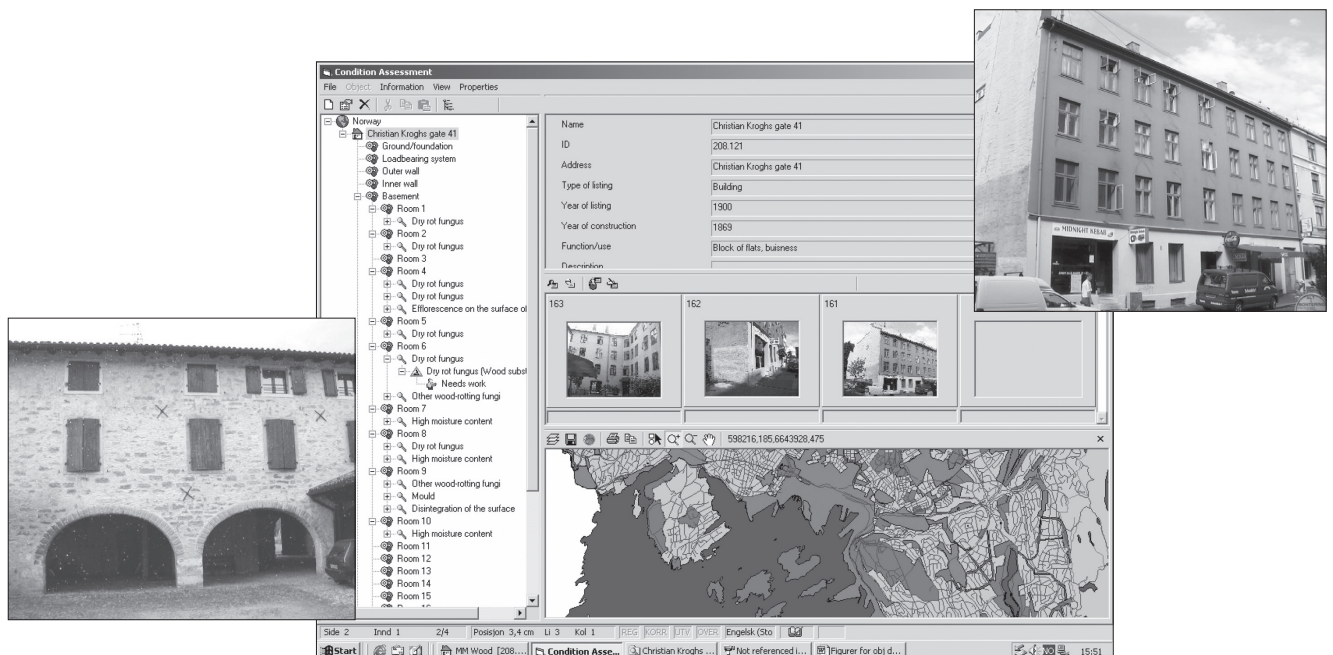


Svein Haagenrud and Guri Krigsvoll

MMWood – System for Maintenance Management of Historic (Wooden) Buildings



Project report 367
Svein Haagenrud and Guri Krigsvoll
**MMWood – System for Maintenance Management
of Historic (Wooden) Buildings**

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Part I MMWood Deliverable

Preface

This report constitute NBI's final report from the EU-project "ENV4-CT98-0796 - System for Maintenance Management of Historic (Wooden) Buildings". Svein E. Haagenrud, NBI acted as Project Co-ordinator for the project that had 11 partners from Norway, Germany, Sweden and Italy. The report is almost identical to the final report to the European Commission, which had Petter Stordahl-NORGIT/Norway, Bengt Eriksson-University of Gävle, Sweden, Eva Riks-Zentrum für Handwerk u. Denkmalpflege, Germany, and Ilaria Garofolo-University in Trento, Italy, as co-authors.

Svein Haagenrud
Project leader

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Part II Summary and Conclusions

The built cultural heritage (BCH) is widely recognised as the most potent symbol of Europe's historic common culture and of its national and regional variations. A broad spectre of European policy statements identifies BCH as a European issue and an important element in ensuring a common identity and in pursuing sustainable development. These policies and the main conservation charters all emphasise the need to protect and enhance BCH, and that significance can only be sustained if the physical assets are maintained in an appropriate and systematic manner.

Methods and tools for obtaining a systematic maintenance strategy on the European level are thus major objectives and focus of the EU Action Plans and FW programs in the Cultural heritage field. Today, most national and regional authorities are lacking a uniform methodology, the needed information and such systems for maintenance organisation and management.

The MMWood project addresses these needs. It builds on its predecessor, the ENV4-CT95-0110 Wood-Assess project, and has completed all its tasks and achieved all its objectives. The MMS application (β -version) is a generic software tool to aid the documentation, inspection and maintenance management of cultural buildings. The technology is open and object oriented and can be extended to any kind of objects.

MMS enables the documentation of the building and collection of information regarding its state and condition. It enables the user to integrate and link documents, drawings, and pictures to the building or to any specific part/location/observation of the building, and to link the buildings to maps in a Geographical Information System (GIS).

The MMS contains several objects, and each object has some related properties. Objects and properties can be defined by the user and put into libraries, and relations between them established. Objects defined here are for example Area/Region, Building Types, Building Part, Inspection Types, Observation and Damage. National standards, guidelines, owners internal systems can be used in establishing the libraries, and it can be established in any language (multilingual). The choice of objects and their properties to be assessed can be decided for each installation via the Configuration Menu. The Configuration part makes the MMS very flexible, which is shown by the detailed documentation and assessments performed and reported for the chosen objects in Germany, Sweden, Italy, and Norway. The flexibility puts requirements onto its management and operation, which is best achieved via task definitions for System Manager and User Manager.

Validation of the prototype of MMS by end users within and outside the project according to an accepted procedure, showed a positive appraisal of the system in terms of total concept, results, and user acceptance. Some problems were encountered on the physical functioning of the system, due to the prototype version and little experience and training.

MMS has a kernel of four main Sub-Modules: the Condition Assessment -, the Decision -, the Environmental Risk Factor - and the Maintenance Management Module, including also an Inspection Module developed for structuring and performing the inspection work in a systematic and objective way. The Decision Module takes the information from the Condition Assessment Module and the Damage Atlas into consideration when calculating/assessing the seriousness of the damage, and uses the Environmental Exposure module to describe/assess the environmental degradation/risk factors of the site. The Decision Module produces the life expectancy of the objects evaluated. The system structures and reworks information from condition checking and gives specialist a good basis for taking correct decisions. MMS covers the entire work process from documentation gathering, reading in inspection data and photos, analysing and reworking of data, print out of work-card to following up of maintenance work with reports and statistics.

The Condition Assessment Module comprises a Condition Assessment Protocol with Damage Atlas, allowing for assessment of damage types and –degrees, causes, effects, consequences, risks, and remedial action for (wooden) buildings. The Damage Atlas contains at present about ten worked examples of various damages for each of the materials/building elements of Wood constructive, Wood substrate and Wood protected, Adjoining materials in wood constructions, Rendering, Brick and mortar, and Natural stone. The Damage Atlas can be extended with other types of damages on materials and building components.

The Maintenance Module is rather general as the project criteria just allow for a couple of objects from each of the countries. A Maintenance Plan also has to involve risk assessments and choice of appropriate conservation strategies, and in order to elaborate that the MMS has to be further loaded with data for specific stock of cultural buildings.

In the Wood-Assess project the methodology for assessing and mapping environmental risk factors and areas for wood on regional, local, and micro scale in Europe was developed. The methodology is developed further adding more materials used in connection with wooden houses, like stone, bricks, rendering, painted rendering, and painted wood, and also making available a module for performing cost-benefit analysis (CorrCost). The Environmental Risk Factor Module (ERFM) is technologically not yet fully integrated.

The ERFM may be an important aid in providing necessary data for predicting service life and maintenance intervals for buildings or building elements. The necessary meteorological and pollution exposure data for exploiting the service life functions are collected for the demonstrator regions. The data are either point measurements from measurement stations, or exhibited as simulation models in GIS. By use of the environmental data and service life functions the expected service life are calculated/ modelled for each object/region and material. European standards are used to account for the impact of topography, terrain roughness, sheltering and building envelope form on the local and micro-environmental exposure of the building.

A reference situation, defined by cold climate and unpolluted air (Lom, Norway) is defined, and the reference service lives are given. From this the percentage reduction in service life is found for each object/region and material. Calculated service life and reference levels for each

material are given as reports from the MMS. Service life is presented both as single values and for one of the regions as GIS based models on different geographical scales (Oslo).

Durability is one of the requirements of the European Construction Products Directive (CPD), and as MMS builds heavily on the internationally recognized methodology and standard for prediction of durability, service life and maintenance intervals (ISO 15686-Service life planning, 2000), its potential application can be extended to cover the whole built environment.

An extensive Thesaurus in English, German, Norwegian, Swedish, Italian and partly Latin has been developed, comprising also pictures linked to many of the terms.

A Technology Implementation Plan including a Collaboration Agreement is delivered concluding with a consensus on the intention and a draft strategy for developing the MM Consortium into a body for future commercial exploitation of MMS.

Part III Full deliverable content description

1 Introduction

1.1 Background

1.1.1 Built Cultural Heritage

The built cultural heritage (BCH) is widely recognised as the most potent symbol of Europe's historic common culture and of its national and regional variations. Conserved and managed properly, it represents a powerful mechanism for emphasizing a common European cultural identity (Bizzarro et al, 1997). The pressures of globalisation and its promotion of global 'branded' cultures make the successful integration of the European culture into the general development of sustainable urban environments even more important. Both the European Sustainable Cities Report (1996) and the EU Commission Green Paper on Urban Environment (1996) identify BCH as a European issue and an important element in sustainable development. They emphasise the need to protect and enhance BCH.

Recognition of the importance of BCH is clearly signalled in the general principles established in the Venice and Burra Charters. The latter reinforces the message that 'cultural significance' is embodied in the 'fabric, setting and contents' of historic buildings and areas.

All charters stress that significance can only be sustained if the physical assets are maintained in an appropriate and systematic manner. The charters define maintenance as the intervention, which by its very nature has the potential to do the least possible damage to cultural significance. The charters and management guidelines developed for World Heritage Sites all recognise that maintenance is the optimum strategy for conservation, and that it should be systematically organised.

Today, most national and regional authorities are lacking resources, a uniform methodology, the needed information and such systems for maintenance management. The results are a reactive instead of a proactive approach, where the need of maintenance and repair is mostly realised at a very advanced stage of deterioration, requiring huge investments in repair and conservation measures.

The problematic therefore requires large scale pooling of resources and has to be dealt with on a European level. (Sustainable Urban Development in the EU: A Framework for Action Com (1998) and ESDP European Spatial Development Perspective (10 May 1999)). Methods and tools for obtaining a systematic maintenance strategy on the European level are thus major objectives and focus of the EU Action Plans (Council Dec o.J 94/C 235/01) and FW programs in the Cultural heritage field.

Specifically, as defined in the 5thFW, Key Action 4, item 4.1 and 4.2, some of the major barriers on the European level in the field of conservation and enhancement of the Cultural heritage are lack of common:

- methodologies for documentation and condition assessment of objects, as well as damage categorisation and assessment,
- methodologies for assessing and mapping Environmental Risk Factors, in order to be able to do risk assessment and also cost benefit analysis based on various Air Quality scenarios,
- multilingual nomenclature on documentation and condition assessment, i.e a Thesaurus.

These are issues addressed both in the previously performed *project: ENV4-CT95-0110 “Systems and Methods for Assessing Conservation State and Environmental Risks for Outer Wooden Parts of Cultural Buildings” (Wood-Assess)*, and in the successor project MMWood.

1.1.2 Wooden built cultural heritage

Europe has a rich culture in wooden buildings. These buildings are rapidly degrading due to environmental impact, wrong conservation techniques, and lack of resources and technological tools for appropriate conservation and maintenance. This calls for joint remedial actions on a European level, which was the goal of the EU-programme “Environment & Climate 1994-1998”, Area 2.2.4.

The development of wooden building types across Europe refers to protection from climate, particularly driving rain, variations in climate, use conditions, resources and the experience of damages and maintenance. The durability of wood buildings is a function of all these influences.

The Wood-Assess project pursued pooling of European resources to develop methods and technologies for proper assessment of the conservation state and for mapping and assessing environmental risk factors to wooden cultural buildings. This will enable prediction of service life and maintenance intervals thus facilitating a more sustainable management of the buildings

1.2 Results and Conclusions from Wood-Assess

Quoted from the Wood-Assess report (Haagenrud et al, 2000):

“The Wood-Assess had the specific objectives

to develop and validate methods and technologies for:

- proper assessment of the conservation state for outer wooden parts of cultural buildings
- measuring the decisive wood rotting factors of moisture, temperature and time of critical moisture and temperature in the micro-environment, and as well integrative damage to wood
- assessing and mapping environmental risk factors to outer wooden parts of those buildings.

The work was, accordingly, organised in three Work-Packages (WP) and the systems and methods were validated by assessing outer wooden parts of chosen buildings in Germany, Norway, Sweden, and Poland.

The project completed its tasks and achieved all its objectives, developing and validating an Assessment Protocol, methods for continuous measurements of moisture and temperature in the micro-environment, and systems for mapping environmental risk factors to wooden cultural buildings (Haagenrud et al, 2000).

In order to develop the *Condition Assessment Protocol (CAP)* types of wooden buildings and their state-of the art regarding conservation and maintenance in the participating countries of Germany, Norway, Sweden, and Poland were surveyed. This included national policies and organisations, criteria for monument definition, inventories and documentation. A short state-of-the art report on durability of wood was also given, although durability studies of wood as such were not within the scope of the project.

The survey revealed a very extensive and diverse documentation need. Many fragmented paper based information systems exist; calling for harmonisation and eventually standardisation and computer based information systems. The development of the CAP addresses these issues.

The theoretical and methodological foundation for the project builds heavily on the internationally recognised methodology for prediction of durability, service life and maintenance intervals, which is now subject to standardisation by the ISO/TC59/SC14 “Service Life Planning” (ISO, 2000). As such the Wood-Assess concept for assessing environmental impact on to building facades can be directly applied to the Factorial approach in the ISO standard. This provides major new methodologies and tools for assessing the climatic risk factors for wood preservation on regional-, local and micro scale in Europe.

From synthesis and further development of the national systems and guidelines for conservation and assessment, a pilot version of a Condition Assessment Protocol has been developed and validated by assessments of pilot objects in Germany, Sweden and Norway. The PC based pilot version of the Assessment Protocol was made available on a Geographical Information System (GIS) platform that could store, integrate and further process data of all kind such as text, pictures, maps etc. A separate PC based system for field inspection and registration was developed, consisting of hand-held computer, a digital camera and bar-code reader for registration of predefined information elements from a Field Handbook.

The Assessment Protocol developed covers the five main phases of *Defining* the task (purpose, extent, costs), *Planning*, *Registration* of basic data and object condition and environmental impact, *Evaluation* and *Reporting*. It did not cover the maintenance management phase. It is adapted to different user levels and needs, and the approach is action oriented, based on registration and evaluation of damage causes and effects, consequences, risks and remedial actions.

During the pilot testing of the applications small and medium sized companies (SMEs) and clients expressed great interest and need for a potential product developed from the Wood-Assess concept. As the project also got a very high rating from the EU, a new project proposal within the CRAFT mechanism was developed, and endorsed by the EU. In this new project, ENV4-CT98-0796 “System for Maintenance Management of Historic (Wooden)

buildings”(acronym MMWood), the Wood-Assess concept is further developed towards the market.

The MM system should bridge a gap between facility management, geographic information systems, expert systems and coordination of restoration experts. It will link data (text, photos, tables, drawings), of different geometric scales (environment, house, room, facade, details, etc.), of different aspects (material information, condition assessment, repair documentation, inspection results), of different user levels and timescales. The services offered by the proposing SME will be much more comprehensive and improved by the aid of the system.

Implementation of such a system puts requirements on its users and it will require maintenance, support and further development to adapt to new technology and knowledge. These issues have been dealt with and regulated in the Consortium Agreement.”

1.3 Objectives and Work Methodology of MMWood

1.3.1 Objectives

The co-operative RTD project “*MMWood*” that started in January 99 and ran for two years comprise the following main tasks:

To *develop* and *validate* for the SMEs an integrated Maintenance Management system for historic (wooden) buildings, adapted to the needs and purposes of various user group levels. Based on the *Wood-Assess concept and results* the modular GIS (Geographic Information System) based system, MMWood, will specifically contain

- a **documentation system** for outer and inner parts of historic (wooden) buildings and components,
- soft- and hardware **tools for the building inspection** in the course of maintenance tasks,
- an **environmental risk factor assessment** module,
- a standardised **maintenance assessment** module based on *complementation of the Wood-Assess process of assessing the symptoms, causes, effects, consequences, risks and remedial actions for environmental damages to the historic buildings, and*
- a **cost and maintenance** planning module.

1.3.2 Project methodology

This section contains the overall description of the five Work Packages of MMWood. They are classified in two parts; the first part is WP1, describing the MMSystem and software development and validation as stated, while the second part comprises the other three WPs describing the acquiring of knowledge and data to be put into the system, following and extending the approach contained in the Wood-Assess project. Project Management is also defined as a separate Work Package, namely WP5.

WP1 - Application Development and Testing deals with developing and validating the MM system, together with different user groups, at pilot objects. Thus WP1 integrates the main aspect of the project.

WP 2 – Assessment of environmental damages to buildings deals with extending the Damage Atlas from wood to include also materials like Rendering, Brick and Natural Stone. It is based on the Wood-Assess protocol of assessing the symptoms, causes, effects, consequences, risks and remedial actions for environmental damages to historic buildings consisting of those materials. The Damage Atlas is a module in the MM system.

WP3 - Object documentation, regulations and management- aims to identify, develop and establish documentation requirements, regulations and management performance for the application of MMS at pilot objects in each of the participating countries.

WP 4 – Environmental risk factor module provides

- dose - response and damage functions for the ingoing materials,
- synthesise the necessary environmental data for exploiting the methods and models developed in Wood-Assess to map the environmental risk factors and resulting service lives for the materials at the chosen locations in the participating countries Italy, Germany, Sweden and Norway.

The results from each of these packages are reported in separate Chapters, each having a more detailed description in the introduction.

2 Work Package 1 – Application Development and Testing

Develop and validate the MMSystem, together with different user groups, at pilot objects.

2.1 Technical approach

Based on the Wood-Assess success of synthesising and developing a common assessment protocol available on a PC/GIS based platform, further needs were defined for a more technologically developed and integrated system.

The present project will have more character of developing a system and software application for the use by SMEs and their clients, the building owners (end-users). More pronounced than the Wood-Assess project it has to follow the obligatory and standardised 5-phases model for developing such products, namely:

Phase Actions

- 1 **User Requirements**-Identification of user needs
- 2 **Functional & Techn. Specification** -User needs translated to functional specifications
- 3 Building the demonstrator application
- 4 **Validation** with users in real life situation, which involves
 - 4a - **verification stage** (a few but a sufficient sample of users to test the technical feasibility of the application and yield of preliminary user acceptance)
 - 4b - **demonstration phase** (a sufficient sample of users to gain large scale acceptance)
- 5 **Exploitation plan**

The project will cover all these phases with the exception of 4b, which will be a follow-up of the project as part of the exploitation and market implementation.

2.2 User requirements

Based upon the Wood-Assess system Norgit developed and distributed a list of user-needs. All partners went through the list, prioritised, and added their own needs. From this the final user requirements were reported (Aurlien, 1999), and used for further work to develop functional (Stordahl, 1999) and technical specification (Stordahl, 1999). The users of the system will be house-owners, or experts that do the inspections for the house-owners. The specific user requirements and priority are different for the different partners as they have different roles in the project.

The used requirement concluded that the inspection should be done by use of a portable computer and a digital camera for taking pictures. MMS should have libraries that consist of categories of elements of a wooden building, observations of symptoms linked to these elements, and a set of predefined questions ensuring the proper registration of relevant information. The flowchart for the assessment protocol in field with MMS is shown in WP2, Figure 6.

Platform: Microsoft 32-bit: Windows NT 4.0

Software: Oracle 8

License: Map Objects 2

The digital cameras used with the system must communicate with the computer through TWAIN-drivers.

2.3 Functional specification of MMS

Figure 1 describes the main parts of the MMS. Not all the modules are implemented in MMS. The Condition Assessment module is described in Figure 2, the Maintenance Management module in Figure 3, while the Decision module is described in Figure 4.

Configuration

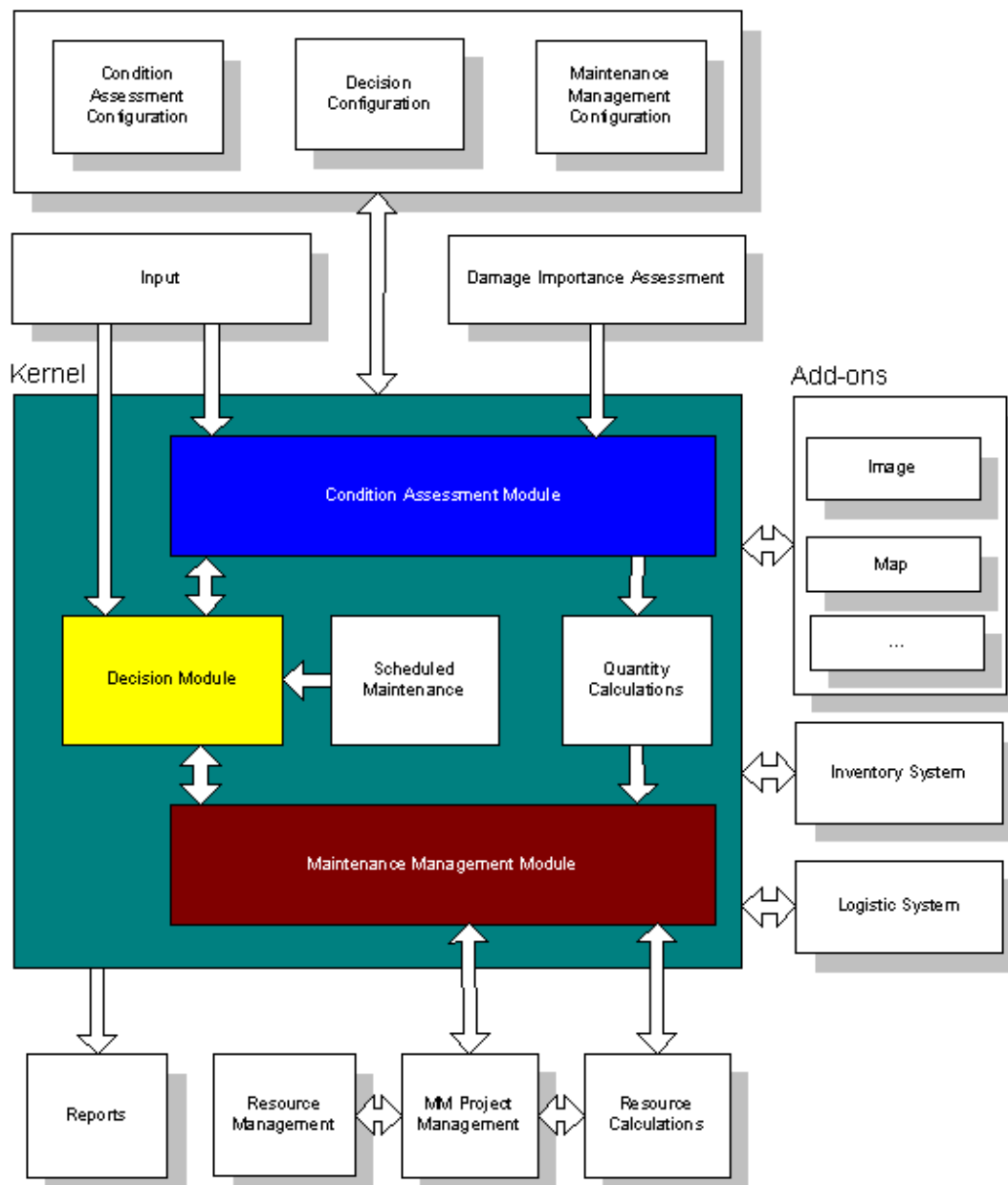


Figure 1: The main parts of the MMSystem.

2.3.1 Condition Assessment Module

The Condition Assessment module (CAMM) is the link between the input module and the Decision Module. The module is responsible for providing the user with the necessary tools to correctly evaluate the consequences of a registered observation, and generate the appropriate damage. An observation is any kind of event connected to the given object, normally the observation leads to a damage, but not necessarily.

The Condition Assessment module takes the following input from the MMSystem:

- Observations from the input module. Including Objects and locations / relations
- List of possible states for known objects
- Set of damage generation rules from the rules configuration database
- Set of damage criteria rules from the rules configuration database

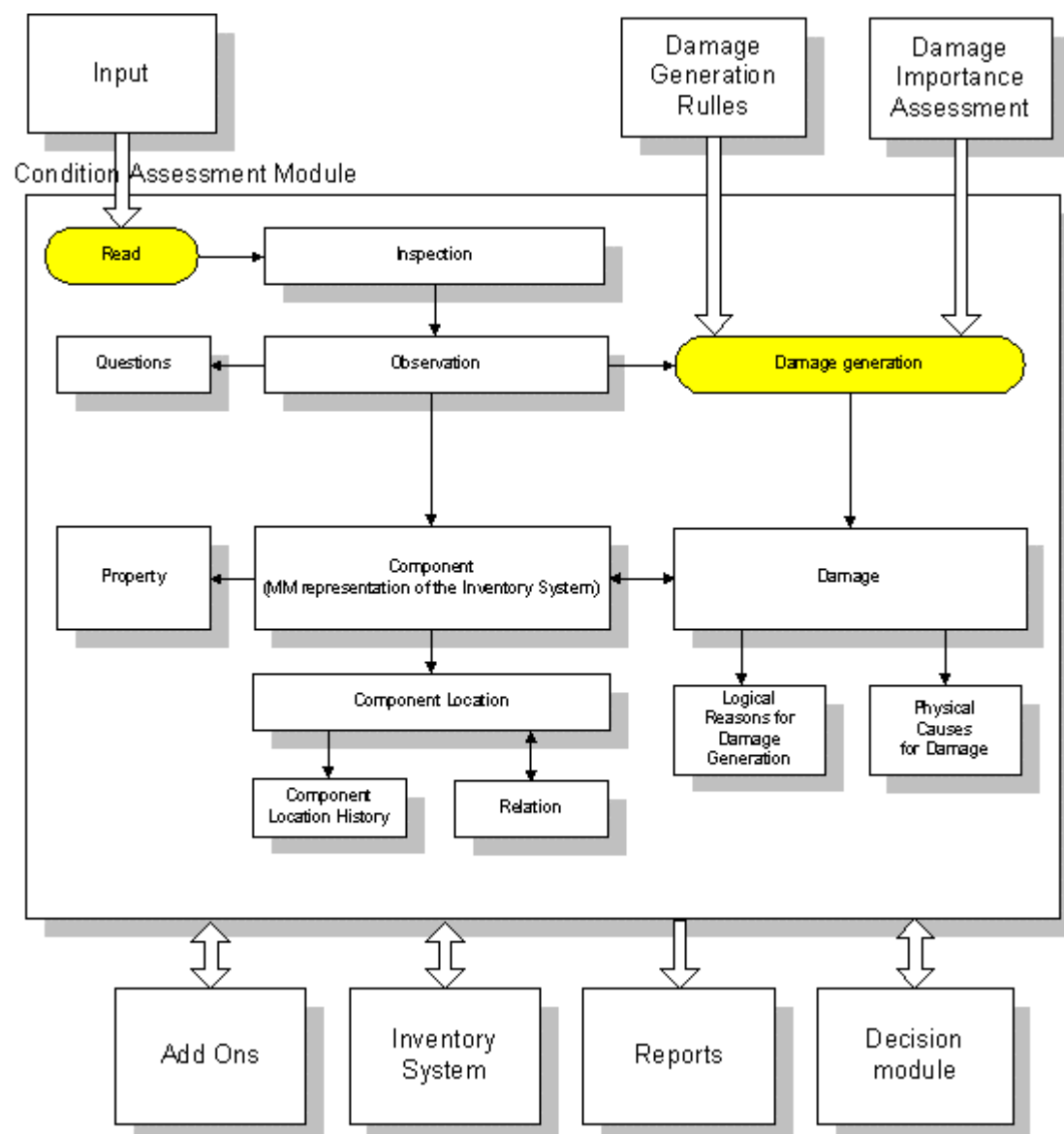


Figure 2: Description of the Condition Assessment module.

2.3.2 Input Module

The Input-module is responsible for presenting information about the state of the objects in the system to MMS in a standardised format. The module must be able to handle a variety of different ways of getting the necessary input from the user, yet still present the final result in a consistent manner.

The applications for handling input will be different depending on which objects are to be assessed, and which equipment the user would like to use for making the assessment. Some different types of input devices are likely to be:

- Desktop PC – to be used when the user receives information about changed state of objects to his workplace, or when the assessment has been done with pen and paper.
- Portable PC – for use out of office, but in stable environments.
- Handheld PC – for use in places where other types of PC is not applicable.
- Other software – input may be automatically generated from other software, based on other information about the objects.

The Input-module will need the following information from the main system:

- List of objects – in order to determine which object is to be assessed. In some cases this information will be gathered from the Inventory system.
- Details for objects, Building parts – in order to determine which part of the object that has been damaged
- List of states/damages – only applicable if there is a given set of states for the objects.
- Earlier assessments – to make sure the user evaluates the same things as on earlier assessments, and to make sure earlier damages are evaluated. This is dependent on both the storage capacity and the output device of the device used for the assessment.

The amount of information available in the input-module will also depend on which type of inventory system is used.

The Input-module will not write its data directly into the CAMM-system, but will store the information in separate tables. The structure of these tables will be identical, independent of which device is used for doing the assessments.

2.3.3 Maintenance Management Module

The MM-module is responsible for turning the user decisions regarding the damages/states of the objects into tasks for further processing. This can consist of the systems own module for making work cards, or export to an external project management application. Figure 3 sows a description of the module.

The input for this module:

- A table of damages/states from the assessment, and the users decisions about what should be done about these.
- The result from the quantity calculations for the damages, i.e. an estimate of what is needed of resources for correcting the damage.

- A set of rules for the objects, guiding which tasks is applicable for which types of decisions. This will be application-dependent, for many objects such rules are not possible to create.

Based on this, the system will generate tasks, which then are sent to the task manager. The tasks can contain detailed information about what should be done, or it can be an empty shell for the user to fill in. The tasks will consist of work cards, which the user creates based on the following input:

- The tasks, telling what decisions has been made.
- The assessment(s) that led to the task.
- A list of assigned resources.
- A list of available technology, i.e. what kind of work-types is known to be available.

Parts of this can be substituted with external applications:

- Logistic system
- Project management tools

The MM-module should be able to generate input-data for external applications.

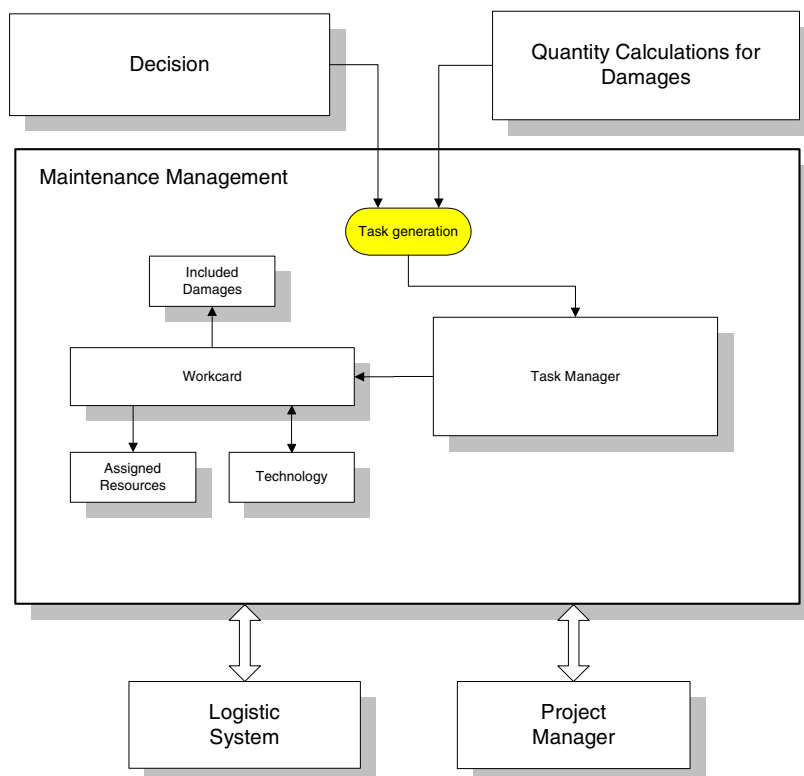


Figure 3: Description of Maintenance Management module

2.3.4 Decision Module

The Decision Module (Figure 4) will be dependent of the type of objects the system is used for. There will however be a bare bone version of the module in the kernel. Further functionalities must be described by the user.

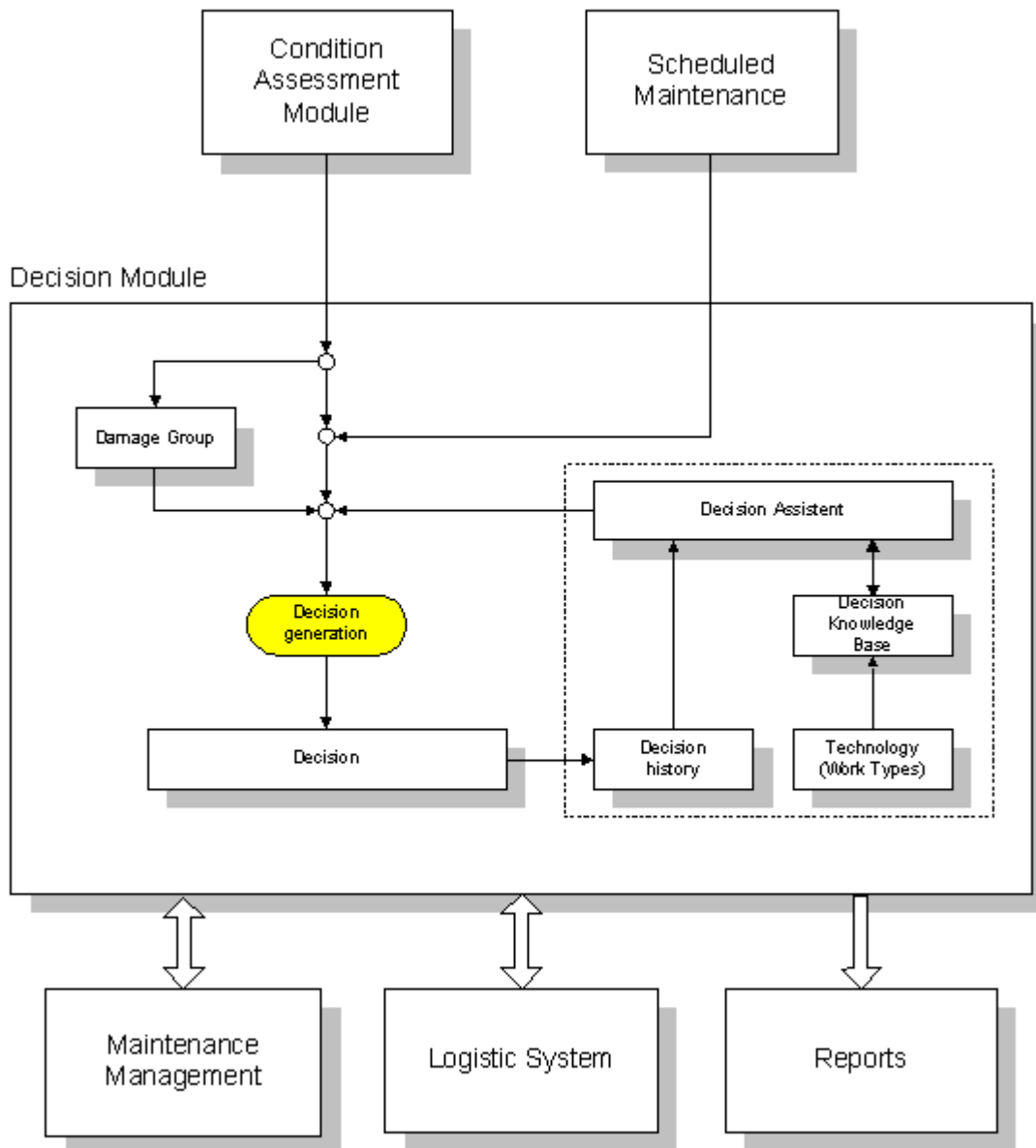


Figure 4: Description of the Decision module.

2.3.5 Add-Ons

Add-Ons are modules that are not required to run the application, but which enhance the usability of the system. Examples of Add-Ons are Photo database (Figure 5) and Maps and GIS-functionalities.

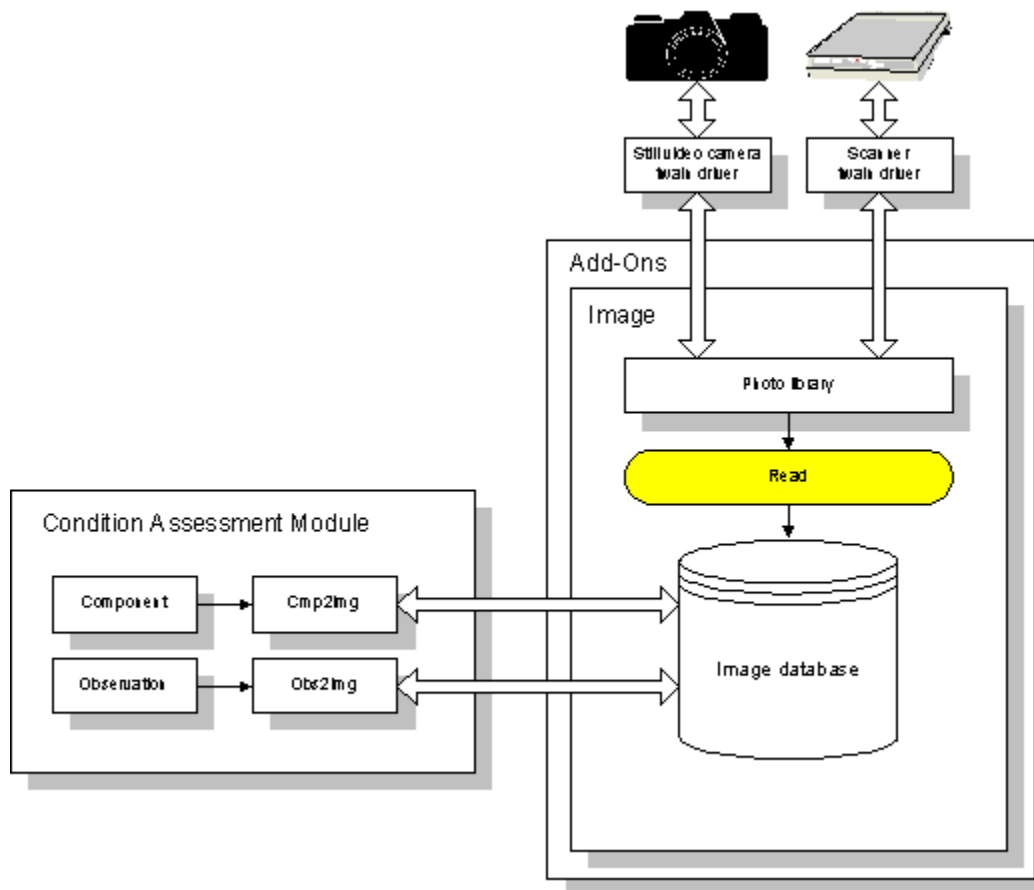


Figure 5: The photo database, including the import functionalities, is an example of Add-Ons.

2.3.6 Relation to other systems

The B1 partner in the project, Oslo kommune Boligbedriften, wanted MMS to be an integrated part of their IBM TiPS facility management system (FM). They will use MMS mainly as a condition assessment system, and the development of this totally integrated system is being implemented in a separate nationally funded project.

In the present project MMS is a stand-alone prototype. The software is however open and generic and developed with integration with other systems in mind.

2.3.7 General constraints

The software will be running on a Personal Computer running the Microsoft Windows NT operating system.

2.4 Functional description

The agreed functional specifications developed from the user requirements can be described as in the following Table 1.

Table 1: Functional specification developed from user requirements. Each requirement has an ID, description, and a given priority. Mainly requirements with priority 1 and 2 are developed.

ID	Description	Priority
1	<i>General:</i>	
1.1	The application will be based on the Microsoft Guidelines for design	1
1.2	The application will have an MDI-interface, meaning the user can have several windows open at the same time.	1
1.3	The application will have a help-file containing at least the same information as the user guide.	3
2	<i>Start up/logon/main interface:</i>	
2.1	Each user of the system must have an unique user identification (user-ID)	1
2.2	An user-ID and a password is required to log on to the system	1
2.3	Users will be divided in 2 different access classes (User and Admin), where only the Admin-class can update library-tables.	1
2.4	Any input to the system is logged with date and user.	2
2.5	A unique number must identify every inspection-object (object).	1
2.6	There will be several ways of finding a specified object:	1
2.7	- by choosing the object by its unique number	2
2.8	- by selecting it from a list of objects	1
2.9	- by searching for it based on a specific set of criteria's	2
2.10	- by searching for it through a map interface (see NS10 for details)	2
3	<i>Field inspections</i>	
3.1	Field inspections will be performed using a portable computer	1
3.2	The inspection part will be a separate application	1
3.3	The inspection-application will have its own database, being a subset of the main database.	1
3.4	Requirements for logon will be as for main application	1
3.5	Because of this information about users etc. must be downloaded to portable computer before inspection starts.	1
3.6	Information about object, damage atlas etc. can be downloaded to portable computer before inspection starts.	1
3.7	The inspection application will have high priority on ease-of-use	1
3.8	2D-drawings of inspected buildings are required, and must be present prior to inspection.	2
3.9	Damages are marked on the drawing, and given a unique ID	2
3.10	Additional identification of location of damage can be given.	1
3.11	List of possible damages is predefined.	1
3.12	Each damage has a separate set of predefined questions/information which the user can fill out	1

3.13	Additional information can be given in form of free-text	1
3.14	Digital photos are linked to a damage, to the building or to a specific building-part	2
3.15	Each object has a predefined list of attributes that can be updated/added while doing the inspection.	1
3.16	After completion of inspections, the inspection-data should be uploaded to the main database.	1
3.17	A list of building-parts can be added/updated during the inspection.	2
3.18	Building-parts can be linked to the drawing.	2
3.19	Damages can be linked to a building-part instead of, or in addition to, to the drawing.	2
4	<i>Analysing inspection-data</i>	
4.1	The user should be able to gather several damages on the object to treat as one. (i.e. group damages)	1
4.2	The user should be able to gather several damages from several objects to treat as one. (i.e. group damages)	3
4.3	One damage can only be in one group.	1
4.4	When analysing the damage the user has several options, marking the damage as: non-existing not to be fixed, with given reason to be fixed	1
4.5	Damaged marked to be fixed should be given a description of what to do (from a predefined list of actions), a responsible for performing the work, a work-priority, and a deadline.	1
4.6	From this input work-cards are automatically generated.	3
4.7	Decisions of actions are stored in an experience-database, and the next time the same damage occurs the last action(s) is suggested.	3
5	<i>Working with work-cards</i>	3
5.1	A work-card must be completed with the following information: start-date for work updated date for deadline expected work-time needed cost for work-time cost for materials etc.	3
5.2	Work-cards must be marked as Sent when they are completed	3
5.3	Work-cards can be printed one by one, or several together	3
5.4	Work-cards must be signed for (with signature and date) when the work is done	3
5.5	Work-cards that are overdue (with another colour) is marked in the list of work-card	3
5.6	Work-cards that are overdue can give a warning to the user in form of a message popping up on start of application	3
5.7	Work-cards can be exported to other programs.	3
5.8	Work-cards can be presented in a complete list, or as a list for the selected object.	3
6	<i>Import/export</i>	
6.1	The application should be able to export data to the database used by the inspection-application. This must include information of the systems users, and main information for the objects that should be inspected. It may also include additional information about the objects (i.e. building-parts, earlier inspections, pending work-cards), and the damage atlas.	1
6.2	The application should be able to import data from the database used by the inspection-application.	1

6.3	The inspection-application requires matching import/export-routines.	1
6.4	The application should be able to import objects from text-files in a given format.	1
6.5	The application should be able to export work-cards to text-files in a given format.	3
6.6	The application should be able to import/export the different libraries listed below	2
7	<i>Reports</i>	
7.1	List of one, several or all work-cards.	3
7.2	List of pending work-cards for one, several or all objects.	3
7.3	List of all or several objects.	2
7.4	List of all static information for an object.	2
7.5	List of all inspections for one, several or all objects.	2
7.6	List of all damages for one, several or all objects.	2
7.7	List of users.	2
8	<i>Library of objects</i>	
8.1	The objects will have several types of attributes connected to them: required attributes "static" attributes "dynamic" attributes	1
8.2	Required attributes will be information like: ID, name, coordinates, drawing	1
8.3	Static information is information that can be added for each object, but which is not required: Owner, address, list of building-parts etc.	1
8.4	Dynamic information is a configurable part where the local admin of the system can add information that are specific to the users/region: Specific information like code from Byantikvaren's yellow-list	2
8.5	The object will contain information telling whether it's a separate building, or part of a larger building-complex.	2
8.6	The object will contain a link to a list of building-parts for the object. This list will contain building-parts from the original list of building-parts for the entire system. The list will contain information linking it to a specific part of the building, either as a link to other building-parts, or a link to the drawing, or both.	2
8.7	The building-parts can have other information than damages connected to them, in form of links to other documents, text, or digital photos.	2
9	<i>Other libraries contained in the applications</i>	
9.1	Library of users, including user-ID, password, full name, class (User or Admin), and competence	1
9.2	Library of damages, linked to damage atlas	1
9.3	Library of building parts	1
9.4	Library of damage atlas, i.e. extended information about the damages	1
9.5	Library of information, questions for damages	1
9.6	Library of links between damages and information/questions, included information of whether input is required	1
9.7	Library of actions for fixing damages	2

9.8	Library of materials	1
9.9	Library of all historically worthy areas or building parts or surfaces, which may not be destroyed by repairing	3
9.10	Library of architectural/historical stile incl. century	3
9.11	Library of craftsman or company, who repaired or fixed damages	2
9.12	Glossary	2
10	Map functionality. The following functionality will be present in the maps:	2
10.1	add and remove map-themes (raster or vector)	2
10.2	select colour, style and symbol for map-themes	2
10.3	zoom all, zoom in, zoom out, zoom to objects	2
10.4	pan	2
10.5	print map to printer, file or clipboard	2
10.6	choose one or several objects by point at them or drag at polygon around them	2
10.7	Show themes with graduated colour, style or symbol (type and size) dependent on properties in each theme	2
11	Presentation of objects	
11.1	Objects will primarily be presented as a 2D-drawing of the objects base for the ground floor	2
11.2	When the base for higher floors diverge, there can be different drawings for each floor	2
11.3	When correct measures for the drawings are available, the objects will be shown in scale	2
11.4	All damages connected to the object will be shown in a separate list	1
11.5	Those damages connected to the drawing will be shown on the drawing	2
11.6	The damages are selectable, both from the drawing and the list	1
11.7	When a damage is selected, further information regarding the damage will be shown.	1
11.8	Other documents connected to the object will be shown in a separate list	2
11.9	When the documents are linked to the drawing, they will be marked on the drawing.	3
11.10	The building-parts registered on the object will be shown in a separate list/tree-view, marking the relation between them	2
11.11	When the building-parts are linked to the drawing they will be marked on the drawing	2
11.12	Showing information like documents and building-parts can be turned on and off in the drawing.	2
11.13	It will be possible to add new damages when viewing the object.	1
11.14	It will be possible to add new building-parts when viewing the object.	2
11.15	It will be possible to add new documents when viewing the object.	2
12	Budgets and economy	3
12.1	The application will have a module showing a summary of all cost registered in the work-cards.	3
12.2	Costs can be shown for one, several or all objects.	3

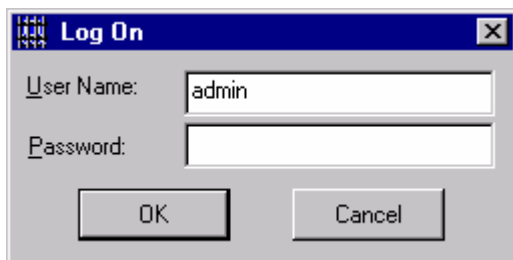
12.3	Costs can be shown and summarized for selected time-periods.	3
13	<i>Technical specifications</i>	
13.1	The application will be in English, but prepared for later translation.	2
13.2	The application will be running on Windows NT 4.0	1
13.3	The database used in the application will be Oracle 7.3.4 or higher	1
13.4	The application will be a client/server-application	2
13.5	The map-functionality will be implemented using ESRI Map Objects	1
13.6	The reports will be made using HTML	2
13.7	The application will be programmed in Visual Basic	1

2.5 Technical specification of MMS

2.5.1 Introduction

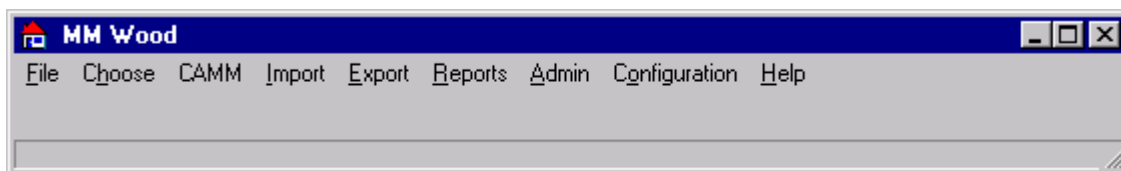
This chapter is intended to give a detailed description of the PC-application MMS, and covers both layout and functionality. The screen-shots provided are however not necessarily as in the final layout of the application.

