LIFECON DELIVERABLE D1.2

GENERIC INSTRUCTIONS ON REQUIREMENTS, FRAMEWORK AND METHODOLOGY FOR IT-BASED DECISION SUPPORT TOOL FOR LIFECON LMS

Olav Lahus, Norwegian National Coastal Admininstration
Michael. W. Johnston, British Energy Generation (UK) Ltd.
Jon Erik Lindberg, Owe Kristiansen, Mona Johansen, Interconsult Norgit AS

Shared-cost RTD project

Project acronym:	**LIFECON**
Project full title:	**Life Cycle Management of Concrete Infrastructures for Improved Sustainability**
Project Duration:	01.01.2001 - 31.12.2003
Co-ordinator:	Technical Research Centre of Finland (VTT) VTT Building Technology Professor, Dr. Asko Sarja

Date of issue of the report : 30.12.2003

Project funded by the European Community under the Competitive and Sustainable Growth Programme (1998-2002)

Project Information

CONTRACT N°: G1RD-CT-2000-00378

ACRONYM: **LIFECON**

PROJECT TITLE: Life Cycle Management of Concrete Infrastructures for Improved Sustainability

PROJECT CO-ORDINATOR: Technical Research Centre of Finland (VTT),
VTT Building Technology
Professor, Dr. Asko Sarja

PARTNERS:

The Finnish Road Administration, Finland

CT LAASTIT Oy Ab, Finland;

Optiroc Oy Ab, Finland

Technische Universität München, Germany

OBERMAYER PLANEN+BERATEN, Germany

Norwegian University of Science and Technology, Norway

Interconsult Group ASA,
(Since 01. 01.2003: Interconsult Norgit AS), Norway

Norwegian Building Research Institute, Norway

Kystdirektoratet, Norway

Millab Consult A.S., Norway

Centre for Built Environment, Sweden

Gävle Kommun, Sweden

Ljustech Konsults AB, Sweden

L.Öhmans Bygg AB, Sweden

British Energy Generation Ltd, UK

Heriot-Watt University, UK

Centre Scientifique et Technique du Batiment CSTB, France.

PROJECT DURATION: FROM 01. 01.2001 TO 31. 12.2003

Project funded by the European Community under the Competitive and Sustainable Growth Programme (1998-2002)

Deliverable Information

Programme name:	Growth Programme
Sector:	TRA 1.9 Infrastructures
Project acronym:	LIFECON
Contract number:	G1RD-CT-2000-00378
Project title:	Life Cycle Management of Concrete Infrastructures for Improved Sustainability
Deliverable number:	D 1.2
Deliverable title:	Generic instructions on requirements, framework and methodology for IT-based decision support tool for Lifecon LMS
Deliverable version number:	Final Report
Work package contributing to deliverable:	WP 1
Nature of the deliverable: (PR/RE/SP/TO/WR/OT)	RE
Dissemination level (PU/RE/CO):	PU
Type of deliverable (PD/WR):	PD Project Deliverable
Contractual date of delivery:	Final Delivery: Month 36
Date of delivery:	30.12.2003
Author(s):	Olav Lahus, Norwegian National Coastal Admininstration, Michael W. Johnston, British Energy Generation (UK) Ltd., Jon Erik Lindberg, Owe Kristiansen, Mona Johansen, Interconsult Norgit AS
Project co-ordinator:	Asko Sarja

Nature:
PR - prototype (demonstrator), RE - report, SP - specification, TO - tool, WR - working report OT - other

Dissemination level:
PU - public usage, RE - restricted to project participants, CO - restricted to commission

Type:
PD - project deliverable, WR - working report

Quality Assurance Form

Deliverable ID	D 1.2
Title	Generic instructions on requirements, framework and methodology for IT-based decision support tool for Lifecon LMS
Deliverable type	FINAL REPORT
Author (s) of deliverable (Name and organisation)	Olav Lahus, Norwegian National Coastal Admininstration, Michael W. Johnston, British Energy Generation (UK) Ltd., Jon Erik Lindberg, Owe Kristiansen, Mona Johansen, Interconsult Norgit AS
Reviewer(s)	Christer Sjöström, Guri Krigsvoll
Approved by reviewer(s) (Reviewer's name and date)	Sign.: _____ Sign.: _____ Date: _____ Date: _____ Sign.: Sign.: _____ _____ Date: Date:
Approved for release WP Leader / Co-ordinator	Sign.: _____ Sign.: _____ Date: _____ Date: _____

