrastructure, and a ‘system’ becomes an information infrastructure when it is embedded in a social context. In other words, an ERP system is *not* an information infrastructure in itself, but only when it has been implemented it can be characterised as an information infrastructure. Hanseth et al. (1996) underscore another important aspect of information infrastructures when considering the *installed-base* of information systems, applications, communication protocols and work routines in designing and re-designing an information infrastructure. In this perspective, an information infrastructure is never developed from scratch. There will always be bits and pieces that are left from the old systems as for instance work-practice, databases, organisational culture, and external institutions.

An information infrastructure consists of a patchwork of different information systems and information- and communications technologies. As global organisations develop enterprise-wide information infrastructures that cut across traditional boarders of work, departments and information systems, they encounter a diversity of interconnected socio-technical challenges. For instance, common for most distributed systems are the technical challenges, as for instance interoperability, scalability and security (e.g. Paepcke et al. 1998, Coulouris et al. 1994). For instance, an enterprise-wide information infrastructure can be large ERPs, as Baan IV or SAP R/3 with modules for accounting, material management, sales and distribution, human resources – and so on. Organisations are also developing in-house distributed systems to support their globally distributed work processes. These systems incorporate a range of different technologies as for instance databases, component technology, wide-area networks, large IT architectures and other legacy systems in the organisations. Typically, these systems can be characterised as being *open systems* – systems that interconnect with other systems and consist of a hierarchy of other systems themselves. Thus, it is difficult to draw a line between what is included in a given information infrastructure and what is not. For instance, is the World Wide Web a part of the Internet infrastructure or is it an infrastructure on its own?

This phenomenon introduces new challenges concerned with both technical complexity and impacts on social- and organisational aspects. Hence, this mesh of challenging technical and non-technical issues makes the processes of design and re-design increasingly complex. The challenge is to understand this phenomenon in an organisational context, how they are linked to the local work practice, how they are designed and re-designed, and how they diffuse. For instance, the recent diffusion and success of the Internet is an example of how such networked systems may develop and support a wide diversity of applications (Leiner et al., 1997). Internet has grown without any grand plan, strong control and much formal co-ordination to a global network that is used in ways that was unthinkable only a decade ago. For example, the World Wide Web was developed decades after the original Internet infrastructure was developed.

To conceptualise both technical and non-technical aspects of information systems a number of theories and frameworks have been used. Rob Kling has used what he calls *web models* to describe the socio-technical nature and how various technical and non-technical aspects are interconnected (Kling, 1987). The prominent idea is that an information system can not be analysed and understood out of *discrete-entity models*, because this phenomena does not have clear-cut borders. Thus, one can not decide *a-priori* what falls into the system and what is not a part of the system. A web-model describes the context in which the information system depends on to function. This context includes the *history* that has built it, the *social relations*, and the *infrastructure* that the information system is embedded in. A second theory, adopted from social theory, is Giddens' *structuration theory* (Giddens, 1984; Orlikowski, 1991; Orlikowski, 1992; Walsham 1993; Walsham & Han, 1991). Walsham (1993) uses this theory to develop a framework for understanding information systems as embedded in a process of organisational change in addition to its context. Structuration theory is concerned with the duality of structure, where social structure is produced and reproduced through human interaction. According to Walsham & Han (1991) structuration theory can, among other things, be valuable for strategy formation "…where existing structure at both the organisation and societal levels conditions the actions of individuals concerned in the strategy formation process and theses in turn produce and reproduce structure over time" (p. 83). Monteiro & Hanseth have used *actor-network theory* (ANT) from social studies of science and technology (STS) when analysing the diffusion and adoption of standards (Monteiro & Hanseth, 1995). They argue that actor-network theory is better suited for understanding how different elements of an information system are connected to organisational issues. This comes from the assumption within actor-network theory that does not differentiate between humans and artifacts. Humans and artifacts are actants that are linked together in an actor-network. Central in ANT is the concept of inscription, that describes how interests and meanings are inscribed in an artifact (Latour, 1991). Different stakeholders inscribe their interests into standards and technology to enforce a preferred set of *programs of action*, and hence no piece of technology is neutral (ibid.). This theory can be used in analysing the diffusion, design of large-scale information systems, and how difficult it would be to make certain re-designs and changes (Hanseth & Monteiro, forthcoming).

Linking information infrastructure and work

The link between work-practice and an information infrastructure implies that work-practice should be taken into consideration when designing or re-designing an information infrastructure. For instance, Bowker and Star have adopted the concept 'work-arounds' (Gasser, 1986), and claim that a too strong standardisation of the information infrastructure will often create work-arounds (Bowker & Star, 1994). This perspective indicates that research in CSCW and related fields, focusing on understanding different aspects of work and collaboration to be relevant also for research and design issues on enterprise-wide information systems. Understanding work and work-practice when designing computer and information systems have been focused in IS (Kyng, 1995; Robinson, 1993; Sachs, 1995; Suchman, 1995). Development and re-design of large-scale information infrastructures will have much in common with the dilemmas concerning the International Classification of Diseases (ICD) (Bowker & Star 1994). The ICD is a list centrally administrated by the World Health Organisation (WHO), and General Practitioners, hospitals, insurance companies, statisticians, governments and others, use it all over the world. The purpose from the WHOs point of view is to have a uniform way of categorising causes of death in order to generate sophisticated statistics. However, in practice, it has proven to be nearly impossible to fully standardise the ICD due to local work-practice, cultural differences and diverging requirements and interests.