2.5.2 Logon



Each user has a separate username and password, and all users are required to log on to the application. The users are divided in two different classes - users and administrators. Parts of the application will only be available for the administrators. All inspections and decisions will be linked to the user.

2.5.3 The main form



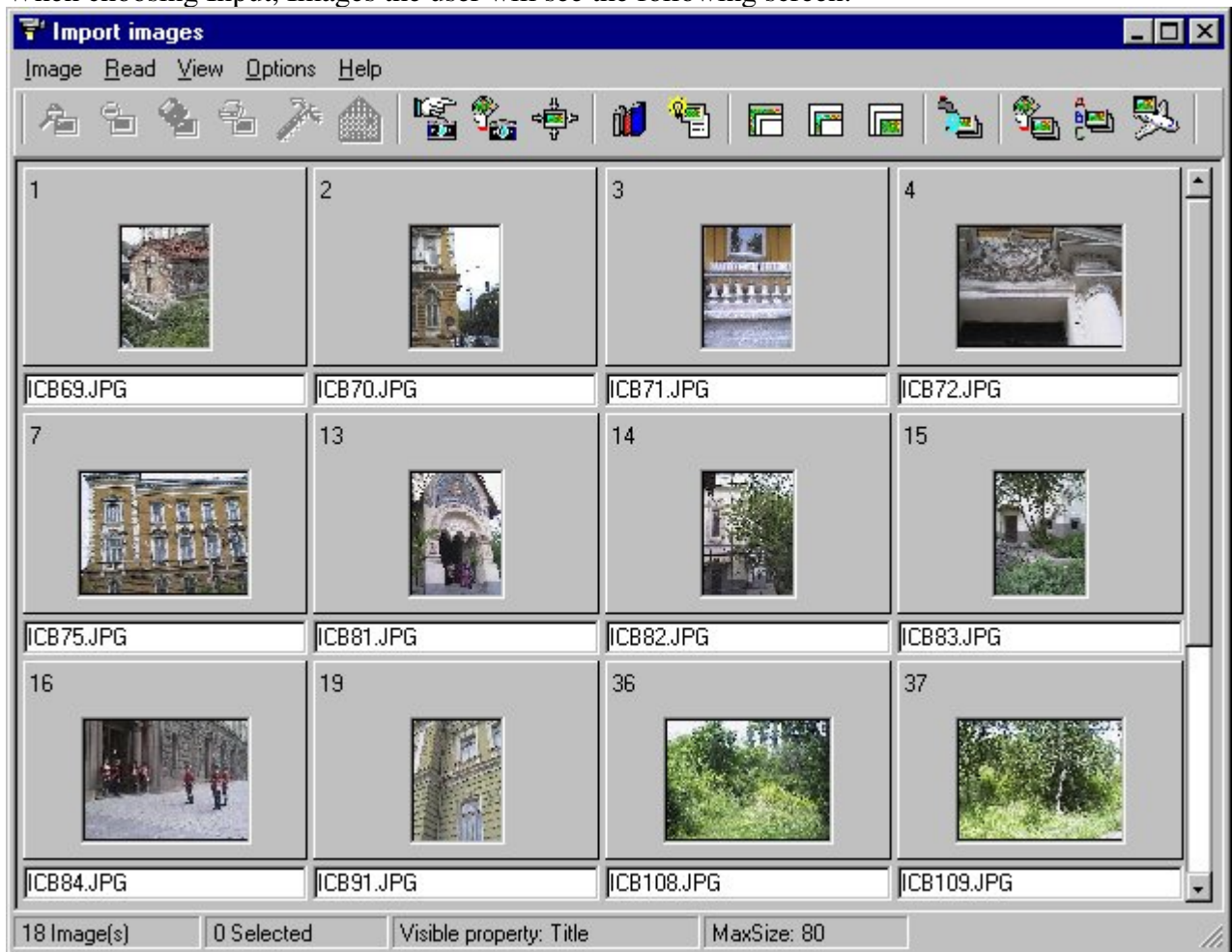
The main form is an MDI-form, i.e. the user can have several windows open at the same time. The application is oriented towards the objects, meaning that the user will have few options available until he has chosen an object to work with. In addition to this there will be options for Import, Export and Configuration that will be available independent of the active object.

2.5.3.1 Input to the system

Input to the system will primarily come from two sources - the inspections of the object, and digital photos taken at the object. These sources are available from the Import-menu. This form will contain a list of all the inspections in the inspection-database that hasn't previously been transferred to the main database. The user should then mark all the inspection he wants to import, and then choose transfer. The inspections will be removed from the inspection-database after they have been transferred. Information about where the inspection-database can be found is given through the Configuration-menu.

2.5.3.2 Reading images

When choosing Input, Images the user will see the following screen:



When choosing Read Images the user will open a new form where he can choose which images should be transferred to the application (the layout of this form will vary depending on which digital camera is connected):



If the camera and its driver supports image numbering the Track-field will contain the numbers, otherwise the user has to enter those manually in order to link the images to the correct damage. When the images are automatically linked, Reference will be marked - otherwise the user has to mark this manually in order to save the images. When the user has chosen the images he wants to save, he presses Save.

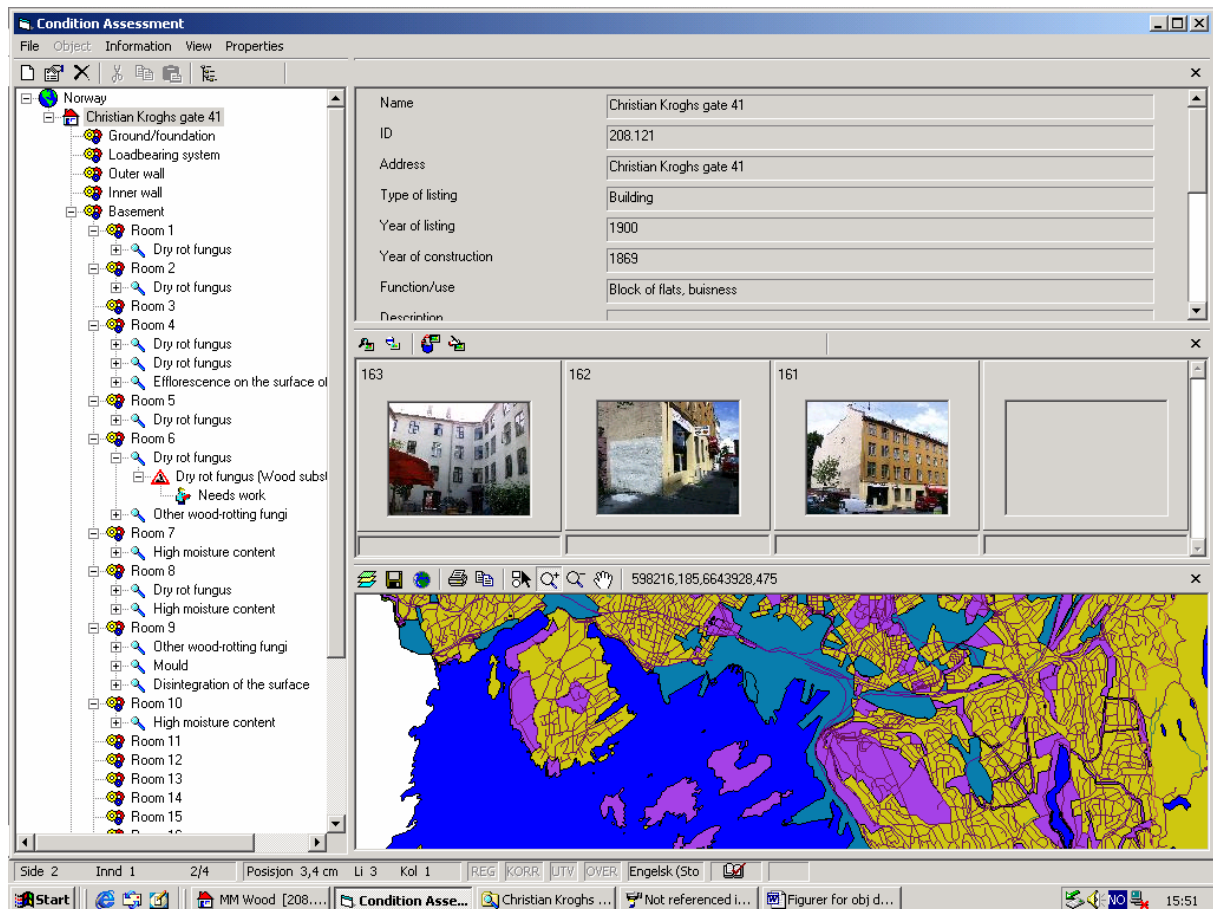
2.5.3.3 Choosing an object

By choosing File, Choose Object the user gets 4 options for finding an object to work with:

- From map
- From list of objects
- By searching
- By giving the objects unique number

These 4 options will be described in detail later.

After the user has chosen an object, this object becomes the active object. The active objects ID will be shown in the caption-bar, and a separate window containing general information about the object will be opened.



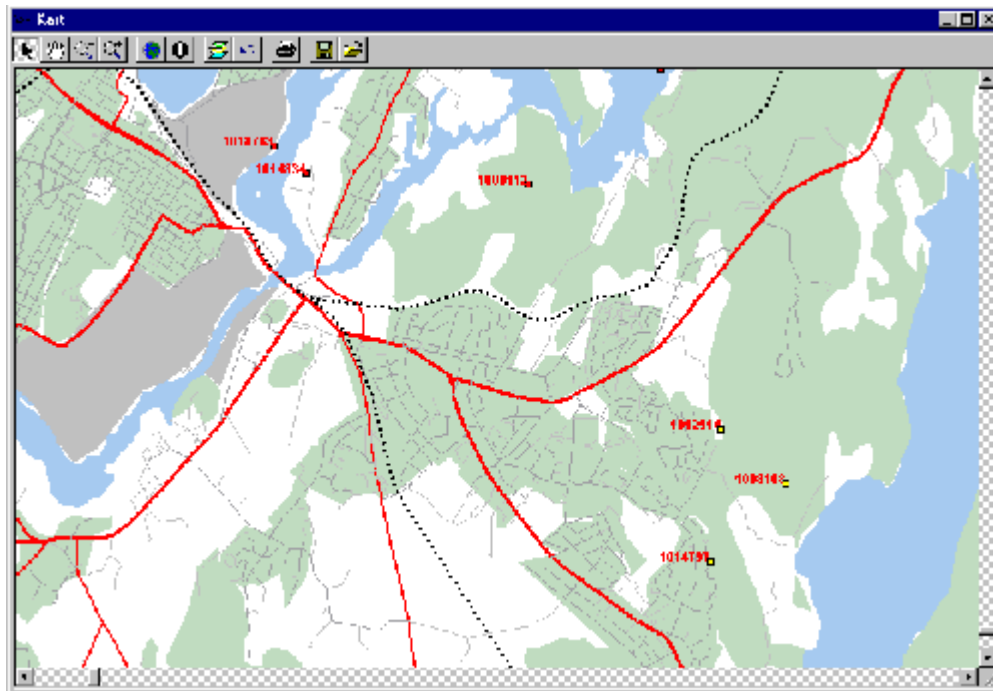
At the same time the Information-menu will be activated, giving the following options for viewing further information regarding the object:

- General information about the object
- Specific information about the object
- Map
- Images
- Inspections, included observations
- Damages
- Drawing of the main floor of the object
- Building-parts connected to the object
- Documents connected to the object

All of these options will be described in the following chapters of this document.

2.5.3.4 Choosing an object through the map

When choosing File, Choose Object, From Map the user will see the following form (object marked with red):

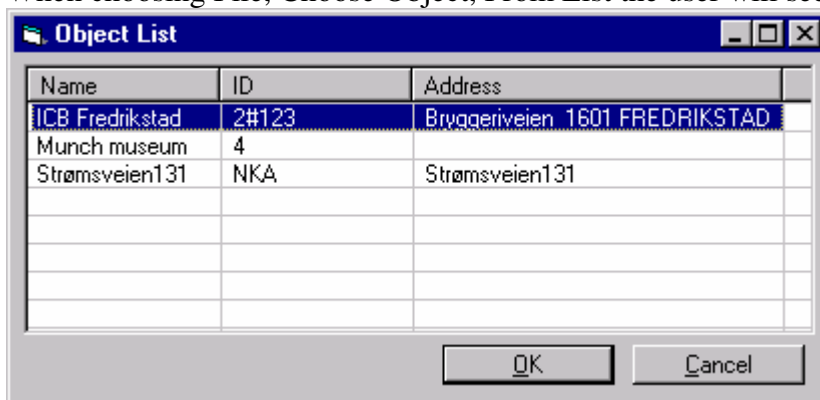


In this form, the following functionality is available:

- add and remove map-themes (raster or vector)
- select colour, style and symbol for map-themes
- zoom all, zoom in, zoom out, zoom to objects
- pan
- print map to printer, file or clipboard
- choose one or several objects by point at them or drag at polygon around them
- show themes with graduated colour, style or symbol (type and size) dependent on properties in each theme

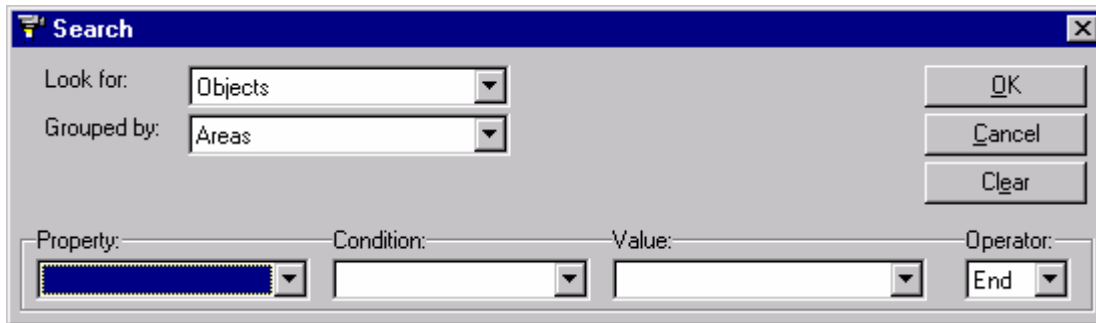
2.5.3.5 Choosing an object from a list of objects

When choosing File, Choose Object, From List the user will see the following form:



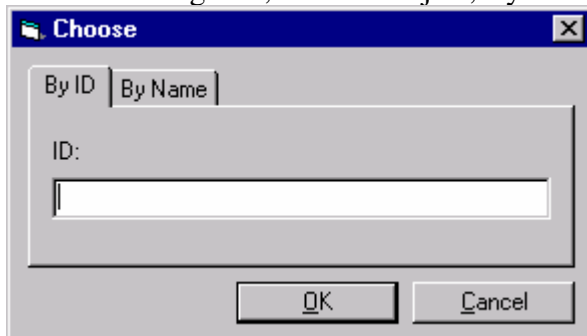
2.5.3.6 Choosing an object by searching

When choosing File, Choose Object, Search the user will see the following form:



2.5.3.7 Choosing an object by entering the objects unique number

When choosing File, Choose Object, By number the user will see the following form:

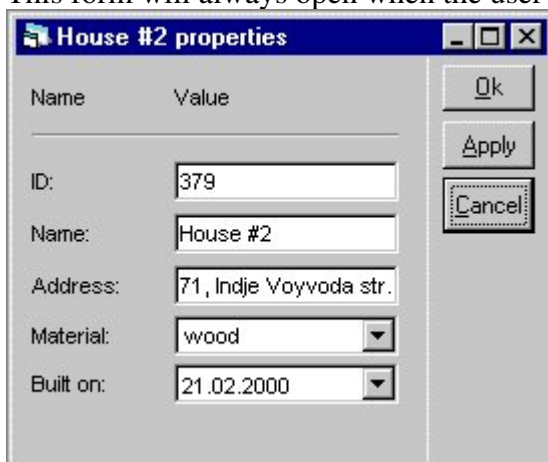


2.5.4 The Information-menu

The Information menu will contain paths to all the different groups of information that are available regarding the chosen object.

2.5.4.1 General information about the object

This form will always open when the user chooses a new object.



It contains all required and static information about the object. This information is changed through the Configuration-menu.

2.5.4.2 Specific information about the object

This form will contain dynamic information, i.e. information that is specific for each installation of the database. This means that each of the partners in this project can specify information that is only relevant to their country/customers.

The form will look like the form for general information. Which information that should be present is chosen through the Properties-menu.

2.5.4.3 Map

The map-form will open with the active object centred on the map. For further information regarding the functionality in this form (included screen-shot), refer to Choosing an object through the map.

2.5.4.4 Images

This form will show a list of all the images linked to the object.



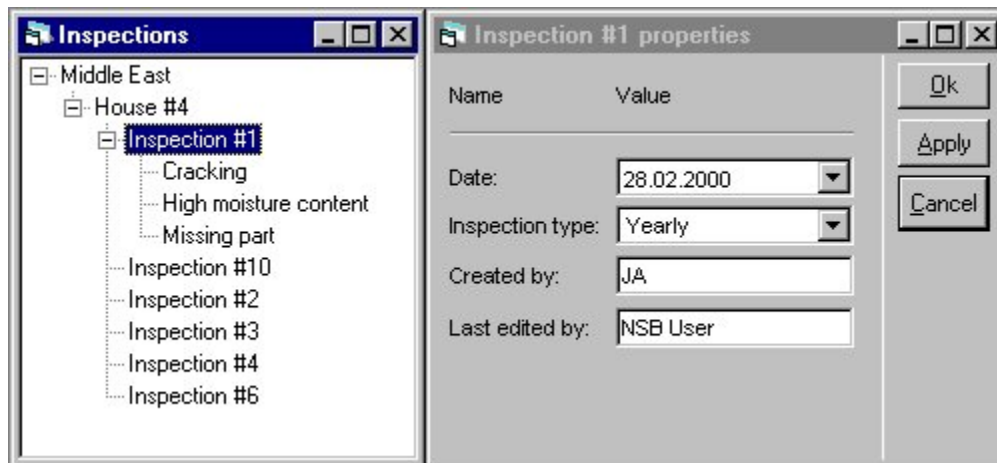
Import of new images (from digital camera or disc) will be done from the Import-menu. The images will be shown as thumbnails. When double-clicking on them, they will be shown in real size in a separate window.

This form will have different contents, depending on what is chosen elsewhere in the application:

- When nothing is chosen, it will display all images linked to the object
- When a damage is chosen, it will display all images linked to the damage

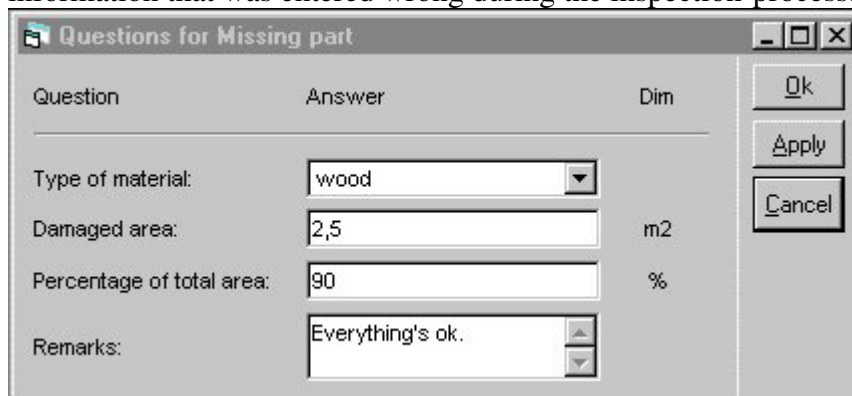
2.5.4.5 Inspections, included observations

This form shows a list of the inspections performed on the object.



Together with the list, another form is opened - showing the properties of the inspection. This includes the date, the name of the person performing the inspection, and the type of inspection performed.

When expanding the Inspection in the tree, all the observations for the inspection are shown. Double-clicking the observation opens the Questions-form, giving the option of correcting information that was entered wrong during the inspection-process:



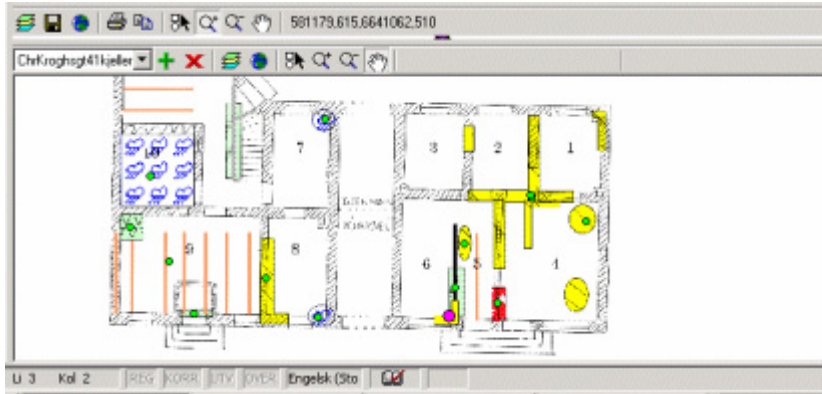
The user can also link images to the damage; this is done by choosing the Connect image-menu.

2.5.4.6 Damages

All damages are listed in the tree structure of an object. Properties of the highlighted damage are showed in a form on the right hand side.

2.5.4.7 Drawing of the main floor of the object

This form shows a graphical presentation of the ground floor of the object.

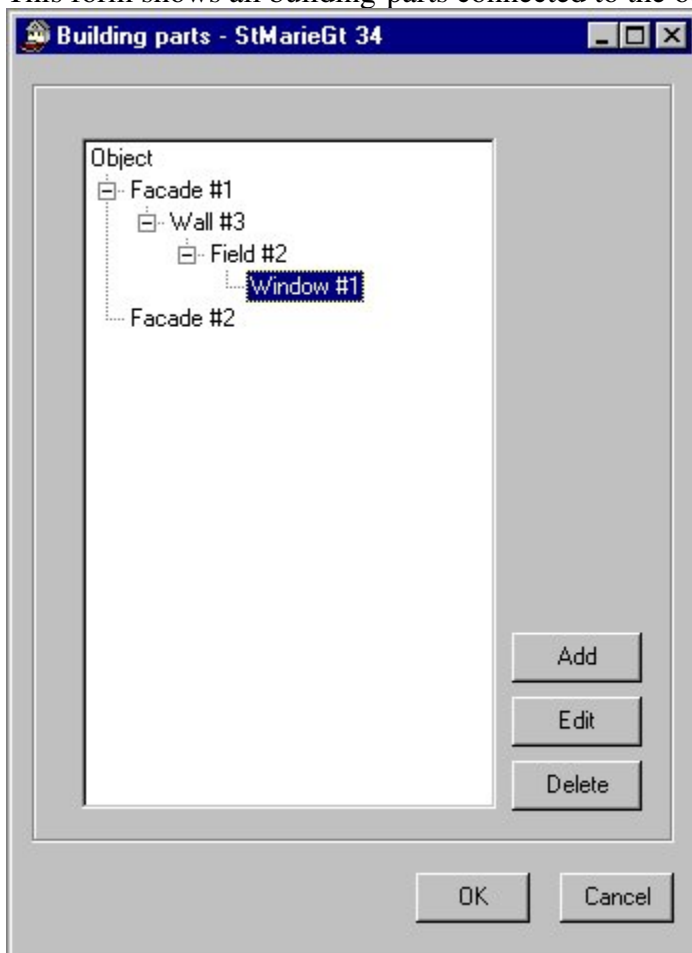


On the drawing there will be marks showing where damages are linked to the drawing. There will be other marks showing where images and/or building-parts are linked to the drawing. The user can zoom in and out, and pan in the form.

Several file-formats may be used as drawing. If the user wants to edit the file, there is a direct link to this (see Documents linked to the object).

2.5.4.8 Building-parts connected to the object

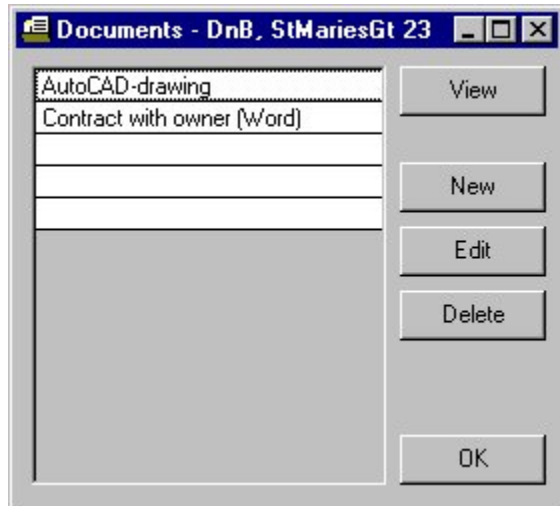
This form shows all building-parts connected to the object.



These are shown in a tree-structure. If the active building-part was linked to the drawing during inspection, it will be marked on the drawing.

2.5.4.9 Documents connected to the object

This form will show a list of documents connected to the object:



The database stores a description of the document, and a command-line for executing the document. The user can view the document, add new documents, edit existing documents (i.e. description and command-line), and delete documents.

The database is NOT storing the documents, its only storing links to external documents. This means that "deleting documents" in the previous paragraph is referring to removing the link to the document, not physically removing a document from disc.

2.5.5 The Configuration-menu

This menu will only be available to the Administrator-class of users, and consists mainly of options for maintenance of the database and the libraries in it. This includes the following options:

- Users
- Library of objects
- Library of work-types
- Library of responsible persons
- Library of observations/damages
- Library of questions
- Library of building-parts

2.5.5.1 Users

This form will show a list of all the users of the system. The following information will be required for each user:

- User-ID (3-8 characters)
- Name (up to 128 characters)
- Password (3-8 characters), optional

- Competence (up to 128 characters), describing the users level of expertise Class (User or Administrator), deciding how much functionality the user has access to
- It will be possible to add new records, edit records, and delete records (provided they are not in use).

2.5.5.2 Library of objects

This form will show all information linked to the object that is not linked directly to an inspection (or damage). This includes the following major parts:

- Required attributes, i.e. object-ID, name, coordinates, drawing
- Static information, i.e. owner, address
- Dynamic/specific information, i.e. special information like code from Byantikvaren's yellow-list
- Images, i.e. images that are linked only to the object, not to a specific damage or building-part
- Building-parts

It will be possible to add new records, edit records, and delete records (provided they are not in use).

2.5.5.3 Library of work-types

This form will show a list of pre-defined work-types. The following information will be required for each work-type:

- Work-type-code (4-digit number), provided for you by the application
- Description (up to 128 characters)
- User-ID (3-8 characters), for the user adding the work-type
- Date (date), date of creation

It will be possible to add new records, edit records, and delete records (provided they are not in use).

2.5.5.4 Library of persons responsible

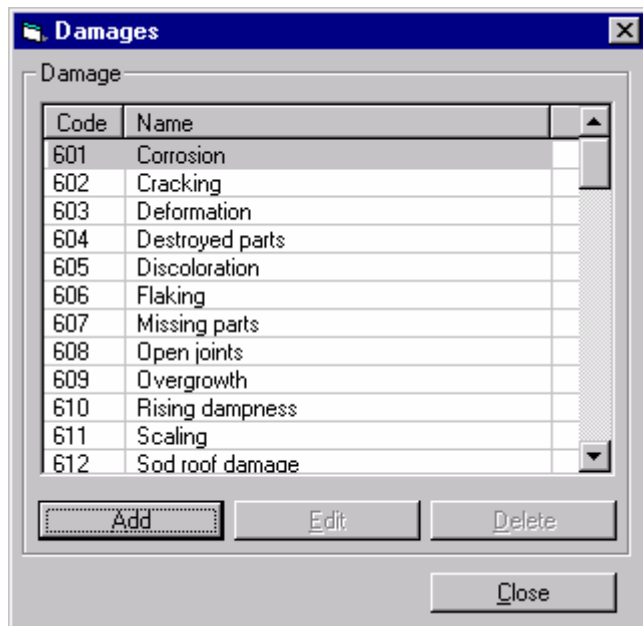
This form will show a list of pre-defined persons or firms responsible, i.e. persons, companies, institution normally fixing damages. The following information will be required for each responsible:

- Responsible-code (4-digit number), provided for you by the application
- Description (up to 128 characters)

It will be possible to add new records, edit records, and delete records (provided they are not in use).

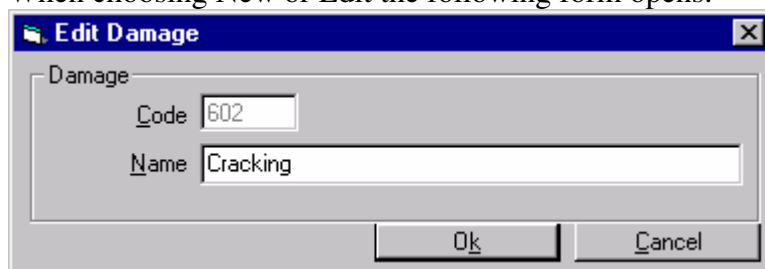
2.5.5.5 Library of observations/damages

This form will show a list of pre-defined damages. It will also show which questions are linked to the damage, the relation between them, and which questions requires an answer.



It will be possible to add new records, edit records, and delete records (provided they are not in use).

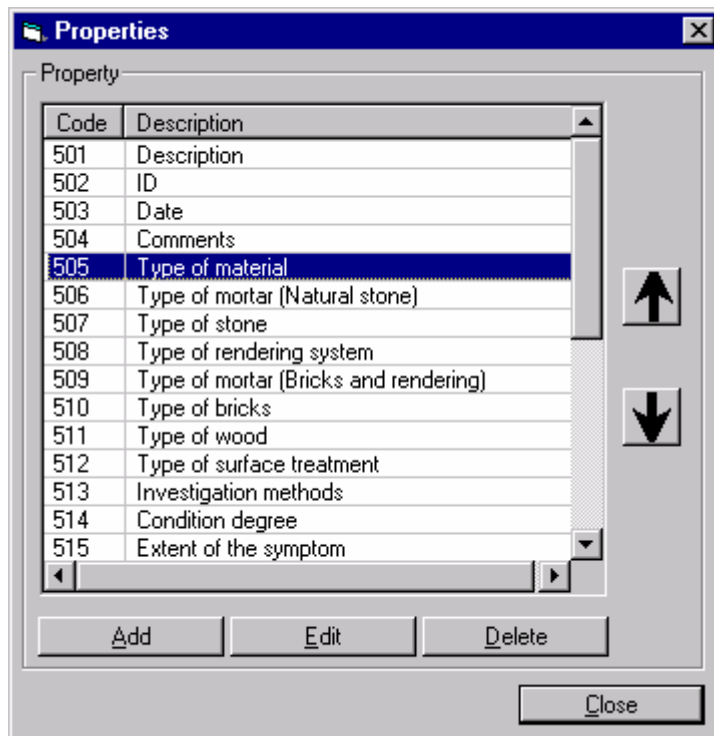
When choosing New or Edit the following form opens:



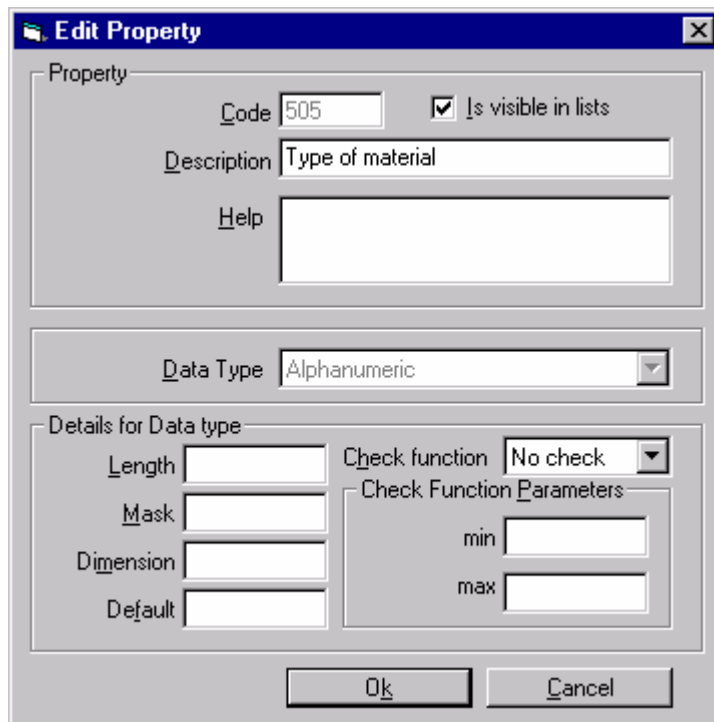
The user will be able to add and remove questions, and change their order, as well as editing the description of the damage.

2.5.5.6 Library of questions

This form will show a list of pre-defined questions:



When choosing New or Edit, the user will open the following form:



The following information will be required for each question:

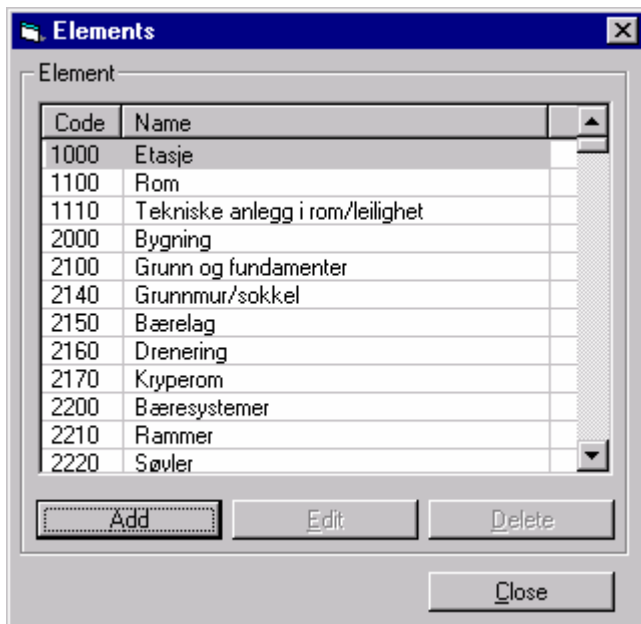
- Question-code (4-digit number), provided for you by the application
- Description (up to 128 characters)
- Help-text (unlimited size)
- Data-Type, included length of input, presentation format, and dimension

- Input Method, keyboard or system dictionary
- Default Value
- Check Function, to check validity of input

It will be possible to add new records, edit records, and delete records (provided they are not in use).

2.5.5.7 Library of building-parts

This form will show a list of pre-defined building-parts:



More examples are shown in chapter 4: Work Package 3 – Object Documentation, Regulations and Management. It will be possible to add new records, edit records, and delete records (provided they are not in use).

2.5.5.8 Library of inspection-types

This form will show a list of pre-defined inspection-types. These are used by the inspection-application to specify what kind of inspection is performed. The following information will be required for each inspection-type:

- Inspection-type-code (4-digit number), provided for you by the application
- Description (up to 128 characters)

It will be possible to add new records, edit records, and delete records (provided they are not in use).

2.5.5.9 Library of materials

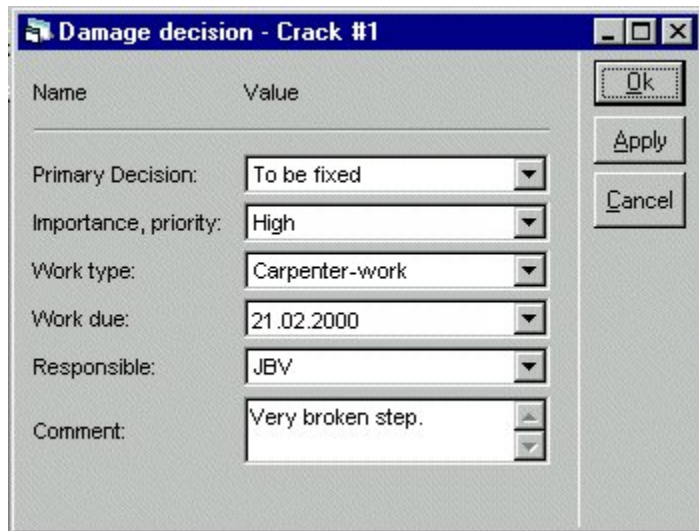
This form will show a list of pre-defined materials. These are used for answering questions regarding some of the damages. The following information will be required for each inspection-type:

- Material-code (4-digit number), provided for you by the application
- Description (up to 128 characters)

It will be possible to add new records, edit records, and delete records (provided they are not in use).

2.5.6 Other functionality

The damages are analysed in MMS. When choosing Decision, the user will see the following form:



Name	Value
Primary Decision:	To be fixed
Importance, priority:	High
Work type:	Carpenter-work
Work due:	21.02.2000
Responsible:	JBV
Comment:	Very broken step.

The user will have to enter the deadline for work due, and choose a work-type and responsible for fixing the damage. Work-type and responsible are found in pre-defined lists, but the user has the possibility of adding more records. The user must also give a priority for the importance of fixing the damage. Optionally, the user can add a comment (in free text).

2.5.7 Reports

The following reports will be needed:

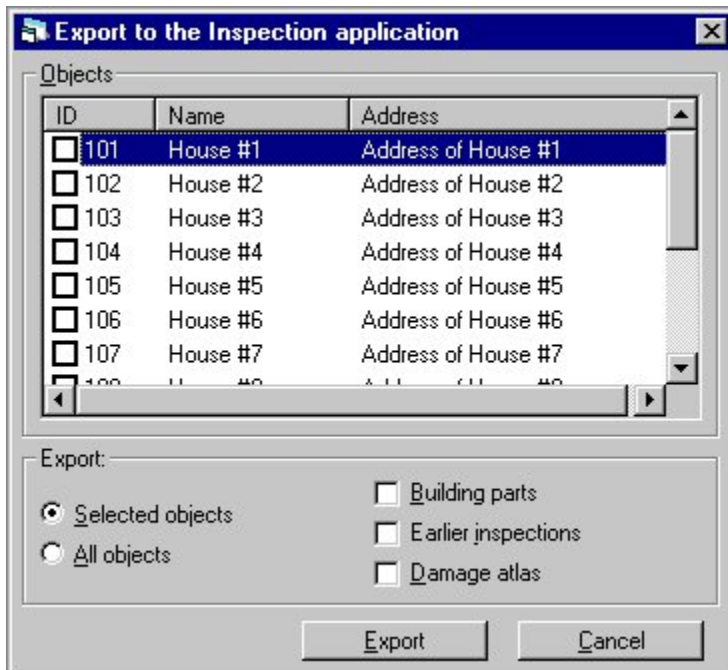
- List of objects
 - All
 - Selected in list
 - One object
- With static and/or dynamic information
- List of inspections
 - For all objects
 - For selected objects
 - For active object
- List of damages
 - For all, selected or one object
 - All, fixed/not fixed, or analysed/not analysed
- One damage
- List of users

Reports will be made in HTML-format, meaning the users will have to have a web-browser installed. The detailed contents of the reports will be decided during the implementation-phase.

2.5.8 Import/Export

2.5.8.1 To/from the inspection-application

Import from the inspection-application will be taken care of through the menu-choices under the File, Input-menu.



Export to the inspection-application will always include the systems users, the list of damages (and other libraries connected to the damages) and the main information for the chosen objects. The following information is optional:

- building-parts
- earlier inspections
- damage-atlas

2.5.8.2 Import/export of objects

It will be possible to import and export objects. This will be done through text files. The exact format will be chosen, and documented, in the implementation-phase.

2.5.8.3 Import/export of other libraries

It will be possible to import and export data from the other libraries. This will be done through text files. The exact format will be chosen, and documented, in the implementation-phase.

2.5.9 General information

Information not related directly to the forms, but more to the functionality and specifications behind them:

The database will be an Oracle-database, probably Oracle 8i. The application will communicate with the database using ADO, through ODBC.

There will be a 1-to-1 correspondence between Observations and Damages, i.e. no method for specifying tolerances like there was in previous versions of MM. There will however still be possible to mark an observation as "no-damage-generating".

There will be no distinction between **main damage** and **following damage**. New damages will always be stacked on top of previous damages, no matter whether it has been observed before or not. I.e. the logic of damages-stages will not be used, thereby simplifying the Read-module. Grouping of damages will be kept as in previous versions of MM.

2.6 Validation of the MMSystem

2.6.1 Introduction

Fulfilment of the project objectives requires co-operation between users as SMEs and building owners, and suppliers as R&D performers. The Evaluation Assessment presents the result of the validation of the project, based on the analysis of the comments, suggestions and ideas by users of the MMS demonstrators at the objects, during the verification phase of the β -version of the programme. As template for the validation plan is Guidelines for Preparation of Validation Plans (Maltby et al 1996) used.

The validation activities comprise two elements: verification and demonstration. According to project plan and requirements for the partners, the validation only cover the verification phase. The verification process was seeking to confirm that the demonstrator implements the specified user requirements as set by the MMWood document D01.01 User Requirements (Aurlien, 1999). Bellow follows in item 2.6.2 - 2.6.8 a general framework for how to conduct validation. Each A-partner and the University of Trento have written a separate validation report (Risk, 2000, Wenander, 2000, Jenssen and Lyngstad, 2000, Frattari and Garofolo, 2000).

2.6.2 Main decision makers involved in the validation of the application

These are groups who are influential in defining the assessment objectives for validation and in determining whether verification results justify proceeding to the demonstration stage of validation. These groups have been identified during the user requirements definition phase of the programme.