Lifecon Deliverables

Deliverable No	Title of the Deliverable
D1.1	Generic technical handbook for a predictive life cycle management system of concrete structures (Lifecon LMS)
D1.2	Generic instructions on requirements, framework and methodology for IT-based decision support tool for Lifecon LMS
D1.3	IT-based decision support tool for Lifecon LMS
D2.1	Reliability based methodology for lifetime management of structures
D2.2	Statistical condition management and financial optimisation in lifetime management of structures • Part 1: Markov chain based LCC analysis • Part 2: Reference structure models for prediction of degradation
D2.3	Methods for optimisation and decision making in lifetime management of structures • Part I: Multi attribute decision aid methodologies (MADA) • Part II: Quality function deployment (QFD) • Part III: Risk assessment and control
D3.1	Prototype of condition assessment protocol
D3.2	Probabilistic service life models for reinforced concrete structures
D4.1	Definition of decisive environmental parameters and loads
D4.2	Instructions for quantitative classification of environmental degradation loads onto structures
D4.3	GIS-based national exposure modules and national reports on quantitative environmental degradation loads for chosen objects and locations
D5.1	Qualitative and quantitative description and classification of RAMS (Reliability, Availability, Maintainability, Safety) characteristics for different categories of repair materials and systems
D5.2	Methodology and data for calculation of life cycle costs (LCC) of maintenance and repair methods and works
D5.3	Methodology and data for calculation of LCE (Life Cycle Ecology) in repair planning
D6.1	Validation of Lifecon LMS and recommendations for further development

Keywords

Generic instructions, requirements, framework, methodology, decision support tool, Lifecon LMS

Abstract

This document describes the requirements to the Lifecon LMS IT prototype as well as functional and technical specifications of the IT prototype as response to and concrete manifestation of user requirements.

List of Contents

1 Introduction

One of the main outputs from the LIFECON project is a prototype of an IT-based integrated life cycle management system (LMS) for concrete structures for the use of all European countries. Prototype applications in all participating countries will be made implementing results, or some parts of them, into facility management systems of participating owner organisations. The LMS can be applied in different structural management systems and analysis, both existing and new ones, in all European countries.

Analysis and description of user requirements for LMS IT system is based on user-centred design process which focuses specially on making systems usable and safe for their users. Adopting the user-centred design process leads to more usable systems and products. It reduces the risk that the resulting system will under-deliver or fail.

The process of user requirements specification based on user-centred design process implies

- early focus on uses, tasks and environment
- the active involvements of users
- an appropriate allocation of function between user and system
- the incorporation of user-derived feedback into system design
- iterative design whereby a prototype is designed, tested and modified

In particular it is an interactive process based upon the design cycle presented in the user-centred design draft standard ISO 13407:1999 /i/.

2 Requirement analysis

Requirements analysis is the process of determining what is required of a future system or product. This may be a computer-based system for a particular customer or a product to be launched onto the open market. The term ‘system’ is used to cover all classes of application including large scale computer-based systems, software packages and standalone electronic products.

Requirements analysis is concerned with what needs to be designed rather than how it is to be designed.

Based on Lifecon project description, two kinds of requirements are developed:

- User requirements and functional specification – specify the system requirements from a user’s point of view, including the functions required to support the user tasks, the user-system interfaces, user support required, physical and organisational requirements, equipment and hardware. They also include usability goals that must be achieved and the approach for installing the system. The ‘user’ may include both end users of an electronic service, and service providers who make use of the network infrastructure.

- System Technical requirements – specify how the system will achieve the required functions and the structure of data that must be available for internal processing to be successful. For example, if a search function is to give a fast response time, the data may need to be indexed in a certain way to support rapid retrieval. Technical constraints will also be specified, such as the maximum communication speed over a network.

Both of these sets of requirements must be carefully developed to ensure the success of the new system. They should be developed in parallel and cross referenced on a regular basis so that conflicting requirements from each area can be identified and addressed.

3 The Lifecon Life cycle Management System - LMS

The LIFECON LMS is an integrated system for life cycle analysis of single civil infrastructures objects and buildings or populations of these.

The system is based on the earlier developed MMS-system[1] for analysis of single civil infrastructures and buildings and the Finnish Road administrations (FINNRA) approach to life cycle analysis of populations' single civil infrastructures. The modular and systematic approach are described in detail in Lifecon Deliverable D1.1 Generic technical handbook for a predictive life cycle management system of concrete structures (Lifecon LMS) /ii/, D.2.1 Reliability based methodology for lifetime management of structures /iii/, D2.2 Statistical condition management and financial optimisation in lifetime management of structures /iv/, D3.1 Prototype of condition assessment protocol /v/ and D3.2 Probabilistic service life models for reinforced concrete structures /vi/ .

The Lifecon LMS will be a modularised IT-system that enables a high level of adaptability at the different user organisations. A short summary of the project from users viewpoint are given in Table 1.

