# Experiences with
# Mobile Application Development
# within MOPAS

**NR** Norsk Regnesentral
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**Sammendrag**/Abstract:

This paper describes a project implementing a pilot application for highly mobile ship surveyors. It demonstrates the usefulness of *seamless integration* and *functional complementation* between various platforms. It is a common problem in today's mobile computing that the content as well as presentation tiers of applications may have to be replicated across platforms. This paper introduces the MOPAS system, in which a *layered architecture* of *dedicated markup-languages* and *translation engines* facilitates seamless integration between HTTP- and WAP-based media. The surveyors, whose work comprised the main source of inspiration for its design, favorably evaluated the system. Future work aims to generalize the MOPAS architecture to cover other media, such as Windows CE over Wireless LAN as well as a wider range of applications for mobile field-workers.

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# 1    Introduction

The possibilities and requirements within the area of personal and business communication are evolving at an unprecedented pace. Some trends which currently propel the industry include an increase in the volume of mobile workers, accompanied by an increase in both the volume and diversity of mobile devices. These devices are being used, in various combinations, to support an incredibly wide variety of use contexts.

This paper addresses issues related to:

1. achieving *seamless access and integration* within mobile applications; and,
2. achieving *functional complementation* within mobile applications

Here, seamless access and integration concerns the availability and usability of services, functions and data for the task-in-hand — within any given use context — at the right time and place, on the end-users' device-of-choice. Additionally, it concerns the smooth integration across functions and services, throughout the entire duration of the use context, regardless of whether or not that use context is contiguous in time or place.

In short, functional complementation points at the need the need for (simultaneous) redundant representation and presentation across some given set of devices, as well as the reduction (or complete elimination of) the need to manually maintain consistencies across multiple media. From a logical perspective, functional complementation concerns the proper partitioning of application functionality; in its most focused form, it addresses such partitioning at the level of individual tasks. In logical terms, a formulation might be: for a given task, functional complementation addresses the proper establishment of possibly-overlapping subsets of task-specific application functionality, where:

* the members of the (sub)sets are individual functions,
* each subset contains one or more of the functions required for achievement of the given task,
* the union of the subsets contains all functions required to carry out the task, and
* the interface associated with each subset is designed (or can be transformed) for effective use upon one or more specific kinds of device(s).

One consequence of this formulation is that for a given device type, interfaces for certain subsets of functionality may be restrictive or even unavailable.

The diverse contexts for mobile work, along with the rich technological variation through which they must often be supported, means that addressing both seamless integration and functional complementation together is an ambitious agenda indeed. Only partial fulfillment may be possible. However, the issue has such deep ramifications for a great number of technology and service providers that it is definitely a worthwhile endeavor. *This paper is offered as a first report on attempting to realize seamless integration and functional complementation across diverse platforms in a mobile environment.*

The **MOPAS** (Mobile Pilot Application Specification) project addresses issues vital to this problem domain. MOPAS' approach includes ethnographic field studies, complemented by application concepts and prototype designs addressing mobile sessions and mobile use contexts. The studies include: determining functionality relevant to the target use context(s); reflection upon user-interface and interaction patterns; analysis of organi-

zational opportunities and hindrances, the characteristics and limitations of various network connections, terminal devices, and more.

In the MOPAS project, work has been done to identify, analyze, prototype and demonstrate the areas in which new integrated functions and services can be used to support ship inspection. The MOPAS work has striven to target and highlight aspects of the ship inspection process which demand functional complementation across devices. At present, the MOPAS prototype has undergone initial evaluation by the ship inspectors which originally volunteered within the project's fieldwork phase; the prototype has received quite positive critique.

The results delivered from the first MOPAS project included:

- a white paper describing the conceptual framework;
- preliminary, functional requirements for a pair of applications which support DnV Inspectors' mobile work contexts:
    - a Checklist application, called *CheckRite*; and
    - a Ship Inspection Support Application, called *SISA*;
- a specification of an architecture for the Checklist application;
- a prototype illustrating support for DnV Inspectors' ship inspection work context; and,
- an initial evaluation of the prototype.

The remainder of this paper is structured as follows: First, we briefly describe the MOPAS project and the conceptual model. Then, the MOPAS architecture and systems are described; it is these sections which help illustrate the manner in which functional complementation was encountered and addressed within the project. Thereafter, a concise recount of the evaluation with potential users is presented, followed by a review of pertinent work within mobile computing. Since this is an early experience paper, we have not attempted to compile an exhaustive survey, instead we try to show that the contributions of this paper show some promising general traits. The paper is concluded with a brief summary.

# 2    MOPAS: Background and Overview

The first MOPAS project was carried out during Q4 1998, as an effort between Norsk Regnesentral (NR) and Telenor Mobil AS [1]. With the imminent wave of WAP-based technology emerging [4], Telenor Mobil initiated the MOPAS project with the intention to explore some of the new possibilities for both general and specialized services and applications, as well as the possibilities for new and general architectural components.

MOPAS' primary project goals were: (1) to further develop and refine a conceptual framework which addresses the requirements and conditions applying to mobile work; and, (2) to design and develop a demonstrator supporting some well-defined work scenario for a selected target user group.

As a target user group for such investigation, the project chose to focus upon a special class of mobile workers: the ship inspectors ('surveyors') for Det Norske Veritas (DnV).