2.6.3 User Groups

It is also critically important to identify these groups as they should ideally be involved in validating the application and will probably represent the main market for the application; they are likely to include:

- Operators of the application,
- Intermediate users of the application like providers of information,
- End-users of the application.

These groups also have been identified in the ‘Analysis of User Requirements’ phase of the project. A distinction should be made between ‘User Groups within the Project’ and ‘User Groups outside the Project’ involved in validating an application because the latter have an important role in independent assessment of the validation results.

2.6.4 Verification site

The verification sites are the installations and the configuration of systems for each partner:

- ZHD / German demonstrator
- Mycoteam / Norwegian demonstrator
- Restaurator AB / Swedish demonstrator
- UTRE-Trento / Italian demonstrator.

2.6.5 Definition of expected impacts and groups of users/non-users affected by the application (called Appraisal Groups)

An impact describes an effect of an application on the people who are affected by the application. Precision in the description of the impacts is very important to as they hold the key for the determination of the benefits or disadvantages of the application.

Similarly, it is important to define precisely the different groups of people affected by the application since:

- Benefits and disadvantages may differ from one group to another in both type and scale,
- Perception of these benefits and disadvantages may vary from one group to the next.

These benefits and disadvantages will be experienced by:

- Operators of the application,
- Intermediate users of the application like providers of information,
- End-users of the application,
- Individuals or groups affected indirectly from the application but who cannot be classed as either operators, end-users or intermediate users.

In the case of the last category, groups may be in close association like corporations or loose associations like communities, interest groups, society, etc. These different groups of users/non-users affected by the impacts of the application should be referred to as APPRAISAL GROUPS.

As for ‘User Groups’, definition of these ‘Appraisal Groups’ will need to make a clear distinction between those connected with the project and those who are independent of the project.

The expected impacts and their related appraisal groups is summarised in Table 4 and Table 3, together with a judgement about the anticipated level of impact, using the following scale:

- ++ Very positive impact
- + Positive impact
- 0 Neutral/uncertain impact

- Negative impact
- Very negative impact

2.6.6 Selection of impacts to be validated and justification of this selection

It may not be possible to validate all the expected impacts; for example:

- It may not be possible to quantify the impact by either measurement or simulation - in such cases, at least an expert qualitative assessment of the impact should be provided.
- It may be judged wasteful of resources to validate impacts considered neutral or uncertain in their scale of impact.
- Impacts may be considered too indirect or too difficult to define to justify validation.
- Resources for validation may be too limited for comprehensive validation.

Each expected impact in Table 4 should be categorised in one of the following ways:

1. Impact to be validated quantitatively
2. Impact to be validated qualitatively
3. Impact not to be validated

In this validation all impacts are categorised as impact to be validated qualitatively.

2.6.7 Confirmation of the adequacy of the demonstration site for impact analysis

In parallel with selection of the impacts to be validated, the proposed demonstration site has been examined to ensure that:

- impacts can be validated;
- the extent and configuration of the site is sufficient to validate the main impacts;

2.6.8 Definition and categorisation of assessment objectives at verification stage of validation

The European Commission has defined 'Verification' as follows:

'The verification stage of validation will use a small but sufficient sample of users in a real-life situation to test the technical feasibility of the demonstrator and to yield preliminary findings on user acceptance'

Assessment objectives at the verification stage of validation will concentrate on:

- testing the physical functioning of the application;
- testing user acceptance of the application.

Assessment objectives will be defined and categorised as in Table 2 in association with their related user/appraisal groups.

Table 2: Definition of Expected Impacts of Application for Different Appraisal Groups

	Impact 1	Impact 2
Impact Appraisal Group 1 <i>End users within the Project:</i> A1 and Students/Trainees, A2, A3, C1, C5	Total concept and appropriate results	User acceptance
Impact Appraisal Group 2. <i>Operators within the Project: A1, A2, A3, C1, C5</i>	User acceptance	Physical functioning
Impact Appraisal Group 3 <i>End users out-side the Project:</i> Deutsche BauBeCon Quedlinburg, Special Investigators. Svenska Bostäder Students, I.T.E.A.	Total concept and appropriate results	Physical functioning

The impacts and indicators for verification and validating is given in Table 3, while the results of the verification are shown in Table 4. The results are shown as the average category obtained, and with the best and worst category in parenthesis.

The evaluation shows a positive appraisal of the system in terms of total concept, results, and user acceptance. Some problems were encountered on the physical functioning of the system, due to the prototype version and little experience and training.

Some the users were not particularly IT-trained, and this is the main explanation for variation in User acceptance.

When evaluating the categorising of impacts Physical functioning one has to have in mind that the system tested and validated was a prototype, with a relatively complex Oracle database. Some of the problems encountered during installation will not be there in the fully developed version. The handling and maintenance of the database demand some experience some of the project partners did not have.

Table 3: Impacts and indicators for verification/validation

IMPACT	INDICATOR (S)
1. User acceptance	
The MMS should be simple to use	<ul style="list-style-type: none"> • Creating and finding an object • Searching for object by use of searching criteria • Easy to link object, building parts or observations to drawings or images • Possibilities to edit drawings and images • Appropriate marking and identification of observations on drawings and images • Use of maps and shape files • Linking documents to objects • MMInsp easy to use • Appropriate and easy analysis and decision-making from observations
The MMS should be easy to understand	<ul style="list-style-type: none"> • User friendliness • Friendly user interface. • Appropriate and easy to understand Libraries • Appropriate and easy to use the Damage Atlas • Need for training and User Manuals • On line manual
The system should have an easy organisation of process and data	
The results from the system should be easy obtainable and useful	<ul style="list-style-type: none"> • Appropriate reports • Possibility to transfer information or reports to other systems for handling of information
Configuration of the system	<ul style="list-style-type: none"> • Appropriate definition of Administrators and Users and their responsibility • Appropriate and easy to understand the configuration
2. Physical functioning	
Installation and operation	<ul style="list-style-type: none"> • Installation of the system • Administrator of the system should be able to update the databases and install new versions • Response time.
Import/export between MMS and MMInsp	<ul style="list-style-type: none"> • Import to MMInsp should provide the Inspector with all necessary information • Export to MMS should update the information in the main data base • Export/Import functions should be easy to use
Easy handling of maps, drawings and pictures	<ul style="list-style-type: none"> • Easy to import images from digital camera • Easy to import existing images (files) into the database • Easy to add new drawing • Easy to add maps and new shape files
Handling of data bases	
Database information maintenance	<ul style="list-style-type: none"> • Ease of making more information available
3. Total concept and appropriate results	
All necessary information gathered in one system	<ul style="list-style-type: none"> • Possibility to have a general view of the building and its state • Possibility to access and working out information in different format • Possibility to refer to a list of criteria and references to guide a correct intervention based on a previous experience
More user friendly information system	<ul style="list-style-type: none"> • More user friendly to update information • Only necessary to update once, the system provides necessary updating of other databases

Table 4: Categorising of Impacts from Validation for the Particular Appraisal Groups. The table shows the average category obtained with worst and best category in parenthesis.

Particular Appraisal Group 1 - End users <u>within</u> the Project	
Impact	Qualitatively Impact
1. Total concept and appropriate results <ul style="list-style-type: none"> • All necessary information gathered in one system • More user friendly information system 	++ (+/++) +
2. User acceptance <ul style="list-style-type: none"> • The MMS should be simple to use • The MMS should be easy to understand • The system should have an easy organisation of process and data • The results from the system should be easy obtainable and useful • Configuration of the system 	+ + 0 (0/+) + (0/+) +
Particular Appraisal Group 2- Operators <u>within</u> the Project	
Impact	Qualitatively Impact
1. User acceptance <ul style="list-style-type: none"> • The MMS should be simple to use • The MMS should be easy to understand • The system should have an easy organisation of process and data • The results from the system should be easy obtainable and useful • Configuration of the system 	+ + 0 (0/+) + (0/+) +
2. Physical functioning <ul style="list-style-type: none"> • Installation and operation • Import/export between MMS and MMIInsp • Easy handling of maps, drawings and pictures • Handling of data bases • Database information maintenance 	0 (---/+) 0 ++ (+/++) 0 (0/+) 0 (-/+)
Particular Appraisal Group 3- End users <u>outside</u> the Project	
Impact	Qualitatively Impact
1. Total concept and appropriate results <ul style="list-style-type: none"> • All necessary information gathered in one system • More user friendly information system 	++ (+/++) +
2. Physical functioning <ul style="list-style-type: none"> • Installation and operation • Import/export between MMS and MMIInsp • Easy handling of maps, drawings and pictures • Handling of data bases • Database information maintenance 	0 (---/+) 0 ++ (+/++) 0 (0/+) 0 (-/+)

3 Work Package 2 – Assessment of environmental damages to buildings

3.1 Objectives

Complementation of the Wood-Assess process of assessing the symptoms, causes, effects, consequences, risks and remedial actions for environmental damages to the historic buildings, with emphasis on the wooden parts.

3.2 Technical approach

The Wood-Assess project developed and tested in some detail a Damage Atlas for outer wooden parts (Haagenrud et al, 1998). The outer wooden parts are sub-divided into Constructive, Wood substrate, Wood protective treatment, and Adjoining materials parts, and an Orientation System was developed and used to locate the symptoms. The damages are classified into three damage degrees, and described both with pictures and text. The scope of the Damage Atlas has been extended to include other materials as bricks, rendering, and stone, and the inner part of the building structure. In order to facilitate maintenance management, also consequences, risks and possible remedial actions have been included.

The Damage Atlas is validated by the SMEs and the RTD performers on the different objects.

3.3 MMWood Condition Assessment Protocol (CAP)

3.3.1 General Description

The MMWood protocol is developed in order to structure the work and the resulting information handling from field inspections, and further as a tool for easing the planning and execution of maintenance work. The protocol is based on the Norwegian Standard 3424, (NS 3424, 1995), and was further developed in the Wood Assess project.

The following materials are now covered in the Damage Atlas; Wood constructive materials, Wood Substrate, Wood Surface Treatment, Adjoining Materials in Wood Constructions, Rendering and Brick and finally the Natural Stone. For each of these materials examples are given and the number of examples varies between 8-13 for the different materials. The complete Damage Atlas is given in MMWood report ENV4-CT98-0796 D02.01. Damage Atlas (Eriksson, 2000).

The flow chart for the Assessment Protocol is shown in Figure 6.

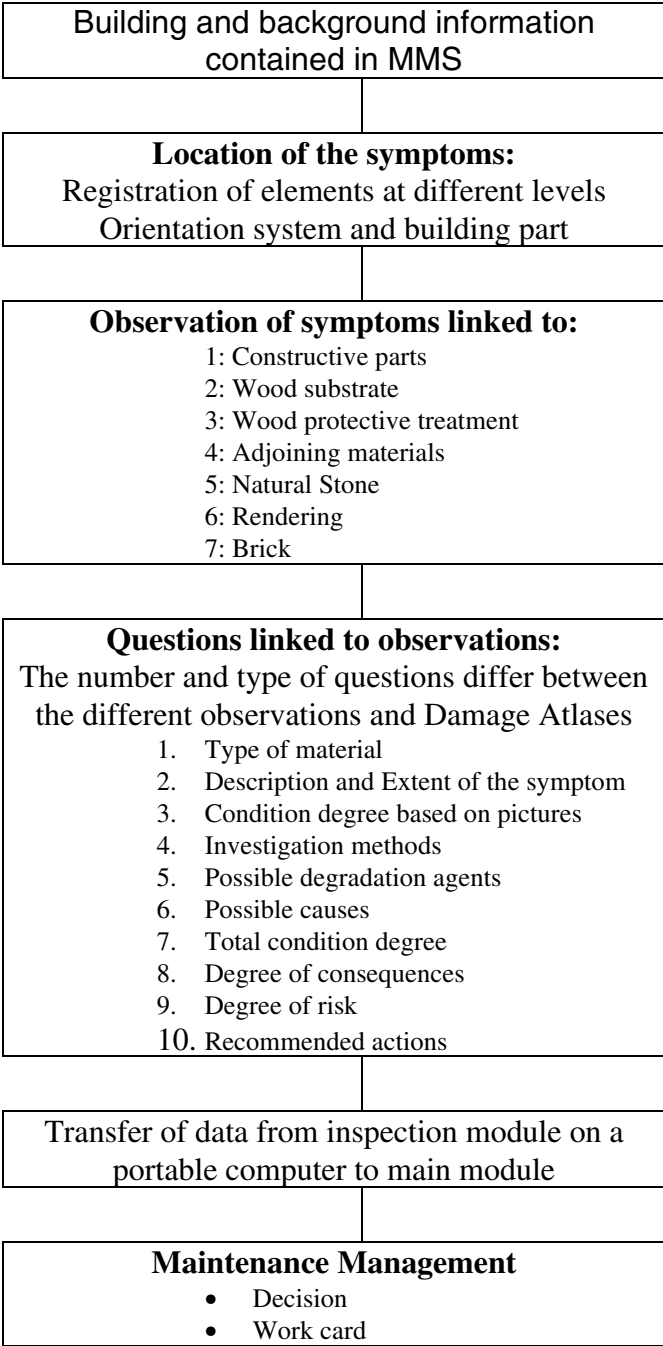


Figure 6: General outline for the MMWood Condition Assessment Protocol

Buildings are exposed to several factors deciding the service life. Figure 7 presents the environmental degradation agents on Wood and Wood protective treatments. In the Damage Atlas several types of damages for different materials are defined, Table 5. The effort has not been to cover all the damages that can occur on buildings, but instead present some of the most usual damages that are likely to occur, and to present them as examples.

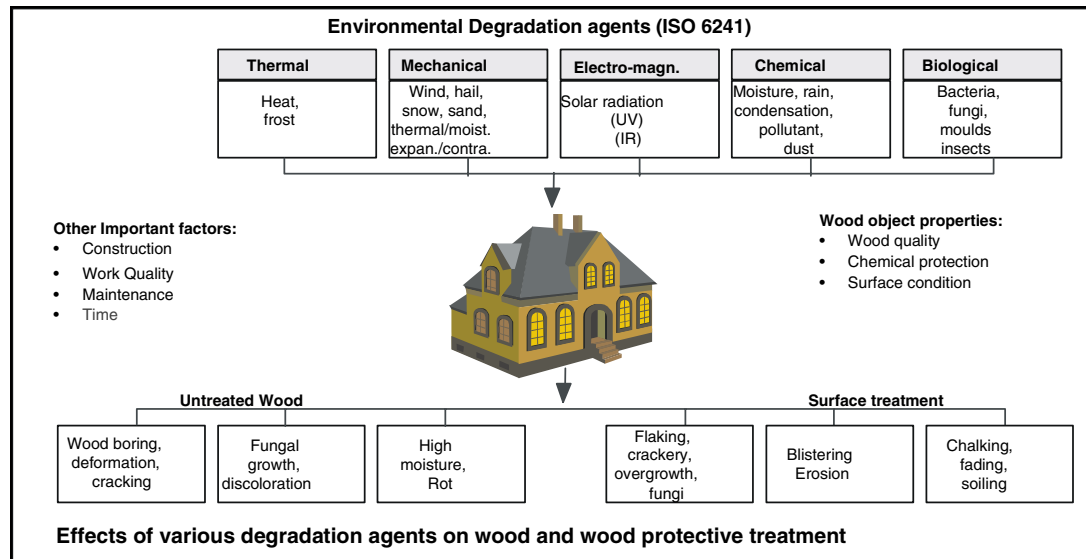


Figure 7: Degradation of wooden objects – model of degradation factors and their observed effects.

Table 5: Types of damages for the various materials in the Damage Atlas

Wood Constructive	Wood Substrate	Wood Surface Treat	Adjoining materials	Rendering and Brick	Natural Stone
Racking	Dry rot fungus	Cracking	Cracking	Crack in masonry	Crack in masonry
Buckling	Other wood rotting fungi	Mildew fungi	Wetness	Crack in unit	Crack in stone
Deflection	Soft-rot	Flaking	Discoloration	Crack in joint	Crack in joint
Shear	House longhorn beetle	Overgrowth	Overgrowth	Exfoliation	Exfoliation
Mechanical cracking	Other wood boring beetles	Blistering	Deformation	Sanding	Sanding
Deformation	Ants	Fading Discolouring	Flaking	Crust	Crust
Open joints	Mould	Chalking	Open joints	Glazed clay bricks	Staining/chromatic alteration
Missing parts	Algae Mosses Lichens Plants	Wearing	Missing parts	Organic growth	Organic growth
Shifting	High moisture content	Soiling	Corrosion	Efflorescence	Efflorescence
Forced parts			Scaling	Crumbling of Bricks	Relief
Spiral grain			Destroyed parts	Crack in render	Material loss
			Rising dampness	Crack in render and substrate	
			Sod roof damages	Rendering without adhesion	
				Sores disintegration	
				Delamination	
				Discoloration	

3.3.1.1 Location of the symptom

The buildings are divided into building elements, and the registration of symptoms may be done on different levels depending on the purpose of the inspection. The used system for building element is from the Norwegian standard NS3451 Table for building elements (NS3451, 1988) or other national or specific standards.

The buildings elements are categorised by physical parts of the building. For relation Building element to Building element, the Building elements at 1st level are related to those one on the 2nd level, they one on 2nd level to those one on 3rd level, and so on. The proposed system is shown in Table 6.

Table 6: Building elements on different levels for location of symptoms based on NS3451.

Code			Building Part
0			Not on Use
1			Floors, storeys
	11		Rooms
2			Building
	21		Ground and foundation
		214	Foundation
		215	Load-bearing layer
		216	Draining, Land draining
	22		Load-bearing system
		221	Frames
		222	Pillar, Column
		223	Beam
	23		Outer wall
		231	Primary Construction
			2311 Main construction
			2312 Insulation
			2313 Timber frame
			2314 Tightening layer
			2315 Nailing strip, stud
		233	Windows and doors
			2331 Window frames
			2332 Window glass
			2333 Surface treatment
			2334
		234	Outside covering and surface
			2341 Outside panel
			2342 Rendering
			2343 Paint
		235	Inside covering and surface
			2351 Panel
			2352 Rendering
			2353 Paint

		237		Equipment
			2371	Ventilator
	24			Inner wall
		241		Primary construction
			2411	Main construction
			2412	Insulation
			2413	Timber frame
			2414	Tightening layer
			2415	Nailing strip, stud
		243		Windows and doors
			2431	Window frames
			2432	Window glass
			2433	Surface treatment
			2434	
		245		Covering and surface
			2451	Panel
			2452	Rendering
			2453	Paint
		247		Equipment
	25			Floors
		251		Primary construction
			2511	Main construction
			2512	Insulation
			2413	Timber frame
			2414	Tightening layer
			2415	Nailing strip, stud
3				HVAC
4				Electrical power
5				Tele and automation
6				Other installations
7				Outside
8				Environmental conditions
	81			Meteorological data
	82			Pollution data

The damage atlas should give some indications on where in the building the damage may occur, which building element and what kind of building material.

The numbering of elements in the categories must follow defined rules, and the orientation system developed in Wood-Assess is used, as follows:

- The different facades are numbered anti-clockwise, beginning at the facade with the main entrance.
- The floors are numbered from bottom to top
- The numbering of elements in the facade or roof follows either the direction left to right or direction bottom to top.

3.3.1.2 Defining the type of damage and possible degradation agents

In buildings there might be several types of damages due to different deterioration factors. The deterioration factors can be either material dependent or material independent. The material dependent deterioration can be divided into predictable and accidental damage. Predictable damages are the result of use, lack of maintenance and the environmental risk conditions such as climate etc. The accidental damages are the result of variable state of the materials or the use of treatment due to errors.

In this condition survey the types of degradation agents are classified according to their nature according to ISO 6241 (ISO 6241, 1984):

- thermal,
- mechanical,
- electro-magnetic,
- chemical, and
- biological.

This systematisation implies that the agents are listed according to their own nature and not to the nature of their action on the building and components; for example, a thermal agent may have a physical action (for example thermal expansion) or a chemical action (for example catalysis); a chemical agent like water may have a physical action (for example swelling) or a chemical action (for example hydration dissolution); moreover the agents in combination may have additional physical actions (for example wetting followed by freeze-thaw cycles), chemical actions (for example photo-oxidation by atmospheric oxygen and solar radiation) or biological actions (for example spread of roots).

Thermal agents may be divided into:

- heat,
- frost,
- fire, and
- explosion.

Mechanical agents may be divided into:

- Snow and rain loads,
- overloads,
- ice formation pressure,
- thermal/moisture expansion/contraction,
- settling of building grounds,
- movement of building grounds,
- vandalism, abnormal use,
- erosion,
- external impact, and
- vibrations.

Electro-magnetic agents may be:

- solar radiation.

Chemical agents may be divided into:

- air humidity,
- driving rain,
- condensation,
- soil moisture,
- ground water,
- surface water,
- seepage, leakage,
- water splash,
- internal moisture,
- oxygen,
- ozone,
- NO (NO_x),
- carbonic acid (CO₂),
- sulphuric acid,
- bird dropping,
- brine (salty fog),
- neutral dust, soiling, and
- vandalism – graffiti.

Biological agents may be divided into:

- plants,
- bacteria,
- moulds,
- lichens,
- mosses,
- algae,
- fungi,
- roots,
- insects,
- birds, and
- rodents.

Causes for accidental or predictable damages as result of variable state of the materials, bad craftsmanship, or lack of maintenance, may be:

- material incompatibility,
- leakage from the roof,
- no horizontal barrier,
- hole in the gutter,
- missing roof tile,
- damage on the roof,
- plugged drain,
- no cladding on the weathering side,
- bad timber quality,
- missing construction part,
- incorrect wood connection,
- water traps,

- large joint, and
- wrong construction design for heat insulation.

These causes may also be registered as observations, with own Consequence degree and Recommended actions.

3.3.1.3 Description of the symptoms

As a basis for identifying the types of damage, the damage atlas gives a description of the most characteristic symptoms and an explanation of how to identify them. The description should include an explanation how to measure the extent of symptoms.

This description should include information on where in the building the damage may occur, what building elements are most exposed.

3.3.2 Questions linked to observations

3.3.2.1 Type of material

For each of the following category of symptoms, possible types of material are predefined:

- Wood constructive parts
- Wood substrate
- Wood protective treatment
- Adjoining materials
- Natural Stone
- Rendering
- Brick

The list may be prolonged, and the materials may be subdivided further, for example:

Wood constructive parts and **Wood surface** cover the different types of wood, as:

- spruce,
- pine,
- oak,
- silver fir,
- hard wood, and
- soft wood.

Wood protective treatment covers different wood surface treatments as:

- paint (film-forming paint),
- linseed oil base
- alkyd oil base,
- acrylic latex base,
- polyurethane base
- stain (penetrating)
- traditional coating,
- tar,
- composite paint,
- Swedish red paint,
- preservation treatment,

- water-borne preservation,
- creosote,
- boron compound, and
- unknown

Adjoining materials can be all kinds of materials, and there is not made one predefined list. Type of material has to be considered when defining each observation for the damage atlas.

Examples of adjoining materials used in the system are:

- clay,
- clay with rendering,
- brick,
- brick with rendering,
- metal,
- bitumen millboard,
- plastic foil,
- heat insulation,
- mortar,
- concrete,
- sealant,
- sod, turf,
- slate,
- tile,
- asbestos cement, and
- birch bark.

Natural stone covers different type of stone, as:

- sandstone,
- limestone,
- marble,
- granite,
- slate,
- tuff,
- travernite,
- soap stone,
- other, and
- unknown.

and mortars connected with natural stones, as:

- lime mortar,
- hydraulic lime mortar,
- cement mortar,
- mortars with organic binders, and
- other type of mortar.

Brick covers different type of units, as:

- low burned clay brick units,
- high burned clay brick units,

- ancient clay bricks,
- glazed units,
- unburned clay units,
- other, and
- unknown,

and different types of mortars, as:

- lime mortar,
- hydraulic lime mortar,
- cement mortar,
- lime cement mortar,
- masonry cement mortar,
- ancient clay mortar,
- other type of mortar, and
- unknown

Rendering covers different type of rendering systems.

3.3.2.2 Extent of the symptom

As a basis for identifying the types of damage, the Damage Atlas gives a description of the most characteristic symptoms and an explanation of how to identify them.

In order to describe consequences of a damage, the extension of the damage must be given. A reference system for the area and depth of the damage is used for some of the damages. For other damages only the area of the damage is necessary. The Damage Atlas gives all the necessary questions for describing the extension for each damage.

3.3.2.3 Condition degree based on Pictures

The condition is described by means of condition degrees. The condition degrees are based on a description of the symptoms and on a visual observation based on typical pictures characterizing the damage degree. This will contribute to an increased objectivity in the expression of the condition.

The following degrees shall be used:

Condition degree 0: No symptoms

Condition degree 1: Slight symptoms

Condition degree 2: Medium-Strong symptoms

Condition degree 3: Strong symptoms (includes a collapse and malfunction)

3.3.2.4 Type of instrument/investigation method

To be able to identify the symptoms, sometimes only a visual investigation and possible comparison with pictures is enough. However, in most cases there will be a need to use some investigation tools. The investigation methods necessary to identify the damage must be given in accordance to the description of the damage.

The most commonly used investigation techniques are described in Table 7. Many of these are the same regardless of material. From the Damage Atlas it is concluded that visual inspection is always used and for many damages of the only one necessary to use. In the different

Damage descriptions, these investigation methods are in some cases more thoroughly described. A more extensive list of investigation methods and tools are described in the Wood Assess project report (Haagenrud et al, 1998, Veit et al, 1998).

Table 7: Investigation methods for the different materials

Wood Constructive	Wood Substrate	Wood Surface Treat	Adjoining materials	Rendering and Brick	Natural Stone
Visual	Visual	Visual	Visual	Visual	Visual
Drill resistance	Knife	Knife	Salt detection device	Callipers	Knife
Endoscopy	Magnifying glass	Magnifying glass	Hygrometer	Magnifying glass	Magnifying glass
Ruler	Microscope	Adhesive tape	Microscope	Water for suction	Microscope
Thermograph	Moisture meter	Colour Atlas	Thermograph	Moisture meter	Salt detection device
	Drill resistance tool		Extensometer	Salt detection device	

3.3.2.5 Possible degradation agents

In this condition survey the types of degradation factors are divided into the following groups:

- Thermal
- Mechanical
- Electro-magnetical
- Chemical
- Biological

All damages have to be characterised with one possible degradation agent, and if possible in addition the more detailed categorisation of the agents.

3.3.2.6 Possible causes

In addition to the 5 main degradation agents, possible causes for the damage may be defined. The types of possible causes vary among the different materials. The reasons can be from different building techniques, depending on material used, to different response to environmental impact. The most typical causes for different materials are shown in Table 8. The table shows that High Moisture Content is a very typical cause almost regardless of material, which of course is to be expected. The typical causes are described in some detail in the specific reports and also in connection with the recommended actions suggested in these reports.

Table 8: Types of the most typical causes for the different materials

Wood Constructive	Wood Substrate	Wood Surface Treat	Adjoining materials	Rendering and Brick	Natural Stone
High moisture content	High moisture content	High moisture content	High moisture content	Inadequate quality	High moisture content
Overloading		UV-radiation	Frost	Lack of compatibility	Frost
Lack of maintenance		Improper preparation	Incorrect design	Poor workmanship	Improper treatments
Moving of settlements		Large variations in surface temperature	Wrong positions		High salt content
		High variations in moisture content	Chemical transformation due to air pollution		Chemical transformation due to air pollution

3.3.2.7 Total condition degree (TCD)

This is an overall evaluation of the damages based on both the visual inspections, the results of the investigations by measurements and the extent of the symptoms. The evaluation of the total condition degree can be done partly in the field and partly in office. The total condition degree is based on evaluation of one or more individual symptoms or an overall evaluation of a set of symptoms. The symptoms indicate the condition in relation to the reference level on which the evaluation of the condition is based. If possible a description of limit states for degradation shall be taken into consideration, such as for example Total condition degree=3 comply with 70% loss of strength.

The TCD shall be used for the evaluation of the consequences. The following degrees shall be used: TCD 0: No symptoms

TCD 1: Slight symptoms

TCD 2: Medium-Strong symptoms

TCD 3: Strong symptoms (includes a collapse and malfunction)

3.3.2.8 Degree of consequences

The consequences of the registered condition shall be evaluated as a basis for recommendations of actions. The consequence degree is established for one or more individual consequences or collectively for a set of consequences.

The following degrees shall be used:

Consequence degree 0: No consequences

Consequence degree 1: Slight consequences

Consequence degree 2: Medium-Strong consequences

Consequence degree 3: Strong consequences

The consequences have to be assessed in connection with the time perspective of the condition survey. In long term all consequences will be serious.

3.3.2.9 Probability of occurrence of non-acceptable condition and Risk

The risk attached to a construction or building element is determined by the probability that a non-acceptable condition (failure) or situation will occur or further develop. Often a detailed analysis is required to determine the probability for a non-acceptable condition to occur. In most cases, this will be performed by a probabilistic approach (Moser, 1999). In this connection evaluation of probability means:

- Probability that possible hidden failure is real
- Probability that an insufficiently documented structure hides failure
- Probability that a condition will become worse
- Probability that situations will occur where failure leads to consequences

Risk is determined by the combination of probability and consequences. This is shown in Figure 8. Low probability combined with serious consequences give the same risk as high probability combined with minor consequences. In connection with the assessment of risk it is important both to evaluate the technical risk for the item as such and the risk for the user or third part. This is related to the consequences on which the assessment is based. It shall be specified which consequences that have been used as a basis for the specification of risk.

- Consequences with regard to aesthetics (for surfaces) or economy (related to maintenance) will normally reflect the risk for the item as such.
- Consequences with regard to health/environment will normally reflect the risk for the user.
- Consequences regard to safety may reflect the risk for the user or third part.

The following degrees for risk shall be used:

- Low
- Medium
- High

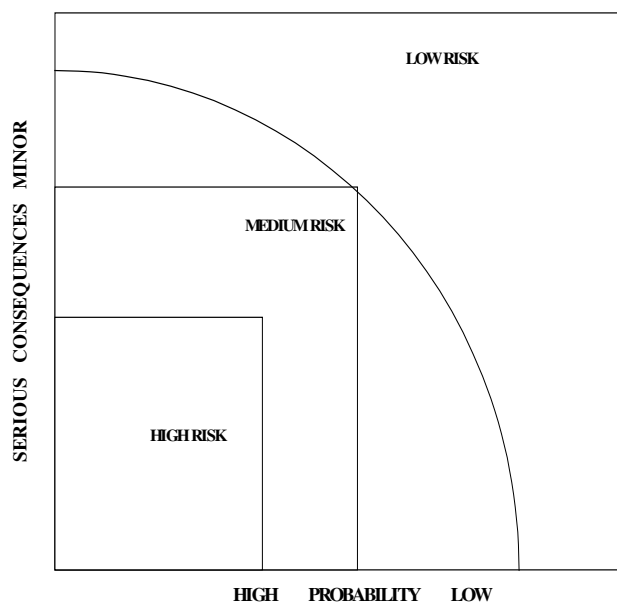


Figure 8: Relations between Consequences, Probability, and Risk.

3.3.2.10 Recommended action

Recommended actions are based on the consequences and shall be specified and given priority in accordance with the purpose of the survey. Also other issues, like cultural, historical or aesthetic value of the building or the specific building part have an influence on the recommended action.

3.4 The Damage Atlas

The complete Damage Atlas with about 73 damages is given in the separate deliverable Damage Atlas (Eriksson, 2000). Here is described about two examples of damages on each of the ingoing materials

3.4.1 Wood, constructive parts

The complete set of examples concerning wood, constructive parts is found in MMWood report ENV4-CT98-0796 D02.01WC. Damage atlas for constructive wooden parts indoor and outdoor (Riks and Ney, 2000).

3.4.1.1 Deflection or bending

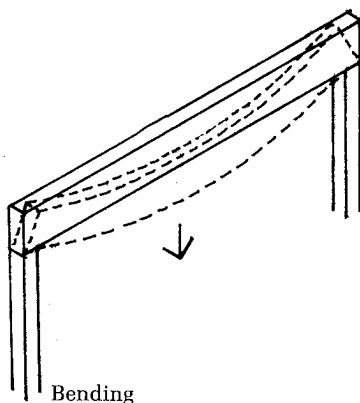
Type of material:

All kind of wood.

Description of the symptoms:

Downward deformation of horizontal load-bearing construction members of wood, with direction either into the centre of the field (following the static moments line) or towards one of the points of support.

Deflection or bending, Example drawing:



Extent of the symptoms:

The seriousness of the deflection depends on the local circumstances like dimension of the beam itself, the length and width of the structural member and the load on it. Only the fact that there is a deflection existing does not necessarily lessen the functionality of the beam.

Condition degrees referred to pictures:

Condition degree 0:

No symptoms

Condition degree 1:

Slight symptoms.

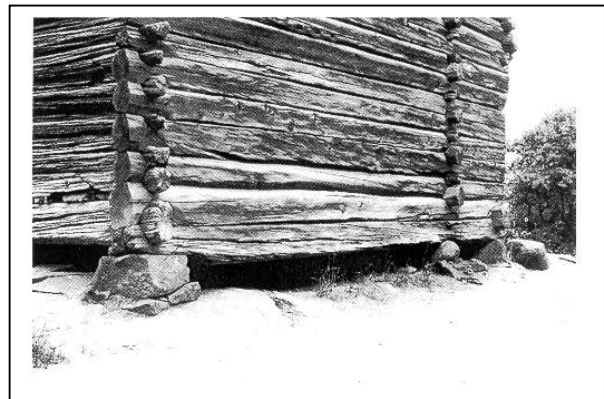
Deflected ceiling; the top perimeter line of the white wall painting is horizontal.



Condition degree 2:

Medium-strong symptoms.

Log construction with deflecting sill. The tensile load at the corner points is increased strongly and leads to open joints in the wall and to damages at the wood joints. The floor inside is also deflecting.



Condition degree 3:

Strong symptoms (includes also collapse and malfunction).

Downstand beam deflected to destruction, post as temporary precaution.



Investigation methods:

Visual. Measurement of the extent of deflection.

Possible degradation agents:

Mechanical

Possible causes:

- Overloading and/or too small dimensions of the structural member.
- Failures of load transmission to neighbouring structural members below, i.e. missing parts
- Damages caused by moisture, insects or fungi that weaken the strength of the wooden material.
- Historical reasons.
- Movement of settlement, insufficient foundation.
- More than one kind of foundation for the same building.

Total condition degree:

Total condition degree 0: No Symptoms

Total condition degree 1: Slight symptoms: Deflection existing, but there is no need for action.

Total condition degree 2: Medium-strong symptoms: The deflection needs actions to be taken in the static system, but the damage **covers** only a small part of the construction

Total condition degree 3: Strong symptoms (includes also collapse and malfunction): The damage is situated in an important part of the static system. It is a strong need for actions to be taken and temporary safety measures might also be necessary.

Consequences:

Consequence degree 0: No consequences

Consequence degree 1: Minor consequences: The owner or user has to decide whether the total condition degree disturbs the plans for the use of the building

Consequence degree 2: Medium consequences: The use of the building is reduced, ~~it must~~ **be** a static repair is necessary

Consequence degree 3: Serious consequences: There is a danger of a collapse of the roof, a building section or the whole building

Recommended actions:

The reasons for the deflection or bending have to be assessed, and experts have to be consulted.

Addition of a load-bearing post or other supporting measures if necessary. If that is not possible, installation of a better load-bearing element or entire system should be considered. Temporary safety measures are necessary at degree 3.

3.4.1.2 Cracking, mechanical

Type of material:

All kind of wood.

Description of the symptoms:

Breaking of the wood substrate grains in transverse direction to the wood fibres.

Extent of the symptoms:

Starting with a fissure crosswise to the wood substrate grains up to the complete break in two parts. The seriousness of the cracking has to be evaluated statically.

Condition degrees referred to pictures:

Condition degree 0:

No symptoms

Condition degree 1:

Slight symptoms.

Rathenow, Zietenkasernen. Caused by fungal infection one piece of the floor is broken



Condition degree 2:

Medium-strong symptoms.

Cracked purlin in the roof.



Condition degree 3:

Strong symptoms (includes also collapse and malfunction).

Pieces of roof trusses are broken because of forcing.



Investigation methods:

Visual, in many cases it is only possible if the element is not cladded. Measurement of the extent (width and depth of the cracking), drill-resistance measurement.

Possible degradation agents:

Mechanical

Possible causes:

- Overloading and/or too small dimensions of the structural member
- Breakdown of the wood substrate by other reasons (damage by moisture or fungi or other)
- Failures of load transmission at other structural members above
- Degree 3 of a deflection.

Total condition degree:

Total condition degree 0: No Symptoms

Total condition degree 1: Slight symptoms: If there is only a fissure, in most cases no action is necessary at this point. The extent of overloading has to be checked and possibly a supporting strap must be added.

Total condition degree 2: Medium-strong symptoms: The cracking extent is more than 50% of the log. The structural members can no longer fulfil their function; help by additional carcassing timbers might be necessary.

Total condition degree 3: Strong symptoms (includes also collapse and malfunction): The log is completely broken. Replacement with a similar or a new (different) part is necessary.

Consequences:

Consequence degree 0: No consequences

Consequence degree 1: Minor consequences: Small repair is necessary.

Consequence degree 2: Medium consequences: There are consequences for the static system of one section of the building. The broken part changes the load application of the other structural parts of a section of the building

Consequence degree 3: Serious consequences: There is a danger of a collapse of the structural member(s).

Recommended actions:

The reasons for the cracking have to be assessed, experts have to be consulted. Shoring might be necessary.

3.4.2 Wood substrate

The complete set of examples concerning wood substrate is found in MMWood report ENV4-CT98-0796 D02.01WS Damage Atlas for Wood Substrate (Andersen and Jenssen, 2000). Information concerning recognising wood rot is among others from Bravery et al, 1987.

3.4.2.1 Dry rot fungus

Type of material

All wooden material, preferably in contact with bricks/mortar (the fungus needs lime or other basic material).

Description of the symptoms

Deformation of the wooden structure, softening of the wood, changing of the colour into dark brown and cracking (large cubic cracks) of the wooden surface.

Extent of the symptoms

The extent of the symptoms is dependent on the area and depth of the damage and the remaining strength of the materials. These factors must be evaluated in connection with where the damage is situated in the construction.

Condition degrees referred to pictures

Condition degree 0:

No symptoms

Condition degree 1:

Slight symptoms

Growth of the fungus mainly on the surface, no or very little softening of the wood.



Condition degree 2:

Medium-strong symptoms

Some decay of the wood is observed. The wooden construction still has more than 50 % of its original strength. Often extensive growth of fungal mycelium.

Condition degree 3:

Strong symptoms (includes collapse and malfunction)

Severe decay of the wood. The wooden construction has less than 25 % of its original strength. Often extensive growth of fungal mycelium.



Investigation methods

Visual examination, or by the use of knife or a drilling instrument. If necessary, samples of wood and/or surface growth should be taken for examination under the microscope.

Possible degradation agents:

Biological - Fungi

Possible causes:

Moisture above the critical level (20 %) in the wood for a critical period of time. The rot will start to develop with a temperature of + 5 ° C or more and if there is calcareous material in the vicinity (the fungus use the basic calcareous substance to neutralise the acid it produces). The optimal growth temperature is between 18 – 25 ° C and it will stop growing at 30 ° C. The high moisture level may be due to several factors.

Total condition degree

If the damage is caused by dry rot fungus, it is of outermost importance that the total extent of the damage is described. The fungus can cause severe damage, and spreads easily to other parts of the construction. When the damage appears in constructive parts it is most severe.

Total condition degree 0:	No symptoms
Total condition degree 1:	Slight symptoms
Total condition degree 2:	Medium-strong symptoms
Total condition degree 3:	Strong symptoms (includes collapse and malfunction)

Consequences and risks

Deformation of the wood can cause severe technical damage (depending on where the damage is situated), and lead to breakdown of the part in question. In the surface growth and in the degraded wood microfungi and other microbes can be found (mould, mites, insects, etc.) which may cause a deterioration of the indoor climate if the spores and/or parts of the microbes are spread to the indoor air.

Consequence degree 0:	No consequence
Consequence degree 1:	Minor consequence
Consequence degree 2:	Medium consequence
Consequence degree 3:	Serious consequence

Recommended actions

Damaged wood should be replaced, and bricks/concrete should be treated with chemicals. The cause of the damage/moisture penetration should always be assessed and the damaged repaired. If there are elements (constructive parts, painting etc.) with high aesthetic or historical value, experts should be consulted.

3.4.2.2 Other wood-rotting fungi

Type of material

All wooden material.

Description of the symptoms

Deformation of the wooden structure, softening of the wood, changing of the colour, and often cracking of the wooden surface. White-rot fungi give the wood a white appearance, and the wood becomes fibrous. Brown-rot fungi gives the wood a darker brown appearance, and the wood will crack in small - medium cubic cracks. Sometimes the outer surface will appear intact and not damaged (outer shell of one to several cm), but the wood might still be damaged. Common brown-rot fungi are *Coniophora puteana* (the cellar fungus), *Antrodia* sp., *Gloeophyllum* sp., *Paxillus panuoides* and *Dacrymyces stillatus*. Common white-rot fungi are *Phellinus* sp., *Corticaceae* sp. and *Donkioporia expansa*.

Extent of the symptoms

The extent of the symptoms is dependent on the area and depth of the damage and the remaining strength of the materials. These factors must be evaluated in connection with where the damage is situated in the construction.

Condition degrees referred to pictures

Condition degree 0:

No symptoms

Condition degree 1:

Slight symptoms

Softening or cracking of the wooden surface. Growth of the fungus may be seen on the surface, but is not always present.



Condition degree 2:

Medium-strong symptoms

Some decay of the wood is observed. The wooden construction still has more than 50 % of its original strength. Growth of the fungus may be seen on the surface, but is not always present.



Condition degree 3:

Strong symptoms (includes collapse and malfunction)

Severe decay of the wood. The wooden construction has less than 25 % of its original strength. Growth of the fungus may be seen on the surface, but is not always present.



Investigation methods

Visual examination, or by the use of knife or a drilling instrument. If necessary, samples of wood and/or surface growth should be taken for examination under the microscope. One should be aware that it might happen that cracks in the wooden surface are hidden by an intact paint film. If the wood is dry on the surface an attack of *D. stillatus* can be difficult to detect, but by adding some water on the surface, the fungi will appear more clearly.

Possible degradation agents:

Biological – Fungi

Possible causes:

Moisture above the critical level (20 %) in the wood for a critical period of time. The rot will start to develop with a temperature of + 5 ° C or more. The optimal growth temperature is between 18 – 25 ° C and it will stop growing at 30 ° C. White-rot fungi seem to develop in connection to very high moisture levels in the materials (leakage). The high moisture level may be due to several factors.

Total condition degree

The total condition degree is dependent on many factors; where in the construction is appears, whether the damage is active or not, the chances for a high moisture level in the area in the future a.s.o.

- Total condition degree 0: No symptoms
- Total condition degree 1: Slight symptoms
- Total condition degree 2: Medium-strong symptoms
- Total condition degree 3: Strong symptoms (includes collapse and malfunction)

Consequences and risks

Deformation of the wood can cause severe technical damage (depending on where the damage is situated), and lead to breakdown of the part in question. In the surface growth and in the degraded wood microfungi and other microbes can be found (mould, mites, insects, etc.) which may cause a deterioration of the indoor climate if the spores and/or parts of the microbes are spread to the indoor air.

- Consequence degree 0: No consequence
- Consequence degree 1: Minor consequence
- Consequence degree 2: Medium consequence
- Consequence degree 3: Serious consequence

Recommended actions

Damaged wood should be replaced if it has little strength left and/or there is a certain possibility that the area might suffer from high moisture level in the future. The cause of the damage/moisture penetration should always be assessed and the damaged repaired. If there are elements (constructive parts, painting etc.) with high aesthetic or historical value, experts should be consulted.

3.4.3 Wood surface treatment

The complete set of examples of damages in connection with wood surface treatment is found in MMWood report ENV4-CT98-0796 D02.01WST Environmental Damage Wood Surface Treatment (Eriksson, 2000).

3.4.3.1 Blistering

Type of material:

Paint films

Description of the symptom:

Blisters on the paint film. These blisters are filled with air or liquid. The blisters can be of very different size.

Extent of the symptom:

It is important to estimate the total area affected by blistering and especially which are at the walls.

Condition degrees referred to pictures:

Condition degree 0:

No symptoms

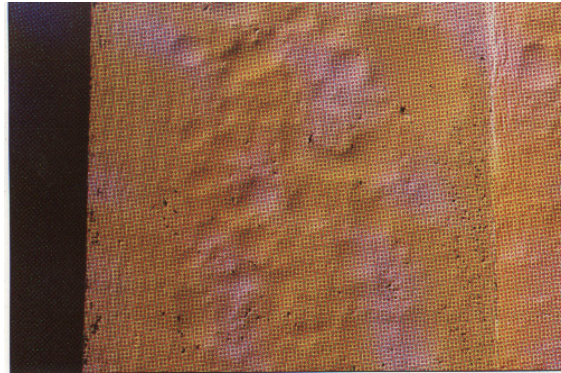
Condition degree 1:

Few and small blisters. Limited damage.



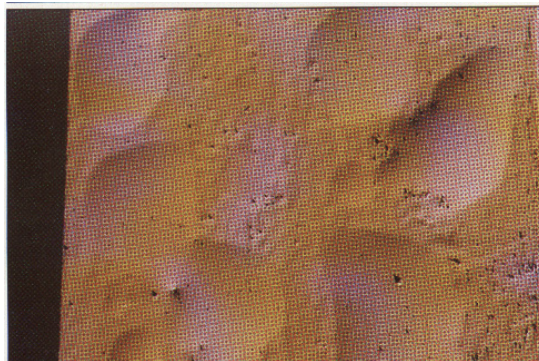
Condition degree 2:

More and larger blisters. The extension of the damage is increasing.