[1] Developed in the finalised EU-project ENV4-CT-98-0796 MMWood (ENS2-8137 Work Programme "Environment & Climate Programme- Cultural Heritage" - "System for Maintenance of Historic (Wooden) Buildings - MMWOOD" - European Project inside the 4th Framework).

Table 1 Project summary from users viewpoint

System name: *Lifecon LMS* *(Life cycle Maintenance and management planning System for concrete structures)*	
Questions	**Assumptions**
What is the system?	Prototype application of an open and generic European model of an integrated and predictive Life cycle Maintenance and management planning System for concrete structures (LMS). The system will facilitate the change of the facility maintenance and management from a reactive approach into a predictive approach.
What functions or services are intended for the system to provide?	An integrated and predictive Life cycle Maintenance and management planning System for concrete structures (LMS), based on technical performance and consequences for concrete structures in different environments. It can be applied in different structural management systems and analysis, both existing and new ones, in all European countries. – The LMS includes Life cycle management framework with requirements and benefits – Procedure for application in the LCC (life cycle costs), LCE (life cycle ecology) and LCP (life cycle performance) systematics into the LMS – Procedure of multi-attribute decision making in the LMS – Implementation of performance and service life models – Budgeting – Scenarios – Predictive Life Cycle Facility Management System (LMS) – Multiple Attribute Decision Making – Performance systematics and models of Structures – Classification of Environmental Exposure – Guide for Condition Assessment of Concrete Structures – Residual Service Life Prediction

Table 2 Project summary from users viewpoint cont.

System name: *Lifecon LMS* *(Life cycle Maintenance and management planning System for concrete structures)*	
Questions	**Assumptions**
What are the aims of the project?	The LMS-system will be based on the development of an international handbook describing a generic model for predictive optimisation and planning of life cycle maintenance and management of concrete structures (LMS) supporting different organisation levels, system levels and processes. The LMS will be applied on network level, and on structural facility/building level. The overall objective of LIFECON project is to contribute the development of facility management towards a system, which is able to guarantee a safe, economic, ecological, health and comfortable operation of concrete infrastructures. This will be done changing the facility maintenance and management planning from a reactive approach into a predictive, integrated and performance based life cycle approach.
Who is the system intended for? (Target market)	Medium and large size owner organisations as well as Facility management consultants
Who will use the system?	Facility management responsible and other M, R & R personnel in medium and large size owner organisations
Why is the system needed?	In order to change the facility maintenance and management from a reactive approach into a predictive approach as well as in order to prioritise within limited budgets. Costeffectivness.
Where will the system be used?	Medium and large size owner organisations both in office and out in the field on inspections
How will the system be used?	The user will follow instructions on screen and make inputs via a keypad (portable computer) or on at touch-screen into a PDA. More complex analsis will be done in office. However other methods of input (speech, remote handset) or output (speech, Braille screen etc.) may be considered.
How will the user learn to use the system?	Via short leaflet or on-screen guidance. Most of the system should be intuitive enough not to require much learning. Complex analysis needs to be guided.

4 Users

4.1 User organisations

Potential interest groups of a Life cycle Maintenance and management planning System for concrete structures (LMS) are:

- Governmental organisations
- Municipal organisations
- Private companies

The main requirements and expectations of a LMS are usually the same. However there may be differences because of specific duties of organisations in the society.

4.1.1 Governmental organisations

Potential governmental organisations for application of a LMS are the states' administrations for public roads, railways, waterways, harbours and shipping. These organisations are responsible for the maintenance of bridges, tunnels, canals, dams, pole basements, quays, lighthouses etc. The governmental administrations usually have a sector responsibility to take care of the traffic needs inside their mandates including the requirements of industrial life and general security. As the MR&R activity of these organisations is financed by public funds they also have a responsibility for using the allocated money cost-effectively. In addition, they have responsibilities and pressures from the society to take care of the ecological, cultural and aesthetic values in their MR&R activity.

4.1.2 Municipal organisations

Potential municipal organisations for adopting a LMS would be organisations for local traffic, water service, drainage, sewage and waste disposal. Typical concrete infrastructures to be maintained by these organisations are bridges, pavements, wells, pipelines, pools, pole basements etc. The expectations of municipal authorities from a management system are much the same as those of governmental authorities. However, a little lighter version of a management system might be adequate, as the number of structures is usually less. A separate network level optimisation module may not be necessary in municipal level applications.

4.1.3 Private companies

Private companies possess a great part of existing concrete infrastructures. Typical such companies are those operating in the production of electricity with nuclear, oil, coal, gas or water power plants. Concrete infrastructures of these companies include containers, reactor buildings, turbine buildings, cooling systems etc. Companies in the area of electricity distribution might also be interested to set up a LMS if they possess a large electric network with concrete pole basements. Other potential companies would be those operating in winning and refining of natural resources such as oil production, mining and wood processing companies. These

companies may possess concrete oil platforms, pipelines, tunnels, silos, basins, reservoirs, basements etc.