The motivation for choosing surveyors as a target group was that NR has had an ongoing series of projects together with DnV. Among these is the IMiS Veritas project [3], an effort aiming to assess, expand and realize new applications of mobile and networking technologies, especially oriented towards knowledge management, business process modeling and mobile services. MOPAS' intention was to leverage NR's core of past experience, in terms of both domain and customer knowledge.

## 2.1     Case Organization

DnV, established in 1864, is one of the world's leading maritime classification societies, with maritime services including the authorized survey, classification and certification of ships and offshore units [2]. DNV is organized as an independent, autonomous foundation. It has 4,400 employees and 300 offices in 100 countries. Employees come from 67 different nationalities.

The objective of DNV's activities is to safeguard life, property and environment. They provides three types of services:

- *Classification*, which is to develop and maintain rules and standards for safe ships, offshore drilling and production units. DNV also verifies compliance with these rules during design, construction and operation.
- *Certification*. DNV is accredited to certify companies with respect to different standards, for example ISO 9000. The main difference from classification is that the certification is grounded in standards developed by organizations outside DNV, typically government agencies.
- *Advisory services*. DNV provides advisory services regarding technical solutions, training and safety, environment and quality management. It is within this section that we have started doing exploratory design for mobile computing.

DNV guidelines, products and services are offered to customers by geographical divisions. The consultants thus meet customers regularly at their sites, sometimes quite far away from the Home Base Unit (HBU). Mobile work is simply necessary for a global company whose business is mainly location-dependent. After all, ships and oil rigs cannot be inspected from a distance: the surveyors must be on site to carry out the job.

## 2.2     Conceptual Framework

The research effort of discerning a fundamental model for mobile work needs to draw on several sources in order to attain a general nature. Accordingly, we have relied on empirical data from several field studies. The studies have all investigated work practices that people in general would consider "mobile." In previous projects we have studied:

- A dispersed and mobile IT support group at a pharmaceutical company. The group members were each responsible for one or two departments, and they spent most of the day wandering between the offices of the users [12].
- Mobile IT professionals in a central IT department of a distributed organization [9].
- Mobile journalists at a radio station. The journalists report live from different places around the city. They spend most the time away from their home base [10].

- Mobile consultants, auditors and surveyors at a large maritime company. This has been the main source of import to the model. The consultants classify and issue certificates for ships all over the world [13].

Based on a compilation of these studies of mobile personnel, we have arrived at a model of mobile IT-use. The purpose of the model is to provide designers with a framework of concepts to understand and talk about how people use IT in mobile settings. In particular, the model reflects the ways in which using IT in mobile settings *differs* from using IT in stationary settings.

The basic reference model consists of the following categories:

- *Mobile IT-use*, which is the phenomenon that the model represents;
- *environment*, that is, the physical surroundings and organizational constraints of work;
- *modality*, describing the fundamental patterns of motion and
- *intention*, which is the working function, i.e., what the mobile worker wants to achieve.
- Intentions are supported by *technology*, which we conceive as the carrying platform or medium;
- *data* that represents relevant information and
- *application*, which is the systematic support for manipulating the data.

The model includes further details, including the richer articulation of the basic categories into subcategories. Each (sub)category is also qualified according to its *observable dimensions* and, in some cases, these dimensions are quantified into discrete "regions".

The new fieldwork and analysis carried out within the MOPAS project has served to refine, further articulate and generally strengthen the model. In return, the model has helped to focus attention upon issues critical to the identification of areas in which functional complementation is (1) required by the worker and (2) can be supported by technology. These areas will be further described in the following sections.

# 3     Application Concepts

After a few visits on site with DnV surveyors, we had generated a handful of potential application candidates for further investigation. It was decided that one of these — the Checklist application concept — be further refined and prototyped. Some of the decisive motivation for this decision was the judgement that a properly designed Checklist application could potentially be used in a very wide range of application areas, including both the professional and non-professional.

Given this decision, the functional requirements for the Checklist application, called *CheckRite*, have been described in the most generic manner possible, purposefully avoiding any implicit references to ship inspection (the application area from which it was originally derived). To couple the use of CheckRite to the ship inspection process, a second

application was proposed, called SISA (Ship Inspection Support Application). These applications are described in the next two sections below.

## 3.1     CheckRite

The following description of CheckRite and its functional characteristics is a very generic one, in order not to limit creativity with respect to its potential areas of application. Briefly, the purpose of the CheckRite application is to support individuals (Checklist Users) who employ Checklists in order to carry out certain of their activities, whether those activities be work-related or not. A Checklist is a (possibly-ordered) list of items, where each item on the list represents a specific point (e.g., "something to be checked").

In their most simple form, Checklists are used by individuals in order to keep track of which items are to be checked, which of these items have been checked, and/or which have yet to be checked. Checklists could also be used: (1) to keep track of the ongoing status of each item on the Checklist, in cases where items can be partially checked (e.g., in progress); (2) to keep track of which items some set of persons are to check, and which person is responsible for each item; (3) as (supplementary) documentation that a certain job has been performed; (4) as part of a (possibly-automated) work / workflow process within some form of organization; etc. These latter kinds of functionality were judged to be outside the scope of CheckRite, however. In short, the functionality of CheckRite — as defined within MOPAS — was defined to allow Checklist Users to:

- generate instances of Checklists from pre-defined Checklist Templates,
- retrieve instances of Checklists from a (possibly pre-created) Checklist Collection,
- view Checklists according to different (preferred) criteria,
- update and modify Checklists
- print Checklists and
- store updated Checklists on the system.