Information infrastructures are socio-technical networks, where the technical artifacts shape and are shaped by work-practice and institutional arrangements. According to Star & Ruhleder infrastructures have "links with conventions of practice" (Star & Ruhleder, 1996: 113), and gives as example how electrical power rates are effected by and effect cycles of day-night work. Thus, an information infrastructure like almost any other type of information system, it cannot be understood as an isolated artifact, separated from a context and work-practice. This implies that analysing work-practice and context there it is used should play an important role when changing or designing an information infrastructure.

The Case of a Maritime Classification Society

Research site and method

Det Norske Veritas (DNV) is an independent foundation that was established in 1864, and their business is distributed throughout 300 offices in more than 100 countries all over the world. Of a total of 4700 employees, over 1000 of them are located at the DNV headquarters outside Oslo. Their customers are from the traditional maritime industry to offshore industry and general industry. In 1997 the turnover was 3,7 billion NoK, making them one of the largest maritime classification companies in the world. DNV provides three main categories of services and products, which are classification, certification, and consulting. DNVs classification activities are mostly directed towards the maritime industry. Classification rules that include IMO (International Maritime Organisation) regulations are used on all types of vessels and offshore units. Classification and certification of materials, equipment, maritime systems and safety management is also included in classification services provided by DNV. Over 4400 ships have DNV class, which constitute about 15 percent of the world's fleet in terms of tonnage. DNV certifies companies, shipping companies and ships according to a range of different standards. For instance, over 13000 ISO 9000-series certificates have been issued to customers in over 40 countries. In addition, DNV provides a range of consulting services in both public and private sectors in all their business areas.

The method used in this study is the 'soft case study' (Braa & Vidgen, 1999), based on an interpretative approach to information systems research (Walsham 1993). Semi-structured interviews have been conducted of 11 employees over a period of 3 months[2]. Of the 11 employees 4 of them were managers in the NAUTICUS project; 4 were senior developers on the NAUTICUS project; 1 former surveyor; and 2 were managers from other parts of the organisation. In this preliminary study persons that had been engaged with the development and implementation of NAUTICUS were selected to be interviewed. All informants were familiar with both DNV as an organisation and the NAUTICUS concept. The interviews were focused around some topics that were selected prior to the study. For instance, topics and questions like "*What is the vision behind the NAUTICUS system?*", "*How will NAUTICUS change today's work processes?*", "*What are the main assumptions behind the design and product model?*", and "*What are the main challenges with implementing a standardised version of the checklists?*" were discussed. In some cases the informant was given a list of the topics that were to be

[2] January 1999 – March 1999

discussed. 8 of the 11 interviews were recorded and transcribed during the analysis of the data.

In addition, informal talks and discussions have been conducted on the basis of the researchers written material as for instance research plans, article abstracts, and theoretical perspectives. Documents as analysis and requirements specifications, design documents, workflow plans, project plans, presentations and various newsletters have also been studied. The understanding of context and events in the development process have been emphasised. However, this study lacks information and examples of the actual work practice of the surveyors and managers. This is partially due to the fact that the NAUTICUS applications were not implemented in the organisation on the time of the case study. That is also the reason why only one surveyor was interviewed. After this preliminary study, the plan is to conduct detailed ethnographical studies of work practice and further studies of the implementation processes. In addition to this preliminary study, the author has also been a consultant at DNV working with analysis, design, coding and testing of the NAUTICUS SiO application. This helped me in getting in touch with the 'right' people and gave an opportunity to be able to focus on both technical and non-technical issues in the case. However, working as a consultant you do not see the world through the researcher's glasses, so my 'software engineering background' and working with purely technical aspects may have biased my interpretations of the situations.

The Nauticus project

Background

The NAUTICUS project dates back to December 1992 when the department in DNV responsible for software development conducted several pre-projects, focusing on some calculation packages for their surveyors. Throughout 1993 and 1994 several analysis and design specifications were written, and the development team did extensive research into various alternative technologies and educated themselves. During 1995 DNV made the strategic decision to go for a common software architecture for all applications in the NAUTICUS family. The IT architecture and IT solutions should be "just as flexible as DNVs will to change its work processes".