Condition degree 3:

Blisters cover large areas and are of bigger size.



Investigation methods:

Visual

Possible degradation agents:

Chemical – moisture

Possible causes:

There are several different types of blistering, where the most common are from sun and linseed oil. Blistering from the sun starts when the paint is only skin-dry and is exposed to solar radiation. Only the latest applied paint film starts to blister and the blisters are often rather small. Linseed oil blisters are often larger and are mostly on walls exposed to the sun. Blisters on acrylic paint often include water and can lead to more severe damages.

Total condition degree:

Total condition degree 0: No symptoms

Total condition degree 1: Slight symptoms – few and small blisters

Total condition degree 2: Medium-strong symptoms, more and often larger blisters

Total condition degree 3: Strong symptoms, an extend part of the surface is covered with blisters.

Consequences:

Consequence degree 0: No consequences

Consequence degree 1: Slight consequences

Consequence degree 2: Medium-strong consequences

Consequence degree 3: Strong consequences

Recommended actions:

- Consequence degree 0: No action
- Consequence degree 1: Repainting on the blisters
- Consequence degree 2: Removal of all previous paint on the area affected before repainting
- Consequence degree 3: Removal of all previous paint on the area affected before repainting.

3.4.3.2 Overgrowth

Type of material:

Paint films

Description of the symptom:

Overgrowth of algae, lichen and moss especially on parts exposed to high moisture over an extended period of time.

Extent of the symptom:

Overgrowth is a slow process and in the beginning mostly a cosmetic damage. It is important to estimate the total area affected by the overgrowth.

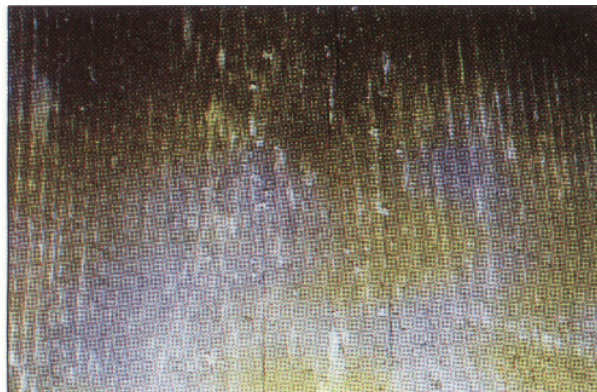
Condition degrees referred to pictures:

Condition degree 0:

No symptoms

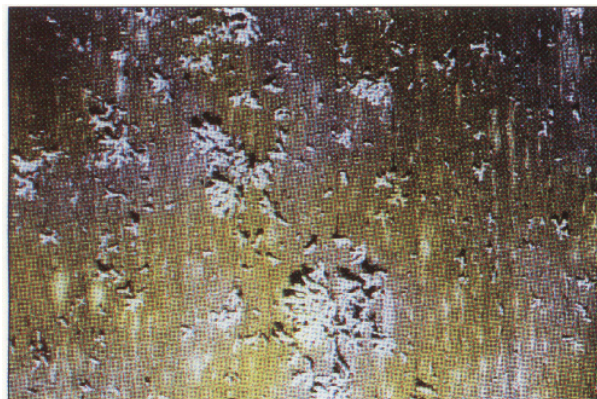
Condition degree 1:

Small signs of growth, a more thorough investigation may be necessary to detect the difference between for instance algae and dirt.



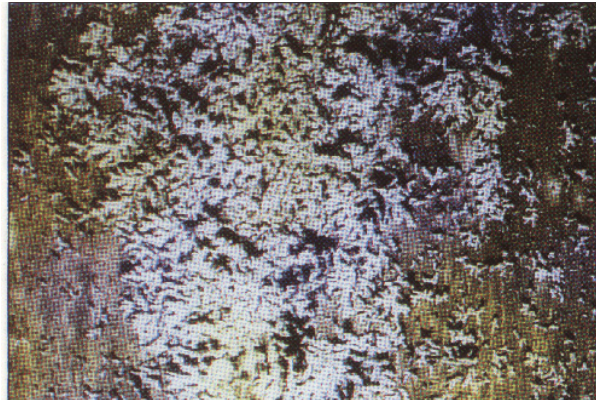
Condition degree 2:

Significant growth on the surface leading to the disappearance of part of the paint film.



Condition degree 3:

Areas of the paint film are covered, could be more severe damages underneath.



Investigation methods:

Visual.

Possible degradation agents:

Biological.

Possible causes:

A high moisture content or direct contact with water is necessary to develop the overgrowth.

Total condition degree:

Total condition degree 0: No symptoms

Total condition degree 1: Slight symptoms

Total condition degree 2: Medium-strong symptoms

Total condition degree 3: Strong symptoms

Consequences:

Consequence degree 0: No symptoms

Consequence degree 1: Slight symptoms

Consequence degree 2: Medium-strong symptoms

Consequence degree 3: Strong symptoms

Recommended actions:

Consequence degree 0: No action

Consequence degree 1: Cleaning with water and soap

Consequence degree 2: Remove the overgrowth and investigate further damages

Consequence degree 3: Remove the overgrowth and investigate further damages

3.4.4 Adjoining materials

The complete set of examples for damage description in connection to adjoining materials in wooden houses is found in the MMWood report ENV4-CT98-0796 D02.01AM Environmental Damages to Adjoining Materials (Garofolo, 2000).

3.4.4.1 Rising dampness

Type of material:

Wood, stone and brick masonry, rendering

Description of the symptom:

Lengthwise diffused stain of variable dimension and colour, close to the ground level, due to the rising water from the underground; decreasing intensity on the way up. Possible efflorescence, detaching and swelling of finishing layers. Organic growth (algae, mosses, mould, etc) and pathogens can be found locally.

Extent of the symptom:

Limited damage close to the ground level, in full contact with the ground.

Condition Degrees referred to pictures:

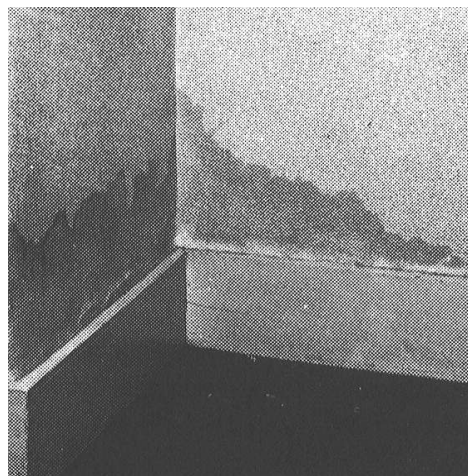
Condition degree 0:

No Symptoms

Condition degree 1:

Slight Symptoms

Rising water sign on the wall slightly visible. Readability of the different level reached by the water after recurring wet-dry cycles. No efflorescence.



Condition degree 2:

Medium-strong Symptoms

Clearly visible stains of medium intensity; possible efflorescence presence; slight cracking and overgrowth of finishing layers.



Condition degree 3:

Strong Symptoms

Dark continuous stains; marked efflorescence; persisting organic growth; wide cracking and detaching of finishing layers.



Investigation methods:

Visual detection. Measurement of % content of water or core recovery or drilling sample (stone powder) for measurement of dampness load of stone materials in different heights and depths in masonry. Investigation of salt load (quality and quantity) due to causes of damages.

Possible degradation agents:

Chemical – humidity, moisture

Possible causes:

Lack of the waterproof barrier, lack of ventilation at foundation level. Accidental contacts with the ground. Inadequate building technique.

Total Condition degree:

Total condition degree 0: No symptoms

Total condition degree 1: Slight symptoms. Rising water up to few centimetres, for a limited thickness of the wall. % content of water within acceptable values, depending on the material.

Total condition degree 2: Medium-strong symptoms. Rising water up to 30 centimetres. % content of water just over the acceptable values, depending on the material. Efflorescence and organic growth localised in limited areas.

Total condition degree 3: Strong symptoms. Rising water over 30 centimetres, with high % content of water lengthwise diffused efflorescence and organic growth.

Consequences and risks:

Consequence degree 0: No consequences

Consequence degree 1: Minor consequences. Readability of water traces on the plaster, discoloration of wood, i.e. aesthetic consequences

Consequence degree 2: Medium consequences. Flaking of finishing layers.

Consequence degree 3: Serious consequences. Detaching of finishing materials, flaking and following lacking of mortar. Rotting of wooden parts. Cracking due to the sensitivity to frost.

Recommended actions:

At first it is important to clarify the causes for the rising dampness, for example by boring investigations and by laboratory methods

Consequence degree 0: No action

Consequence degree 1: Repair of finishing layers (painting with protective materials, open for diffusion), control/repair of ventilation in cellars and floors.

Consequence degree 2-3: Ventilation of foundation wall, waterproof barrier at the foundation level, external cavity walls, injected damp-proof courses, waterproof plastering surfaces, high capillarity tubes in the ground.

3.4.4.2 Wetness

Type of material:

Wood, stone and brick masonry, rendering, metal roofing plates

Description of the symptom:

Limited stains of variable dimension and colour, due to the condensation (cold bridges), to the leakage at roof and pipe level, damages at chimney pots; decreasing intensity on the way down; stains with constant intensity. Possible efflorescence and detaching and swelling of finishing layers. Organic growth (algae, mosses, mould, etc) and pathogens can be found locally.

Extent of the symptom:

Damages localised at the level of the floor, around the openings, along the length of the cavity containing pipes or chimney.

Condition Degrees referred to pictures:

Condition degree 0:

No Symptoms

Condition degree 1:

Slight Symptoms

Slightly visible stains and efflorescence.



Condition degree 2:

Medium-strong Symptoms

Clearly visible stains of medium intensity, accentuated stains after rains and or concentrated in cold areas; possible efflorescence presence; slight cracking and overgrowth of finishing layers.



Condition degree 3:

Strong Symptoms

Dark continuous stains; marked efflorescence; persisting organic growth; wide cracking and detaching of finishing layers.



Investigation methods:

Visual detection. Measurement of % content of water (hygrometer with deep electrodes for direct measurements or with the speedy moisture tester using CaC₂, calcium carbide) or core recovery or drilling sample (stone powder) for measurement of dampness load of stone materials in different heights and depths in masonry. Investigation of salt load (quality and quantity) to assess the causes of the damages.

Possible degradation agents:

Chemical – humidity

Possible causes:

Lack or cracking of the waterproof barrier, lack of insulation or vapour barrier, lacking of ventilation in the inner spaces, leakage of pipes and roof finishing material, inadequate material for the finishing layers, cracking of the finishing layers.

Total Condition degree:

Total condition degree 0: No symptoms

Total condition degree 1: Slight symptoms. Small limited stain penetrating a limited thickness of the wall. % content of water within acceptable values, depending on the material.

Total condition degree 2: Medium-strong symptoms. Wide stains with a % content of water just over the acceptable values, depending on the material. Efflorescence and organic growth localised in limited areas.

Total condition degree 3: Strong symptoms. Strong symptom: wide and dark stains, with high % content of water. Lengthwise diffused efflorescence and organic growth.

Consequences and risks:

Consequence degree 0: No consequences

Consequence degree 1: Minor consequences. Readability of water traces on the plaster, discoloration of wood.

Consequence degree 2: Medium consequences. Flaking of finishing layers.

Consequence degree 3: Serious consequences. Detaching of finishing materials, flaking and following lacking of mortar. Rotting of wooden parts. Cracking due to the sensitivity to frost.

Recommended actions:

At first it is important to clarify the causes for the wetness, for example by boring methods and laboratory methods.

Consequence degree 0: No action

Consequence degree 1: Repair of finishing layers

Consequence degree 2-3: Ventilation of foundation wall, waterproof barrier at the foundation level, external cavity walls, injected damp-proof courses, waterproof plastering surfaces, high capillarity tubes in the ground.

3.4.5 Clay brick masonry and rendering systems

The complete set of examples of damage descriptions for clay brick masonry and rendering systems is found in the MMWood report ENV4-CT98-0796 D02.01RB Environmental Damage to Rendering/Brick (Waldum and Eriksson, 2000). Standardised methods concerning rendering and plastering are for instance CEN EN CBQD-1, CEN prEN 1015-12, and CEN prEN 998-1.

3.4.5.1 Crack in unit

Type of material:

All qualities of clay brick units. For specially hard-burnt clay brick cracks may be of less importance (higher width of crack can be tolerated).

Description of symptom:

Cracks in unit occur normally as vertical cracks in stretcher or head face of the brick. Cracks parallel to the stretcher face can sometimes be a start of a delamination (can indicate a crack through the 1. row of holes in hollow units).

Extent of the symptom:

The width of the cracks, location of units with failure and number of units per m² should be reported.

Condition degrees referred to pictures:

Conditions degree 0:

No symptom

Condition degree 1:

Slight symptoms

Vertical crack $b \leq 0.1$ mm



Condition degree 2:

Medium-strong symptoms



Condition degree 3:

Strong symptoms

No picture available

Investigation methods:

A visual inspection of the surface of the masonry combined with measurements of crack width will be the base for the evaluation. A slight knock with a light hammer on the surface can disclose a deeper delamination.

Possible degradation agents:

Mechanical – overload

Possible causes:

Vertical crack in a clay brick unit can often be traced back to the manufacturing of the unit. Another degradation factors will be frost, overload etc.

Total condition degree:

In order to determine how serious the cracks are freeze/thaw-test of the units should be carried out.

Consequences and risks:

The consequences will to some degree depend on the frost resistance of the unit – limited frost resistance and frost failures can be introduced.

Consequence degree 0: No consequences
Consequence degree 1: Minor consequences
Consequence degree 2: Medium consequences
Consequence degree 3: Serious consequences

Recommended actions:

If frost is detected to be an important degradation cause, units with failures should be replaced.

Consequence degree 3: With frost failures on more than 5 units per m² a replacement of the masonry should be considered. An alternative to a new masonry wall will be to remove all loose material and to apply a rendering with good compatibility to the masonry.

3.4.5.2 Scaling

Type of material:

All kind of clay brick masonry, unit and mortar joint.

Description of the symptom:

On unit: Crater shaped sore on the unit surface. A grain of "unslaked" lime will occasionally be located in the bottom of the crater. An alternative pattern will be small sores on the edge of a unit.

On the mortar joint: The mortar surface is scaling (flaking).

Extent of the symptom:

The area and depth of the damage has to be evaluated in connection to the location of the damage. With carefully use of awl or knife on the scaling spots, the risk for further development of the damage can be estimated.

Condition degrees referred to pictures:

Condition degree 0:

No symptoms

Condition degree 1:
Slight symptoms.

Craters or flakes with $t < 1.0\text{mm}$ in the
unit or mortar joints



Condition degree 2:
Medium strong symptoms



Condition degree 3:
Strong symptoms

Scales with $t > 3-4\text{ mm}$ in unit or
mortar joints.



Investigation methods:

Visual inspection with a precise description of the character of the scaling.

Possible degradation agents:

Mechanical.

Possible causes:

On units: Impurities in the raw material. Surface with properties that differ from the rest of the brick unit. Sores on edge can often be traced back to manufacturing process and transportation.

On mortar joints: Lack of compatibility between the surface material and the background, poor workmanship, unsuitable surface treatment or frost action.

Total condition degree:

Measurement of the area and depth of the scaling.

Consequences and risks:

The consequences are primarily linked to the joints. With insufficient freezing/thawing resistance the scaling of the mortar joints can continue and ruin the tightness and stability of a brick wall.

Consequence degree 0: No consequences

Consequence degree 1: Minor consequences

Consequence degree 2: Medium consequences

Consequence degree 3: Serious consequences. The stability of the wall is reduced.

Recommended action:

Assess the causes for the damage.

Condition degree 3: Units with damages has to be replaced. If joints with failure are spread over a defined area, a repointing should be considered.

3.4.5.3 Crack in render and substrate

Type of material

On all kinds of renders and rendering systems and masonry substrates.

Description of the symptom

The crack normally has a width $b > 0.3$ mm and often a discontinuity over the crack can be registered. In a few cases it is possible to detect the crack on the inside of the wall (massive, single-leaf masonry walls).

Extent of symptom:

It is important to determine the overall amount of cracks both in rendering and substrate (background). The position of the cracks with regard to external loads, openings etc. and the main direction and pattern of the cracks should be reported (can crushing of the render be detected at the edges of the crack?).

Condition degrees referred to pictures:

Condition degree 0:

No symptom

Condition degree 1:

Slight symptoms

Width of crack $b < 0.5$ mm



Condition degree 2:

Medium strong symptoms

Picture lacking

Width of crack $0.5 \text{ mm} < b < 3.0$ mm

Condition degree 3:

Strong symptoms

Width of crack $b > 3.0$ mm



Investigation methods

Visual description of the crack with detection of the location, orientation and length. Measurement of the width of the crack with a calliper, a magnifying glass (compartior) etc. In order to check if the crack goes into the substrate it sometimes will be necessary to carefully remove the rendering over the crack. Measurement of possible movements over a crack can be done using gypsum leads.

Possible degradation agents:

Mechanical – Settlement of the ground

Possible causes:

Vertical cracks clear down to the ground and sloping cracks often located near corners can often be traced back to settlement of the ground. Local deformations caused by vertical and lateral loads and poor bond between the materials in the masonry (unit and mortar) will be another factors that can cause cracks. Unsatisfactory use of control joints in the masonry is also an ordinary degradation factor.

Total condition degree:

Total condition degree 0: No symptoms.

Total condition degree 1: Slight symptoms. Width of crack < 0.3 mm.

Total condition degree 2: Medium strong symptoms. Width of cracks $0.5 \text{ mm} < b < 3.0 \text{ mm}$.

Total condition degree 3: Strong symptoms. Width of cracks $b > 3.0 \text{ mm}$. Several cracks over or up to this size.

Consequences:

The consequences of fine cracks (< 0.5 mm in width) will be a reduction of the tightness of the wall and cracks always represent an aesthetic problem. Wider cracks and cracks which are growing, always call upon actions because they indicate possible instability.

Consequence degree 0: No consequences

Consequence degree 1: Minor consequences, mainly of aesthetic character.

Consequence degree 2: Medium consequences. Reduction in tightness of render. Changed properties of the wall.

Consequence degree 3: Serious consequences. Instability of wall and reduced load-bearing capacity.

Recommended actions:

Consequence degree 1 and 2: Stable cracks without movements should be repaired (filled up with mortar etc) in order to avoid water and air penetration.

Consequence degree 3: For cracks with movements an analysis of the possibility for collapse should be carried out. If a collapse of part of a wall is considered possible in the future, a repair and strengthening of the background should first be done (in contact with a specialist). With no possibility for collapse or other severe damages (Consequence degree 1 and 2) a sealing of the crack with an adequate compound can be recommended.

3.4.5.4 Rendering with sores and disintegration (Eroded surface)

Type of material:

On all kind of rendering/rendering systems.

Description of the symptom:

Sores in the surface caused by disintegration of the render. Particles from the rendering can for instance be rubbed off with a soft brush.

Extent of symptom:

It is important to describe the symptoms as completely as possible. (The height from the ground, the position in relation to windows. For eroded areas, the correlation between driving rain and areas with symptoms etc.).

Condition degrees referred to pictures:

Condition degree 0:

No symptom.

Condition degree 1.

Slight symptoms.

Depth of sores < 1.0 mm

A few particles can be rubbed off with a brush



Condition degree 2:

Medium strong symptoms.

Depth of sores 1.0 mm < t < 3.0 mm

Local disintegration.



Condition degree 3:

Strong symptoms.

Sores and disintegrated materials deeper than 3.0 mm into the surface in more than 25 % of the area of a wall



Investigation methods:

Visual characterisation, including an evaluation of the quality of the render in the bottom of the sore. Measuring of the disintegrated areas and the depth of the sore.

Possible degradation agents:

Mechanical

Possible causes:

If few eroded spots limited to a local area, unsatisfactory mixing procedure or dripping water on the surface shortly after application of the mortar can be the degradation factors. Unsatisfactory frost resistance of the rendering can also cause this type of degradation. Unsatisfactory detailing is another degradation factor.

Total condition degree:

Measurements of strength and freeze/thaw resistance of material from areas without symptom are recommended.

Total condition degree 0: No symptoms.

Total condition degree 1: Slight symptoms. Depth of sores < 1.0 mm. A few particles can be rubbed off with a soft brush.

Total condition degree 2: Medium strong symptoms. Depth of sores < 3.0 mm. Local disintegration.

Total condition degree 3: Strong symptoms. Sores and disintegrated material deeper than 3.0 mm into the surface over more than 25 % of the area of a wall.

Consequences and risks:

Eroded surface is of great importance for the appearance. Disintegration will open for accelerated degradation, increased water absorption, penetration of water, etc.

Consequence degree 0: No consequences

Consequence degree 1: Minor consequences

Consequence degree 2: Medium consequences

Consequence degree 3: Serious consequences

Recommended actions:

Assess causes for damages. The actions to be taken should be based on the results from the analyses of the causes for the damage. If the quality of rendering in general or the final coat is found not to be adequate, a new rendering coat should be applied. For repair of sores a rendering mortar compatible with the existing mortar must be chosen.

For condition degree 3 a completely new render on the entire wall should be considered bearing the historic value of the render in mind. Disintegrated material has to be removed.

3.4.6 Natural stone

The complete set of examples for damage descriptions of concerning natural stone is found in the MMWood report ENV4-CT98-0796 D02.01S Environmental Damages to Natural Stone (Andersson and Wenander, 2000). Conservation of stones and buildings and properties of stone are among others described in Ashurst and Dimes, 1990, and Winkler et al, 1973.

3.4.6.1 Sanding

Type of material:

Sandstone and other fine graded stones.

Description of the symptoms:

Material is evenly lost from the surface. The structure of the surface does not change appreciably, but carved figures and sharp edges in the stone are lost in the process. This type includes uniform dissolution of mono-mineralic stones as well as sanding.

Extent of the symptoms:

The extent of the symptom is dependent upon the size of the sanding area, and the depth of the sanding.

Conditions degree referring to pictures:

Condition degree 0:

No symptoms

Condition degree 1:

Slight Symptoms

Smooth powdering of surface layer when brushed by hand.



Condition degree 2:

Medium-strong Symptoms

Coarse surface. Heavy sanding when brushed by hand.



Condition degree 3:

Strong Symptoms (includes collapse and malfunction)

Total collapse of stone when brushed by hand.



Investigation methods:

Visual examination and by rubbing a finger to the surface, which easily detects sanding. There can also be reasons to use different kinds of technical instruments or laboratory analyses to investigate the damage or to find out the reason for it.

Possible degradation agents:

Mechanical

Possible causes:

Uniting, softer material in the stone dissolves and weathers, which leads to that also more weather-resistant material erodes. The phenomena also occur under exfoliating surfaces where substantial pulverisation can occur.

Total condition degree:

- | | |
|---------------------------|---|
| Total condition degree 0: | No symptoms |
| Total condition degree 1: | Slight symptoms |
| Total condition degree 2: | Medium-strong symptoms |
| Total condition degree 3: | Strong symptoms (includes collapse and malfunction) |

Consequences and risks:

Loss of material. Weathering of sculptured surfaces with artistic treatment.

- | | |
|-----------------------|---------------------|
| Consequence degree 0: | No consequence |
| Consequence degree 1: | Minor consequence |
| Consequence degree 2: | Medium consequence |
| Consequence degree 3: | Serious consequence |

Recommended actions:

Consolidation. An expert should be consulted.

3.4.6.2 Relief

Type of material:

All kinds of natural stone.

Description of the symptoms:

The originally smooth surface has become rough with dents or minor holes and previously sharp edges have become rounded. The symptoms include various forms such as relief, pitting, alveolar, weathering and delamination. The symptom can therefore appear in a lot of different patterns.

Extent of the symptoms:

Shallow, surface related symptoms are a part of the natural ageing of the stone materials. An assessment must be done when the depth of the relief actually deteriorates technical and aesthetic properties of the stone.

Condition degrees referred to pictures:

Condition degree 0:

No symptoms

Condition degree 1:

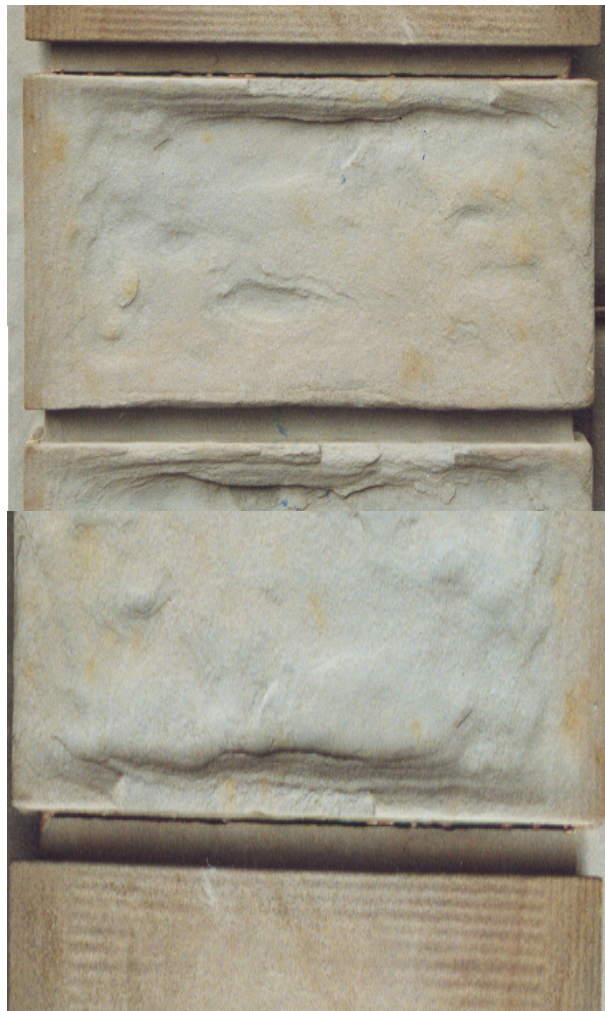
Slight Symptoms

Slight change of surface-level.
Beginning of alveoli creation.

Condition degree 2:

Medium-strong Symptoms

First step of craters/holes, which
is more than 10 mm of depth.



Condition degree 3:

Strong Symptoms (includes collapse and malfunction)

Big alveoli or “waves” in the surface. Total change of the surface appearance.



Investigation methods:

Visual examination and by scraping with a sharp metal object to detect whether the deterioration process is active or not. There can also be reasons to use different kinds of technical instruments or laboratory analyses to investigate the damage or to find out the reason for it.

Possible degradation agents:

Mechanical

Possible causes:

Less weather-resistant minerals in the stone dissolves and weathers, while more resistant ones are remained intact. In the long run also more weather-resistant minerals will erode. Sedimentary stones, like sandstone, consist of different layers with varying resistance to relief. Sedimentary stones with a large proportion of clay or more soluble adhesive-minerals also show a faster deterioration pace, than other types of stones. Inadequate surface treatment of the stone can speed up the deterioration process.

Total condition degree:

- Total condition degree 0: No symptoms
- Total condition degree 1: Slight symptoms
- Total condition degree 2: Medium-strong symptoms
- Total condition degree 3: Strong symptoms (includes collapse and malfunction)

Consequences and risks:

In an initial face the problem of relief-degradation is mainly aesthetic. When the degradation of the stone is allowed to continue, the technical and physical characteristics of the stone will change. This can lead to higher water-permeability and cause problems related to moisture and damp.

- Consequence degree 0: No consequence
- Consequence degree 1: Minor consequence
- Consequence degree 2: Medium consequence
- Consequence degree 3: Serious consequence

Recommended actions:

When the deterioration has reached a level where there is a risk of technical or disturbing aesthetic damages, one of the following actions can be taken: Remodelling with a stone-mortar which is compatible to the stone. This action is mainly recommended on decoratively carved parts. Other solutions are consolidation or exchange of stone. An expert should be consulted.

4 Work Package 3 – Object Documentation, Regulations and Management

4.1 Objectives

Identify, develop and establish regulations and management performance for the application of MMWood at one "pilot object" in each of the participating countries, considering

- fundamental and object-specific documentation requirements,
- long-term strategy and consequences for MMWood concerning the interaction of the parties usually responsible for the objects (owner, experts, officials, users, administration etc.),
- management performance and its preconditions for the implementation of the MMWood system, and
- implementation of MMWood in current repair and maintenance projects at one object in each of the participating countries in close contact with the responsible persons.

4.2 Technical Approach

For the practical use of the notified target group it is an urgent need to develop an implementation strategy under the different requirements and work much closer and in more details on practical cases of pilot objects. Each of the partners A1, A2, A3, and C5 have chosen one object or one ensemble of objects in their countries, see Table 9. The concerning responsible user-groups authorities have been involved and have a serious interest in the system development. Each concerned object partner has throughout the project worked at the object to test and ensure all phases of implementation of the MMSystem.

Table 9: Objects for validation

Country, City	Role of Object Partners	Characterization of the Object	State of Activities at the object	Resp Partner
Germany Quedlinburg	Owner (municipality)	Half-timbered-house (double house 6m x 11m and 6m x 8m, 3 floors) built in 1734	Building is unoccupied, it is administered on trustee, restoration is intended	A1
Sweden	Owner (municipality)	A vertical wooden log mission-hall in Stockholm and a rendered brick building with dwellings in Vällingby.	Regular maintenance, when needed.	A2
Norway Oslo	Owner (municipality)	Small half-timbered houses, one and two floors, from the 1700 and 1800 ~100 m ²	In restoration/partly modernisation	A3
Italy	Owner (province)	Vernacular buildings in Northern Italy	Restored, maintenance plan should be developed	C5

4.3 Object information (Object property in MMS)

4.3.1 Definitions of object types

The system manager is free to define the different types of object depending of the use of the system. A building manager has other needs than a construction consultant. Object types may be different types of buildings, either different building functions or different building techniques. Object types may also be different construction typologies as building, bridge, and other forms for infrastructure. Figure 9 shows an example for defining Object types.

Since all partner have been working with buildings, all have chosen different building types as types of object. Norwegian standard for building categories (NS3457, 1995) is used as a suggestion for building types, while the partners can use their own system or national standards. Eventually a European standard would fit. Figure 9 shows the system used by the Italian partner.

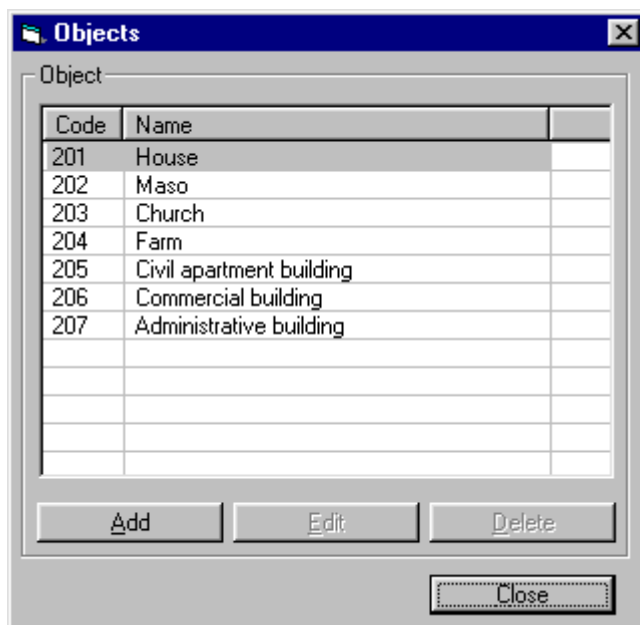


Figure 9: Object types defined by the Italian partner.

4.3.2 Definition of Object properties

The system manager is responsible for defining the Object properties, and to decide whether they should be compulsory or not. The object properties are searchable information. A lot of work was done early in the project to find what should be the minimum of object properties, and suggestions for other relevant parameters (Riks and Stenstad, 1999). The chosen object properties for each partner are shown in chapters concerning the objects, chapter 4.7.

The decision concerning what object properties that are relevant is very linked to the role of the user. A building manager has other needs than a consultant.

4.4 Building part information and relations

The system has been configured with a definition of all the building part useful to define the chosen object and the existing damages. The system manager is free to define the building parts. The Building parts may be defined with codes in increasing order, Figure 10, or with

codes from standard or other systems. Some of the partners have chosen to use the codes and building parts defined in the Norwegian standard NS3451 Table for building elements (NS3451, 1988).

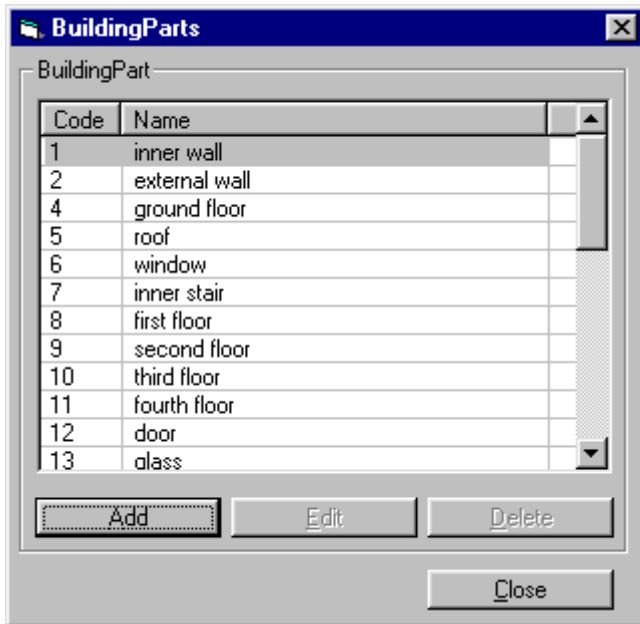


Figure 10: Chosen building parts by the Italian partner.

The MMS-configuration also demand a relation between Object type and Building parts, and further between Parent building parts and Child building parts in several levels. Examples showing how to make the relations are shown in Figure 11 and Figure 12.

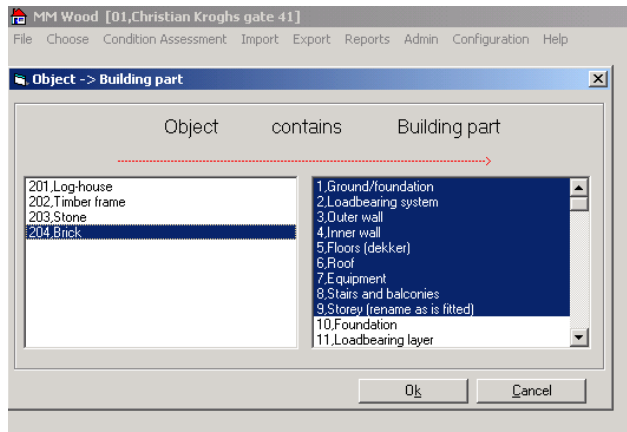


Figure 11: The relation between Object and Building.

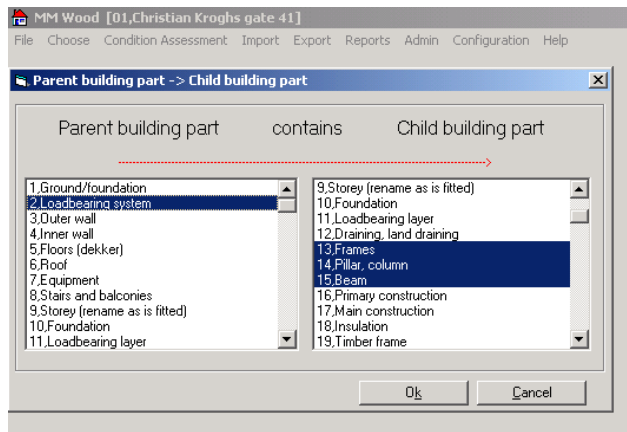


Figure 12: The relation between building parts on different levels.

The system manager is also responsible for defining the Building part property, and decide which property is compulsory. There is no restriction in number of properties, but the manager should have in mind what information is important and suitable. All building part properties are searchable; so the user should preferable avoid too much free text. Examples of Building part properties are shown in Figure 13.

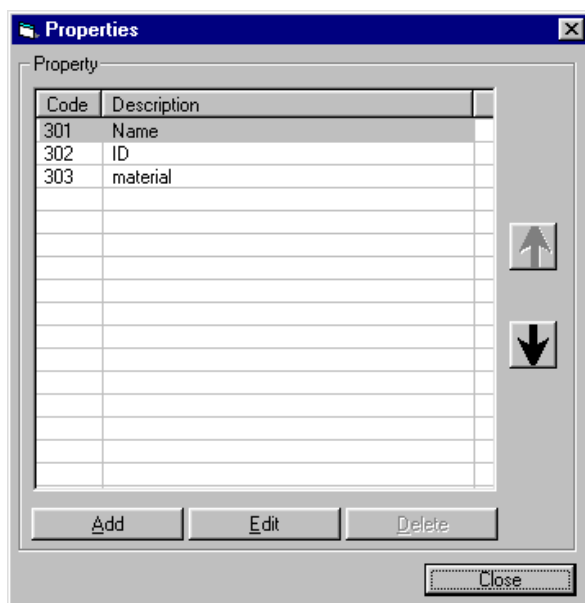


Figure 13: Building part property chosen by the Italian partner.

4.5 Orientation system

An orientation system was defined in the Wood Assess-project; see chapter 3.3.1.1, but all partners have chosen to use their own system during the testing. Since all building parts and damages may be linked to drawings and pictures, the need for an orientation system is limited. Further is shown an example from the Italian partner.

An orientation system has been chosen to identify the different building parts. The facades of the building have been divided into axis (x and y) depending on the number of floor (x) and

on the number of windows (y). So, for example, Window S-2-4 means the window on the south facade, at the second floor in the fourth position (Figure 14):

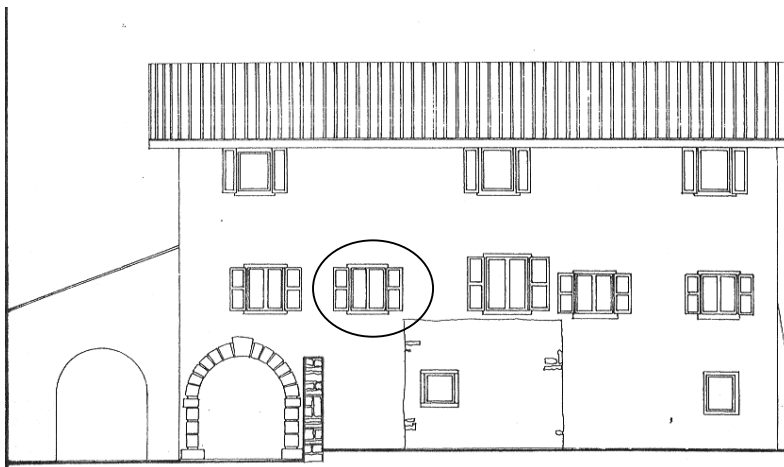


Figure 14: The position of the window S-2-4 by use of the orientation system.

4.6 Inspections, Observations and Damages

The system manager is responsible for defining the types of inspections. Inspection types may be types already defined by the user or firm. Four different kinds of inspection types have been used in the MMWood project: General Inspection, Yearly inspection, Monthly inspection, and Special inspection, Figure 15.

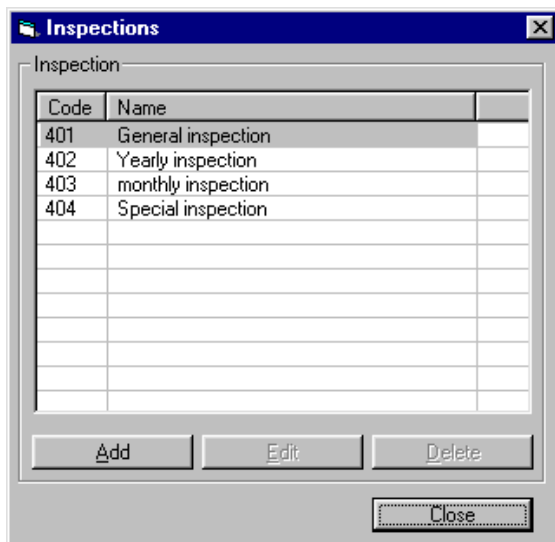


Figure 15: Defining different types of inspections.

Different types of inspections, with different levels, were defined in the Wood Assess project. The purpose of the Condition Assessment determines the inspection level. Different types of inspections, and different levels, will have different “check-list” or building elements to assess.

The MMSystem has a predefined list of Observations and Damages according to the Damage Atlas (Eriksson, 2000). The system manager should put more predefined observations and damages into the system when they are needed. The Observations should be linked to one or several Inspection types. There is also a relation between Observation and Damage.

Figure 16 shows examples of relations between the annual inspection and the different observations that can be made during that particular inspection type.

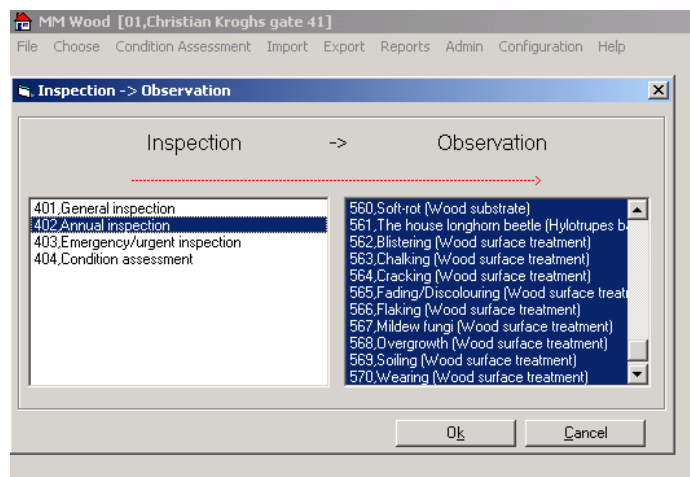


Figure 16: Relations between the annual inspection and the possible observations that can be made during that particular type of inspection.

All Observations has predefined Questions. The questions are treated as properties, and all are searchable. Hence the user should as far as possible use predefined alternative answers. Figure 17 shows an example of a predefined observation questionnaire.

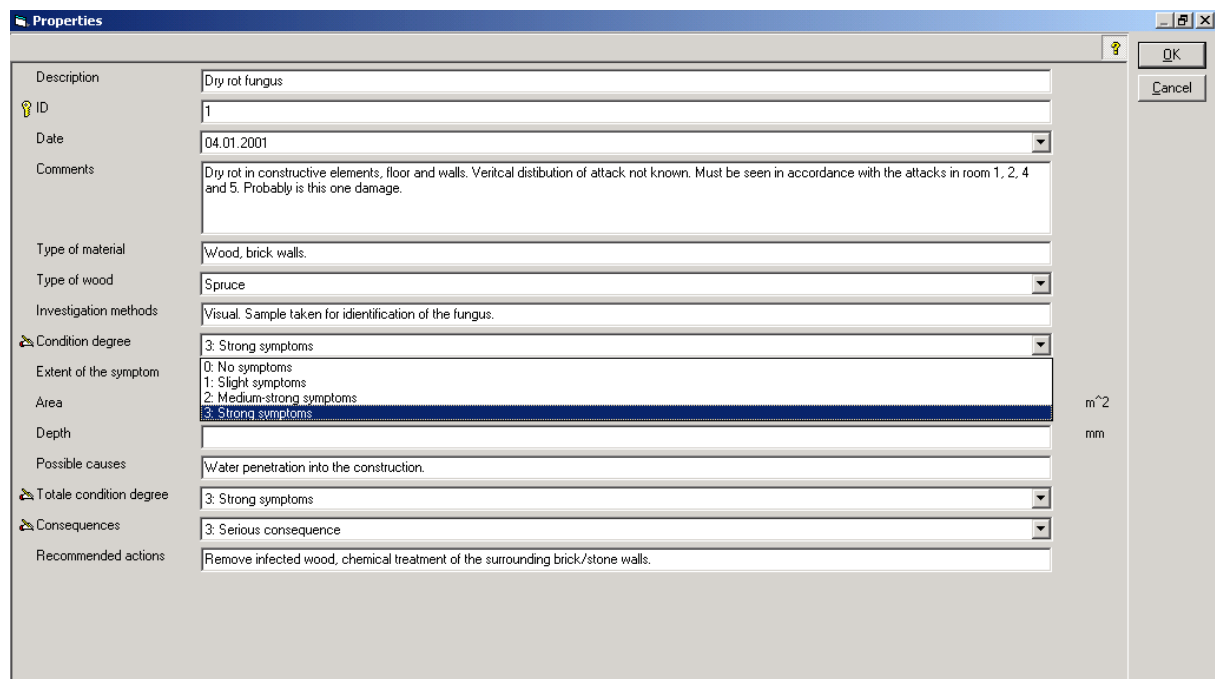


Figure 17: The figure shows the properties of chosen damage. Properties with a symbol of a hand in front of it are mandatory to fill in. An example of a pull down list (condition degree) is shown.

4.7 Documentation of Objects

The objects are documented by both a report on building information and by the MMSystem. More detailed information will be found in the separate reports. Differences in documentation between the partners may be caused by different purposes for the condition assessment, very different condition of the objects, and the partners' different specialised skills.

4.7.1 Documentation of the German object

More detailed information about the German objects in Quedlinburg can be found in the MMWood reports ENV4-CT98-0796 D03.01a Building Documentation German demonstrator (Riks, 2000) and ENV4-CT98-0796 D03.02a Documentation German demonstrator Quedlinburg (Riks, 2000).

4.7.1.1 Object information and Configuration of the system

The following building types, single- and multifamily houses, churches, castles, batteries, schools were used as object types. The object chosen is a double house, and the inspection is for the western part of the double house, Augustinern 22. The building has a 3-storied half-timbered construction with partly basement and joint saddleback roof. This part of house is rendered. The double house is located in a line with other houses in city road-hugging property. The front side shows to the south. On the backside of the building are gardens for each half part of the house. At the investigated part exists a younger side building.