In the preliminary version of CheckRite's functional specification, all of the functions above are subordinate to a use case called "Use Checklist", shown in figure 1a. The figure also illustrates other actors which have been identified with respect to CheckRite. A second, major use case within CheckRite (not illustrated) is that of Tailoring Checklists. Tailoring can be performed by both Checklist Tailors and Checklist Users. Checklist Tailors can modify Checklist Templates prior to their instantiation; such modification could be the addition, deletion or editing of points on the Checklist Template. In contrast, Checklist Users are limited to the modification of *instances* of Checklists. Such tailoring will be illustrated in section 4 which describes the prototype.
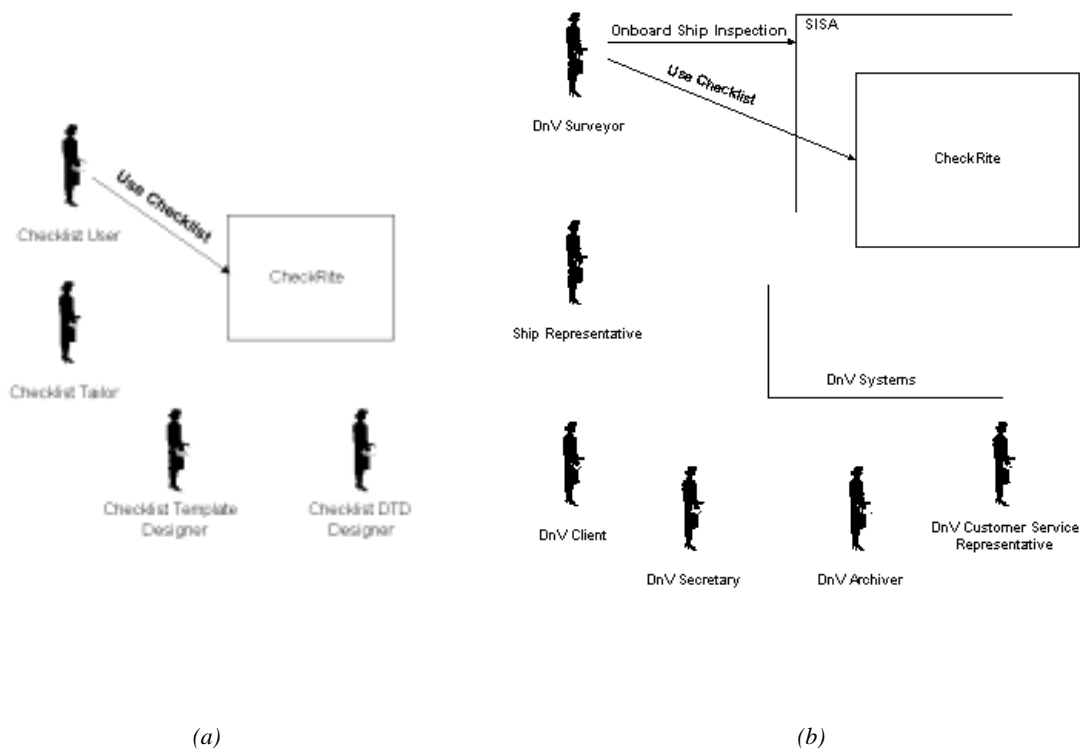
        *(a)*                                  *(b)*

***Figure 1 :***    *CheckRite (a) and SISA (b): actors and use cases in focus*

## 3.2    SISA

As mentioned above, SISA (Ship Inspection Support Application) was conceived as a second application, in order to directly couple the use of CheckRite to the ship inspection process. It must be understood that the description of the functional requirements for SISA is presently considered to be very preliminary and incomplete. Briefly, an attempt was originally made to generalize use cases, actors, functionality, etc. to general contexts involving "Inspection". Yet despite the sound empirical basis of study which existed, the MOPAS studies were in fact limited to *ship inspection by DnV Surveyors*; trying to make unfounded generalizations was considered to be too speculative. For this reason, the functional requirements drafted for SISA are provided solely in terms of use cases which have been concretely observed.

The primary goal of SISA is to provide DnV Surveyors with better electronic integration and documentation facilities, while carrying out the job of *Onboard Ship Inspection*. Secondarily, SISA should also be integrated with other systems so as to better support the Surveyor's wider needs when carrying out other phases of a Ship Inspection Assignment.

Figure 1b depicts the actors and use cases focused upon herein; the coupling between SISA and CheckRite arises when the DnV Surveyor acts as a Checklist User. The figure also illustrates that no explicit inclusion relationships have been defined with respect to Check-Rite, SISA and DnV Systems. In other words, there are currently no assumptions concern-