From the beginning the NAUTICUS project has focused on "improving existing work processes". New work processes were designed and described in DNVs workflow modeling technique. These projects were conducted in the various departments and sections together with users. Improving the existing work processes and "learn to work smarter" was emphasised since the start of the NAUTICUS project in 1993:

> "Standardisation of work processes are very important in the NAUTICUS project – especially for the production systems like NAUTICUS CMC, NAUTICUS NB and NAUTICUS SiO" (DNV Manager)

Three main work processes were outlined for DNVs classification activities: 1) New building, 2) CMC (Certification of Material and Components), and 3) SiO (Ships in Operation). Each work process has a "process owner" who is responsible for the given process in DNV world wide. Each of these work processes is to be supported by an application within the NAUTICUS family. The requirements specifications for a SiO support tool was finished in 1993 and after comprehensive testing it was implemented at the DNV office in Bergen in February 1999. The applications for CMC and New Building are currently in a design phase, and are planned to be implemented during 1999.

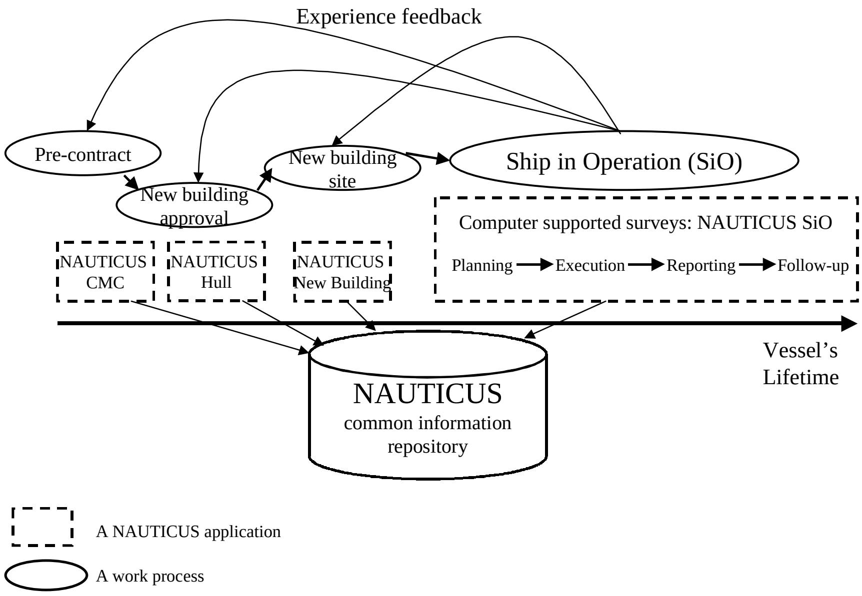


Figure 1: NAUTICUS vision: life-cycle information management.

The NAUTICUS development team has consisted of between 50 to 80 systems developers working fulltime. Where about one half of the developers are external consultants and the others are employees in DNV Software. Many of the developers have a background as engineers in the maritime industry and have themselves been surveyors or approval engineers. This combination of IT professionals and domain experts has according to several of the managers been successful. It is expected that the total number of users will be between 10000 and 50000 when all applications in the NAUTICUS family are implemented.

Strategy: a 'digital nervous system'

Most activities in DNV include some manipulation, use or production of paper-based documents as for instance reports, checklists, drawings, comments on drawings, status overviews, type approval certificates, renewal lists for certificates and approval letters. Therefore, DNV has a large installed-base of paper-based information, and DNV sees it as their main challenge to go from being paper-based to have all information available on a digital format:

> "We have to go from being paper-based to digital in order to stay competitive" (DNV Senior Manager)

The vision is to be able to share knowledge and experiences through the different phases in a lifetime of a vessel as illustrated on figure 1. The vision is that the experience gained during 'operation' could be used to increase the quality of future constructions. However, to be able to achieve this there is a need for a common terminology and a standard representation of various parts of a vessel. Therefore, DNV has adopted a 'product model' philosophy, which will support a universal information infrastructure for DNV. The product model is implemented in NAUTICUS in terms of the Common Ship Description (CSD). The CSD is a model described with the UML[3] standard for object-oriented modeling, and basically describes how NAUTICUS' 'common information repository' is structured and what data it contains. In this context, the CSD is much more a data model, than an enterprise model that describes the organisation. A *product model*

[3] Unified Modeling Language (Booch et al., 1999)

is a standardised way of describing every component assembled as a product. Product modeling deals with exchanging, sharing and storing product data in order to support information management over the life cycle of a product. Product data is a digital representation of physical products as for instance ships, cars, airplanes and buildings. Early in the NAUTICUS project it was decided to go for the ISO 10303 standard called STEP (STandards for the Exchange of Product Model Data), developed by the ISO technical committee 'TC 184/SC 4 Industrial Data'. One of the reasons for this was that it gave DNV the opportunity to exchange data with other organisations using the same standard for their product models. Several maritime organisations have adopted the product model standard STEP, and EMSA[4] represent European interests within the shipbuilding activities at ISO/STEP meetings. In addition to be a product model, the relevant work processes in DNV have also been included.