The Figure 18 shows the general properties of the chosen object.

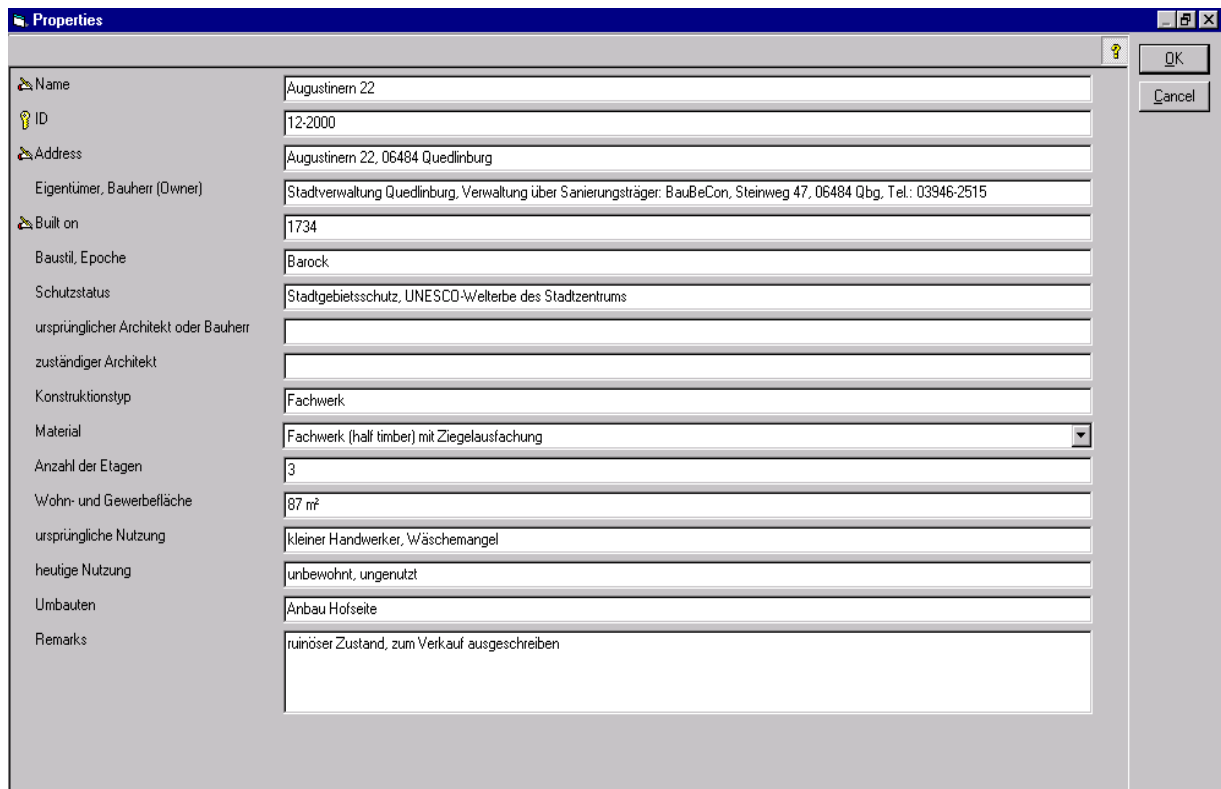


Figure 18: Object property for the German object Augustinern 22.

The predefinition of objects and building parts follows mainly the Norwegian standard NS3451 (NS3451, 1988) and NS3457 (NS3457, 1995). Figure 19 shows one example for coupling the object with building parts.

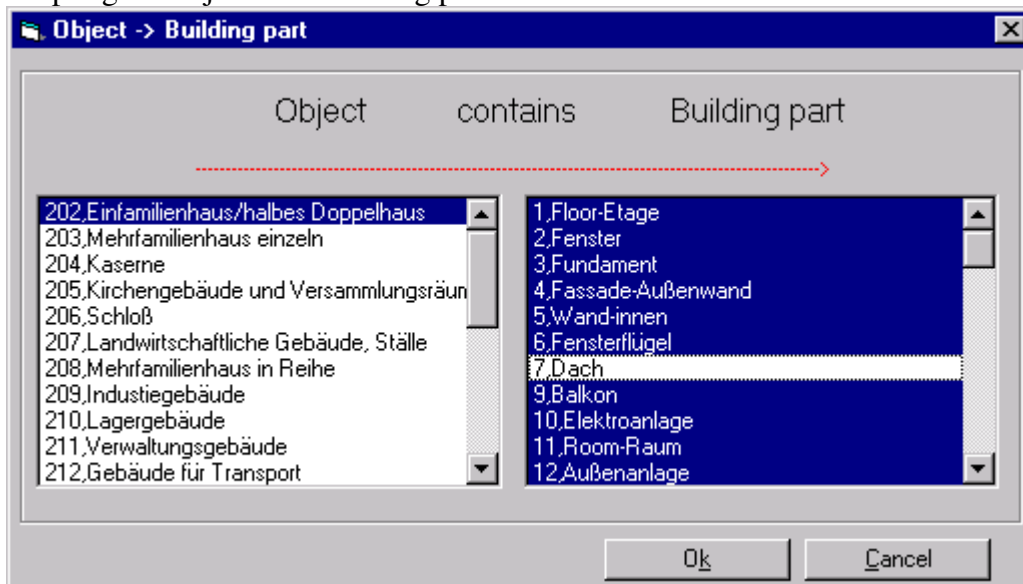


Figure 19: Relation between Object and Building part in the German configuration.

Nearly every building part has to be coupled with groups of building parts, which lies in the next layer: For example Wall-Window-Window frame/Window glass/Window board. Figure 20 shows one example of the coupling between parents building part and child building parts:

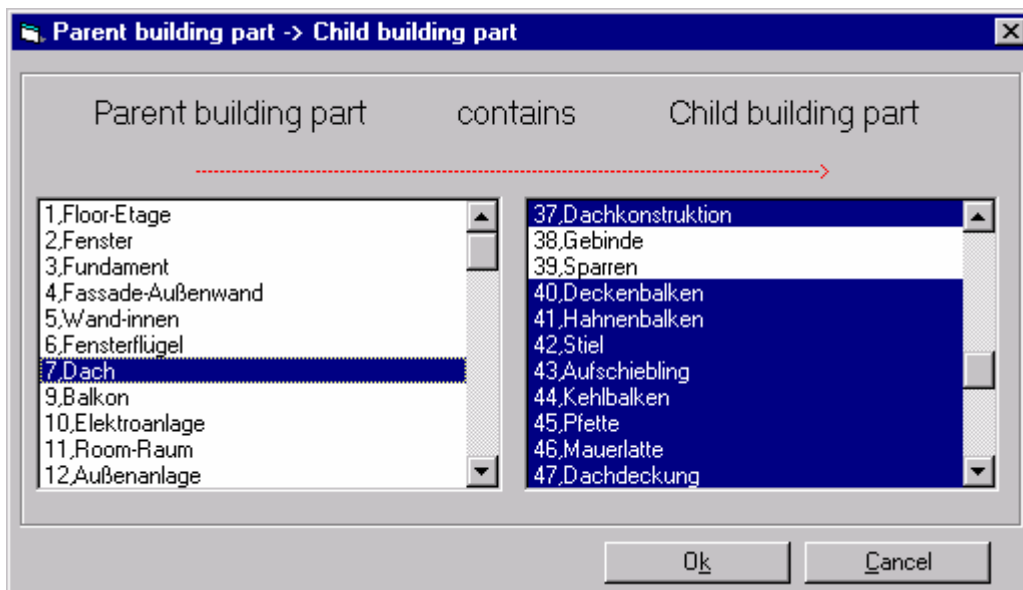


Figure 20: Relations between Parent building part and Child building part in the German configuration.

Figure 21 shows one detail of connecting object in Quedlinburg with parent building parts and children building parts:

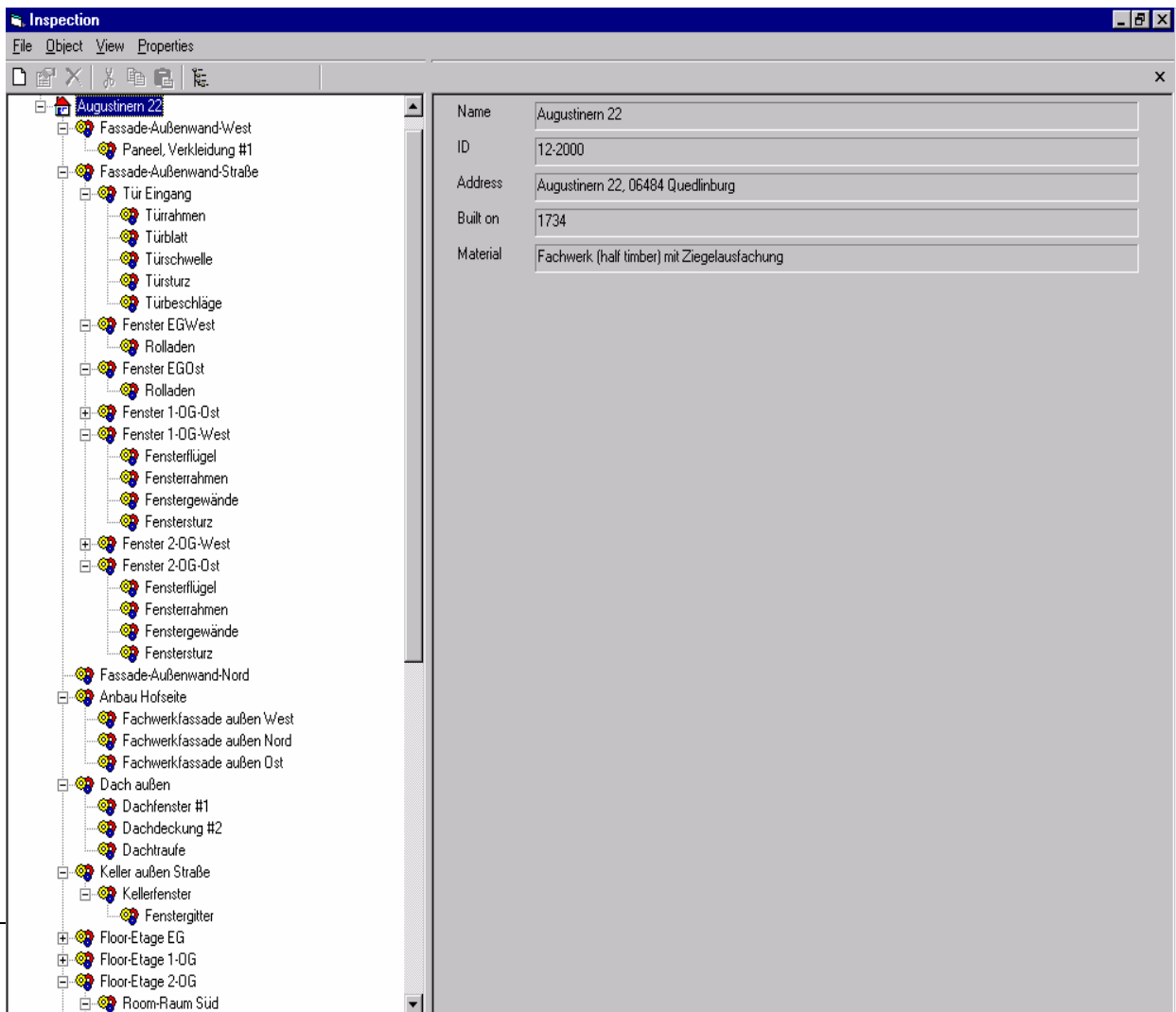


Figure 21: Tree structure for object in Quedlinburg with parent building parts and children building parts.

The MMS system is built up in a very general way and that also includes the inspection types. In our system we have defined the following inspection types: General inspection, Wood constructive inspection, Moisture and salt inspection, Annual inspection, Follow up inspection, and Emergency inspection. Figure 22 shows the Wood constructive inspection. The system has predefined different observations all based on the damage atlas developed in WP2. After defining an inspection this have to be related to one or several observations, Figure 22.

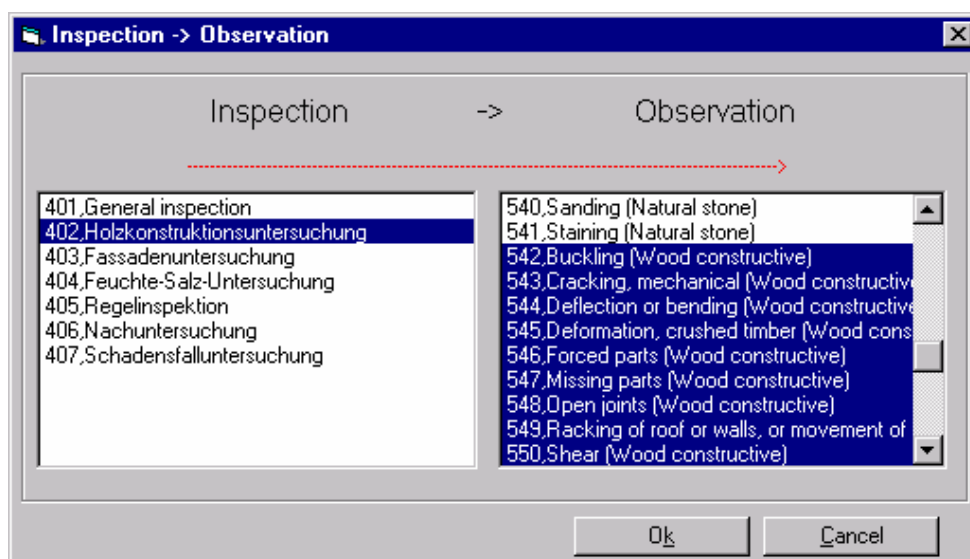


Figure 22: Inspection types and relations between Wood constructive inspection and the belonging observations in the German configuration.

4.7.1.2 Condition Assessment of Object

The condition assessment of the object Augustinern 22 in Quedlinburg was performed in Summer 2000 as test and finally in December 20001. The Germany partner ZHD with project-team Potsdam carried out the condition assessment. Some parts of information for the object were former project (archive, measurement). The inspection type used was a General inspection. Figure 23 and Figure 24 show the facade of the chosen object, while Figure 25 and Figure 26 give the section and plan drawings. In Figure 27 part of the inspection tree is given for the object chosen.



Figure 23: Street-Facade of Augustinern 22+23

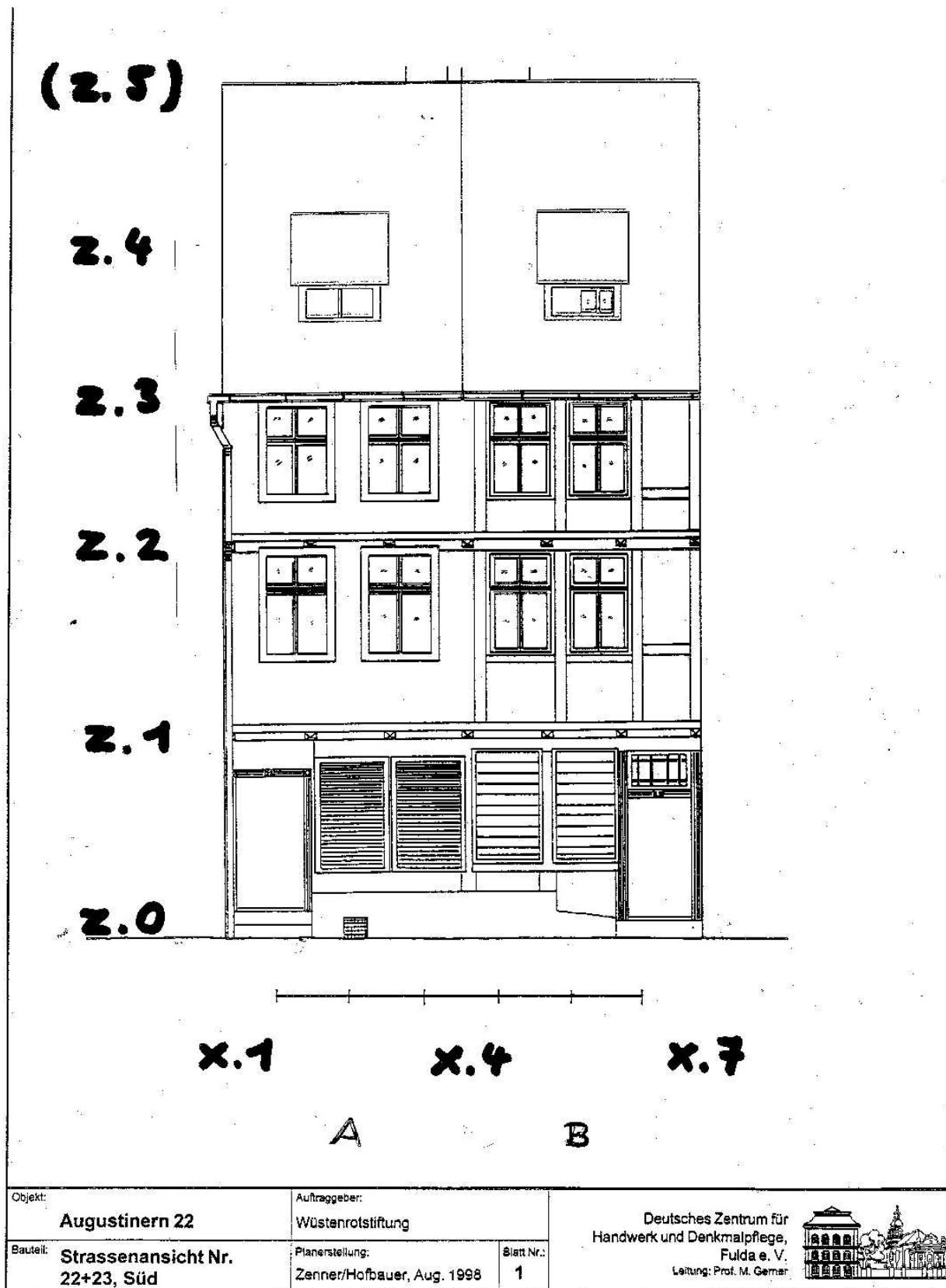
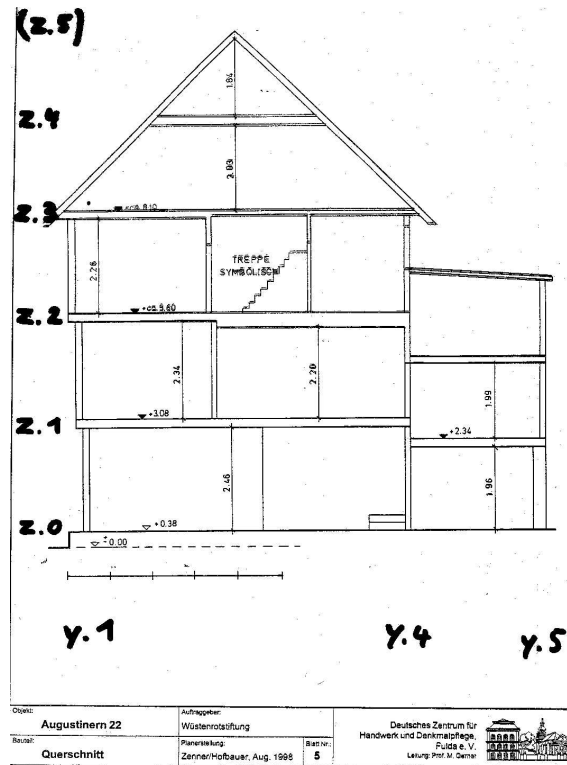
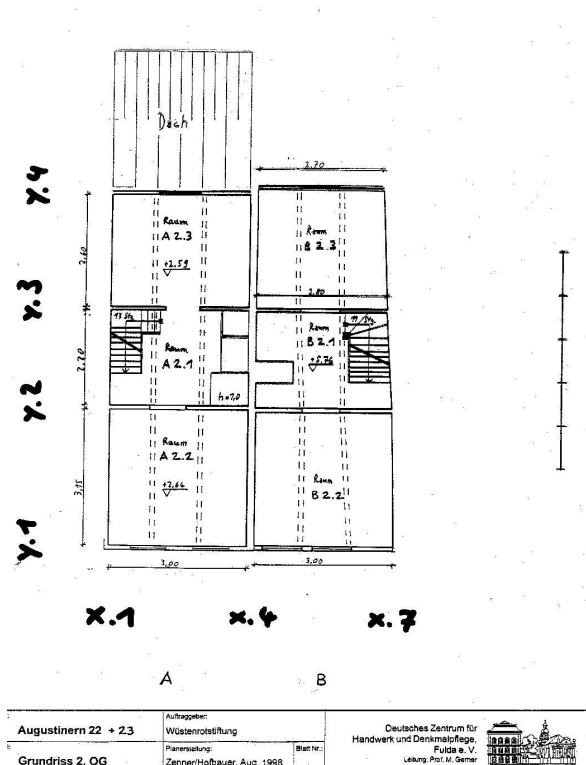


Figure 24: Drawing of the street-facade Augustinern 22+23



Augustinern 22
Querschnitt
Auftraggeber: Wüstenrotstiftung
Planzeichnung: Zerner/Hofbauer, Aug. 1998
Blatt Nr.: 5
Deutsches Zentrum für Handwerk und Denkmalpflege, Fulda e. V., Leitung: Prof. M. Gerner

Figure 25: Drawing of section of Augustinern 22



Augustinern 22 + 23
Grundriss 2. OG
Auftraggeber: Wüstenrotstiftung
Planzeichnung: Zerner/Hofbauer, Aug. 1998
Blatt Nr.:
Deutsches Zentrum für Handwerk und Denkmalpflege, Fulda e. V., Leitung: Prof. M. Gerner

Figure 26: Drawing of ground-plan of 3 floors

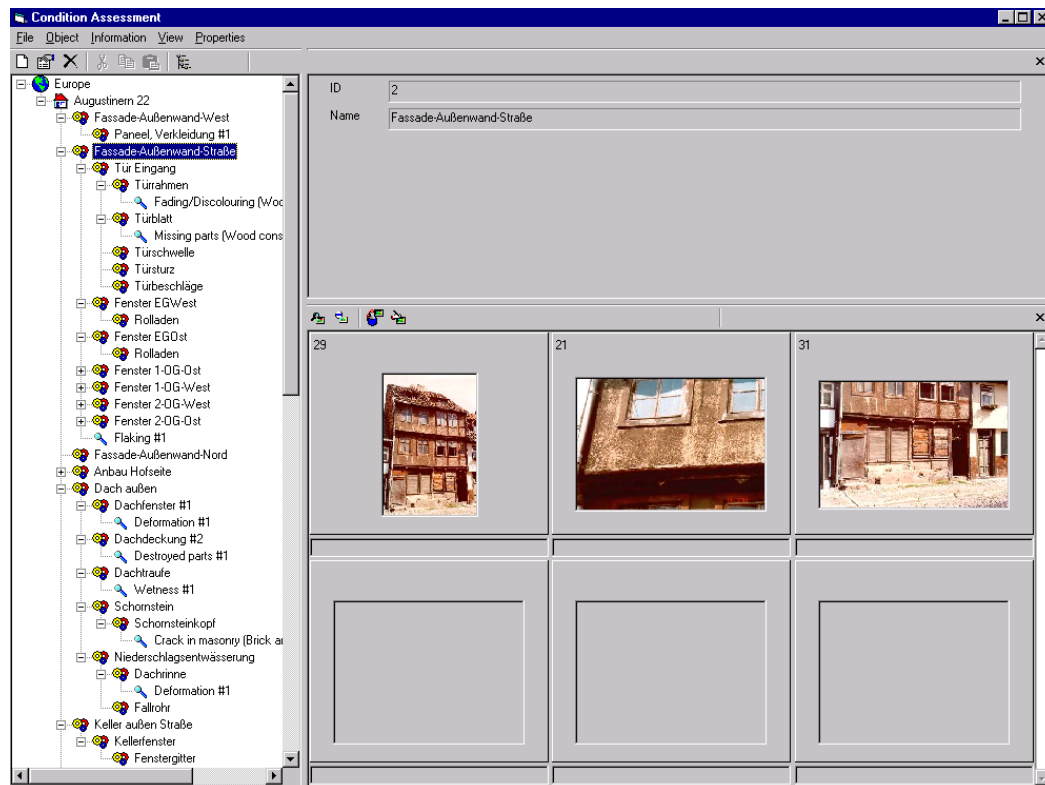


Figure 27: Detail of building part tree of the chosen object with observations during the General inspection.

Figure 28 will illustrate the next step (partly at object, partly at office) for estimation the damage and the decision. In General inspection we used images to show the actual/acutely situation too. Figure 29 shows the properties of door regarding to the wood treatment

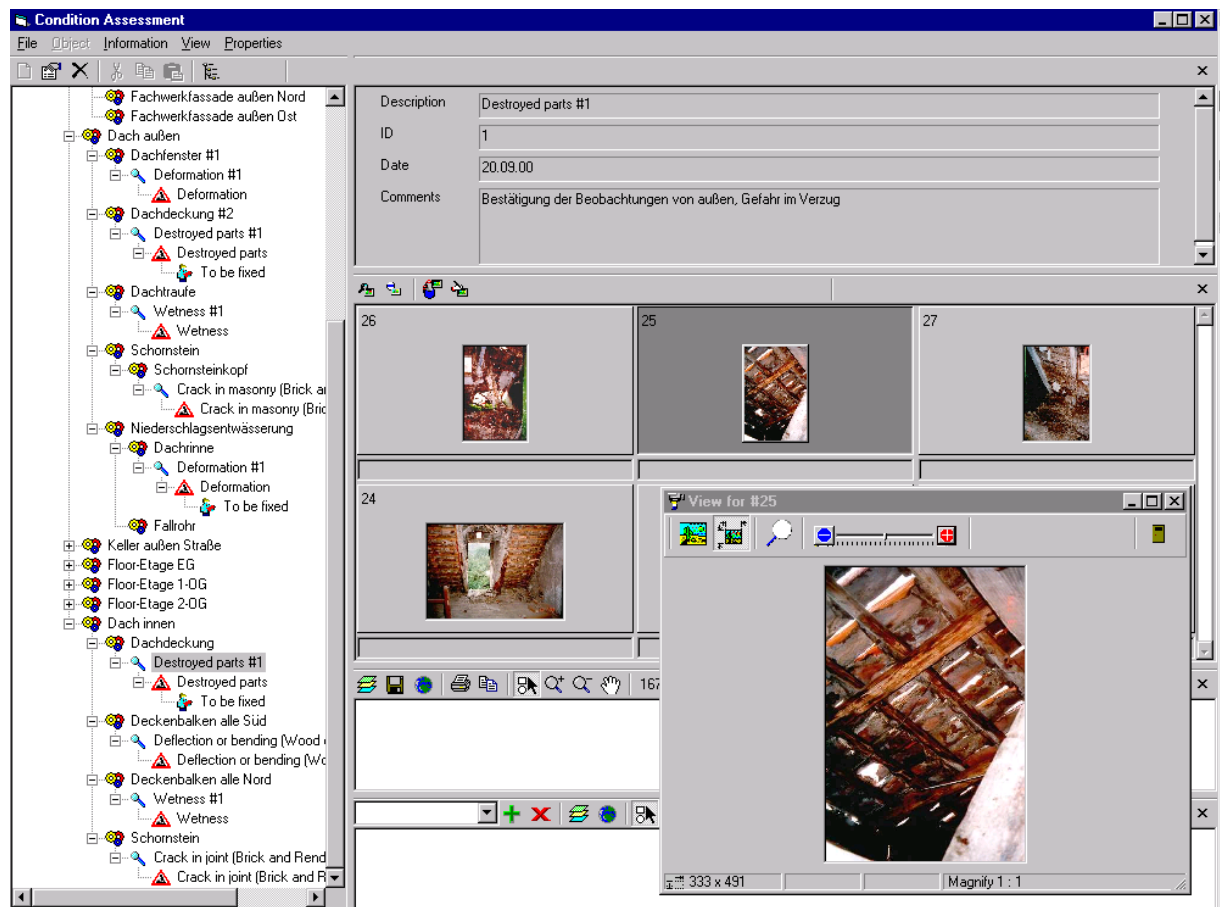


Figure 28: Detail of the Condition Assessment regarding to the roof.

4.7.1.3 Conclusion

The building is in overall poor condition, due to lack of maintenance during long time of vacancy. To work with MMSystem in historic buildings with lot of details arouse the need for a lot of preparations for the small object. On the other side it would be profitable, if all the data will be used for cover the restoration and renewal with special investigation and mapping/survey the measures. The data can be used later as or for facility management system.

When a good system for the configuration is found and incorporated into the MMSystem, it can usually be used all-round.

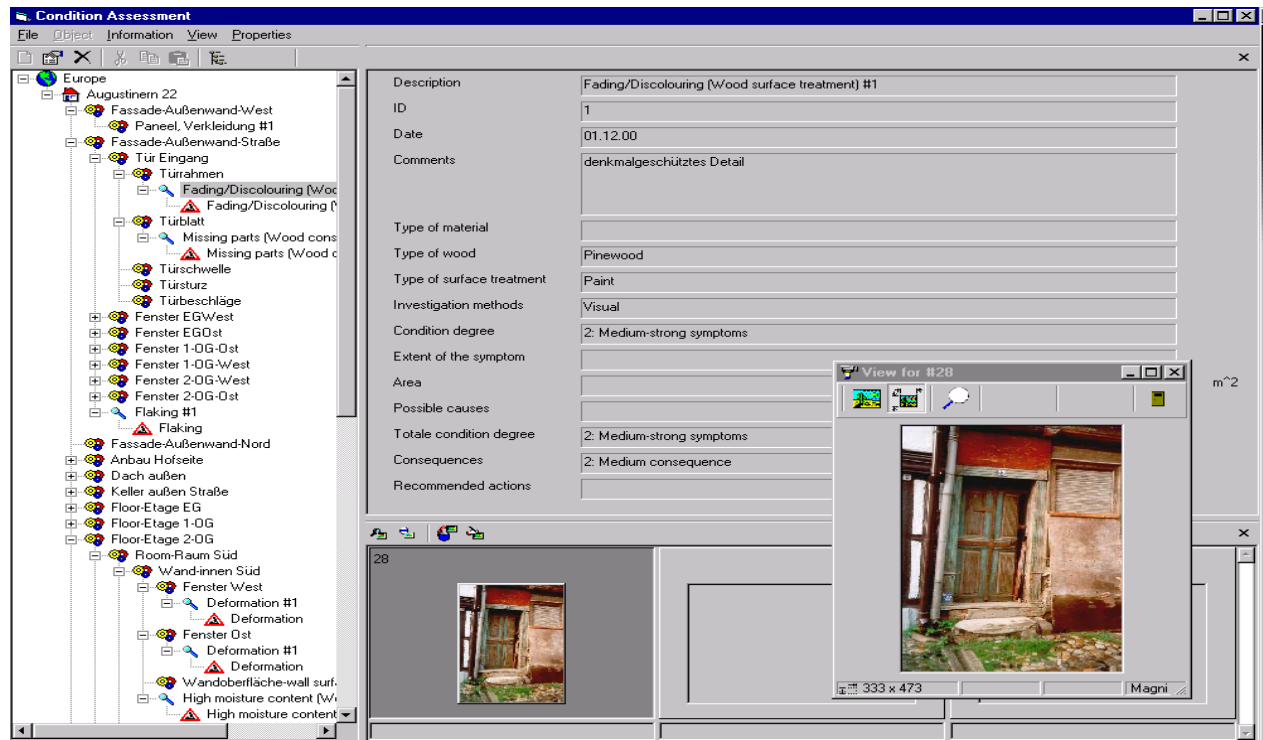


Figure 29: The properties of door regarding to the wood treatment:

4.7.2 Documentation of the Swedish object

More detailed information concerning the Swedish objects, Vällingby and the “Mission Hall”, can be found in the MMWood reports ENV4-CT98-0796 D03.01b Report Building Documentation Swedish demonstrator (Wenander, 2000) and ENV4-CT98-0796 D03.02b Documentation Swedish demonstrator Vällingby (Wenander, 2000).

4.7.2.1 Object information and Configuration of the system

The basic properties of the chosen object are given in Table 10. The ID is based on the system used by the owner of the object. Since the system is very general, any ID for an object can be defined.

Table 10: Object properties of the chosen object.

Object name	Ritbrädet 1
ID	Hus 70-76
Address	Jämtlandsgatan 70-76
Building year	1952
Building material	Rendering over concrete
Owner	Svenska Bostäder
Original use/function	Apartments
Number of parts of buildings	2
Number of floors	3
Floor area	751 m ²

Figure 32 to Figure 37 show photos and drawings of the object.

Several building parts are defined in the system, based on a combination of Swedish and Norwegian standards. The building parts are defined in several layers, for instance: Building-Outer wall-Window-Window frame-Board.

In the building part system used for the inspection/demonstration on the chosen building in Vällingby, the codes for the building parts are one digit codes for the main construction or construction elements for instance facade, two digits for major parts of the one digit building parts connected so that they start with the same digit and so forth for smaller and smaller parts. This is illustrated with an example. Code number 2 is Building and connected to building is for instance Roof construction, which has code 26. Connected to the roof is Roof window with code 263, and the in next level we can have the glass in that window given by the code 2632.

Many different observations all based on the developed Damage Atlas were predefined in the system. After defining an inspection, the inspection has to be connected to one or several observations. For instance an inspection called Follow-up inspection for paint was connected only to observations about different damages on paint.

4.7.2.2 Condition Assessment of Object

The condition assessment of the object Ritbrädet 1 in Vällingby was performed on the 31st of October 2000. Assisting in this condition assessment was personal from the Swedish partner Restaurator AB. The inspection type used was a demonstration inspection. In Figure 30 part of the inspection tree is given for the object chosen. The figure shows first the two buildings, and then on the next level also the different facades. The next level given in the figure is for instance windows and the surface treatment.

In the demonstration inspection at Ritbrädet 1 in Vällingby the following pre-defined observations were found: Missing parts, Flaking, Deformation, Overgrowth, High moisture content, Chalking, Discoloration, Rising dampness and Cracking. For some of these observations suggested decisions are also given. Figure 31 illustrate the only major damage that was found in the inspection. The damage is high moisture content in the wall outside the bathroom on the northern facade on house 4.

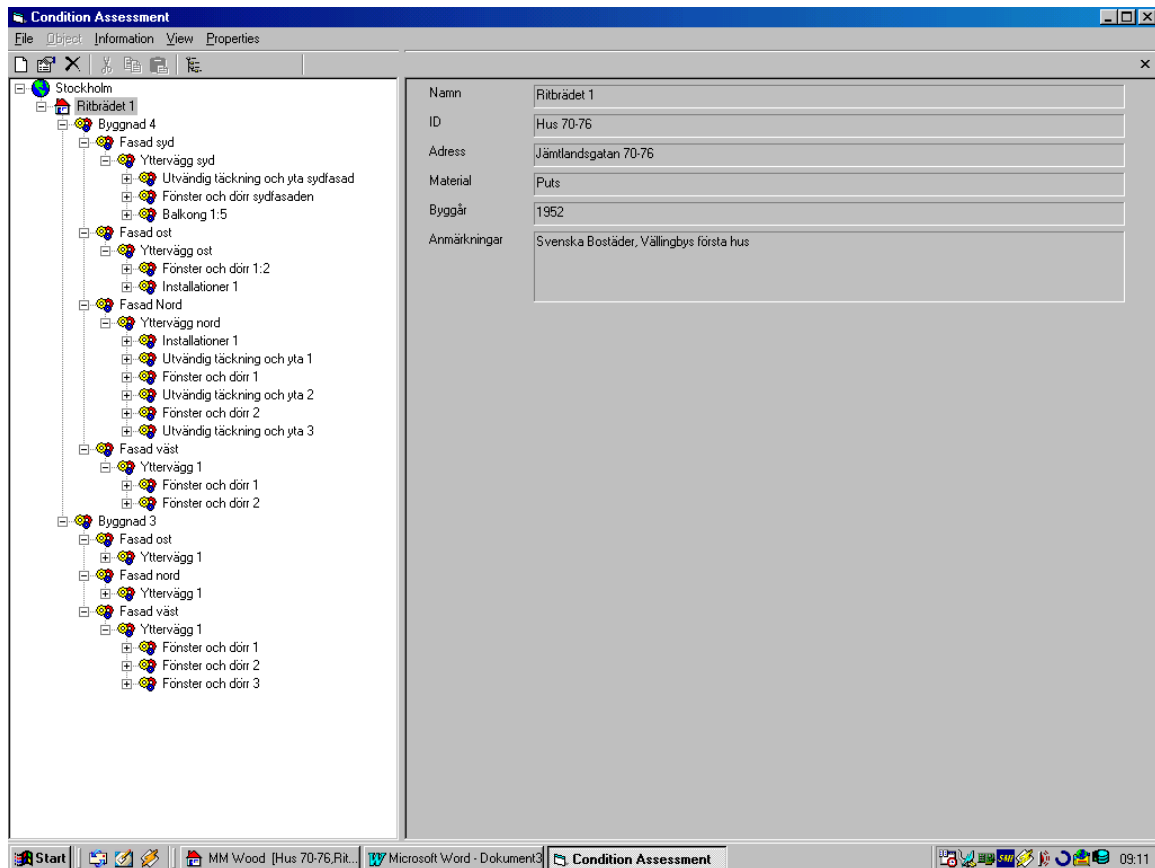


Figure 30: A schematic overview of the inspections performed at the chosen object.

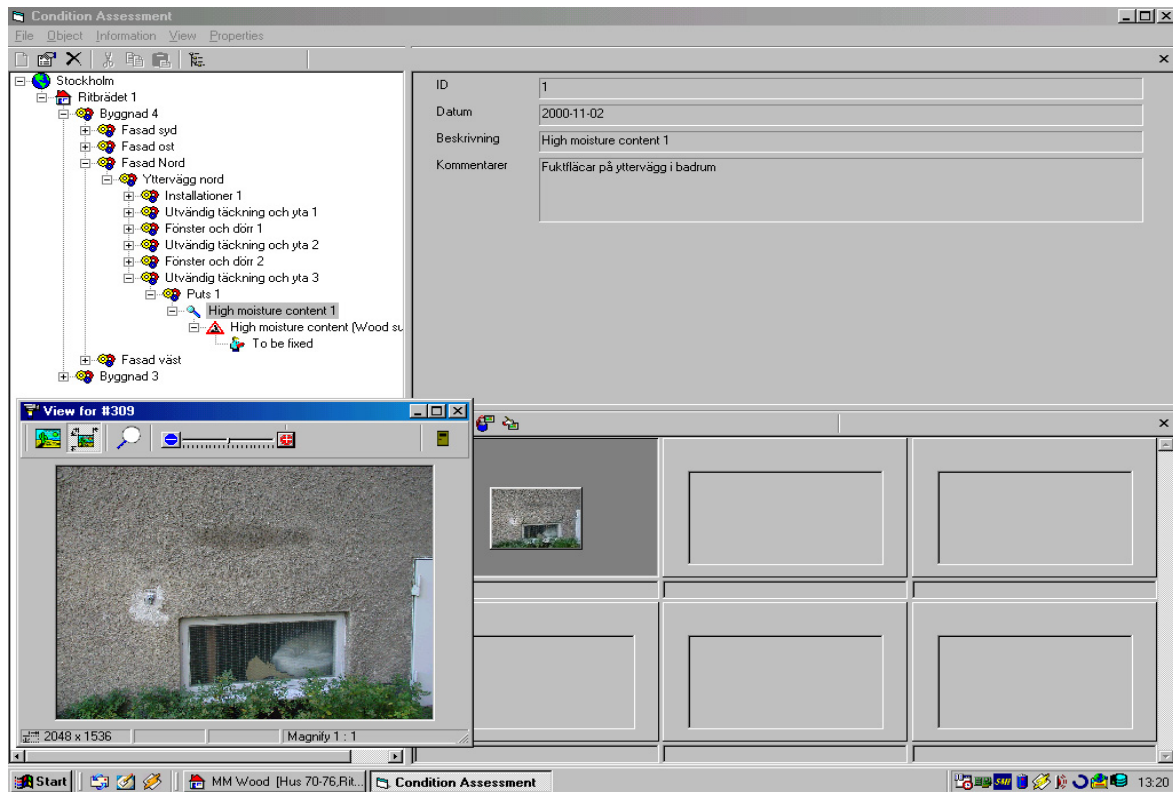


Figure 31: A schematic overview of the damage high moisture content on the north facade at house 4 in the Vällingby object.



Figure 32: The south facade of the object in Vällingby.



Figure 33: The south facade of the object in Vällingby.



Figure 34: The north facade of the object in Vällingby.

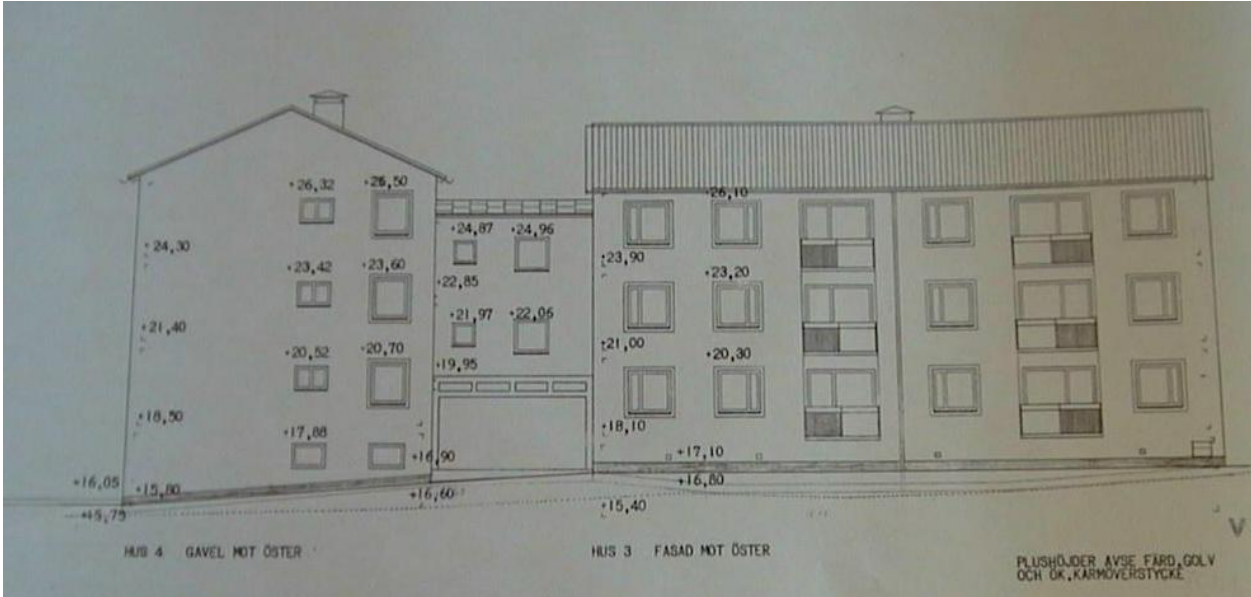


Figure 35: The north facade of the object in Vällingby.



Figure 36: The east facade of the object in Vällingby.

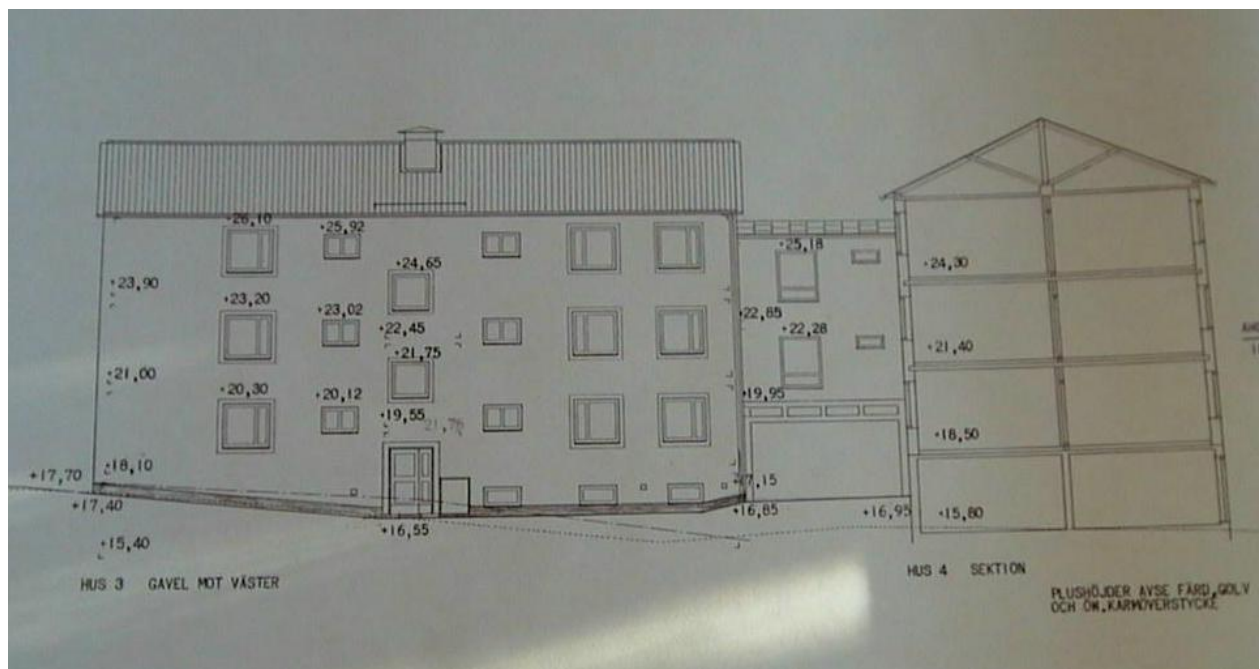


Figure 37: A drawing of the west facade of the object in Vällingby.