ing the manner in which these applications and systems interoperate, nor whether one system is embedded within or encapsulated by another, etc.
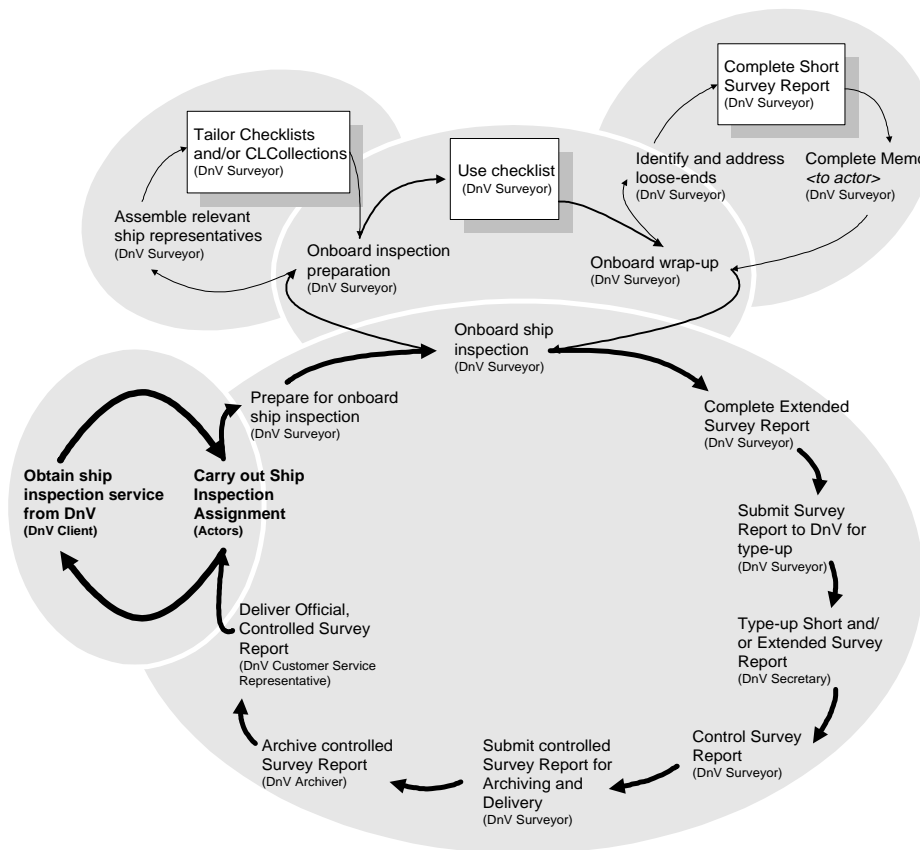


*Figure 2 :  Overview of use cases for SISA*

Figure 2 illustrates the overall structure of the use cases captured for SISA, as well as a sequential flow from one use case to the next. Here, it is important to remember that although the illustration above is based upon an understanding gathered through observations and study, it in no way provides a complete picture of the potential *variety* and *multiplicity* of scenarios within this overall use context. Instead, it represents a relatively accurate picture of how the business and processes flow in some number of scenarios. One can expect that there exist a very large number of variations of this overall flow, depending upon the concrete user, concrete case, unexpected situations and exceptions which naturally and unavoidably arise.

The figure depicts four *levels* of use cases (represented here by a stack of shaded ellipses), where each deeper level is accompanied by a new level of detail. In other words, the level 1 use case *Carry Out a Ship Inspection Assignment* expands into level 2; *Onboard Ship Inspection* expands into level 3; and *Onboard Inspection Preparation* and *Onboard Wrap-up* each expand into their respective level 4 details.

SISA's primary goal is to support *Onboard Ship Inspection*, a use case which is one part of a more encompassing work context (*Carry Out a Ship Inspection Assignment*). Briefly, a Ship Inspection Assignment (invented term) may be started when a DnV Client contacts DnV and requests some ship inspection service. Alternatively, a Ship Inspection Assign-

ment could be booked in advance between a DnV Client and a DnV Surveyor. It concludes when DnV delivers an Official, Controlled Survey Report to the DnV Client. A Survey Report is a report completed by DnV Surveyors following the inspection of a ship or one (or more) of the ship's subsites/units. The steps for creating an Official, Controlled Survey Report are shown in figure 2.

The shaded boxes in the figure are the use cases called *Use Checklist*, *Tailor Checklists and/or CLCollections*, and *Complete Short Survey Report*. The first two are use cases from CheckRite, while the third is unique to SISA. Section 4 will demonstrate how the prototype addresses functional complementation within *Onboard Ship Inspection*, by specifically illustrating the functionality and interfaces devised supporting *Use Checklist*, *Tailor Checklists and/or CLCollections*, and *Complete Short Survey Report*.

# 4 The MOPAS Prototype

This section intends to briefly describe how the design of the MOPAS prototype served to demonstrate support for the task of *Onboard Ship Inspection*. First, a description is provided which briefly presents how the job is done today. In section 4.2, screen-shots from the prototype are presented and explanation is provided as to how it could support the task-at-hand. Finally, this section closes with a brief overview of the Checklist application architecture which underlies the prototype concept.

## 4.1 Onboard Ship Inspection

The following description is based upon empirical field notes recorded by Lunde [5], as well as more in-depth project discussions and reviews.

Prior to the actual ship inspection itself, the surveyor prepares a collection of electronic and paper documents he will need once on-site; this activity transpires within *Prepare for Onboard Ship Inspection*, see figure 2. One document amongst this collection is a list describing which parts of the boat are to be inspected; it is based upon records from earlier inspections, etc.

Once on the boat, the surveyor greets representatives from the boat (e.g., the Machine Chief, the First Machinist, a technical inspector from the shipping company which owns the boat, etc.); they often gather in a convenient room which is clean, relatively quiet and offers enough room for the paperwork. (In one case observed, this room was the ship's lunch canteen.) Together, these persons supply information and documentation which may lead the surveyor to update his "inspection checklist"; he may add and/or delete items to be inspected (this corresponds to use case *Tailor Checklists and/or CL Collections*). Once the items/parts to be checked are finalized and agreed upon, the inspection tour begins.