However, in order to implement a product model, it is necessary to be able to agree upon the same definitions and terminology in practice. This is a challenge as pointed out by a DNV Software manager:

> "Our business is 135 years old and we have long traditions – a 'stiffener' is not a 'stiffener' among different groups and departments… Thus, some political problems come to the surface, and if we want a product model as a foundation the prerequisite is that we manage to speak the same language."

The challenges connected to the different terminology used throughout the organisation are especially confronted when trying to include paper-based documents in NAUTICUS. The transition from paper-based to digital is changing the way documents are used and the status of a document in the organisation.

Adjusting the design: implementing non-standardised checklists

The plan: NAUTICUS SiO application

The NAUTICUS Ships in Operation (SiO) application has been built to support a surveyor in conducting a survey on a vessel. Currently this application is in use at only one DNV survey station at Bergen in Norway. In the near future, DNV stations in Holland and Singapore are likely to implement the application. DNV has defined four generic work processes, which are the following: *planning, execution, reporting, and follow-up*. All these generic tasks are going to be supported by NAUTICUS SiO.

The actual surveys are identified by NAUTICUS SiO as a 'survey job'. During the planning phase a surveyor is supposed to decide the scope of the given survey. In this phase the surveyor is using the application to create a new survey job, and defines the scope for this survey job according to the type of survey to be conducted. The surveyor can use existing information stored in the NAUTICUS database to direct his attention to the likely and potential unsafe conditions of the vessel. For instance, the surveyor can browse earlier surveys reported by other surveyors and their comments on for instance hull, equipment, machinery and safety systems, and electrical installations. This is done at the survey station before travelling out to the vessel. On the vessel the surveyor can bring the NAUTICUS SiO application on a laptop, or he may choose to bring the printed checklists. When the survey has been conducted, the surveyor must update, add and verify the relevant information through the NAUTICUS SiO application. This is called

[4] European Marine STEP Association.

‘recording’ in the NAUTICUS SiO application and this is the execution phase of the survey, even though it is likely to be done at the survey station after the actual survey has taken place. Recording is done according to a standardised set of checklists, tailor-made for the different types of surveys. When the recording is completed, various types of survey reports can be generated by NAUTICUS. These reports can then be sent electronically to the DNV headquarters for verification and registration. The maintenance task is related to maintenance of the data in the common NAUTICUS database. A customer service manager has responsibility of distribution of experience in all processes related to ship in operation.

Often, the ship can be leaving the port before the survey is completed. NAUTICUS SiO supports this by making it possible to send the survey job to the closest DNV station to the next port. When the survey job is completed it is verified at the headquarters in Oslo.

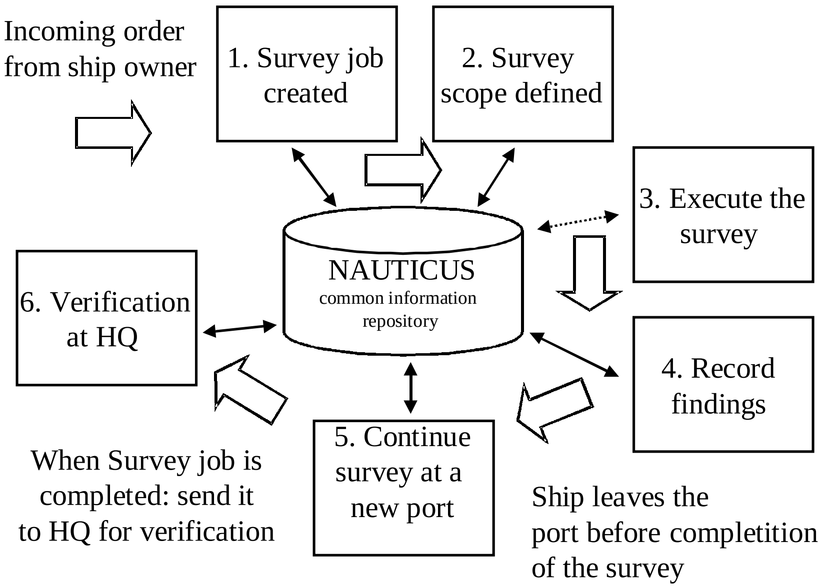


Figure 2: A survey job as a baton in the NAUTICUS SiO application.

Installed-base: checklists as paper-based an private

There are a total of 74 different checklists to be used in different kinds of surveys and types of vessels. Some surveys are conducted when the ships are in dock and some when the ship is travelling. When the ship is in dock it is possible to conduct more detailed surveys, and different components, as for instance propels and propeller shafts are dismantled and tested. During the annual survey things like fire equipment, machinery and documentation are inspected. For example, there are checklists called ‘MC.A Main Class, Cargo Ships – Annual’, and ‘MC.R – Main Class, Cargo Ships – Renewal’. The checklists consist of ‘items’ with a description. The description is formulated as a question to the surveyor, as for instance: “*1.1 Are current certificates on board valid?*” and “*9.2 If item above is answered with Yes, are the deficiencies and/or damages repaired*”. As seen on Figure 3 the first item is to be answered with ‘Yes’, ‘No’ or ‘Not applicable’, and the second is to be answered with text. In addition, for each item the surveyor should specify a certain ‘action’, as for instance a ‘Condition of Class’ or ‘Item repaired’. If any irregularities are found, the surveyor reports the ‘findings’ and the result of a ‘finding’ can be a ‘Condition of Class’, which is a very serious matter for the owner of the ship, and if not repaired the certificate could be withdrawn.