4.7.2.3 Conclusion

When performing the inspection the first thing that was observed was the overall very good condition of the chosen object. In the detailed observation no immediate need of actions to be taken was found, except for the high moisture content observed on the facade outside a bathroom.

4.7.3 Documentation of the Norwegian object

More complete description of the Norwegian objects, Fredensborgveien 5 and Christian Krogh's gate 41, may be found in the MMWood reports ENV4-CT98-0796 D03.01c Report Building Documentation Norwegian demonstrator (Andersen, 2000) and ENV4-CT98-0796 D03.02c Documentation Norwegian demonstrator Oslo (Lyngstad and Krigsvoll, 2000).

4.7.3.1 Object information and Configuration of the system

In the MMSystem certain object types, including for instance log- and timber frame houses, brick or stone houses/buildings were defined. The object chosen and presented is a brick building. The building is a four-storey block of flats with an L-shaped outline, originally erected in 1869 as a three-storey building. Table 11 gives the basic properties of the chosen object. Photos and drawings of the object are given in Figure 43 to Figure 47.

Table 11: Object properties of the chosen object.

Object name	Christian Krogh's gate 41
ID	208.121
Address	Christian Krogh's gate 41
Building year	1869
Building material	Brick
Owner	Oslo municipality
Original use/function	Apartments
Number of buildings	1
Number of floors	5
Floor area	Approx. 1000 m ²

Several building parts are defined in the system, based mainly on Norwegian Standard NS 3451 (NS3451, 1988). The building parts are defined in several layers, for instance: Building-Outer wall-Window-Window frame-Board.

The MM System is built up in a very general and flexible way, and that also includes the inspection types. In our system we have defined the following inspection types: General inspection, Annual inspection, Emergency/urgent inspection and Condition Assessment.

Many different observations all based on the Damage Atlas were defined into the system. Every defined type of inspection was related to the observations that can be made during that particular inspection.

4.7.3.2 Condition Assessment of Object

The condition assessment of the object Christian Krogh's gate 41 was performed during several visits in the period from 1998 to 2000. The inspection type used was a general inspection. In Figure 4 part of the inspection tree for the chosen object is shown, together with some of the general information about the building, some photos and placement on the map.

The following building parts are registered on the "upper" level for the building; ground/foundation, load bearing system, outer wall, inner wall, basement, floors, ground

floor, 1st floor, 2nd floor, 3rd floor, 4th floor, attic, roof, HVAC and electrical power. More building parts may be added at any time.

As an example of the next level; the basement have the following building parts: room 1 – 16, see Figure 39.

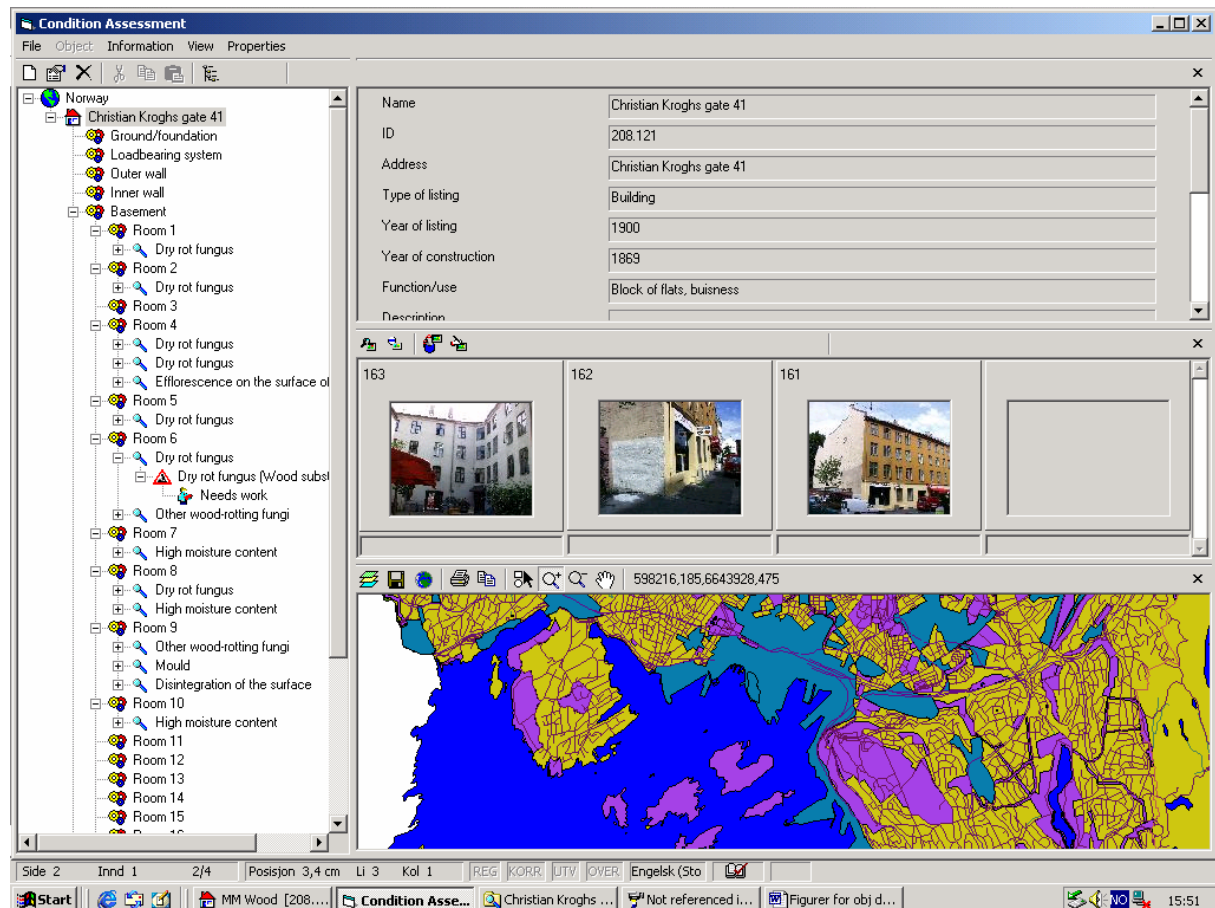


Figure 38: The figure shows a schematic overview of the chosen object.

During the inspections at Christian Krogh's gate 41 the following observations (observations as defined in the Damage Atlas) were made: dry rot fungus, other wood-rotting fungi, mould, high moisture content, wood-boring beetles, efflorescence of the surface of the masonry, cracking in the rendering, flaking, disintegration of the surfaces. The system defines all of these observations as damages. For some of these damages suggested decisions are also given. In the decisions it is possible to specify the type of work needed, the cost and the time for when the work should be finished. Other properties than shown here can be specified; it is only a matter of configuration of the system.

Some of the questions have pull down list with predefined alternatives. Using predefined lists where this is possible is supposed to make the registration more standardized and less subjective and observations/objects more comparable.

Details on one of the damages in the basement are shown in Figure 39, Figure 40, and Figure 41.

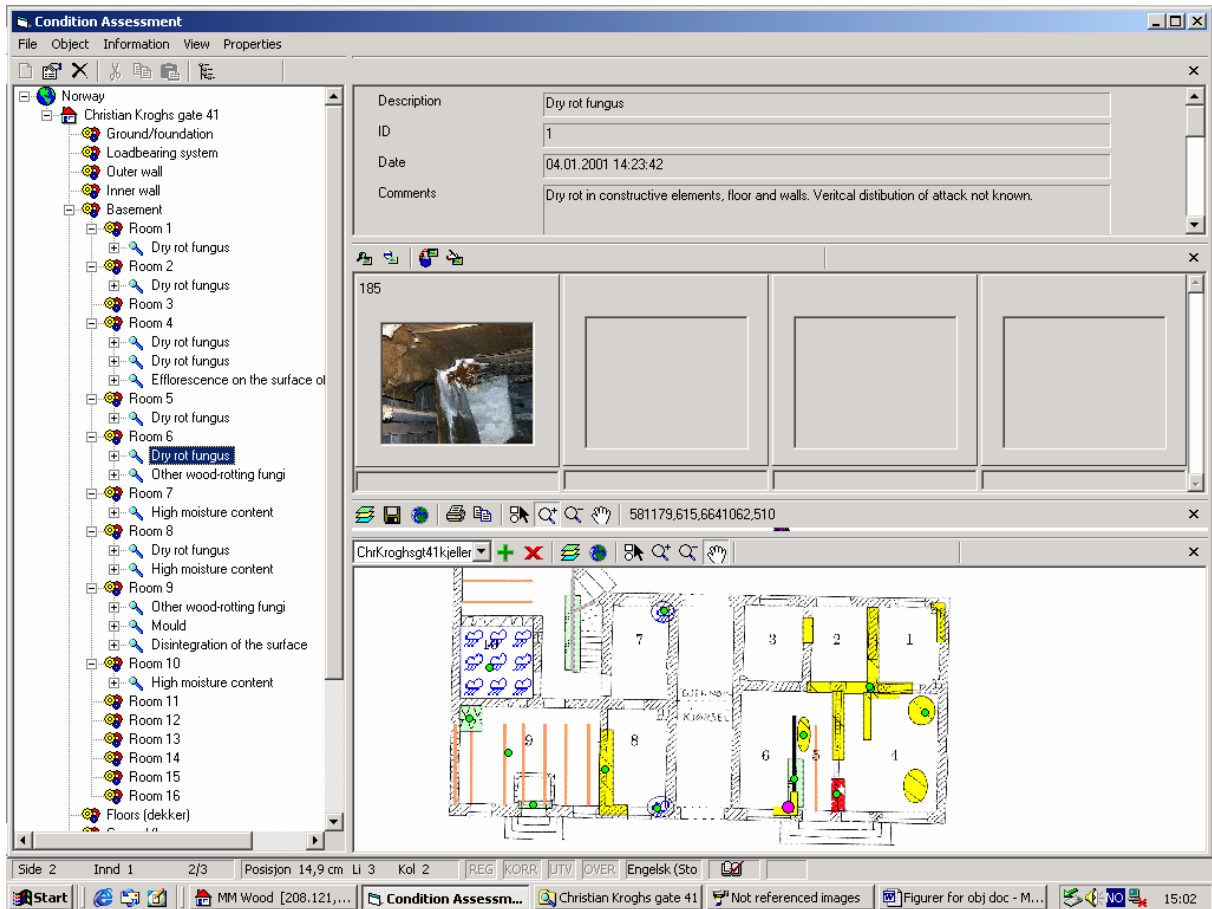


Figure 39: A schematic overview of the damage dry rot fungus in room 6 in the basement, showing photo and placement on the drawing of the basement (pink dot).

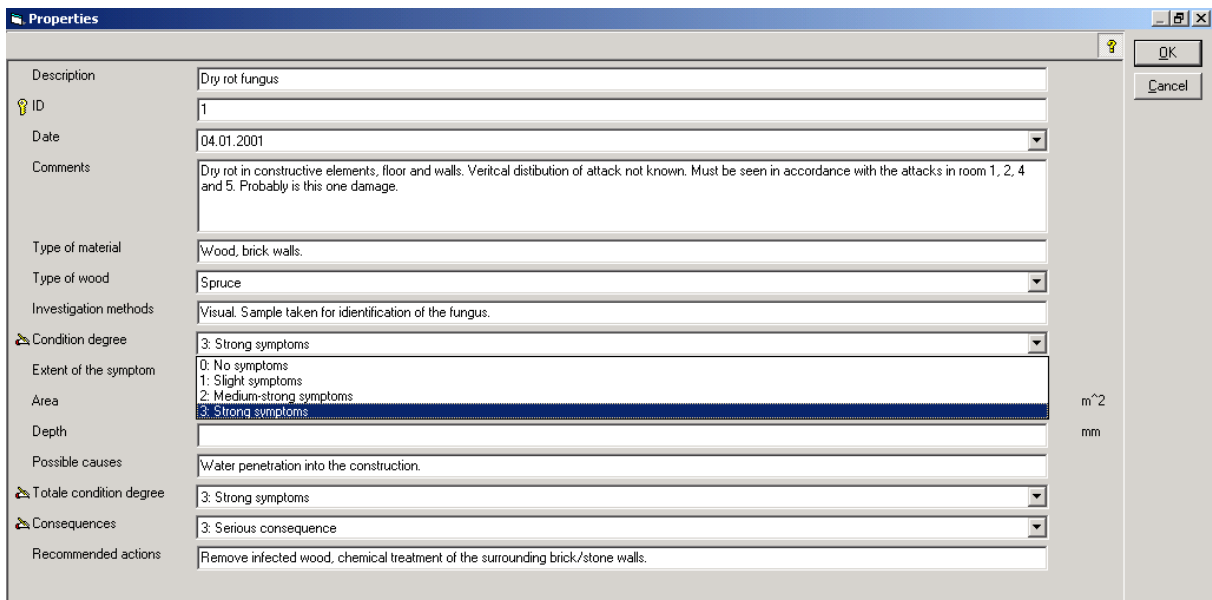


Figure 40: The figure shows the properties of the damage shown in Figure 39. Properties marked with a symbol of a hand in front are mandatory to fill in. An example of a pull down list (condition degree) is shown.

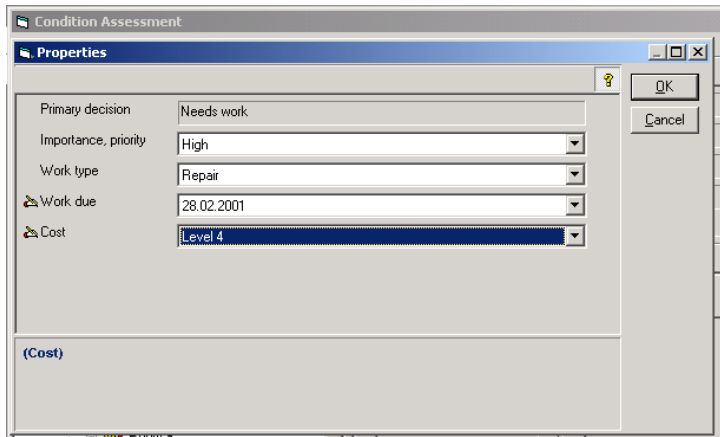


Figure 41: The figure shows the decisions taken regarding the damage described in Figure 39 and Figure 40.

From the system it is possible to get several kinds of reports. Figure 42 shows the report called “list of damages”.

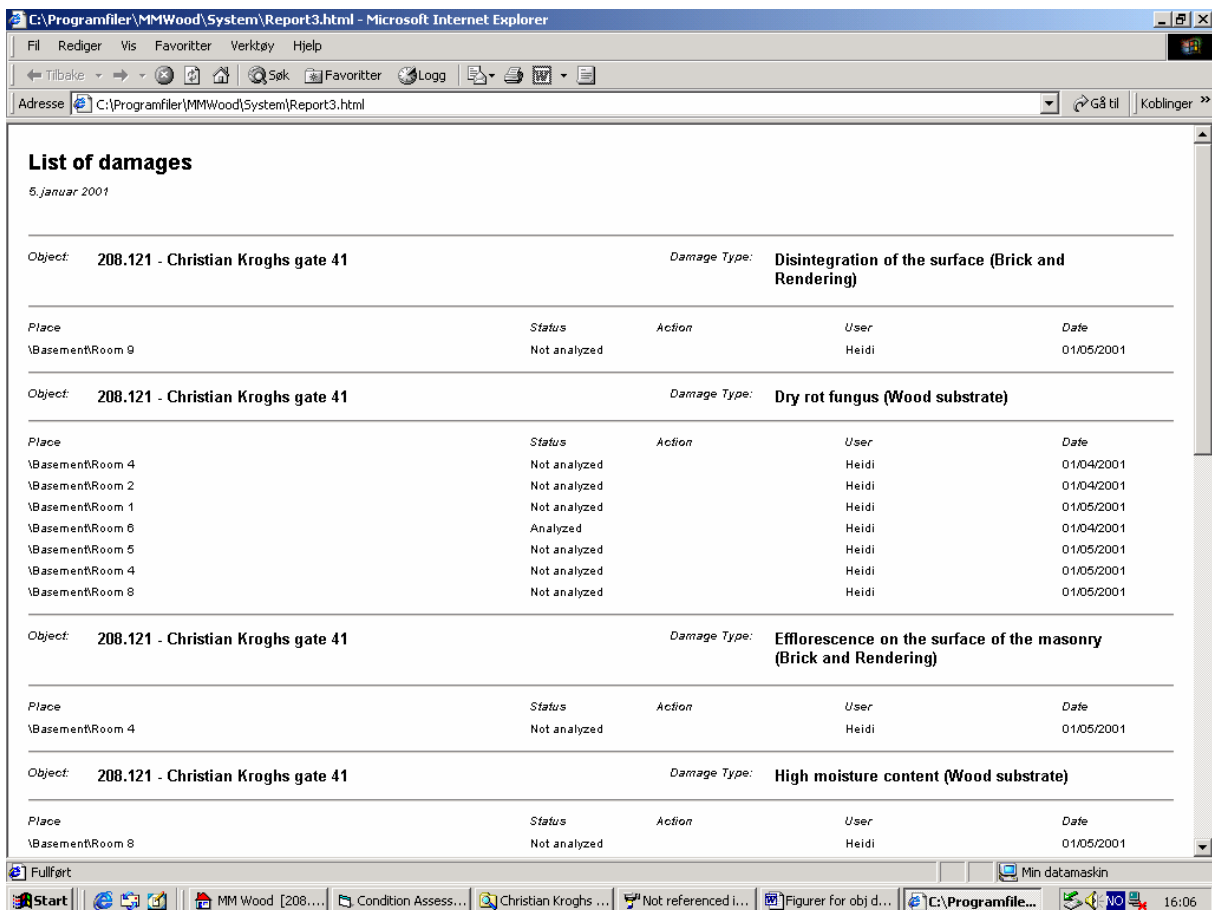


Figure 42: Example of report List of damages.

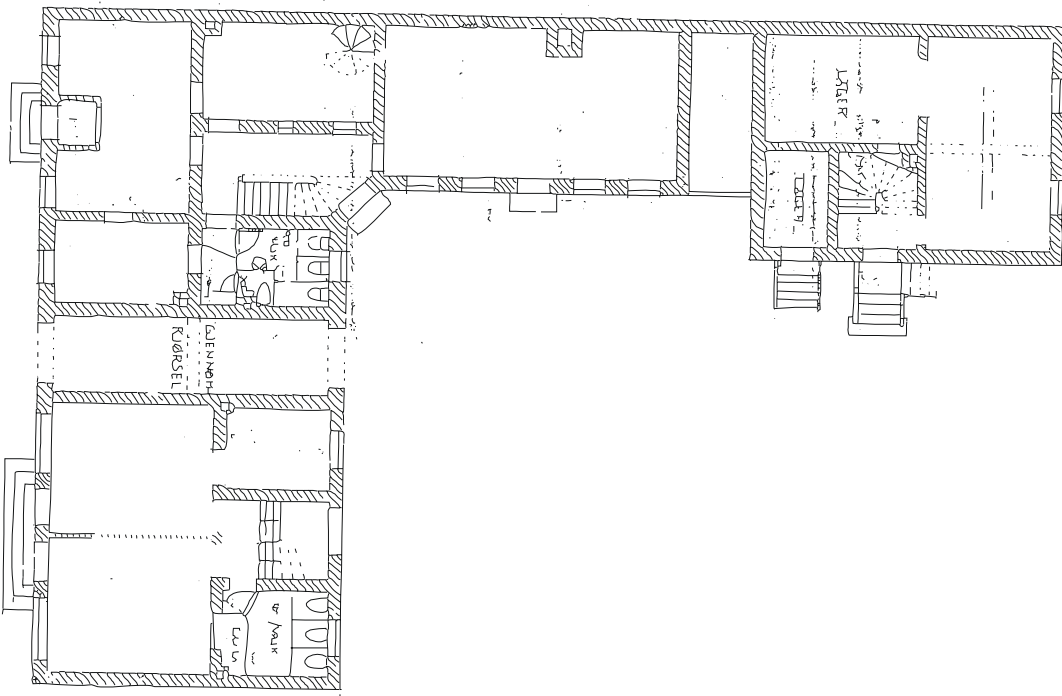


Figure 43: Drawing of ground floor of Christian Krogh's gate 41.



Figure 44: Front facade Christian Krogh's gate 41



Figure 45: Front facade Christian Krogh's gate 41



Figure 46: Detail from the facades



Figure 47: Detail from the facades

4.7.3.3 Conclusion

The building is in an overall relatively poor condition, due to lack of maintenance during a long period of time. Much work needs to be done. It will be too extensive to go into details on the different decisions/suggestions for work here.

4.7.4 Documentation of the Italian object

This documentation shows an extract of the documentation done at the Italian object “Maso S. Cassiano”. More detailed information can be found in the MMWood reports ENV4-CT98-0796 D03.01d Report Building Documentation Italian demonstrator (Garofolo, 2000) and ENV4-CT98-0796 D03.02d Documentation Italian demonstrator Riva del Garda (Frattari et al, 2000).

4.7.4.1 Object information and Configuration of the system

The chosen object properties for the Italian object are shown in Table 12.

Table 12: Object property for the Italian object.

Name	Maso S. Cassiano
ID	M-01
Address	Voa dei Molini 28 – Riva del Garda
Material	Stone – wood
Built in	1600 ca
Owner	I.T.E.A. Istituto Trentino per l’Edilizia Abitativa (Via Gardina 22 – Trento – Italy - tel 0461/803111)
Original owner	Municipality of Riva del Garda
Original architect	-
Works/rooms/details of value	No
Building protected or preserved	The Building is protected – law n.1089, date 1939
Area protected or preserved	P.R.G (urban development plan)
Fire Risk	No
Number of parts of buildings	2
Number of floors of the building	3

Floor surfaces	987
Volume	3410
Clear heights	Max 2.60 – min 2.10
Building alteration	1983
Building addition	-
Mostly function	Habitation
Remarks	

The chosen building types is: House, Maso, Church, Farm, Civil apartment building, Commercial building, and Administrative building. See Figure 9. The Italian object refers to the category “Maso”.

The following Building Parts has been defined in the configuration:

Inner wall – external wall – ground floor – roof – window – inner stair – first floor – second floor – third floor – fourth floor – door – glass – shutters – window sill – stone window mullion – window lintel – window frame – wooden beam – eaves channel – bent tile – floor – rendering – eaves – ceiling – inner rendering – stone window drip – facade – window jamb – drainpipe – fence – wall – coping

For each building part, some properties have to be defined. The building part properties chosen are a few and very simple: name of the building part, identification number, and material.

Examples of some photos and drawings linked to Object are shown in Figure 48, Figure 49, and Figure 50.



Figure 48: The main facade (south) of Maso S. Cassiano



Figure 49: The court

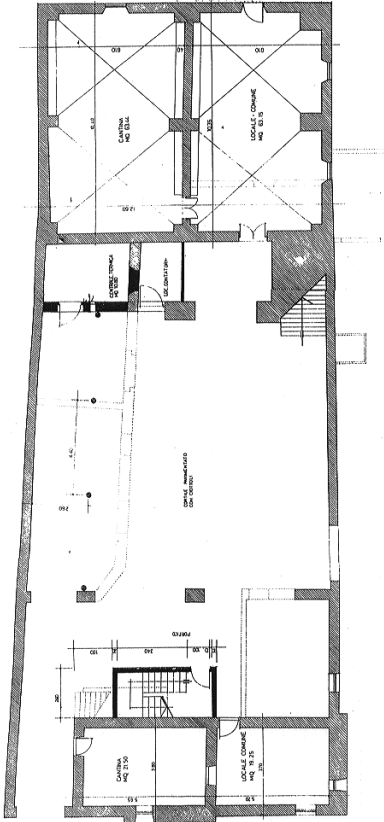


Figure 50: Drawing of the first floor

The object and its parts have been defined through a tree structure. The main building parts have been defined, and they have been divided into sub-building parts, going from the general to the particular.

The tree structure as appears in the Condition Assessment Module, with a particular example (Facade south – window S-1-1) is shown in Figure 52.

In particular, the three facade of the south building has been analysed together with the roof structure and the fence of the court. So, the building has been divided into five main parts: facade south – facade north – facade east – roof – fence.

Each main building part has been divided into sub-building parts, and so on. For each building part, the damaged elements have been analysed. For example, the following tree structure has been defined for the facade south with particular reference to the window S-1-1:

- Maso S. Cassiano
 - Facade S
 - Rendering 1
 - Rendering 2
 - Window S-1-1
 - Window sill
 - Window jamb right
 - Window lintel
 - Window frame
 - Window S-1-3
 - Window S-2-1
 - Window S-2-2
 - Window S-2-3
 - Window S-2-4
 - Window S-2-5
 - Window S-3-1
 - Window S-3-3
 - Window S-3-5
 - Door (main entrance)
 - Drainpipe right

An orientation system has been chosen to identify the different building parts. The facades of the building have been divided into axis (x and y) depending on the number of floor (x) and on the number of windows (y). So, for example, Window S-2-4 means the window on the south facade, at the second floor in the fourth position, Figure 51.

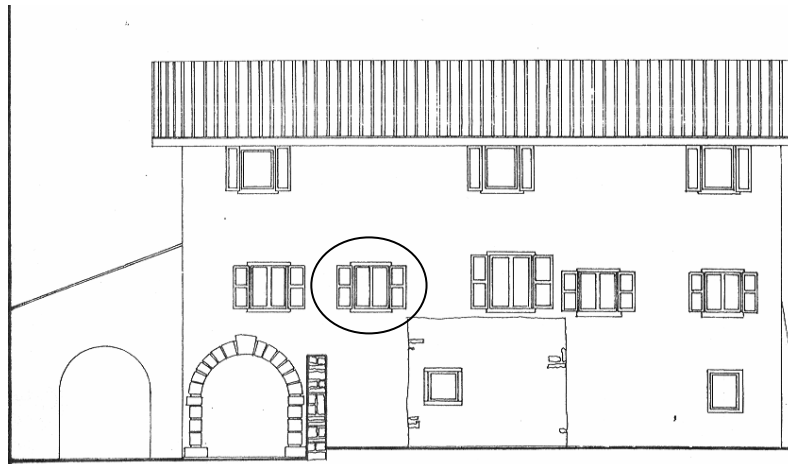


Figure 51: The position of the window S-2-4

All the observation proposed in the MMWood has been included. Only some of them have been used related to the building parts of Maso S. Cassiano. In particular: Corrosion, Cracking, Deformation, Destroyed parts, Discoloration, Flaking, Overgrowth, Scaling, Wetness, Crack in masonry, Crack in stone, and Missing parts.

4.7.4.2 Condition Assessment of Object

A monthly inspection has been simulated to investigate Maso S. Cassiano. It has been concluded the 13.10.2000. The South part of the building has been observed, together with the external stone fence, according to what is written in 4.7.4.1.

Maso S. Cassiano has been divided into five main parts. Every part has been divided into sub building parts; only the parts presenting problems have been taken into account and deeply monitored. Figure 52 shows the Condition Assessment module and the chosen tree structure. On the left there is the tree structure defining the building and its parts divided into sub-building parts, while on the right there are (from the top to the bottom): the object properties, some meaningful photos of the building or of a particular building part, the map of the site and the drawings (plants, sections, details and so on).

In this example, a particular case of the tree structure is shown:

```

Maso S. Cassiano
  Facade South
    Window S-1-1
      Window sill
        Crack in stone
          To be fixed
    
```

So, the user knows that a damage (crack in stone) is present in the window sill of the window named S-1-1 (according to the chosen orientation system) of the south facade, and that this damage is to be fixed.

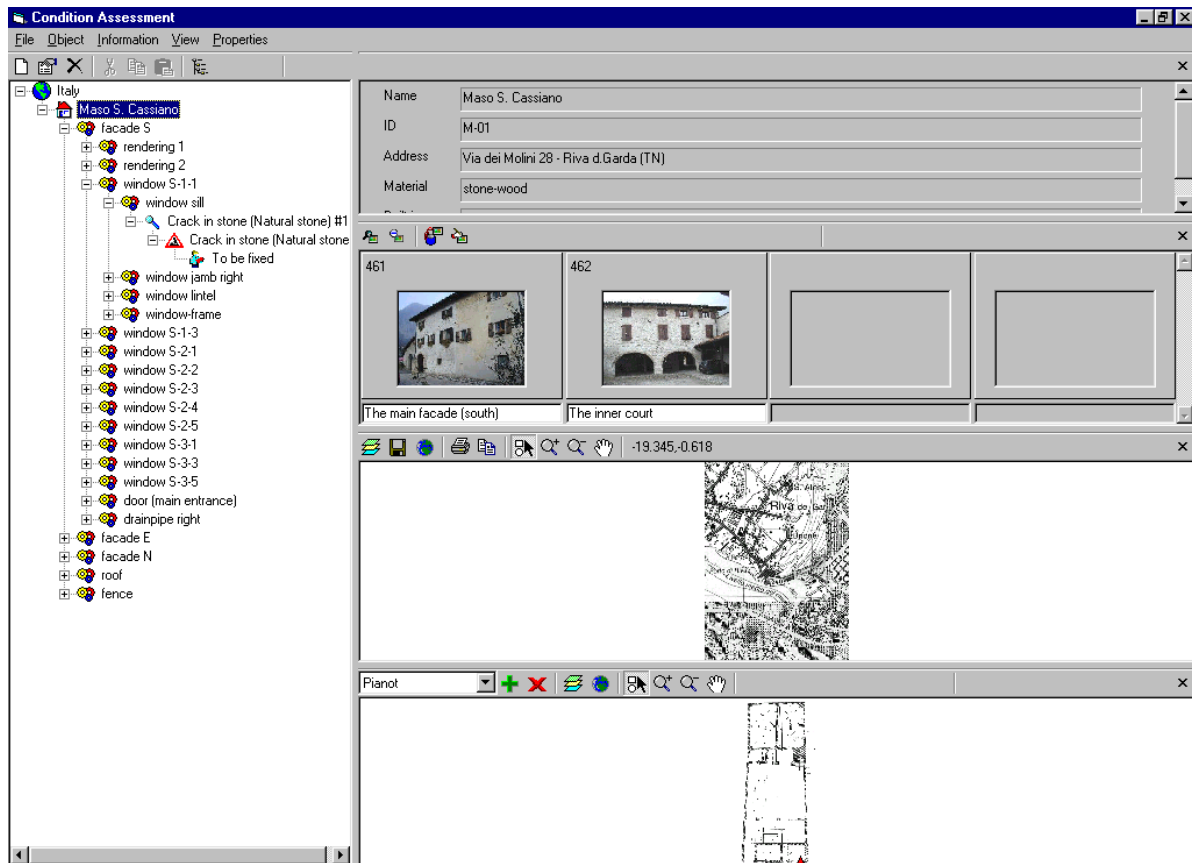


Figure 52: The Condition Assessment Module and the tree structure

Following, two examples are shown regarding the investigation of three different parts and so three different damages.

Observation done (an example) – Figure 53, Figure 54, and Figure 55.

Building part: Facade S – Window S-1-1 – Window sill

Observation: crack in stone

Damage: crack in stone

Status: analysed

Last edited by: admin

Action: Action 1

Decision: to be fixed

Importance, priority: low

Work type: mason

Work due: 01.04.2001

Responsible: Tecnico 1

The screenshot shows a 'Properties' dialog box with the following fields and values:

- Description: Crack in stone (Natural stone) #1
- ID: 01
- Date: 13/10/00
- Comments: A crack is clearly visible, in the middle of the sill, dividing it into two different parts
- Type of material: natural stone
- Type of mortar (Natural stone): Hydraulic lime mortar
- Type of stone: Limestone
- Investigation methods: visual
- Condition degree: 2: Medium-strong symptoms
- Extent of the symptom: (empty)
- Length: (empty)
- Width: (empty)
- Possible causes: deformation, physical tension due to varying temperature
- Totale condition degree: 2: Medium-strong symptoms
- Consequences: 1: Minor consequence
- Recommended actions: filling up the cracks with mortar

Figure 53: Questionnaire related to the observation Crack in stone.

The screenshot shows a 'Properties' dialog box with the following fields and values:

- Primary decision: To be fixed
- Importance, priority: Low
- Work type: mason
- Work due: 01/04/01
- Responsible: Tecnico 1

Figure 54: Decisions concerning the damage Crack in stone.

The screenshot shows a 'Properties' dialog box with the following fields and values:

- Name: Crack in stone (Natural stone)
- Status: Analyzed
- Last edited by: admin
- Action: Action 1

Figure 55: Status concerning the damage Crack in stone. Status is Analysed or Not analysed.

Observation done (an example) – see Figure 56, Figure 57, Figure 58, and Figure 59.

Building part: Fence – Main entrance – Coping

Observation: overgrowth

Damage: overgrowth

Status: analysed

Last edited by: admin

Action: Action 1

Decision: to be fixed

Importance, priority: low

Work type: mason

Work due: 02.05.2001

Responsible: Tecnico 1

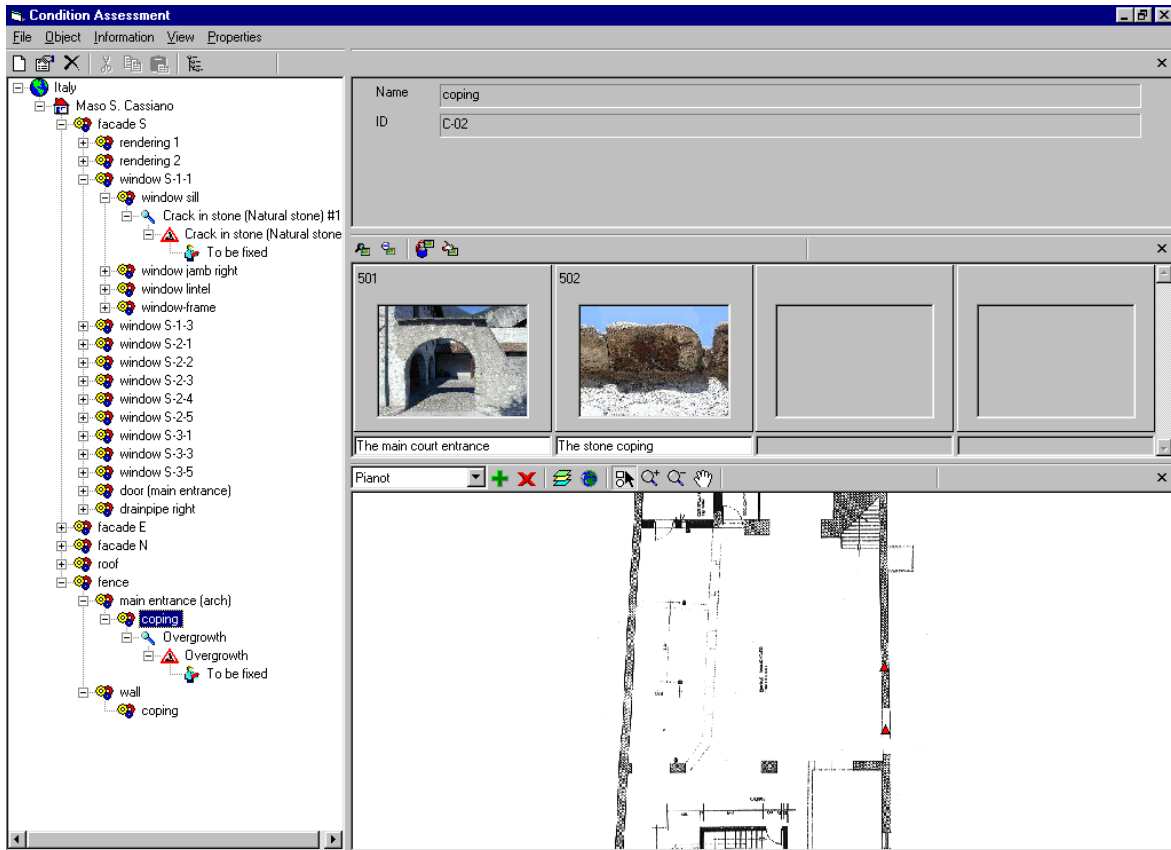


Figure 56: Figure showing the tree structure with the Observation, Damage, and Decision.

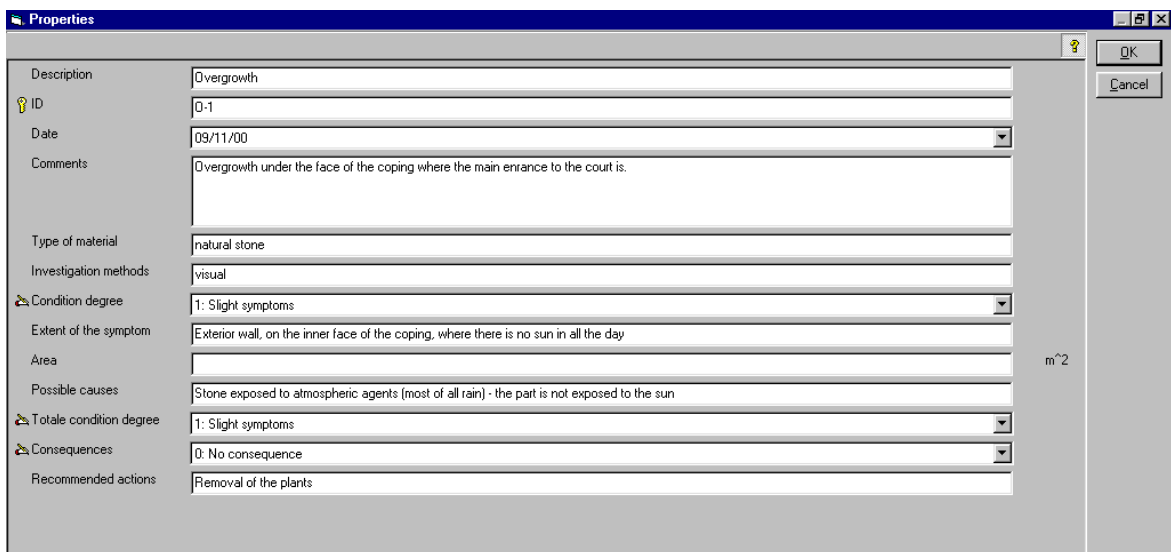


Figure 57: Questionnaire for the observation Overgrowth

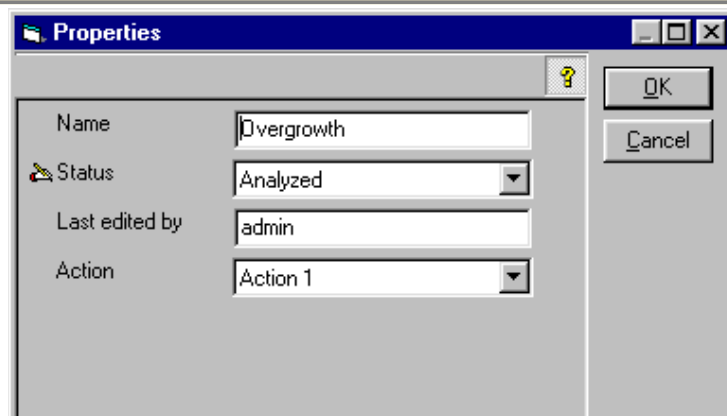


Figure 58: Status concerning observation Overgrowth

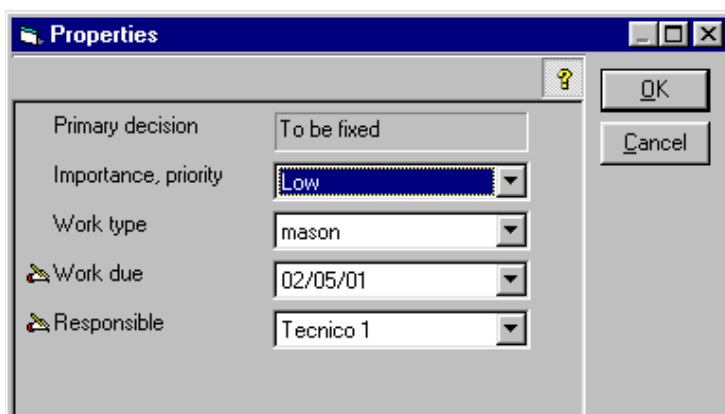


Figure 59: Decisions concerning observation Overgrowth

4.7.4.3 Conclusion

The Italian object “Maso S. Cassiano” has been analysed. An in field inspection has been made in order to have the maximum number of information about the structure, its parts and the existing damages. A lot of photos and drawings have been taken with reference to the various building parts and to the existing damages. Back in office, the system has been configured in all its parts.

A tree structure of the building has been made, and the different building parts have been deeply analysed: each part has now its own code (ID) and name. All the data collected have been put in the system, with reference to pictures and drawings that have been appropriately commented.

For every building part, observations have been made according to the Damage Atlas and to the data collected in field. In particular, the following information has been defined: type of material, investigation methods, condition degree, extent of the symptom, possible causes, total condition degree, consequences, recommended actions.

The damages have been properly analysed and decisions have been taken about the priority, the type of work and when it is due, and a responsible for the work has been named.

5 Work Package 4 – Environmental risk factor module

5.1 Objectives

Provide and synthesise the necessary environmental data for exploiting the methods and models developed in Wood-Assess for the participating countries Italy, Germany, Sweden and Norway.

5.2 Technical approach

The Wood-Assess project developed the methodology for assessing and mapping environmental risk factors and -areas for wood on regional, local, and micro scale in Europe based on assessing both Scheffer's Climatic Risk Index (SCRI) (Scheffer, 1971) for potential wood decay and also the potential of a WETCORR based CRI for the micro-environmental conditions (Haagenrud et al, 1998).

It was shown that yearly and monthly SCRI could be calculated and mapped by use of available meteorological data for temperature and precipitation from a very extensive network of stations in all four countries. In order to increase the spatial resolution and thus the reliability of risk factor assessment, the temperature and precipitation can be modelled on the regional and local level taking into account the effects of topography and sunny and shaded areas. A cell based digital terrain model in GRID/ArcInfo has been developed to give a good description of SCRI on a regional and local scale based on available meteorological data. Digital maps with models of precipitation, temperature and relative humidity can probably also be obtained from the national meteorological office and form a proper basis for more detailed modelling of SCRI.

Extending the list of materials also arouse the need for other models than used in Wood Assess. The emphasis was put on existing methods to calculate or predict service life, and models for defining the necessary environmental input.

Many studies have been performed to establish dose-response functions or service life equations (Haagenrud, 1997; Henriksen and Haagenrud, 1996; Butlin et al, 1994, Haagenrud, 1997). Service life equations for some building materials were also found statistically by inspection in field in 3 European cities, the MOBAK study (Kucera et al, 1993).

Climatic and possibly other environmental data will be provided together with digital maps for the regions under considerations. Using European standards like prEN 13013-3 "Calculation of driving rain index for vertical surfaces from hourly wind and rain data" (CEN, 1997) and the models and mapping techniques established, environmental risk factors will be elaborated for the regions and the local environment for the pilot objects.

A pilot version of for performing cost-benefit analysis (CorrCost) is also made available for the project. It contains modelling of air quality parameters and best available damage-functions and is used to exhibit the environmental risk factors in the test location Oslo.

5.3 Materials chosen

In addition to wood, the present project covers other materials in connection with wooden houses. The chosen materials are:

- wood,
- painted wood
- stone,
- bricks,
- rendering,
- painted rendering.

5.4 Service life prediction

5.4.1 Introduction

The degradation of buildings are influenced by a whole set of factors such as environmental degradation agents classified in Wood Assess according to ISO 6241 (ISO 6241, 1984), quality of material, protective treatment, quality of work, maintenance and so on.

The relationship between the environmental degradation agents and the observed effect are expressed as dose-response functions. If performance requirements and their limit states are included into the functions, it transforms into a damage function.

Service life equation may also be found from building assessment and a statistical treatment of building or building part condition, age of building or building part, maintenance interval, and environmental factors, like the MOBAK study (Kucera et al, 1993).

A simple approach to service life consists of giving just one plane figure for the estimated service life for the respective component. Somewhat more advanced is the approach according to ISO 15686-1 (ISO 15686-1, 2000, ISO 15686-2, 2001), where average values for the reference service lives RSLC of the different building parts are set up and combined with factors according to the following equation, and one single value for the estimated service life of the component ESLC is derived:

$$ESLC = RSLC * A * B * C * D1 * D2 * E * F$$

where

A = Quality of component

B = Design level

C = Work execution level

D1 = Indoor environment

D2 = Outdoor environment

E = In use conditions

F = Maintenance level

It is quite evident, that the real behaviour of a group of similar building parts cannot be characterised significantly by one single value. Hence a more detailed analysis is required, in most cases a probabilistic approach. Figure 60 shows a schematic density curve based upon experience or manufacturer's data. However, if sufficient data from experience, from testing or from manufacturer is not available, a density curve of the estimated service life can be

defined by professional estimate or by the recursive Delphi method. This is best done by setting values to the average (50%) and to the minimum and maximum values. The fractiles are partial integrals of the density function, whose total integral is 1.0 or 100% equal to all elements included.