While moving from place to place on the boat, the surveyor carries with himself the updated checklist (a paper document) and a pen, in order to mark off the items as he inspects them. Depending upon where in the boat the parts are, the surveyor may wear cover-alls,

gloves and heavy boots to protect his clothing from grease and grime; sometimes even ear protection is required, for example, in the motor room.

The inspector often puts down or tucks away his paper checklist while inspecting individual parts. When he has completed the inspection of a part (or set of parts in the same proximity), he uses his checklist to mark off which items have been checked, as well as to review which other items need to be inspected. When marking, he sometimes makes small, shorthand notes next to certain items, in order to remind him that he needs to make extended comments about those items when writing the (short) Survey Report. These activities correspond to the use case called *Use Checklist* in figure 2.

Once the parts to be inspected have been checked, the surveyor (and others helping on the inspection tour) return to a convenient room (e.g., the lunch canteen), in order to discuss any loose-ends and/or issues which couldn't be properly discussed or followed up during the tour (e.g., due to noise, lack of adequate lighting, etc.). When these issues have been adequately covered, the surveyor begins the preparation of a short Survey Report. The purpose of this document is for the ship owners to prove that the required inspections have been carried out.

When preparing the short Survey Report (i.e., use case *Complete Short Survey Report* in figure 2), the surveyor first copies the points from the checklist over to a Survey Report form, one line in the report for each item checked. In certain fields, he uses standardized codes and/or abbreviations; another field is used for more extended comments upon specific items. These comments may include Memos for Surveyors (MS) and/or Memos for Owners (MO).

Once the Survey Report is drafted and signed, the original is given to the ship for archiving, and a copy is sent to the home office for type-up, control, formal finalization and internal archiving (i.e., use cases *Submit Survey Report for type-up* and its successors, as depicted in figure 2). The original draft of the Survey Report — archived on the ship — acts as an onboard surrogate for the finalized Survey Report later delivered to the ship owners (use case *Deliver Official, Controlled Survey Report*).

## 4.2    WWW- / WAP-based Support

This section depicts how the MOPAS prototype served to demonstrate support for the task of *Onboard Ship Inspection*. The application prototype was designed so as to be executed upon a combination of WWW- and WAP-based devices. In the spirit of functional complementation — and following the principles of the conceptual model for *mobile IT-use* — the functions in the MOPAS prototype were designed to be available on specific devices. The partitioning of application functionality in the prototype was based upon our derived understanding of the surveyor's environment, modality, intentions, and data. WWW and WAP were employed as the technologies for the application.

**12909 LYSHOLMEN (OSLO, Lys Line AS): ME (Main Diesel Engine)**

Comment: Annual inspection

**Choose items to inspect**

| | ID/POS | Description | Last checked |
|---|---|---|---|
| ☐ | ENT | IN ITS ENTIRETY | |
| ☐ | COV 1 | Cylinder cover with valves etc. | 97.12 |
| ☐ | COV 2 | Cylinder cover with valves etc. | 96.08 |
| ☐ | COV 3 | Cylinder cover with valves etc. | 97.10 |
| ☐ | COV 4 | Cylinder cover with valves etc. | 97.10 |
| ☑ | COV 5 | Cylinder cover with valves etc. | 98.11 |
| ☑ | COV 6 | Cylinder cover with valves etc. | 98.11 |
| ☐ | CYL 1 | Cylinder liner | 97.12 |
| ☐ | CYL 2 | Cylinder liner | 96.08 |
| ☐ | CYL 3 | Cylinder liner | 97.10 |
| ☐ | CYL 4 | Cylinder liner | 97.10 |
| ☑ | CYL 5 | Cylinder liner | 98.11 |
| ☑ | CYL 6 | Cylinder liner | 98.11 |
| ☐ | PIS 1 | Piston & rod | 97.12 |
| ☐ | PIS 2 | Piston & rod | 96.08 |
| ☐ | PIS 3 | Piston & rod | 97.10 |
| ☐ | PIS 4 | Piston & rod | 97.10 |
| ☑ | PIS 5 | Piston & rod | 98.11 |
| ☑ | PIS 6 | Piston & rod | 98.11 |

***Figure 3 :*** *WWW-based Checklist tailoring*

Figure 3 illustrates use of the interface designed for Checklist tailoring. Here, an extensive list of items-to-be-inspected is illustrated; it is conceived that this kind of list can be automatically generated during the *Prepare for Onboard Ship Inspection* use case, based upon in-house records. As described in section 4.1, however, even an automatically generated list requires tailoring once the surveyor reaches the site: there is almost always certain information about the ship which only becomes made known to the surveyor when he arrives.

The figure depicts how the surveyor can tailor the (pre-prepared) list by clicking upon the check boxes next to the items. When the surveyor completes this step, the list contains exactly those items/parts to be inspected during that visit; this list is stored on a server accessed by the browser. Here, the surveyor has selected cylinder covers, cylinder liners and piston and rods, designated by COV5, COV6, CYL5, CYL6, PIS5, PIS6.