Originally, the surveyors derived the ‘checklists’ from the ‘DNV rules’ to make it easier to execute a survey. The different checklists have been made by different people and are used in many different contexts. For instance, on some occasions the checklists are given to the captain or others on the ship prior to a survey, so they have an opportunity to prepare for the survey. Thus, there is no standard representation of the checklists, and since they were not part of the official documentation, surveyors could choose to use them or not:

> "The most experienced surveyors do not use the checklists at all. Some surveyors use them for their own private documentation – There are historical reasons for this – It has not been mandatory to include the checklists as official documentation. But inexperienced surveyors use them down to every detail – this is the only way to do it if you are a beginner. An experienced surveyor can just walk down in a machine room, and do four or five surveys without any checklist." (Former surveyor)

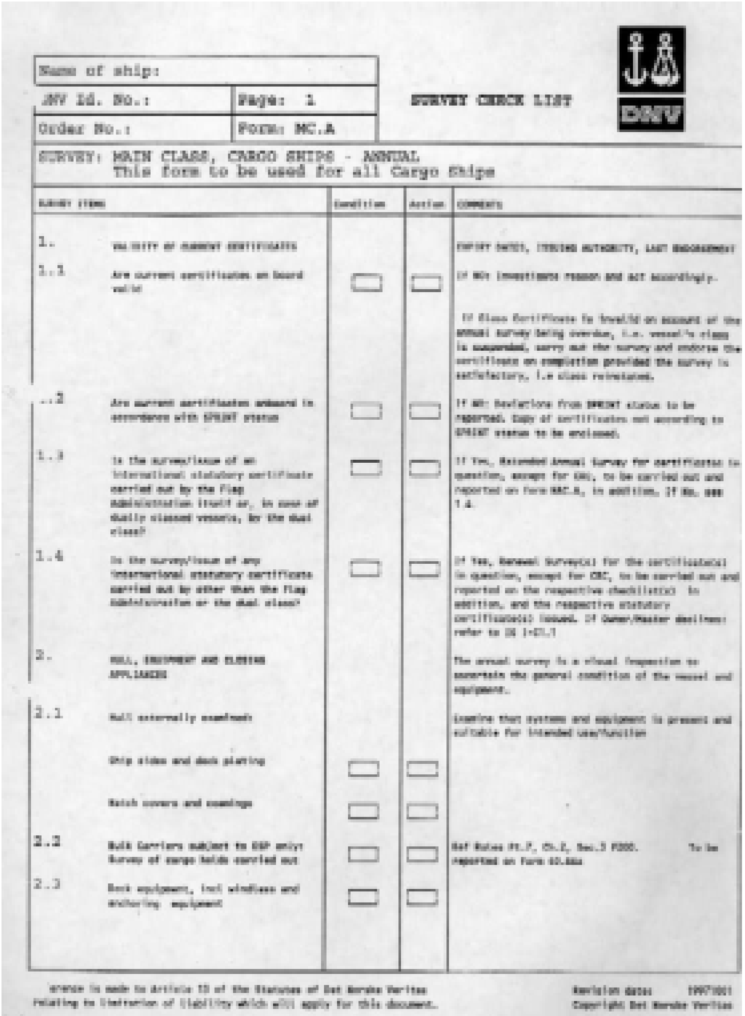


Figure 3: The paper-based checklist.

In the 1980s the lists were formalised, first as a list without any 'hints' and then they were extended with 'hints' and 'descriptions' for every item. For instance, an item described as "*Remote stopping of fans and fuel oil pumps tested*"; has the following additional comments connected to it: "*The remote stopping shall normally include the following fuel oil pumps and fans: fuel oil transfer, fuel oil booster, nozzles cooling (when fuel oil is used as coolant), fuel oil purifiers, oil burning installations, forced draught to boilers, ventilation of engine and boiler room*". In this way the checklists represent ‘knowledge’ that has been accumulated by the surveyors’ experiences over decades. The way the different items on a list are structured is not arbitrary, but it is related to the context of use and the background and experience of the surveyor who made them.

In a period the checklists were used as official documentation together with the actual ‘Survey Report’, which is sent to the DNV headquarters in Oslo for verification and registration. DNV went back from this routine, and the last years the checklists have not been part of the official documentation. Whenever new DNV rules, international rules (defined by IMO and others), or changes in practice have occurred, the checklists have been changed through a process including the surveyors themselves.