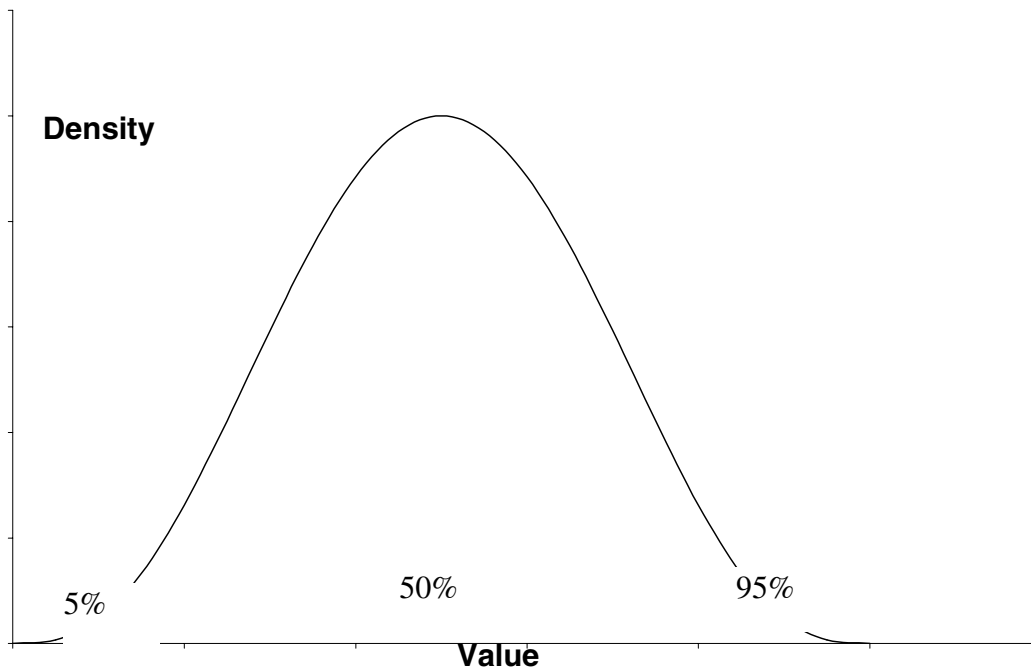


Figure 60: Visualised typical fractiles defining density distributions.

Then a design life with confidence levels are chosen like in structural engineering.

5.4.2 Wood

For wood the Scheffer's index (Scheffer, 1971) gives information of the rotting tendency as function of climatic parameters as temperature and moisture. This function expresses the average impact of most important rotting fungi in the US.

Scheffer's Climatic Risk Index (SCRI),

$$SCRI = \frac{\sum_{Jan.}^{Dec.} [(T - 2)(D - 3)]}{17}$$

T = Monthly average temperature

D = Number of days with precipitation more than 0.01 inch (monthly values)

Scheffer's CRI was developed in response to the demand from the US-authorities for an easy way to predict the decay hazard of wood structures in different areas of USA. The most important requirements for such a climatic risk index were:

1. The index should correlate satisfactory with measured decay rates obtained experimentally in different climates and recognise the level of decay in different parts of the country.
2. The index should use climatic data, which were regularly available from the meteorological offices.
3. The index should be easy to use and should therefore
 - a. contain as few elements as possible,
 - b. range from 0 to approximately 100.

Temperature and moisture were recognised as the two most dominating factors for the decay of wood by rotting. For temperature it was known that the rotting processes stops at low temperatures and a limit of +2°C was selected. For moisture the duration of rain was taken as the dominating factor. For practical reasons basically to increase the amount of data available the factor days with precipitation above 0.01-inch (D) was selected to represent duration of rain.

The guiding classification proposed by Scheffer:

- SCRI 35 – the least favourable conditions for decay
- SCRI 35 to 65 – the intermediately favourable conditions for decay
- SCRI 65 – the most favourable conditions for decay

Since the participating countries measure and report the data in metric terms the precipitation limit of 0.1-mm instead of 0.01-inch should be selected. Defining the European guiding classification, when using 0.1-mm precipitation as limit for days with precipitation, and taking into concern European wood instead of American, will be an important issue.

The MOBAK (Kucera, 1993) study gave a service life equation for painted wood, where the service life indicates the degradation of paint.

Painted wood

$$L = \frac{1000}{1.03 \cdot \text{SO}_2 + 87.5 + 260 \cdot \text{rain} \cdot \text{H}^+}$$

5.4.3 Rendering/stone/bricks

The influences that affect the rate of weathering of stone, bricks and rendering are temperature, moisture, and air pollutants. The average rainfall is a major controlling factor of weathering rate because the rainwater will carry air pollutants into the stone by absorption. The absorbed rain and industrial pollutants will accelerate the weathering rate. It is these factors and the mineralogy that results in the variability of behaviour for natural stone.

Stone exposed to air pollution may show signs of weathering by undesirable discolouring, loss of polish and surface erosion. Air pollutants, or acid pollutants, can have serious detrimental affects on carbonate stones, such as limestone and marble. Rainfall that is absorbed into the stone is a controlling factor of weathering. The amount of CO₂ in the water causes the rate of dissolution of the carbonate minerals. Depending on the mineral composition of the stone, the water can cause the mineral to dissolve by percolating water

solutions or by chemical decomposition. Higher temperature increases the chemical agitation of the minerals. Hence, such reactions are greater in the tropical areas than in the colder temperature zones.

Depending on the location of a building, the temperatures on the surface of a dark stone facade can become very high during the summer and very cold during the winter. The changes in temperatures can cause decomposition of a stone facade due to differential volume changes (expansion and contraction) of the various mineral grains that comprise the stone. The different rates of thermal expansion of individual mineral types that comprise a single stone will cause the deterioration. All minerals expand with increasing temperature, but they expand at different rates and in different directions. The volumetric or linear expansion of the different minerals can cause micro cracking. The micro cracking will lower the strength of a stone and allow other weathering phenomena to enter and accelerate the disintegration process.

Damage to the stone can result as entrapped water expands under freezing conditions within the pores, and fissures that comprise the structure of the stone. The absorbed water forms expansive ice crystals that produce high compressive forces on the walls of the pores, cracks, and fissures. The compressive forces will produce tensile stresses on the crystalline bonds between components of the stone. Cyclic wetting, drying, freezing and thawing can eventually lead to fatigue of the crystalline bond and cause decomposition of the stone. Because of this, the tensile strength of the bond between mineral grain particles is of greater importance than the overall compressive strength when considering the durability of a stone.

The pores may also contain clays, some of which will expand when they become wet. The swelling of these clays will also produce large compressive forces within the stone. It may not be apparent that the swelling is occurring because of the expansion of the clay may be a normal characteristic for the particular stone. The tensile strength of the bond between crystals may be great enough to resist the forces of the expansive clay. However, the stone may deteriorate rapidly when installed on the side of the building and the clay becomes wet and freezes.

The service life will also be influenced by the quality of bricks, stone, or rendering, and of cause the quality of work.

Possible dose-response functions for calculations of service life (Kucera, 1993, Kucera et al, 1995, Tidblad et al, 1998) are:

$$\text{Bricks with plaster} \quad L = \frac{1000}{0.124 * SO_2 + 15.5 + 13 * \text{rain} * H^+}$$

$$\text{Bricks with painted plaster} \quad L = \frac{1000}{0.278 * SO_2 + 18.8 + 70 * \text{rain} * H^+}$$

Bricks \quad If $SO_2 < 10$, $L=70$ years, else $L=65$ years

For stone the corrosion rates, R = corrosion (μm), are expressed as:

$$\text{Limestone} \quad R = 3.3 + 0.6 * TOW * SO_2 + 37 * \text{rain} * H^+$$

Calcareous stone $R = 2.8 + 0.6 * TOW * SO_2 + 37 * rain * H^+$

For Mansfield sandstone the corrosion after a number of years, t, is expressed as:

$$R = t^{0.91} * (2 * [SO_2]^{0.52} + 28 * rain * [H^+]) \quad T \leq 10^\circ C$$

$$R = t^{0.91} * (2 * [SO_2]^{0.52} * \exp\{-0.013(T-10)\} + 28 * rain * [H^+]) \quad T > 10^\circ C$$

A similar set of functions exists for limestone:

$$R = t^{0.96} * (2.7 * [SO_2]^{0.48} + 19 * rain * [H^+]) \quad T \leq 10^\circ C$$

$$R = t^{0.96} * (2.7 * [SO_2]^{0.48} * \exp\{-0.018T\} + 19 * rain * [H^+]) \quad T > 10^\circ C$$

T = average yearly temperature, and t = number of years.

From the expressed corrosion rates and the performance requirement (PR) damage functions for stone are found.

$$\text{Limestone} \quad L = \frac{PR}{3.3 + 0.6 * TOW * SO_2 + 37 * rain * H^+}$$

$$\text{Calcareous stone} \quad L = \frac{PR}{2.8 + 0.6 * TOW * SO_2 + 37 * rain * H^+}$$

Further in calculations the performance requirement is degradation less than 5mm.

5.5 Use of a draft European standard, prEN 13013-3

The available regional exposure data can after appropriate adjustment be used for characterisation of the local and microenvironment at a building. The prEN 13013-3 “Calculation of driving rain index for vertical surfaces from hourly wind and rain data.” (CEN, 1997) is mainly based on the British standard BS 8104:1992 “Code of practice for assessing exposure of walls to wind-driven rain.” (BS 8104:1992).

The standard specifies a procedure for analysing hourly rainfall and wind data derived from meteorological observations so as to provide an estimate of the quantity of water likely to impact on a wall of any given orientation. It takes account of topography, local sheltering and the type of building and wall. It specifies the method of calculation of:

- The annual airfield index, which influences the moisture content of masonry wall.
- The spell index, I_s , which influences the likelihood of rain penetration through masonry wall.

The airfield index is the quantity of driving rain that would occur during one hour at a height of 10m above ground level in the middle of an airfield, at the location of the wall. The airfield annual index is the airfield index for a given direction totalled over one year.

A spell is defined as the period, or sequence of periods, with wind driven rain on a vertical surface of a given orientation, and the airfield spell index is the airfield index for a given direction totalled over the worst spell likely to occur in any 3-year period.

The formula to calculate the spell index is:

$$I_s = 2/9 * \sum v r^{8/9} \cos(D-\Theta)$$

where v is the hourly mean wind speed in m/s, r is the hourly rainfall in mm, D is the hourly mean wind direction from the north, Θ is the angle between north and a line normal to the wall and the summation is taken over all hours for which $\cos(D-\Theta)$ is positive, i.e. all those occasions when the wind is blowing against the wall. Figure 61 shows an illustration of the angles for different wind directions and wall orientations.

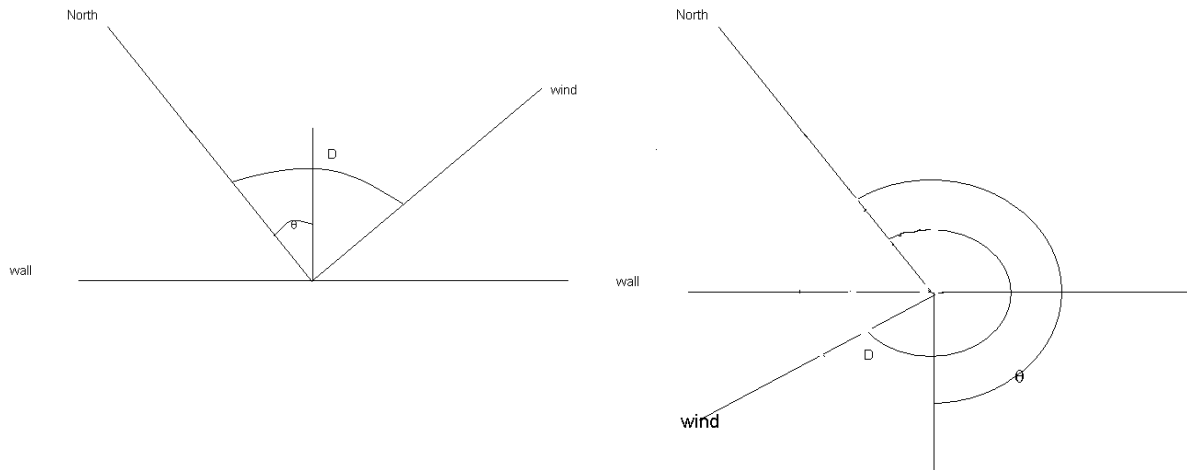


Figure 61: Illustration of mean wind direction, D , and Θ , which is the angle between north and a line normal to the wall.

After calculating the I_s for a period of time, the next step is to estimate the actual buildings location and exposure compared to an airfield. That is performed by estimating the values of four different parameters, the roughness coefficient C_R , the topography coefficient C_T , an obstruction factor, O , and a wall factor, W and converting the airfield indices into wall spell indices, I_{ws} , by the formula:

$$I_{ws} = I_s \times C_R \times C_T \times O \times W$$

The prEN has categorised, described and illustrated the C_R , C_T , O and W factors. The factors in Table 14, Table 15, Table 16, and Table 17 are from BS 8104. These descriptions should be used when categorising the environmental exposure of the test objects. The estimated values for the coefficients were found for the objects Augustinern 22, Vällingby, Christian Krogh's gate 41, and Maso S. Cassiano. The values are shown in Table 13.

Terrain roughness factor, C_R = factor which allows for the general conditioning of the wind speed by the roughness of the terrain upwind of a wall. (Relates to terrain roughness category, which is a description of the general terrain upwind in terms of average height and spacing of protective features, e.g. buildings, trees, and hedges.)

Topography factor, C_T = factor which allows for the effect of local topography on wind speed.

Obstruction factor, O = factor which relates to shelter from the very local environment, and allows for obstructions, such as buildings, fences or trees, close to and upwind of the wall. It is also concerned with the line of sight.

Wall factor, W = factor which allows for the characteristics of the proposed wall. It is the ratio between the quantity of rain falling on the wall and the quantity falling on equivalent unobstructed space.)

Table 13: Estimated values for the roughness coefficient, C_R , the topography coefficient, C_T , the obstruction factor, O , and the wall factor, W .

	Factor	Augustinern 22	Vällingby	Christian Krogh's gate 41	Maso S. Cassiano
South wall	C_R	0.75	0.85	0.75	0.85
	C_T	1.0	1.0	1.0	1.0
	W	0.4	0.4	0.3	0.3
	O	0.2	0.5	0.4	1.0
East wall	C_R	0.75	0.85	0.75	0.85
	C_T	1.0	1.0	1.0	1.0
	W	0.3	0.3	0.4	0.3
	O	0.2	0.5	0.3	1.0
North wall	C_R	0.75	0.85	0.75	0.85
	C_T	1.0	1.0	1.0	1.0
	W	0.4	0.4	0.4	0.3
	O	0.2	0.5	0.2	0.2
West wall	C_R	0.75	0.85	0.75	0.85
	C_T	1.0	1.0	1.0	1.0
	W	0.3	0.3	0.4	0.3
	O	0.2	0.5	0.3	1.0

Table 14: Terrain roughness factor R .

Terrain roughness category	Description of the terrain upwind of (i.e. facing) proposed wall	Terrain roughness factor R
0	Land offering no effective shelter to the wall, which is less than 8 km from a coast or large estuary.	1.15
1	Land offering no effective shelter to the wall, which is 8 km or more from a coast or large estuary. Examples are open country with walls or hedges more than 200 m apart and land that falls away in the direction upwind of the wall if this means that buildings or trees offer little protection.	1.00
2	Land with frequent low-level obstructions such as walls, hedges or single storey buildings. Examples are farmland and low-density housing development especially those with a large proportion of single storey buildings.	0.85
3	Land with closely spaced obstructions, such as buildings and trees. Examples are built-up areas, well-wooded parkland and forests. The obstructions should offer a substantial degree of wind shelter.	0.75

Table 15: Values of topography factor *T*, for land that does not slope down steeper than 1 in 20.

Description	Topography	Remarks
<i>Valley or grouping of buildings liable to produce a funnelling of the wind</i>	1.2	
<i>Steep-side, enclosed valleys known to be sheltered from the wind</i>	0.8	<i>Such cases are rare</i>
<i>All other cases (where nearby slopes are less than 1 in 20)</i>	1.0	<i>For effects of slopes steeper than 1 in 20.</i>

Table 16: Obstruction factor, *O*

Distance of obstruction from proposed wall, m	Obstruction factor <i>O</i>
> 4 to 8	0.2
> 8 to 15	0.3
> 15 to 25	0.4
> 25 to 40	0.5
> 40 to 60	0.6
> 60 to 80	0.7
> 80 to 100	0.8
> 100 to 120	0.9
> 120	1.0

Table 17: Wall factors, W.

Description of wall	Average value	Distribution
two storey gable	0.4	
three storey gable	0.3	
1) multi-storey (flat roof)	0.2 for e.g. ten storey (but note higher intensity at top)	0.5 for top 2.5 m 0.2 for remainder
two storey eaves wall	0.3	
three storey eaves wall	0.4	
two storey flat roof (pitch <20°)	0.4	

1) These data apply to multi-storey blocks of normal aspect width. No data are available for exceptionally narrow buildings.

5.6 Environmental information

The partners responsible for the object have also been responsible for collecting the necessary environmental information.

5.6.1 Necessary meteorological data

For calculation of Scheffer's index:

- Average monthly temperatures for at least one year, preferably for a longer period, T.
- Monthly records for days with precipitation = 0.1 mm for at least one year, D, preferably for a longer period. The precipitation limit of 0.1 mm instead of 0.01 inch is selected since the participating countries measure and report the data in metric terms.

For calculation of service life for other materials:

- Average yearly temperature, temperature in a “normal” year
- Average yearly amount of precipitation, rain, in meters. Precipitation in a normal year.
- Average yearly humidity, %.
- Distance from the meteorology station to the building/buildings in the project to evaluate representativity.

Time of wetness, TOW, is calculated from average temperature and humidity, following the equation:

$$TOW = (-10700 + 176 * RH + 120 * T) / 8760$$

For calculations of Spell index, I_s , the necessary data are:

- hourly values of precipitation
- hourly values of wind speed
- hourly values of wind direction.

The standard suggests that the data used should be for a period of at least 10 years.

5.6.2 Necessary pollution data

Pollution data is necessary for calculation of service life. For historical buildings historical data may be of interest, but for predicting of service life recent and future concentrations may be as important.

- Yearly average concentration of SO_2 , $\mu g/m^3$, for the surroundings of the building. This can be either a single value or a field for the town or area.
- Acidity, concentration of hydrogen in rain, H^+ , mg/l.

5.7 Location of objects and measurements stations. Maps.

The meteorological stations and pollution measurement stations are not necessarily located close to the object. To decide how representative the measurements are for the region and the particular object, the distances between object and stations are shown on maps. The maps are also used to find the environmental risk factors for the regions where the objects are located. Further the maps are used to find the difference in climate between object and meteorological station. The availability of digital maps differs from region to region.

5.7.1 Germany - Quedlinburg

The first map covers the region of Saxony-Anhalt. The pollution station of Wurmberg is shown on the map, Figure 62. The distance from Wurmberg to Quedlinburg is 38 km. The second map (Figure 63) shows the centre of Quedlinburg. Quedlinburg is a little town in low mountain range, 124 m a.s.l. in Central Germany and former GDR. Because of the near mountain area Quedlinburg has more rain than what is normal in Germany.

The 2 pilot objects, Marschlinger Hof 7 and Augustinern 22/23 are shown on the map. The meteorological station situated in the centre of Quedlinburg is also shown on the map. The distances from the objects to the meteorological stations are a few hundred meters.

The town of Quedlinburg is situated near and West of largest industrial area in former GDR. Pollution was characterised by high industrial dust with deposition of airborne solid matter including heavy metal particles. After the political system in East Germany (GDR) had disappeared the situation changed complete: The industry was shut down, the traffic is three or four times higher and the fuel has been changed from brown coal to oil or gas.

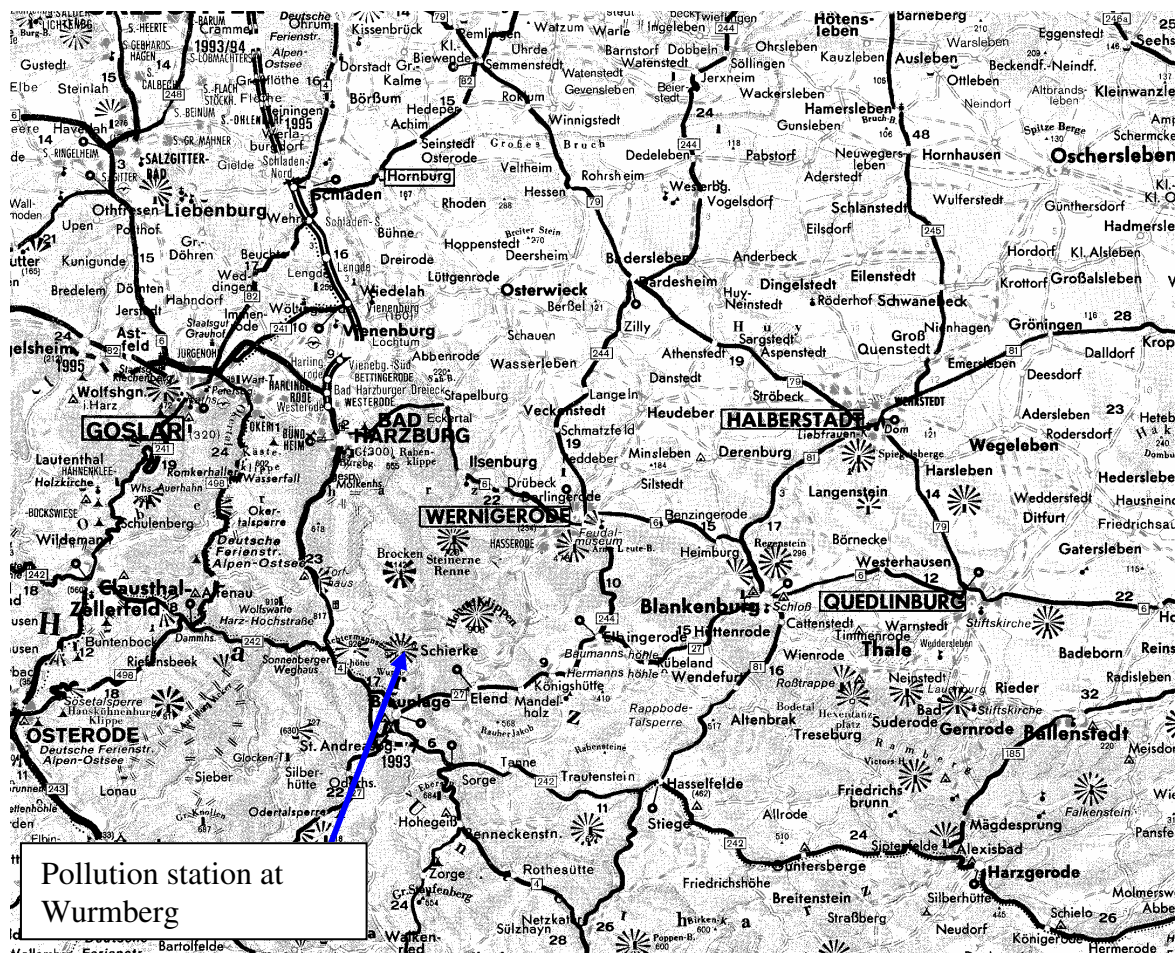


Figure 62: Region of Saxony-Anhalt. Pollution station at Wurmberg, 38 km from Quedlinburg.

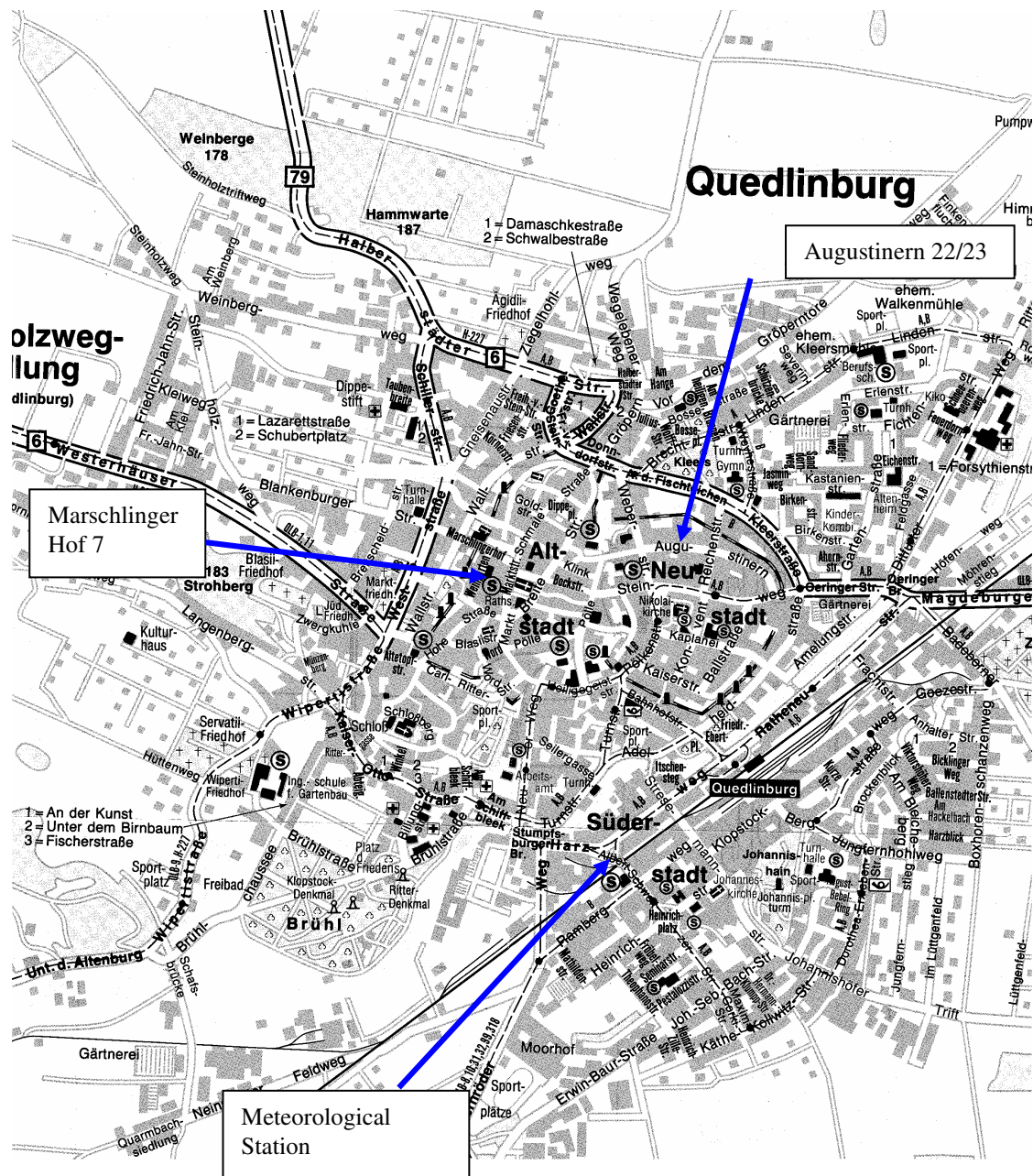


Figure 63: Map centre of Quedlinburg. The map shows the 2 demonstrator objects and the meteorological station.

Information on the pollution situation is among others from Berichte des Landesamtes für Umweltschutz Sachsen-Anhalt 1998. Heft 27: Immissionsschutzbericht Sachsen-Anhalt 1997.

5.7.2 Sweden

There are chosen three demonstrator objects in Sweden, one in Gävle and two in the Stockholm area. Both Gävle and Stockholm are situated on the East Coast of Sweden. Meteorological data for both objects are from “Klimatdata for Sverige” (Taesler, 1972) in addition to newer measurements.

5.7.2.1 Gävle

The map in Figure 64 shows the region Gävle-Sandviken. The object in the Gävle area is a school in Bergby some 20-25 km north of Gävle. The house was erected in 1919 and the owner is Gävle community. The area around the school is fairly open with some forests and without any large hills. For the object outside Gävle the meteorological station in Gävle has been used. The station is located in a similar climatic environment as the object. The pollution data however is not that well organised in the community. The only available pollution data is some measurement performed at the Royal Institute of Technology, Built Environment and some seasonal approximations from the community. It is expected that the small town of Bergby has lower pollution level than Gävle.



Figure 64: Map showing the region of Gävle-Sandviken.

5.7.2.2 Stockholm

Two objects are selected in the Stockholm area and the geographical distribution of the sites is shown in Figure 65.



Figure 65: Map of Stockholm area with the geographical areas of the objects marked

One of the objects in Stockholm is a Mission-hall in the area of “Vita bergen” which is on the south end of the old town. The building is situated on the mountainside and is surrounded by large trees, which may give rise to a more humid climate than the observations at the meteorological station in Stockholm (see Figure 66). The second object in Stockholm is a three-story blocks of flats in Vällingby, Northwest of Stockholm (see Figure 67). In the beginning Vällingby was an agricultural landscape but today it is a “satellite town”.

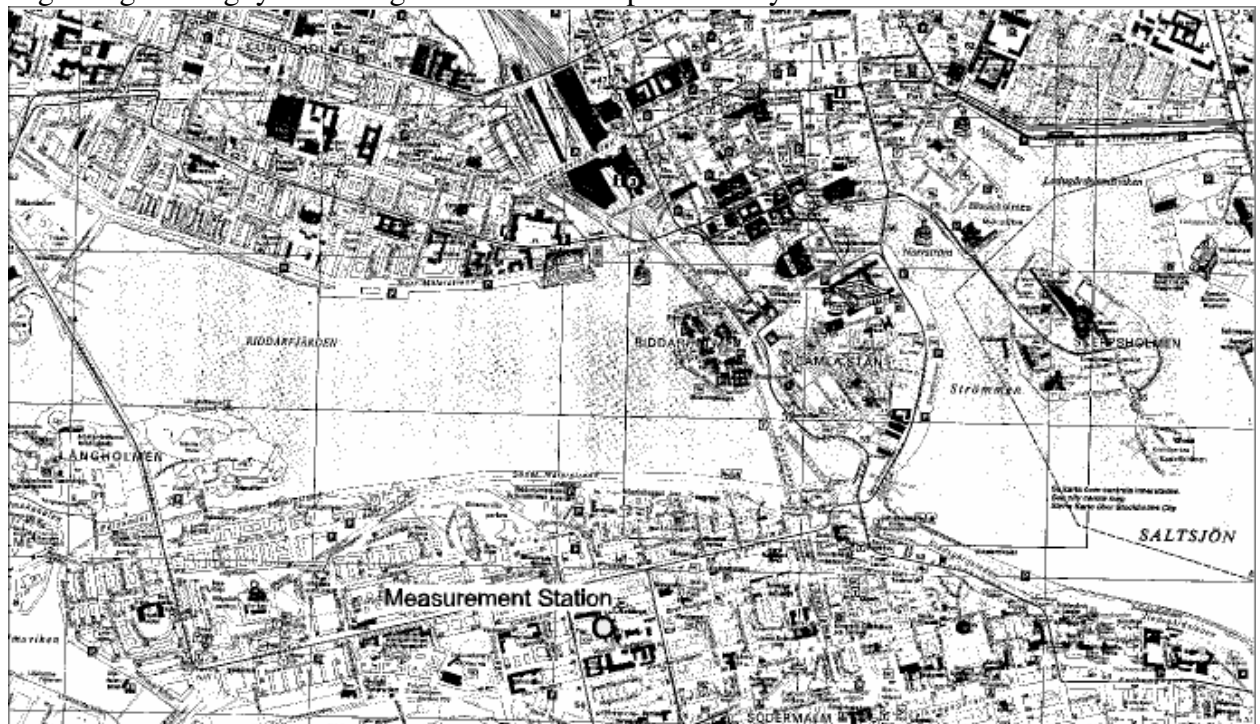


Figure 66: Map of Stockholm South with the object site and the meteorological site marked



Figure 67: Map of Vällingby with object site marked.

For the two objects in Stockholm we have used the pollution measuring and meteorological station located in the city 2 km and 12.5 km from the object.

5.7.3 Norway - Oslo

The two Norwegian objects are both located in the centre of Oslo. Figure 68 shows a map of Oslo showing the meteorological stations. Figure 69 shows a map of the centre of Oslo showing the 2 objects and the station for pollution measurements.

The meteorological station used in further calculations is Blindern. The distances from Blindern to the objects are 2.9 km and 3.5 km. The temperatures measured at the sea level at the Fornebu airport and Blindern do not differ much, the difference is due to height difference. The demonstrator objects have both heights above sea level between Blindern and Fornebu. The amount of precipitation was also collected at the pollution station in Nordahl Brun's gate. The data from this station was used as acid rain data for the objects. The distance from the station to the objects is 400 m and 900 m. Meteorological data are from Statistics Norway 1992-1998.

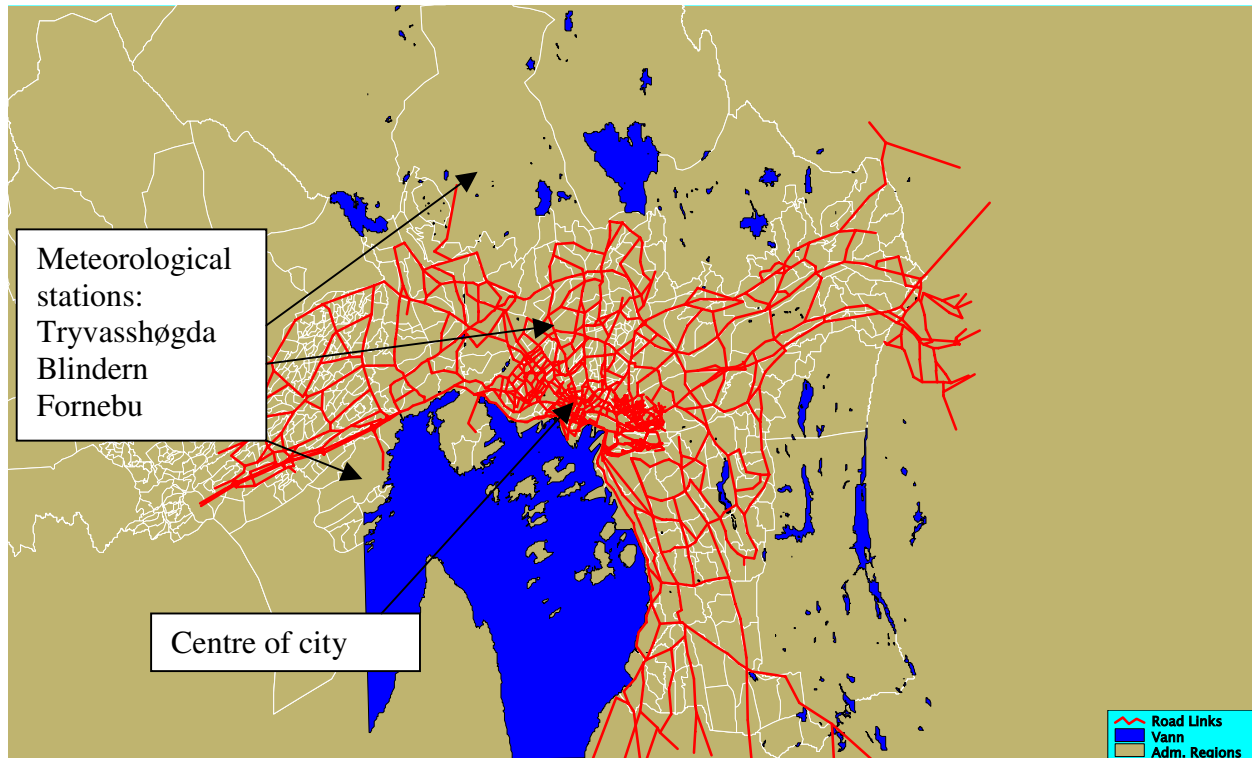


Figure 68: Map of Oslo showing the meteorological stations.

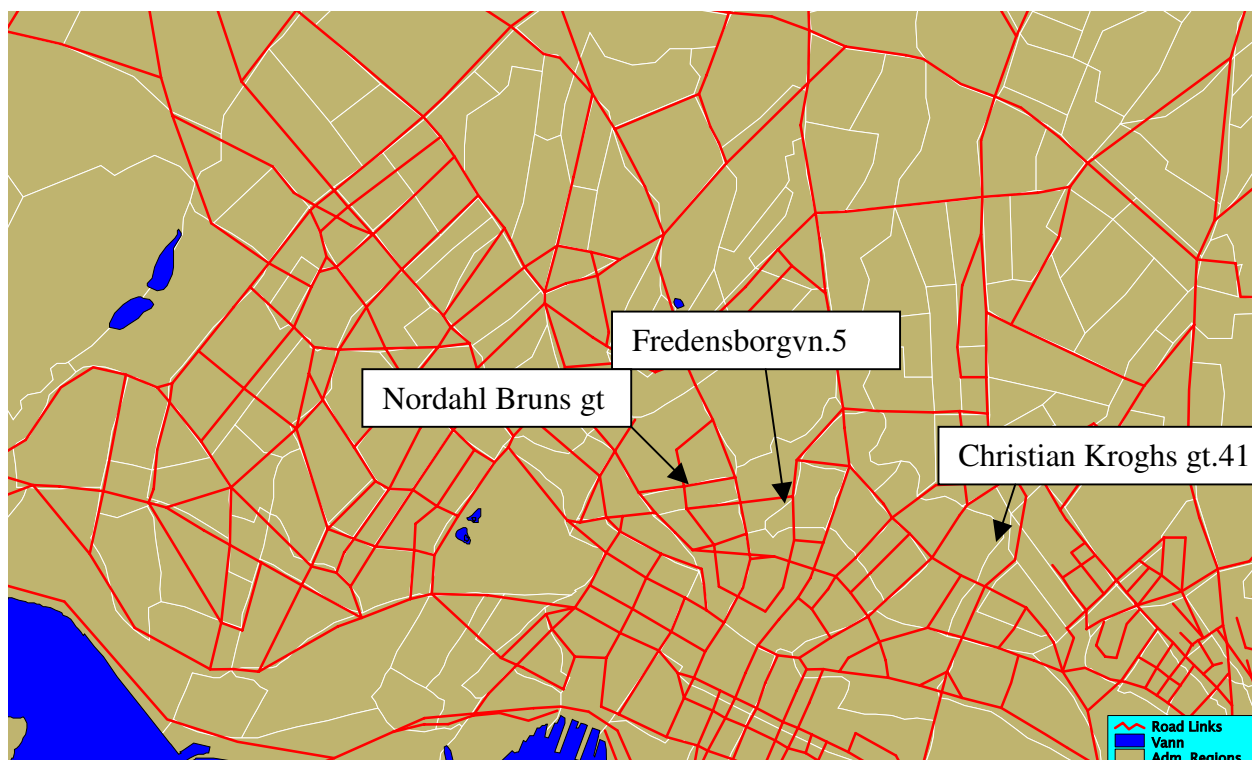


Figure 69: Map showing the centre of Oslo. The 2 demonstrator objects, Fredensborgvn.5 and Christian Krogh's gt.41 are shown on the figure. Nordahl Brun's gate, where the pollution measurements are done are also shown.

5.7.4 Italy - Trento

Riva del Garda is a small town in the Autonomous Province of Trento with 13822 inhabitants in 1994. It is situated 30 km south from Trento, on the Garda Lake, 73-m a.s.l., and it covers an area of 42.46 km². Surrounded by mountains and by rich Mediterranean vegetation with olive, lemon, palm, and laurel trees, Riva lies in a little flat land and has a typical Mediterranean climate because of the warm winds coming from the lake. Riva is well connected to other areas by the mean of numerous roads; two of them are national road, very busy especially during summer time. There are some industries in the surroundings of Riva, but they are small except for the paper mill.

The chosen object is situated in the surroundings of Riva on the West side; it is a building made by two main bodies of three floors each one with a court inside, rectangular based, with the main facades exposed to the north and south. There are some buildings near the object, but they are smaller and at a certain distance, so that they do not interact with it. On the West side of the building, at a distance of about 800m, there is a mountain, while on the east side there is the flat land.

Most of the data collected regards a meteorological station situated in Riva del Garda. When the data was not allowable, other meteorological stations have been considered, in particular:

1. Meteorological station in Arco for what concerns the relative humidity values. Arco is a small town situated 5 km north from Riva del Garda and 25 km south from Trento, 91 m a.s.l., and it has the same geographical characteristics of Riva del Garda;
2. Pollution station in Trento for what concerns the hydrogen concentration values. Trento is the capital of Trentino-Alto Adige, 196m a.s.l., 30 km north from Riva.

Probably there is no difference between the data collected in the centre of Riva and the meteorological situation near the object, even if there is the mountain “protecting” the building from the action of the wind. The main wind direction is North-South, and not East-West.

For what concerns relative humidity values, they are collected in Arco. Even if Arco and Riva have more or less the same meteorological situation, Riva probably has a higher relative humidity due to the presence of the lake.

Acidity, concentration of H⁺, is collected in Trento, which are the pollution station nearest to Riva. Trento is a bigger town than Riva, and the stations collecting H⁺-concentration are positioned in “strategically” points of the town to control pollution.



Figure 70: Trentino – Alto Adige Region

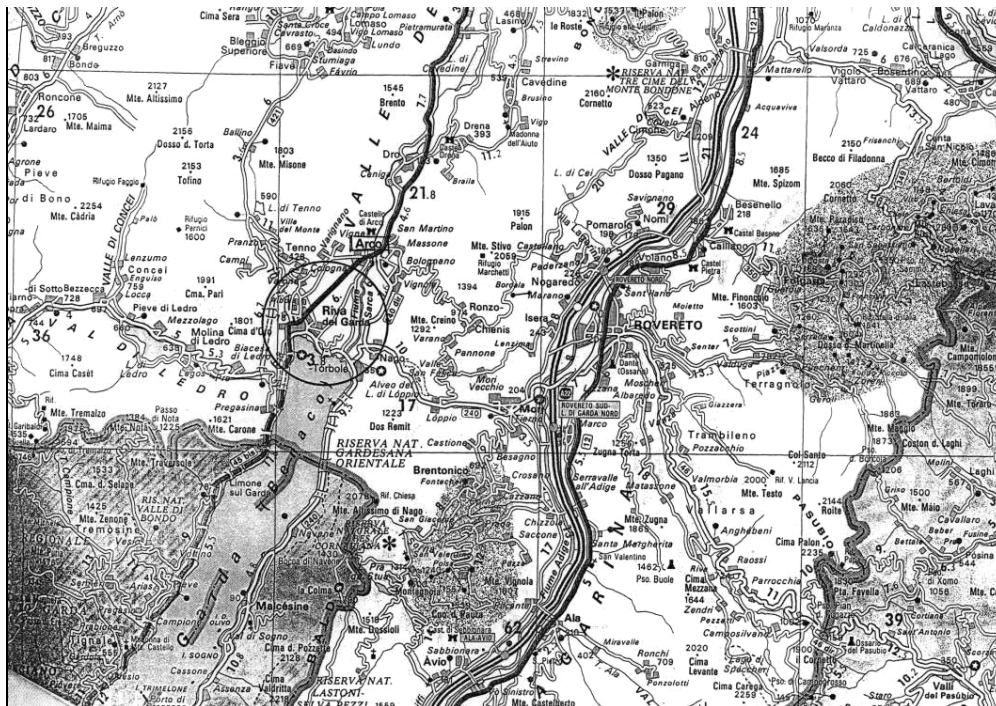


Figure 71: The zone of the Garda Lake.

5.7.5 Reference area

For the evaluation and comparison of the calculated service lives a reference area has been selected. The criteria for the reference area have been an area with only minor air pollution typical for a background-unpolluted area. The criteria for the climatic parameters are more complicated to select since the changes in the climate depends on the geography and the least aggressive area will differ from country to country. As a common reference area in this project an area in Norway, Lom, has been chosen. This area is known as region with a large number of old heritage wooden buildings, so the lifetime for wood long. The following environmental data is valid for the Lom area:

$$\text{SO}_2 = 1 \mu\text{g}/\text{m}^3$$

$$\text{pH} = 5.6$$

$$\text{H}^+ = 2.51 \cdot 10^{-3} \text{ mg/l,}$$

$$\text{Precipitation} = 0.37 \text{ m/y}$$

$$\text{Temperature} = 2.4^\circ\text{C (yearly mean value)}$$

$$\text{Relative humidity} = 58\% \text{ (yearly mean value)}$$

All values except pH and H^+ are measured values. For acid rain the unpolluted rain in equilibrium with the CO_2 in the air is chosen.

5.8 Meteorological data

The partner responsible for the pilot object has been responsible for collecting necessary meteorological data, and detailed descriptions of the data and sources for information are found in the MMWood reports ENV4-CT98-0796 D04.02a ERFM Report German demonstrator (Riks, 1999), ENV4-CT98-0796 D04.02b ERFM Report Swedish demonstrator (Eriksson, 1999), ENV4-CT98-0796 D04.02 ERFM Report Norwegian demonstrator (Krigsvoll, 1999), ENV4-CT98-0796 D04.02d ERFM Report Italian demonstrator (Garofolo, 1999), and ENV4-CT98-0796 D04.02 Technical report on Environmental Risk Factor Module (Krigsvoll and Henriksen, 1999). The availability and quality of data are generally good in most countries. However for our purpose the quality will differ from country to country, mainly due to distance from demonstrator object to the most relevant meteorological station.

The location of the demonstrator objects and meteorological stations are shown on maps in chapter 5.7. This chapter also describes the distances between object and station, and how representative the measurements are for the particular object.

For calculation of Scheffer's index the collected data are:

- Average monthly temperatures for at least one year, preferably for a longer period, Table 18.
- Monthly records for days with precipitation = 0.1 mm for at least one year, Table 19.

For calculation of service life for other materials, the collected meteorological data are:

- Average yearly temperature and average yearly amount of precipitation, Table 20.
- Average yearly humidity, %, and Time of Wetness (TOW), Table 21.

Table 18: Average monthly temperature for the different meteorological stations.