The surveyor was observed to carry out the Checklist tailoring task while in a relatively stationary position on the ship; it is conceivable that he might also carry out parts of this operation during the *Prepare for Onboard Ship Inspection* use case. The detail required within the interface for Checklist tailoring is rather great. Thus, this interface was designed for use through a WWW browser. With this technology, the surveyor could efficiently utilize the application's checklist tailoring functionality upon a desktop, laptop or even a PDA; these kinds of devices offer a proper match with the surveyor's *modality* within this task-step. Trying to make this piece of application functionality available upon a WAP-

based phone would unavoidably yield a clumsy and unusable interface: the screen space required for this function is simply beyond that available on a WAP-based phone.
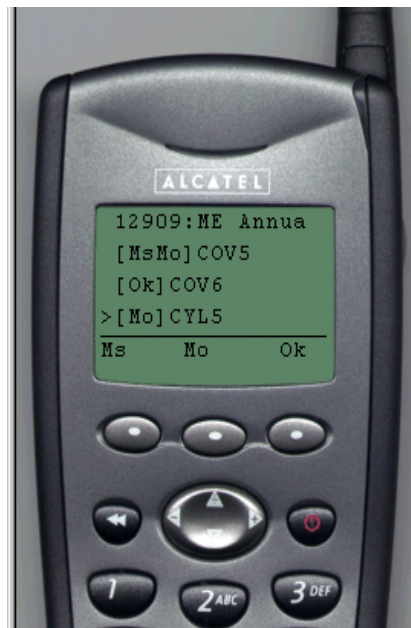


*Figure 4 :* *WAP-based Checklist use*

Figure 4 illustrates the interface designed for *Use Checklist*. The figure illustrates the exact list of items to be inspected during the visit, in highly condensed form (e.g., COV5, COV6, CYL5, etc.); it has been retrieved from the server by the application browser. Within the browser, the list can be scrolled up and down, and the individual items marked using the "soft keys" (these are the three programmable keys located in a horizontal row immediately below the screen).

The figure depicts how the surveyor can mark each of the items using the soft keys; the marks can either be "MS" (Memo to Surveyors), "MO" (Memo to Owners), or "OK". The primary role of the markings was to offer the surveyor a near-equivalent to the manner in which he presently works: that is, to make a mark which indicates whether a part is "OK", or whether it requires more extended comments when writing the Survey Report. At any time, marks made in the browser could be saved on the server.

Since it was possible, the prototype also offered the possibility of typing in textual comments using the phone's "alphanumeric" keyboard; as expected, this manner of typing in notes was found to be very cumbersome (see section 5.2).

The surveyor was observed to carried out the *Use Checklist* task while in a highly mobile mode. The inspection of parts often transpired in tight quarters and — as often as not — in environments which were wet, greasy, noisy and/or poorly lit. In addition, the surveyor often required both hands free while carrying out the inspection work. Quite simply, there was simply no space for a device more cumbersome than a clipboard / folder.

For this environment and modality, the interface for the *Use Checklist* functionality was designed for use through a WAP browser on a WAP-enabled phone. Only little detail is required within the output interface for this task-step and, in most cases, the user input could be limited to a set of four buttons (soft keys plus scrolling button).

Det Norske Veritas
SURVEY REPORT
MOTOR / TURBINE MACHINERY

REP. No.:  Page 1
DNV Id. No.:

Name of ship: LYSHOLMEN    Owner: Lys Line AS

| Main system | | Item | | C E | Repairs reported separately (Form 40.9a) ○ Yes ● No |
| Code | Position | Code | Position | *) | Description of code |
|------|----------|------|----------|-----|---------------------|
| ME | | COV | 5 | | Main Diesel Engine, Cylinder cover with valves etc. |
| ME | | COV | 6 | | Main Diesel Engine, Cylinder cover with valves etc. |
| ME | | CYL | 5 | | Main Diesel Engine, Cylinder liner |
| ME | | CYL | 6 | | Main Diesel Engine, Cylinder liner |
| ME | | PIS | 5 | | Main Diesel Engine, Piston & rod |
| ME | | PIS | 6 | | Main Diesel Engine, Piston & rod |

Repairs/Remarks:

COV5  Ms
COV5  Mo
COV6  Ok
CYL5  Mo

Position of all items/parts to be copied from Inventory List.
Survey date to be endorsed on vessel's Inventory List.
Is this the last page of the report? ● Yes ○ No

CMS ☐  PMS ☐  Comm. Mach. Renewal ☐
(If applicable, copy to be inserted in vessel's ring binder.)

*) Name of Chief Engineer:    Date of Approval Letter:

| Station: | Place: | Survey started: 98.11 | Survey completed: 98.11 |
| | | | For DTP use only |

Surveyor's name (Capital letters)    Surveyor's signature

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Form No.: CME.001 MOPAS PROTOTYPE 1 (Based on April 1998 issue)

*Figure 5 :   WWW-based completion of short Survey Report*

Figure 5 illustrates use of the interface designed for *Complete Short Survey Report*. Here, a Survey Report form appears with a number of fields pre-completed. Quite simply, the marks made during the *Use Checklist* task have been retrieved from the server and inserted appropriately into the form. In the "Repairs / Remarks" field, the surveyor finds his annotations as to which items require extended comments: COV5 (MS, MO) and CYL5 (MO). Comments could be directly typed in within this field.