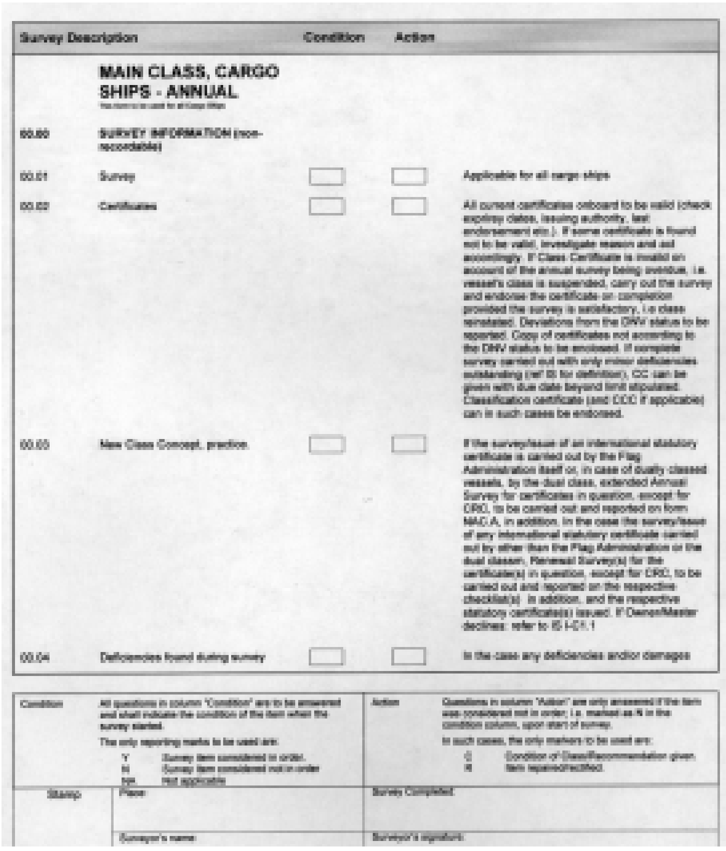


Figure 4: Preliminary checklist used in NAUTICUS SiO.

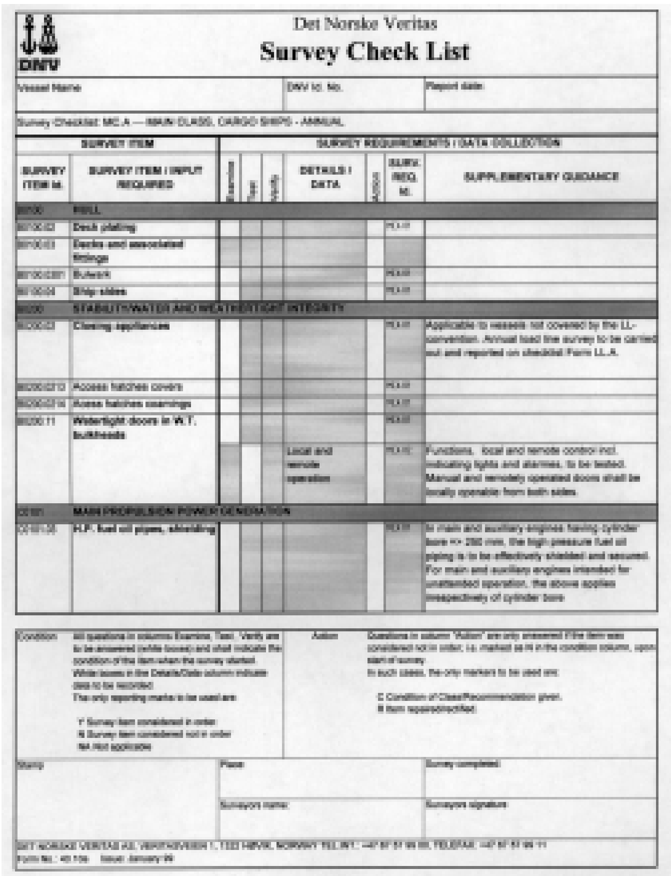
Transition: checklists as digital and public

When developing NAUTICUS SiO the plan was to import the paper-based checklists into the common NAUTICUS database and use them during the ‘recording’ phase as shown on Figure 2. The data for the checklists were stored in a FoxPro database, where the data was structured in the most convenient way for just printing them out on paper. The NAUTICUS SiO development team’s initial idea was to import the FoxPro database with the checklist data into the new data structure in the NAUTICUS database. In the common OO-model for NAUTICUS the description of the checklist data was more generic. Thus, this made it impossible to import the data directly into the NAUTICUS SQL Server[5], without any programming to adjust the old checklist data. Some of the checklist data were of “bad quality”, and since the various items in the checklists were not structured in

[5] A relational database system.

a standardised way, the checklists had to be reorganised before migration could take place. However, this was not only a technical problem. Different parts of the organisation had to agree upon a standard representation for the checklists. Some surveyors and groups outside the systems development group argued that the whole checklists system had to be revised before NAUTICUS SiO could be used at all. On the other hand, the systems development group offered slightly improved checklists to be used in a transition phase. From the system developers' point of view, due to the complexity in the NAUTICUS it was increasingly challenging to change the functionality in the applications and data representation in the CSD model.