	Jan	Feb	March	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
Quedlinburg 1961-1990	0.3	0.6	3.7	7.6	12.5	15.8	17.3	16.8	13.7	9.6	4.8	1.8	8.7
Quedlinburg 1998	4	6.8	5.8	10.1	14.7	17.3	17.4	17.2	14.1	9.3	2.6	2.5	10.2
Gävle 1988-1998	-0.3	-0.2	1.4	4	10.6	13.8	16.8	15.3	10.6	5	0.2	-1.6	6.4
Gävle 1931-1960													5.4
Stockholm 1988-1998	0.8	1.0	2.1	5.0	11.8	15.1	17.8	16.8	12.2	6.6	1.9	0.2	7.6
Stockholm 1931-1960													6.6
Oslo 1991-1997	-2.8	-2.8	1.3	5.1	10.8	14.6	17.3	16.5	10.6	5.7	0.8	-2.3	6.2
Oslo 1961-1990	-4.3	-4.0	-0.2	4.5	10.8	15.2	16.4	15.2	10.8	6.3	0.7	-3.1	5.7
Oslo 1931-1960	-4.7	-4.0	-0.5	4.8	10.7	14.7	17.3	15.9	11.3	5.9	1.1	-2.0	5.9
Riva del Garda 1994-98	5.2	6.4	9.6	12.2	16.9	20.4	19.3	23.2	18.4	14.2	9.0	5.4	13.4
Trento 1994-1998	-1.3	-0.5	2.8	5.3	10.0	13.5	16.1	15.6	10.8	7.5	2.3	-1.2	6.7
Lom 1931-1960	-9.7	-8.6	-3.3	2.1	8.2	12.5	13.9	12.8	8.2	3.5	-3	-7.2	2.4

Table 19: Average monthly days with rain for the different meteorological stations.

	Jan	Feb	March	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Quedlinburg 1961-1990	14.2	12.6	13.5	13	14	13.5	12	12	11.4	11.1	13.2	14.6
Quedlinburg 1998	15	6	16	18	9	19	13	9	12	20	14	10
Stockholm 1988-1998	14	16	14	12	10	13	16	15	13	14	16	16
Oslo 1991-1997	13	12	9	11	11	11	13	14	13	15	16	14
Riva del Garda 1994-1998	7.4	3.2	2.2	7.6	9.2	9.2	7.6	6.2	8.4	5.6	6.8	6.2
Lom 1901-1937	10	7	6	4	5	7	10	14	10	8	10	10

Table 20: Average yearly temperature and precipitation.

		Temperature	Rain, m
Quedlinburg	1961-1990	8.7	0.4945
Quedlinburg	1998	10.2	0.4601
Gävle	1931-1960	5.4	0.591
Gävle	1988-1998	6.4	0.502
Stockholm	1931-1960	6.6	0.572
Stockholm	1988-1998	7.6	0.430
Oslo	1991-1997	6.2	0.680
Oslo	1961-1990	5.7	0.763
Oslo	1931-1960	5.9	0.740
Trento	1994-1998	6.7	-
Riva del Garda	1994-1998	13.4	0.812
Lom	1931-1960	2.4	0.37

Time of wetness, TOW, is calculated from average temperature and humidity, following the equation: $TOW = \frac{-10700+176*RH+120*T}{8760}$. The actual measuring periods used for the calculations of TOW are listed in Table 21.

Table 21: Average yearly humidity and time of wetness, TOW.

		Humidity, %	Time of wetness
Quedlinburg	1961-1990	75	0.40
Quedlinburg	1998	73	0.38
Gävle	Oct-March	80-85	0.4-0.5
Gävle	April-Sept	60-75	0.15-0.45
Gävle	1988-1998		0.37
Stockholm	Oct-March	80-88	0.40-0.57
Stockholm	April-Sept	55-75	0.06-0.47
Stockholm	1988-1998		0.37
Oslo	1987-1995	71	0.31
Arco (Riva del Garda)	1994-1998	69,5	0.36
Lom	1931-1960	58	0.20

5.9 Pollution data

Necessary pollution data are collected by the responsible partners from measurement station as close to the object or as representative as possible. The collected data, average concentration of SO₂, µg/m³, and acidity, concentration of hydrogen in rain, H⁺, mg/l, are shown in Table 22 and Figure 72 and Figure 73.

For Oslo the SO₂-concentration on regional scale is calculated by AirQUIS (Bøhler, 1998), a model giving the SO₂ data in a geographical grid based on emission data in the area. The results are shown in Figure 74.

As shown in Table 5, Figure 72, Figure 73, and Figure 74 the SO₂ and H⁺ concentration varies on both local, regional scale and European scale. Hence the service life based on pollution levels also has variation on local and regional scale.

Table 22: Average SO₂ concentration and acidity, pH and H⁺.

	SO ₂	pH	H ⁺
Quedlinburg	13.8	4.67	2.14*10 ⁻²
Gävle 1988-1998	5.0	4.55	2.282*10 ⁻²
Stockholm	8.3	4.46	3.47*10 ⁻²
Oslo 1987-1995	8.3	4.64	2.29*10 ⁻²
Riva del Garda 1994-1998	11.8		
Trento 1994-1998		5.9	1.38*10 ⁻³
Lom 1995	1.0	5.6	2.51*10 ⁻³

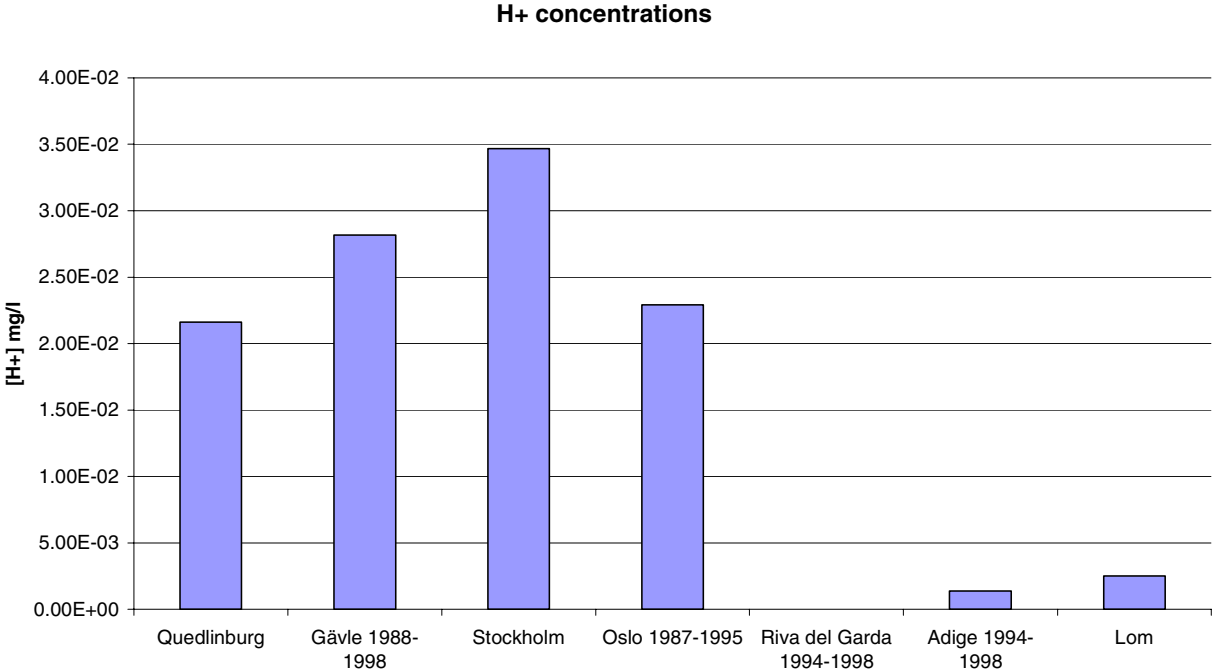


Figure 72: Pollution levels, concentration of H⁺, in the region of the demonstrator objects.

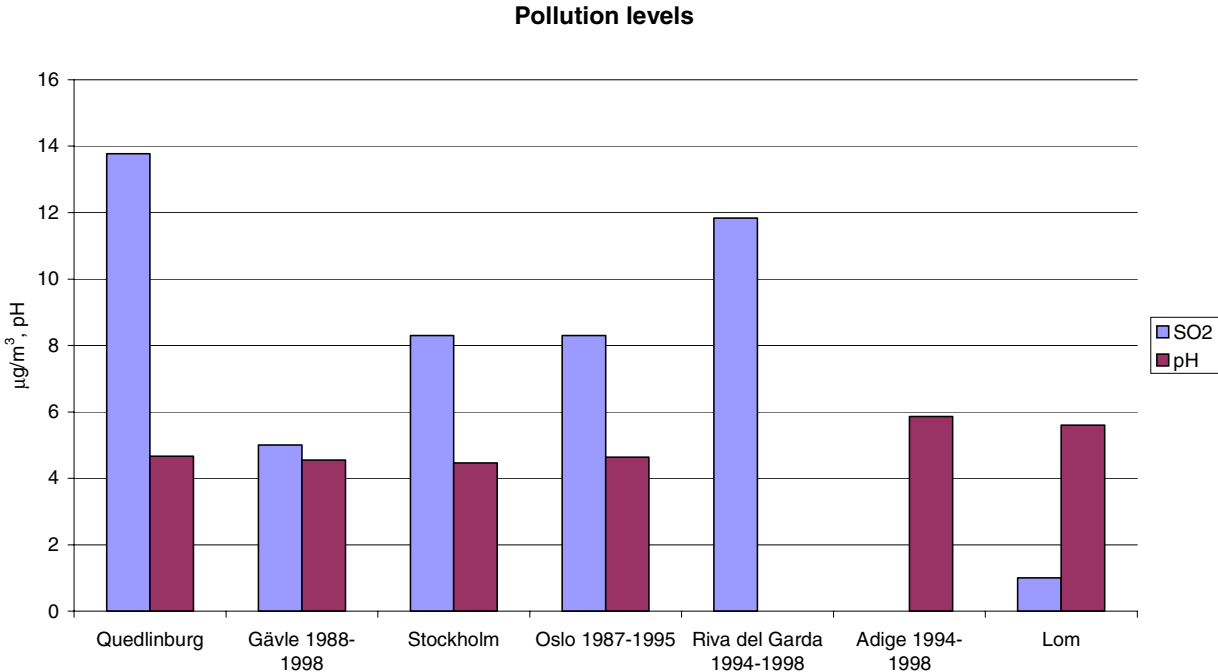


Figure 73: Pollution levels, Concentration of SO₂ and pH, in the regions of demonstrator objects.

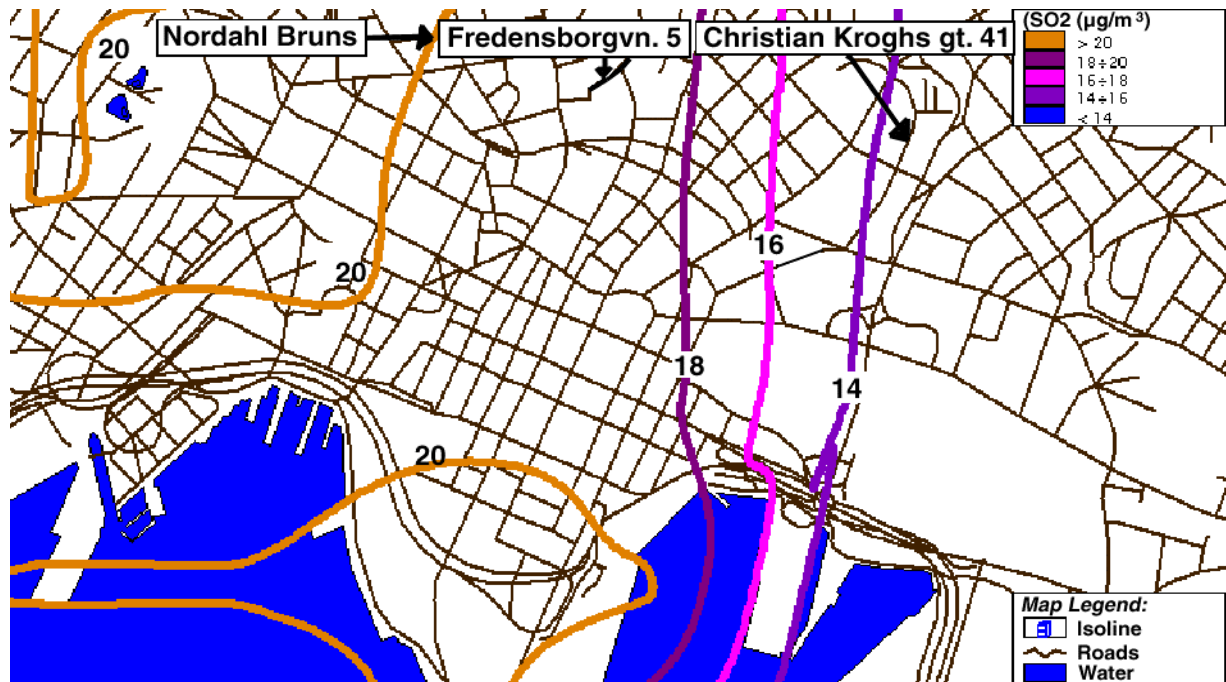


Figure 74: SO_2 -concentration in Oslo, 1994

5.10 Environmental Risk Factors

5.10.1 Scheffer's index

Scheffer's index is calculated from the data in Table 18 and Table 19 for all demonstrator objects. The results are shown in Table 23 and Figure 75. Due to missing information of number of days with rain in Gävle, the number of days with rain for Stockholm is used in the calculation of Scheffer's index.

Table 23: Scheffer's index for the area of the demonstrator objects.

		Scheffer's index
Quedlinburg	1961-1990	46.7
Quedlinburg	1998	59.9
Gävle	1988-1998	39.2
Stockholm	1988-1998	44.9
Oslo	1991-1997	37.6
Oslo	1961-1990	36.8
Oslo	1931-1960	37.6
Riva del Garda	1994-1998	33.7
Lom	1901-1930	18.1

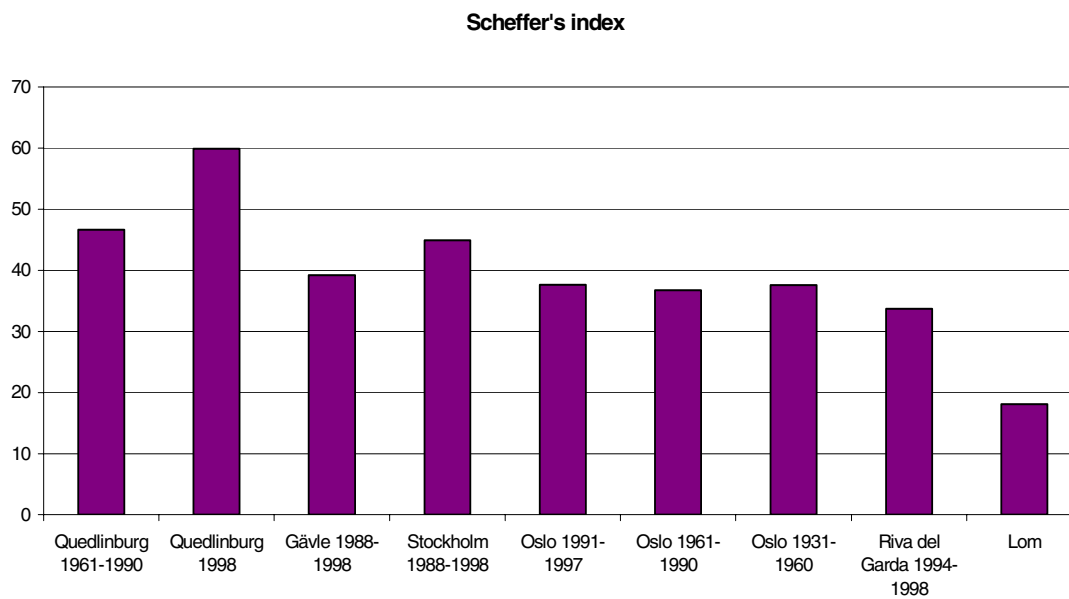


Figure 75: Scheffer's index for the area of the demonstrator objects.

Following the classification proposed by Scheffer Quedlinburg, Gävle, Stockholm, and Oslo have the intermediately favourable conditions for decay, while Riva del Garda has the least favourable conditions for decay. The reference site Lom with known long lifetime for wood constructions has a Scheffer's index that is only 55% of the one in Riva del Garda. Scheffer's index is also modelled for a geographical area, where the temperature is depending on the topography. This is shown in Figure 76

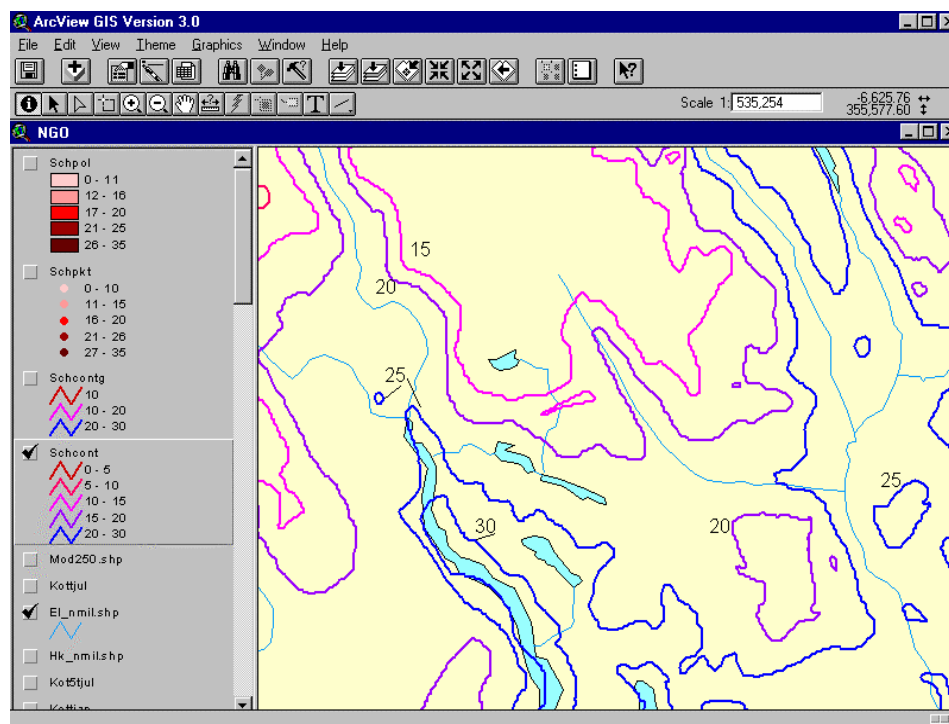


Figure 76: A smaller section of the iso-line map of the average Scheffer's index in the area around Maihaugen in South East Norway.

A European network of test sites has now been established in a EU/Cost 2 project for establishing a COST climate index for Europe based on the same parameters as Scheffer's index. The study is co-ordinated by Building Research establishment in UK. The field exposure is based on wood samples of L-joints and lap joints. The study has started in different years in different countries. In UK they already have 7 years with results but other countries started in 1998. To day 11 European countries have started field-testing. The study also included is two sites outside Europe. The study has no fixed time limit, but the results from the MMWood project should be compared to the one found in the COST project.

5.10.2 Service life

Service life for the chosen materials are calculated from the pollution data in Table 22, yearly precipitation (the longest average periods are used where there are data for more than one period) from Table 20 and time of wetness from Table 21. When calculating for Riva del Garda the Trento acidity is used. The service life equations used are more detailed defined in the MMWood report ENV4-CT98-0796 D04.01 Damage Functions for Wood, Brick, Rendering, and Stone (Krigsvoll, 1999). The calculated service lives are shown in Table 24.

When the pollution data or meteorological data are available on a regional scale as a data field, the service life can be calculated as a field. SO₂-concentration is available as a data field in Oslo, and service life for painted wood is calculated as a field. The results are shown in Figure 77 and Figure 78. The difference in service life painted wood Oslo from Table 24 to Figure 78 is due to difference in SO₂-concentration.

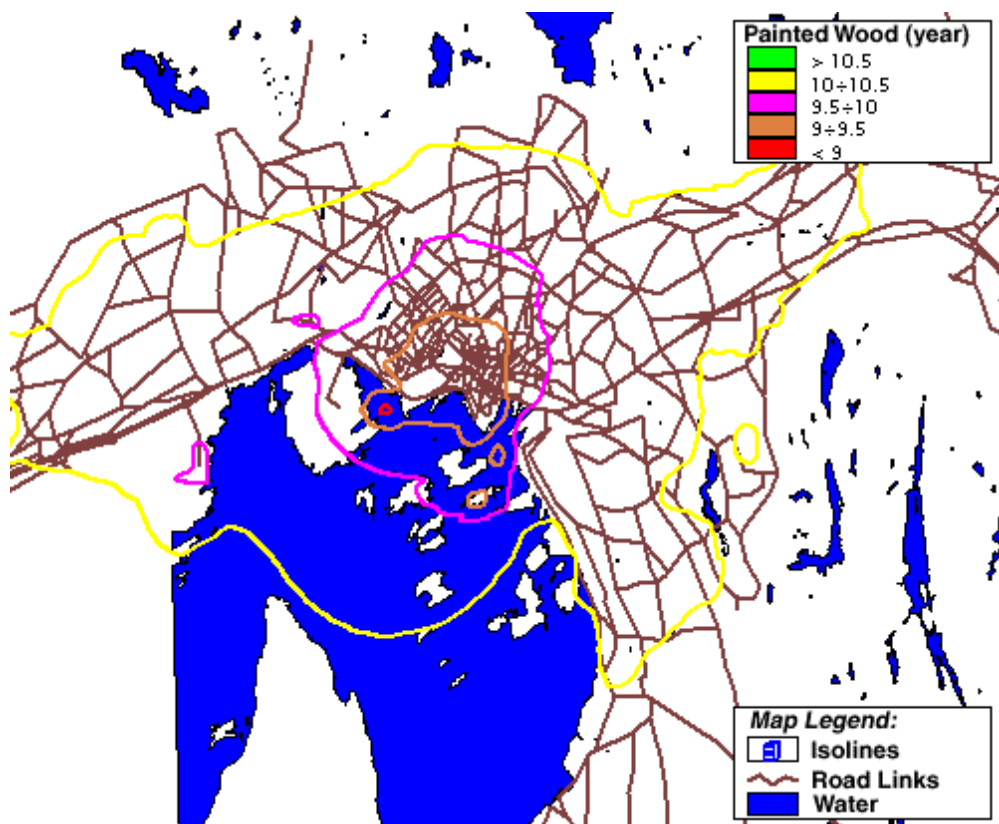


Figure 77: Service life of painted wood, Oslo

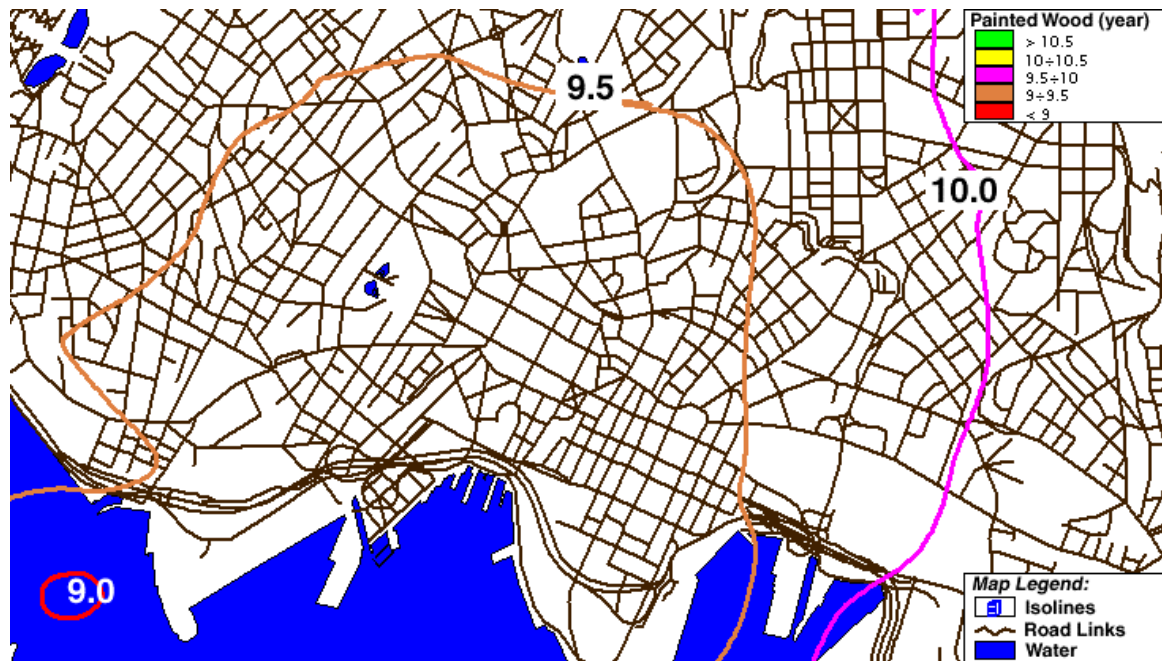


Figure 78: Service life of painted wood, centre of Oslo.

Table 24: Calculated service life, number of years.

	Painted wood	Bricks with plaster	Bricks with painted plaster	Limestone	Calcareous stone	Bricks
Quedlinburg	9.83	58.1	44.2	787	854	65
Gävle	9.66	57.4	43.2	739	798	65
Stockholm	9.66	57.4	43.2	739	798	65
Oslo	10.41	60.5	47.4	1032	1151	70
Riva del Garda	10.03	58.9	45.3	1043	1165	65
Lom	11.26	64.0	52.2	1500	1692	70

As seen in Table 24, the calculated service life differs from region to region, particularly those for limestone and calcareous stone. The service lives are calculated with the pollution level of today or the last decade. Since the pollution levels differ through time, calculation of more exact service life for materials with a long service life, need pollution levels for the different time periods.

On the basis of the predicted service lives for the different material, knowledge of amount of materials, and the costs for different types of maintenance and repair, the annual cost for maintenance can be calculated. This is shown in Andreassen et al. 1998.

For calculation of an environmental risk factor it is enough to compare calculated service life for different areas, and define guidelines or levels for high, medium and low environmental risk. Table 25 shows the calculated service life for each material as percentage of the calculated service life for the reference area selected for the project.

Table 25: Calculated service life as % of the service life for the materials in the reference area.

	Painted wood	Bricks with plaster	Bricks with painted plaster	Limestone	Calcareous stone	Bricks
Quedlinburg	85.0 %	90.2 %	81.9 %	47.7 %	45.5 %	92.9 %
Gävle	82.3 %	88.6 %	78.8 %	45.2 %	42.9 %	92,9 %
Stockholm	87.6 %	93.1 %	85.0 %	56.5 %	54.7 %	92.9 %
Oslo	88.7 %	93.5 %	86.2 %	61.5 %	60.0 %	100,0 %
Riva del Garda	89.0 %	92.1 %	86.3 %	68.9 %	68.1 %	92.9 %
Lom	100%	100%	100%	100%	100%	100%

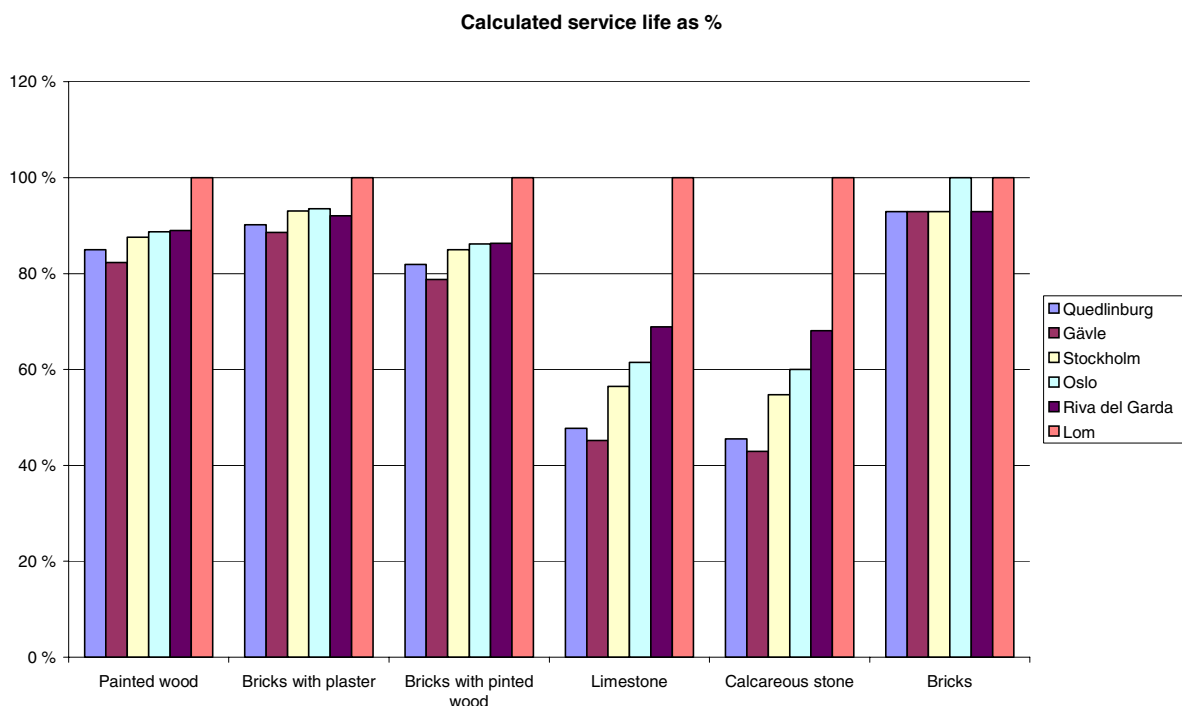


Figure 79: Calculated service life as % of service life in reference area.

As shown in Table 25 and Figure 79 the service life for bricks is reduced with less than 10%, for bricks with plaster and painted plaster with 7-21%, for painted wood 10-18%, and for limestone and calcareous stone the service life may be reduced with more than 50%.

5.11 Wind and spell indexes

The available regional exposure data can after appropriate adjustment be used for characterisation of the local and microenvironment at a building, prEN 13013-3 “Calculation of driving rain index for vertical surfaces from hourly wind and rain data.” (CEN, 1997)

The standard specifies a procedure for analysing hourly rainfall and wind data derived from meteorological observations so as to provide an estimate of the quantity of water likely to impact on a wall of any given orientation (see item 5.5). It takes account of topography, local sheltering and the type of building and wall, and introduces two indexes, Spell index and Wall spell index. Table 26 gives the information obtained from available data for the demonstrator

objects. Necessary wind and rain data (Spell index I_s) have been hard to obtain, and therefore the calculations of wall spell index is missing.

Table 26: Wind and Spell indexes for the demonstrator objects.

Test object	Main wind direction	Spell index I_s	Wall spell index I_{ws}
Fredensborgveien 5 No	Southwest/ Northeast	Not calculated	$<0.06 \cdot I_s$
Christian Krogh's gt 41 No	Southwest/ Northeast	Not calculated	$<0.09 \cdot I_s$
Marschlinger Hof 7 Ge	Southwest	Not calculated	$< 0.06 \cdot I_s$
Augustinern 22/23 Ge	Southwest	Not calculated	$< 0.06 \cdot I_s$
School in Bergby Se		Not calculated	$< 0.26 \cdot I_s$
Mission-hall Stockholm Se		Not calculated	$< 0.26 \cdot I_s$
Block Vällingby Se		Not calculated	$< 0.17 \cdot I_s$
Riva del Garda It	North/South	Not calculated	$< 0.26 \cdot I_s$

There are no local wind measurements for wind in the surrounding of any of the buildings but the dominating wind will probably be along the street canyon. In Oslo both buildings are in the middle of a block, the buildings have a good local shelter for driving rain and the Wall spell index is estimated to be less than 0.1.

5.12 Quality and availability of data

The temperature, relative humidity and rain data needed for assessing the risk for material damage are fairly easy available from a very extensive network of station in most countries in Europe. Most of the meteorological stations have long time series of data of good quality as also illustrated in this report. The parameter "days with precipitation" are normally not reported today on a regular base but will often exist in the data files. To obtain these values you will normally have to pay for it. However the long-term average in climatic condition in Europe is not changing drastically and old databases can give got information about the situation even to day.

Wind data is observed on some meteorological stations but the number of station is limited. Extrapolation of the data over fairly long distances can work well in flat terrain. However in areas with hills and mountains, wind will canalise up and down the valleys. Lack of sufficient data for wind and rain is often the limited factor for calculating the Spell index. If data is available the quality of the data is expected to be good since qualified people who needs the data run this automatic station.

The pollution data needed may be obtained either by measurements or by modelling from emission inventories. H+ and pH are available from the EMEP database for most of Europe. These data is reported as yearly average data each year. The data is valid in rural areas and in urban areas without too high local pollution. Local pollution can change the pH up and down. In heavy industrial areas, the pH in rain will be lower and the acidity will increase. In other areas like in the Trento area alkaline pollutants have changed the pH the other way. SO₂ is measured in most cities with a pollution problem. The number of measuring sites is reduced these days since the pollution levels are reduced in most European countries. It is also a trend that the authorities are using models based on emission data to day and reduce the measurements even more. The quality of the reported values depends to some degree on the institution responsible for the measurements. According to the EU quality standard the long-

term data should have accuracy better than 25%. However as illustrated from the Gävle data in report D04.02b, the quality control is some time bad and unrealistic data can be reported and need to be excluded before using of the data for lifetime estimation. Modelling of long term average may have the same accuracy as the measured ones. However the model is completely depended on good data in the emission database. So far sufficient good emission data seems to be the most complicated part to obtain.

5.13 Conclusions

This study has shown that it is possible to obtain sufficient data for estimation of expected lifetime for materials as well as for calculating the risk for rot according to Scheffer's index. Even if the European standard for driving rain for estimating the risk for climatic impact is a very interesting parameter for the evaluation of deterioration hazard (Henriksen et al 1998), the parameters needed can be scarcely and not that easy to obtain from existing databases.

It is also important to remember that the calculated lifetime based on environmental impact easy can be reduced in real life. Wrong or bad craftsmanship and complicated design can have decisive influence on the lifetime of the building or building parts. Badly designed construction can give local effects with higher environmental impact than described by the measured environmental data. Another limitation is that the equations are derived from inspections without specific knowledge of the details of the materials and surface treatment used or from standard test programs where some parameters have to be kept constant. It is therefore possible to improve the existing service life equations for all materials taking into account differences inside the type of material used and the surface treatment applied.

However, even when keeping these limitations in mind, estimation of the lifetime based on the environmental impact will be an important tool for planning maintenance intervals for the building stock at risk.

6 Work Package 5 – Project Management

6.1 Consortium structure

The project follows the required structure of the CRAFT mechanism for EU projects comprising with the partners and personnel involved as shown in Table 27. List of personnel involved includes only person playing a vigorous part in the project.

Table 27: Partners in the Consortium and personnel involved in the MMWood project. Partner A1-A3 are the SMEs, while C1-C7 are the R&Ds.

Partner number	Partner name	Address	Personnel
A1	German Centre for Crafts and the Preservation of Historic Monuments (ZHD)	Friedrich-Ebert-Str. 83 D-14469 Potsdam Germany	Eva Riks eva.riks@zhd-potsdam.de
A2	Restaurator Tord Andersson Conservation AB	Högbergsgatan 33 SE-116 20 Stockholm Sweden	Tord Andersson tord.andersson@restaurator.com Leif Dreborg leif.dreborg@restaurator.com Vicki Wenander lvicki.wenander@restaurator.com
A3	Mycoteam as	P.O.Box 5 Blindern N-0313 Oslo Norway	Kolbjørn Mohn Jenssen kolbjorn.mohn.jenssen@mycoteam.no Heidi Lyngstad heidi.lyngstad@mycoteam.no
B1	Oslo Kommunale Boligbedrift	Økernvn.11 N-0640 Oslo Norway	Terje Lüder-Larsen terje.luder.larsen@okb.oslo.no Trond Stang trond.stang@okb.oslo.no
C1	Norwegian Building Research Institute	P.O. Box 123 Blindern N-0314 Oslo Norway	Svein Erik Haagenrud seh@byggforsk.no Guri Krigsvoll guk@byggforsk.no Vidar Stenstad vis@byggforsk.no Tormod Aurlien ta@byggforsk.no
C2	University of Gävle, Built Environment	S.Sjötullsgatan 3 P.O.Box 88 S-801 02 Gävle Sweden	Bengt Eriksson b.eriksson@hig.se
C3	NORGIT	P.O.Box 229 N-1605 Fredrikstad Norway	Petter Stordahl petter.stordahl@norgit.no Mona Johansen mona.johansen@norgit.no
C4	Environmental Centre Fulda,	Johannisstrasse 44 36041 Fulda Germany	Volker Strauch
C5	University of Trento Laboratory of Building Design	via Mesiano 77 38050 Mesiano di Povo Trento Italy	Antonio Frattari antonio.frattari@ing.unitn.it Ilaria Garofolo ilaria.garofolo@ing.unitn.it Rossano Albatici rossano.albatici@ing.unitn.it
C7	Norwegian Institute for Air Research	Postboks 100 N-2027 Kjeller Norway	Jan Fredrik Henriksen jfh@nilu.no Elin Dahlin emd@nilu.no

6.2 Management structure and responsible personnel

The project management procedures are defined in the Consortium Collaboration Agreement (CCA). The CCA was signed by the main Contractors of the Wood-Assess project in Nov. 1997, and accepted by the new partners in joining the proposal and the subsequent contract. The CCA meets the requirements of the Commission Model Contract and defines the role of the Project Manager to ensure effective control and liaison for the project. The overall rights and the obligations of the partners are also defined by the agreement. The Collaboration Agreement was modified in 2000 as basis for the Technology Implementation Plan (Haagenrud, Skancke, 2001).

The Co-ordinator appointed Professor, Dr.ing Svein Haagenrud, as Project Manager (PM) with the full support of NBI. The PM is *responsible* for the various management issues, including technical, financial, planning and control matters, and is the contact point towards the Commission. PM is using the project management system MS Project to *monitor and update* the project plan for all of the consortium's activities and the Management Board will *monitor progress* against this plan.

The project leader is assisted by a Technology Implementation Manager (TIM) (Torstein Skancke, ICG, InterConsultGroup - owner (64%) of NORGIT) and a Management Board (MB), formed by the SME partners. Chairman of the MB will be Eva Riks, A1, and the members are as shown in Table 28.

Table 28: Project Management Board

Chairman, A1 and C4	Eva Riks
Project Manager, C1	Svein Haagenrud
Technology Implementation Manager, ICG	Torstein Skancke
A2	Leif Dreborg
A3	Kolbjørn Mohn Jenssen

The group operated on the principle of unanimous decisions. If disagreement sustains and voting needed, a two-third majority was required to resolve the issue.

Each partner submitted a management report to the Management Board every quarter and these formed the basis of the consolidated management report prepared by the Project Manager, and discussed by the Management Board (telephone conference). Partner management reports identify deviations to the planned technical progress and resource usage plus critical areas.

The Management Board held quarterly meetings using email and telephone-conferencing facilities. They meet at the beginning of the project activity, at the milestone reviews, and at the work-shops being conducted at the object location in each country.

For each Work Package, a technical task leader was nominated from among the partners, for the detailed co-ordination, planning, monitoring and reporting of the tasks, and for the co-

ordination of this task with the other tasks of the project. Task leaders formed the Technical Liaison Group (TLG) together with representatives of the users at the geographical sites. The group provided scientific and technical focus to the project and ensured scientific quality and technical excellence. The TLG communicated regularly by e-mail/fax/telephone and held physical meetings as and when necessary, and communicated any decisions to the Management Board.

Table 29: Technical Liaison Group

Chairman	Prof. Svein Haagenrud
System Evaluation Manager	Tormod Aurlien, C1
WP1 leader	Petter Stordahl, C3
WP2 leader	Bengt Eriksson, C2
WP3 leader	Eva Riks, A1
WP4 leader	Guri Krigsvoll, C1
	Ilaria Garofolo, C5
A1 Representative	Eva Riks
A2 Representative	Tord Andersson
A3 Representative	Kolbjørn Mohn Jenssen

A representative from each of the object owners formed the User Focus Group, Table 30.

Table 30: User Focus Group formed by the object owners

Object Owner Representative Norway	Trond Stang, OSLOKB
Object Owner Representative Germany	Joachim Schröpel, Deutsche BauBeCon AG, Geschäftsstelle Quedlinburg (Sanierungsträger Quedlinburg)
Object Owner Representative Sweden	Bo Rickegård, Gävle Kommun, Gillis Edholm, SvenskaBostäder
Object Owner Representative Italy	I.T.E.A (Istituto Trentino per l'Edilizia Abitativa)

A plan for self-assessment was established to ensure that guidelines for software and system developments were set up in the beginning of the project according to existing and emerging international standards and that they are observed during the course of the project;

Contractors are ultimately responsible for the performance of associated contractors and subcontractors.

6.3 Board meetings and Work-shops

The project started January 1999, and according to plan, finalised in December 2000.

The project had a start-up seminar at NBI, Oslo, in January 1999, and a Mid-term meeting arranged January 2000. There have been arranged 3 workshops, Quedlinburg, Germany, in August 1999, Trento, Italy, May 2000, and Gävle, Sweden, September 2000.

Additionally there was a workshop in Gävle, Sweden, in connection with WP2. The project coordinator and the authors responsible for D02.01 and D02.01W,-RB, and -S participated.

Totally 6 telephone conferences for reporting have been held in 1999, and 6 in 2000.

Totally 32 Deliverables were planned and completed. List deliverables is shown in chapter 7.1.

6.4 Quality Assurance

A system for quality assurance to ensure the quality of the deliverables was developed. The Quality assurance system is described detailed in the MMWood report ENV4-CT98-0796 D05.02 Quality Assurance (Aurlien, 1999).

The QA-plan described the review procedure subject to all deliverables. The peer review was organised by the contractors, and as far as relevant with the participation of the user group of the project.

Based on the deliverable categories and the contractual requirements, the following review procedure was adopted.

1. Prior to issue of the draft deliverable, a review will be conducted in accordance with the author's own internal quality assurance procedures. The deliverable will then be issued at version 0.1.
2. A peer review will then be conducted by a minimum of two nominated MMWood reviewers against the agreed specification. The cross-check will be held according to the order given in Table of Deliverables List.

This review will be recorded using the MMWood Quality Assurance Form.

6.5 Technology Implementation Plan

A Consortium Agreement was introduced to all partners early in the project, and all partners signed the agreement. This was found as common ground for further negotiations during the project period. Simultaneously as finalising the project, all partners participated in the work with the Technology Implementation Plan. This plan, describing the products from the project and each of the partners' further plans, are delivered as a separate document, ENV4-CT98-0796 D05.03 Technology Implementation Plan (Haagenrud and Skancke, 2001).

7 References

7.1 Deliverable from the MMWood project ENV4-CT98-0796

7.1.1 WP1 MMSystem Integration

Aurlien, T. (1998)	D01.01	Summary report on user categories and needs.
Stordahl, P. (1999)	D01.02F	MMWood Functional specification.
Stordahl, P. (1999)	D01.02T	MMWood Technical specification.
Riks, E. (2000)	D01.04a	Validation report German demonstrator.
Wenander, V. (2000)	D01.04b	Validation report Swedish demonstrator.
Jenssen, K.M. and Lyngstad, H. (2000)	D01.04c	Validation report Norwegian demonstrator
Frattari, A. and Garofolo, I. (2000)	D01.04d	Validation Report Italian demonstrator.

7.1.2 WP2 Assessment of environmental damages to buildings

Eriksson, B. (2000)	D02.01	Damage Atlas.
Riks, E. and Ney, K. (2000)	D02.01WC	Damage atlas for constructive wooden parts indoor and outdoor
Andersen, H. and Jenssen, K.M. (2000)	D02.01WS	Damage Atlas for Wood Substrate.
Eriksson, B. (2000)	D02.01WST	Environmental Damage Wood Surface Treatment.
Garofolo, I. (2000)	D02.01AM	Environmental Damages to Adjoining Materials
Waldum, A. and Eriksson, B. (2000)	D02.01RB	Environmental Damage to Rendering/Brick.
Andersson, T. and Wenander, V. (2000)	D02.01S	Environmental Damages to Natural Stone.

7.1.3 WP3 Object Documentation, Regulations and Management

Riks, E. and Stenstad, V. (1999)	D03.01	Building documentation system.
Riks, E. (2000)	D03.01a	Building Documentation German demonstrator.
Wenander, V. (2000)	D03.01b	Report Building Documentation Swedish demonstrator
Andersen, H. (2000)	D03.01c	Report Building Documentation Norwegian demonstrator.
Garofolo, I. (2000)	D03.01d	Report Building Documentation Italian demonstrator
Riks, E. (2000)	D03.02a	Documentation German demonstrator Quedlinburg.
Wenander, V. (2000)	D03.02b	Documentation Swedish demonstrator Vällingby.
Lyngstad, H. and Krigsvoll, G. (2000)	D03.02c	Documentation Norwegian demonstrator Oslo.
Frattari, A., Garofolo, I., and Albatici, R. (2000)	D03.02d	Documentation Italian demonstrator Riva del Garda.

7.1.4 WP4 Environmental risk factor module

Krigsvoll, G. (1999)	D04.01	Damage Functions for Wood, Brick, Rendering, and Stone.
Krigsvoll, G. and Henriksen, J.F. (1999)	D04.02	Technical report on Environmental Risk Factor Module.
Riks, E. (1999)	D04.02a	ERFM Report German demonstrator.
Eriksson, B. (1999)	D04.02b	ERFM Report Swedish demonstrator.
Krigsvoll, G. (1999)	D04.02c	ERFM Report Norwegian demonstrator.
Garofolo, I. (1999)	D04.02d	ERFM Report Italian demonstrator.

7.1.5 WP5 Project Management

- Haagenrud, S.E., Stordahl, P., Eriksson, B., Riks, E., Krigsvoll, G. and Garofolo, I. (2001) D05.01. System for Maintenance Management of Historic (Wooden) Buildings. MMWood. Final report.
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7.2 Other references

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