The surveyor was observed to carry out the *Complete Short Survey Report* task while in a stationary position on the ship; in fact, it was the same location in which he carried out the Checklist tailoring task. Like that task, the detail required within the interface for the *Complete Short Survey Report* task is rather great. Thus, this interface was designed for use through a WWW browser. As before, with this technology the surveyor could efficiently utilize this subset of the application's functionality upon a desktop, laptop or even a PDA. Again, a proper match was made between the surveyor's modality, environment and task-step.

# 4.3    Checklist Application Architecture

The MOPAS checklist application architecture [6] consists of three different data format stages and two processing stages. The first data format stage is an XML DTD called the Checklist Markup Language (CLML). Its purpose is to store checklists in their original, inert form. The second data format stage is another XML DTD called the Checklist Presentation Markup Language (CPML). Its purpose is to represent networks of menus generated from checklists. Such menu networks support navigation through checklists and alteration of checklist variables. The third data format stage consists of a number of device specific languages, such as HDML or WML for handheld devices, and HTML for PC based WWW browsers. The purpose of a device-specific language is to present checklists to users on a particular kind of device.

The two processing stages are the checklist engine and the stylesheet transformations. The checklist engine transforms a CLML specification into a menu network written in CPML. Stylesheet transformations are applied to this specification in order to produce checklist documents in device specific languages. The checklist engine also contains functions that let it receive and store data from user devices, as well as functions for sorting and extraction.
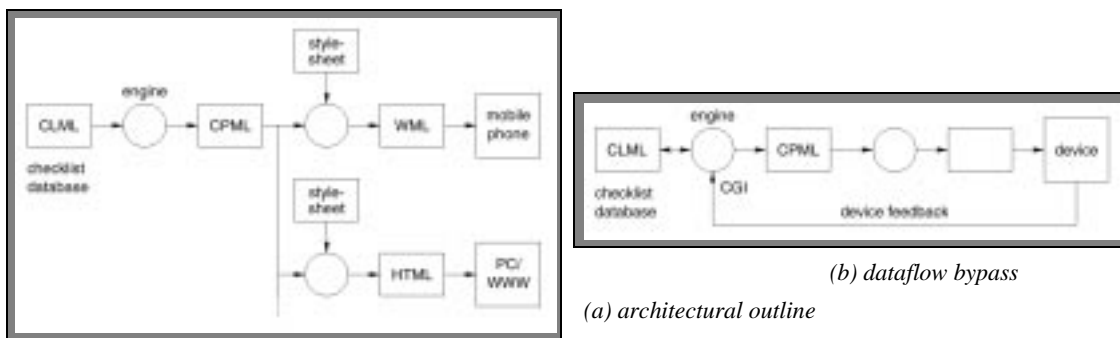


*(a) architectural outline*

*(b) dataflow bypass*

*Figure 6 :    Checklist Application architecture*

Figure 6a shows the outline of the checklist application architecture. Checklists are stored in the Checklist Markup Language (CLML) in a checklist database. The checklist engine reads the checklist and creates a menu network in the Checklist Presentation Markup Language (CPML). Transformations on the CPML specification can be done with stylesheets written in DSSSL or XSL. Different stylesheets can be used to effect different transformations in order to support devices with different characteristics. The engine has a function to receive data from the user device through a common gateway interface (CGI), as well as functions to perform tasks like storing a checklist in the checklist database, and sorting and extracting data in order to have it presented in another form. As shown in figure 6b, this data flow bypasses the transformation steps via CPML and the device specific languages.

# 5    Evaluation

The WAP- / WWW-based prototype described in this paper was demonstrated to selected users at Det Norske Veritas. The applications were populated with data similar to the ones used by DNV surveyors. The demonstration showed several research aspects pertaining to the project: Validity of fieldwork observations, the application design and the technical fit between WAP-telephones and stationary workstations. The purpose of this preliminary evaluation was to establish if the proposed system could serve as a basis for further development of mobile services for DNV surveyors.

The assessment was conducted as follows, with two DNV surveyors:

- System walkthrough
- User testing
- Interviews, questions and comments

The nature of the assessment did not make it possible to draw any final conclusions, due to the informal and brief nature of the demonstration. It can, however, be interpreted as an early possibility for the users to contribute the redesign of our research agenda.

## 5.1    User Sentiments

Both surveyors thought it was a good idea to support checklist generation and deployment in the fashion demonstrated by our prototype. For the surveyors, it is important to be able to give a report to the customer soon after the survey. It gives a professional image and makes the customer happy. The biggest disadvantage is that the time for personal reflection is reduced and the reports may carry fewer nuances. Moreover, they were weary of the verification step of report writing. In the manual system used today a supervisor checks the report. The system should also be able to support quality assurance work pertaining to the reports themselves. The surveyors were interested in the possibilities of including automatic error checking in the system, for instance for mandatory entries.

Both surveyors were positive about the integration between telephony and workstation systems. They considered it useful to be able to bring a small terminal along around the vessel, and use this to check off simple items. More elaborate comments on the other hand were better supported by the PC-based system. They were both interested in extensions to the system to cover certificates and other inspection routines.

The surveyors made several suggestions about how the systems could be improved. They agreed on functions that should be assigned to each of the buttons on the WAP-telephone.

## 5.2    Hardware Challenges

During the evaluation, several hardware configurations were demonstrated. Generally, the surveyors think that laptops are too heavy to lug around while doing the inspection onboard a vessel. They tend to leave it in the captain's cabin, and use the fax or printer there for manual duplication of the documentation. They would have liked to have something

lighter, but thought that the PDAs that we brought had too small keyboards. They thought that perhaps something in the mid-range could have been more appropriate.