For instance, in the worst case a change in functionality could trigger: 1) changes in the overall COM based IT architecture, 2) changes in the CSD model and re-generation of server code, 3) changes in the SQL database schema and database scripts, 4) re-building (compiling and linking) of software components and distribution of these components, and 5) changes in the application code and user interfaces. This process is time-consuming, and requires careful planning and co-ordination among different developers and groups. In the case of the checklists the changes needed included everything except changes in the overall IT architecture.


DNV

Det Norske Veritas

Survey Check List

Closing appliances

Access hatches covers

Watertight doors in W.T. bulkheads

Local and remote operation

Functions, local and remote control incl. indicating lights and alarms, to be tested. Manual and remotely operated doors shall be locally operable from both sides.

Figure 5: Standardised checklist planned to be used in NAUTICUS SiO.

It was argued that there was a great potential for improvements in terms of co-ordination between checklists and surveys, and possibilities for custom made checklists. Moreover, since the common OO-model was based on a product model philosophy, the DNV organisation had to revise all their checklists to satisfy this way of representing the checklist data. A group of people were put together to reorganise the existing checklist to satisfy the database structure and the surveyors terminology and way of working. This group has been working for over a year with adjusting the checklists to the product model philosophy. When the NAUTICUS SiO application was put into use in Bergen they still used the preliminary checklist system as shown on Figure 4, which has only small changes compared to the original paper-based checklists.

Implementation: the filofax strategy

One of the main goals for the new NAUTICUS SiO application is to be able to record a finding on a specific item in the checklist. This is to be implemented to be able to meet the vision of 'life-cycle information management' as shown on Figure 1. This opens up possibilities for generating statistics for a particular type of vessel or survey. In the planning of a survey the SiO surveyor can get an overview of previous findings related to an item in the checklist. On the other hand, for making this possible each surveyor must always relate a finding to a specific item in the checklist. In this way, the implementation of NAUTICUS SiO will change the role of the checklists, and hence, the role of the SiO surveyor:

> "The consequences will be that a surveyor's job will change from having the role of a 'verificator' to be a 'data collector' for DNV … We have 130 years of experience and tradition to support the former … and suddenly it is changing." (Former surveyor)

If NAUTICUS SiO is going to be used by the surveyors, the application must in some way or another improve the current situation for the surveyors. One improvement is the possibility for a surveyor to be able to browse all information on a ship before the execution of the survey, and another improvement is that the different survey reports are automatically generated by the system. However, to be able to point at one concrete improvement from the old system and the old checklists when implementing NAUTICUS, the checklists have been made available on filofax format:

> "We have made a filofax-version of the new checklists – a 'leather packet' for everyone. This is a very concrete advantage to the old system, where the secretaries printed out the checklist for the surveyor … The filofax is very flexible. Before, we always used to walk around with lots of A4 paper in our pockets." (Former surveyor)

Discussion

Common for all work processes in DNV are that they 1) depend upon paper-based documents and other artifacts; 2) are distributed in time and space; 3) involve many different stakeholders; and 4) are knowledge-intensive activities. In terms of actor-network theory these work processes can be understood as complex networks of heterogeneous actants (Callon, 1991; Latour, 1991; Law, 1992). The paper-based checklists are actants in a *stabilized* network of surveyors, managers, ship owners, information systems, rules and procedures, various documents etc. Thus, the paper-based checklists are a part of an aligned actor-network, which is part of a larger social system. Following Law (1992), a social system is nothing other than patterned networks of heterogeneous materials. This implies that implementing standardised checklists by including them in the organisational information infrastructure will have impact on a wider socio-technical network. The content and structure of the checklists are stored in a database system used to maintain and generate the paper-based checklists. The surveyors use the checklists in order to communicate with the crew on a vessel so that the crew can make various preparations prior to the survey. The ship owners also have access to the checklists for controlling that their vessels are following regulations and standards. These are some of the aspects that will be affected when implementing standardised checklists.

The surveyors' interests in what to document during a survey and some of their experienced based knowledge about different types of vessels are *inscribed* in the structure of the paper-based checklists (e.g. if the vessel is more than 10 years old, the surveyor is supposed to go through all sub-items related to a particular heading). Since the paper-based checklists were derived from the DNV-rules on classification, the surveyors' interpretation of these rules for a specific context (e.g. type of vessel; the age of the vessel; what to look for on a particular type of vessel) is inscribed in the checklist content. Today's system leaves much flexibility to the surveyor on how she wants to use the checklist in a particular situation. For instance, some surveyors' does not use the complete checklist, but only a small part of it, and some don't use it at all. By deploying NAUTICUS SiO with standardised checklists according to a product model philosophy, DNV is trying to inscribe different *programs of action*. The new information infrastructure, which the checklists are going to be a part of, represents different inscriptions than those incorporated in the paper-based checklists. This is not only because of the standardisation, but also because of the checklists are now a part of a surveyors' documentation that other surveyors and managers can look into through the NAUTICUS applications.

In addition, the standardised checklists are planned to be used to generate statistics and experience data. This is one of the main reasons for formalisation and standardisation of the checklists. These changes involve changing the aligned network of work practices and artifacts and thereby a new *translation* of the different interests. For instance, the current work practices and routines are far from those described in figure 2. There are two distinct differences between them. Firstly, when NAUTICUS SiO application is used, a survey will be a collaborative process where several surveyors can be working on the same survey job. The survey job will function as a baton between different surveyors, and in this context it will be important that they share the same terminology and use the application in more or less the same way. As it is today, when surveyors want information on any previous survey or other relevant information about the vessel, they have to make a phone call to DTP in Oslo, where all documents are stored. Secondly, the NAUTICUS SiO application will completely change the meaning and status of a survey checklist.

Aligning the standardised checklists and the uniform design represented by the product model proved to be a too complex organisational task. Hence, during the process of implementing the NAUTICUS SiO application, it became clear that a standardised version of the checklists could not be included in the first version of the application. It proved difficult to align a standardised version of the checklists with the current work-practices and the installed-base of the existing NAUTICUS database and product model. It was easier to align less standardised checklists, because this did not impose so strong inscriptions on how to use them, and it did not require complex changes in the installed-base (database that included the old checklists used to generate the paper-based checklists). In this way, the design seems to *drift* during the later phases of the project when the system comes "closer" to the organisational environment. Similarly, Ciborra (1996) has observed that groupware systems seem to drift when put into use.

Some advantages with striving for a uniform and common ICT solution can also be identified. The standardisation of the various work processes was welcommed by the developers, because this gave them a good picture of the requirements for the NAUTICUS applications. This thinking has also lead to lean and well-designed IT architecture and models. For instance, generic and reusable classes have been described in the CSD model in order to capture many different aspects of the ‘real world’. Thus, a standardised and uniform design is always both *enabling* and *disabling* (Orlikowski, 1992) for the implementation processes and use of the information infrastructure.

DNV should focus on identifying those aspects of the NAUTICUS applications and product model philosophy that would not apply for the current organisational and technical context. Thereby it will be less challenging to align the design with the current installed-base.

Conclusion

This paper started out with looking at web-models, structuration theory and actor-network theory in order to understand and conceptualise large-scale information infrastructures in a context. Using web-models in an analysis illuminates history, infrastructure and social relations as the context for implementing an information infrastructure. In the case of the checklists, this helped to emphasise the important historical aspects of the checklists. Using structuration theory and especially the concept of the duality of structure is fruitful for looking at a particular design (e.g. standardised checklists and uniform product models) as being always both enabling and disabling. Actor-network theory is particularly useful for mapping the heterogeneous network of artifacts, work-practices and humans, and to illustrate how different interests are described into material. Furthermore, according to actor-network theory the implementation of the non-standardised checklists was easier because it was possible to align them with the existing heterogeneous network of actants. Worth mentioning, however, is that actor-network theory has also been criticised, among other things for paying little attention to social structures, and for the concept of symmetry between humans and non-humans (Walsham, 1997).

An analysis that isolate an information infrastructure from the social and organisational context will not be able to explain why it is so hard to implement technically sound and standardised solutions[6]. Future research and practice on information infrastructures should use insight and vocabulary from the above theories and try to define some frameworks and guidelines for: 1) how to align new designs and re-designs with the installed-base of social structures and information systems; 2) how to implement large-scale information infrastructures in a global organisation as DNV; and 3) to understand why and how certain adjustments are done to cope with the installed-base in relation to the specific technologies used, a specific design, and/or the existing work-practices.

The preliminary case study of DNV has pointed at issues that can answer some aspects of these questions. However, the study was limited in both length and depth and the NAUTICUS systems had not been taken into use at the start of the study. To get more insight of the implementation processes and how the information infrastructure is shaped by use and shapes use, prolonged case studies should be conducted. On the other hand, the case study do indicate that standardised and complex designs (i.e. the product model and the standardised checklists) are adjusted during implementation in order to be aligned

[6] For instance, what is considered as ‘technically sound solutions’ in textbooks on information systems development (e.g. Boman et al., 1997; Booch et al., 1999; Pressman, 1992)

with institutionalised practice of the surveyors and the existing information systems. These 'adjustment strategies' are often not planned actions, but hey are rather 'situated actions' (Suchman, 1987) or 'emergent strategies' (Mintzberg & Waters, 1985), where the resources available and the opportunities of the context as organisational environment, existing information infrastructure and work practice lay the foundations for those adjustments.

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