They were generally skeptical to the durability of mobile telephones; how much humidity, grease or physical abuse can it handle. They also thought that text input on mobile telephones was much too cumbersome.

The importance of close integration with vertical information systems containing information about the ship's classification and models was emphasized.

# 6      Related Work

We share the views of Abowd et. al. [7] when they maintain that although effective use of mobile technology will give rise to an interaction paradigm shift, it is difficult to predict what that shift will be. The model and architecture presented in this section aspires to aid this process. Relatively few researchers are involved in establishing a set of maximally beneficial mobile *applications* [7]. Our model contributes to this enterprise, as we show below by applying the model to existing research in mobile computing.

Mobility is essential also in work that is not designated as *mobile work*. It supports interaction and offers awareness, and is essential in the use of shared resources [8]. Bellotti and Bly [8] report on a field study of distributed work at a design consulting firm, in which they found much more mobility than anticipated, in particular what we previously called *walking* [13]. Their paper points to shortcomings in parts of CSCW research that exclusively concern itself with desktop support (i.e., *stationary* modality). They found an interesting relationship between *modalities* and *applications* in this example of *mobile IT-use*: While local mobility is important to local collaboration, it often severely penalizes long distance communication.

Abowd et al. [7] describe a set of prototypes of a mobile, context-aware tour-guide for their lab. It is particularly concerned with maintaining and exploiting data from the *environment*, namely location and orientation. The model could frame this application idea in the following manner:

- *Mobile IT-use*: The application supports visitors to the lab, presenting them with necessary information to navigate about the building, understand the projects and enjoy the visit.
- *Environment*: IT research labs usually do not adhere to a significant layout, i.e., it is impossible to say what people do only by glancing. Although visitors are frequently from abroad, such labs are usually not sign-posted in many (if any) languages.
- *Modality*: Typically, tourists walk. They are usually content to carry a book or handheld device, but not larger items which restrict the freedom of mobility. Tourists do no stay for long; however, they are likely (in this case especially) to stop and talk with "the natives."
- *Technology* is, as in the many of our field studies, comprised of manual documents, laptop computers and the existing infrastructure such as telephony or transportation.

- *Data* for tourist guides may include coordinates of position and orientation, "invisible structures" such as organizational charts or project information, notes, and real-time voice.
- *Programs* support the intention of visiting. Abowd et al. [7] suggest many interesting solutions for the mobile tour-guide: personalized tours, language translation, note-taking, synchronous communication and group interaction. Some concrete services suggested were Cartographer, Librarian, Navigator, and Messenger.

Many more applications are well covered by the model, even if mobile IT-use is not on their agenda. Hagimont and Ismail [11] describe a protection scheme for mobile agents, in which access to objects is controlled by means of mutually suspicious agents. It is concerned with the use of mobile code to support *stationary work*. It is still possible to apply the model to the use of the protection scheme, for instance in the shared calendar example of the authors.

The phenomenon examined in this example is *mobile calendar use*. The *application* may be described as effortless organization of meetings. An agent manages calendars, and creates *proposal objects*, i.e., *data*. *Technology* is manifested as networks, which may or may not be connected. Agents exchange tokens, as access-right signifiers. These tokens may be part of the organizational *environment*, inasmuch as they can limit initiators' capability of manipulating the calendar of their boss; alternatively, these tokens may be physical, if no server exists to negotiate capability requests. In a truly mobile use situation, the meaning of environment is even richer, insofar as it may constrain the possibilities of operating the technology in the first place.

Pratel and Crowcroft [14] present an almost identical approach. They describe a ticket-based service access for the mobile user. In this case, *mobile IT-use* is targeted with tickets instead of capabilities. It falls nicely within the model, and brings especially to the fore the relationship between available *applications* (for which tickets are "purchased"), mediating *technology* and the use context of *environment* and *modalities*, which direct the users' *intentions* and continually introduce constraints such as, for instance, which service provider is available.

For further work, we will continue to combine empirical studies with the conceptual framework of the model to produce *innovative*, *mobile-aware* applications. By technical experimentation and empirical evaluation, such applications can inform re-design and improvement of the model, and, thus, contribute to improving the research agenda.

# 7    Summary

Generally, the users thought that the core ideas of MOPAS seemed useful, and would have liked to have seen them demonstrated on other checklists that they constantly use. The way the workload was balanced between the PC and telephone was also appreciated. They were, however, concerned about the possibilities of inspection reports becoming less subtle and harder to change. Some of the hardware considerations put forward may be accommodated with the existing design, others require more experimental technology. For instance, they foresaw a need for prolonged disconnected operation, which means that the

checklists have to be downloaded in advance. This is not easily implemented with the stateless, pull-oriented technology of WAP today.

The MOPAS project addresses issues vital to the problem domain of mobile IT-use. In MOPAS, work has been done to identify, analyze, prototype and demonstrate the areas in which new integrated functions and services can be used to support ship inspection. The MOPAS work has striven to target and highlight aspects of the ship inspection process, which demand functional seamlessness and complementation across devices. At present, the MOPAS prototype has undergone initial evaluation by the ship inspectors who originally volunteered within the project's fieldwork phase; the prototype has received quite positive critique. This paper provided an overview of the MOPAS work, with a special focus upon how it has addressed the requirements for seamless access to checklist information, within a ship inspection process.

# Acknowledgments

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