Private companies have an interest to maintain their infrastructures as economically as possible. However, they also have a responsibility on the safety of structures and security of people. Nuclear power plants are obliged to safeguard the radiation security by special regulations. A general requirement of private companies would be that the structures must be robust and maintenance free enough to guarantee a continuous production. Unintended breaks in the production as a result of MR&R actions would be extremely expensive.

4.2 Users at Different Levels of Organisation Hierarchy

A LMS system provides benefits for all hierarchical levels of an organisation; from chief manager to central administration, local administration and repair consultants.

The different levels of an organisation are responsible for decision making at different levels of the structural hierarchy consisting of network, object, module and component level.

By networks we understand stocks of bridges, tunnels, quays etc. Objects refer to single bridges, tunnels, quays etc. Modules form the main parts of objects such as a superstructure and a substructure of a bridge. Components are basic elements of structures such as columns, beams, walls and slabs. Usually there is a correspondence between the level of organisation hierarchy and the interest level in structural hierarchy (Table 3).

Table 3 Correspondence between the level of organisation hierarchy and the interest level in structural hierarchy

Level of organisation hierarchy	**Level of structural hierarchy**
Chief manage	Network
Central administration	Network, object
Local administration	Local network, object
Repair consultants	Object, component/module

4.3 Users, Stakeholders and Main Task Goals

Different users and stakeholders are identified in order to identify groups of people with similar needs, and to allow each set of needs to be considered separately (Table 4). For each groups of users and stakeholders, it is important to identify their main roles or task goals in order to find how useful and appropriate the LMS-product can be to them.

User groups are defined as those who use the system directly (‘hands on’) but may play no part in buying it. They include: end users, installers, maintainers. Stakeholder groups are defined as

those who influence or are affected by the system, but may not be the actual users. They include: recipients, marketing staff, purchasers, support.

Conserning theLifecon LMS, three groups of end users are identified as well as other stakeholders (Table 4).

Table 4. Users, Stakeholders and Main Task Goals

Users, Stakeholders and Main Task Goals	
System name: *Lifecon LMS* *(Life cycle Maintenance and management planning System for concrete structures)*	
USER GROUPS/ STAKEHOLDERS	MAIN TASK GOALS
<u>End users</u> Group 1: Chief managers/Central-administration	To be able to give economic justification of decisions To have an objective basis for decisions, based on engineering, economic and ecological grounds To have sufficient information to determinination of medium and long-term targets, and to apply the appropriate maintenance strategies to achieve these targets To be able to develop strategic guidelines for preservation of assets To be able to optimize MR&R strategies based on engineering and economic grounds To make selection of justifiable maintenance decisions within budget constraints To be able to show value for money in infrastructure provision and maintenance To be able to justify need for allocation of funds To be able to evaluate whole life costing, including user costs To be able to evaluate implications of lower standards of performance To be able to evaluate the impacts of changes in various planning policies may have on the aggregate characteristics of the bridge stock (scenarios) To be able to produce, evaluate and compare a desirably large number of scenarios in order to craft a long-term plan.

Table 5. Users, Stakeholders and Main Task Goals cont.

Users, Stakeholders and Main Task Goals	
System name: *Lifecon LMS* *(Life cycle Maintenance and management planning System for concrete structures)*	
USER GROUPS/ STAKEHOLDERS	MAIN TASK GOALS
Group 1: Chief managers/Central-administration	To be able to present the variety of the scenario information in a concise form. To be able on a national level to monitor the stock of objects as network performance through a broad range of indicators (measure of effectiveness). To be able to perfume "What-If" analysis and provide information in tabular and graphical forms. To have templates for tabular and graphical outputs, and to be able to configure them for a desired combination of output characteristics. To be able to vary the budget inputs using graphical objects and obtain system response instantaneously. To have the "What-If" module generate tabular output as reports and graphical output as views. To be able to define and monitor strategic targets like Control of condition (Preservation of assets, Striving to an optimal condition level), Control of structural requirements (Structural safety and security, Functionality and serviceability), Control of costs (Life cycle costs, Delay costs, Risk costs, User costs), and Other requirements (Ecological efficiency, Aesthetic appearance, Cultural values).

Table 6. Users, Stakeholders and Main Task Goals cont.

Users, Stakeholders and Main Task Goals	
System name: *Lifecon LMS* *(Life cycle Maintenance and management planning System for concrete structures)*	
USER GROUPS/ STAKEHOLDERS	MAIN TASK GOALS
Group 2: Local administration/ maintenance engineers	To have a well organised condition assessment system and inventory for the structures To make optimisation of MR&R actions for specific components, modules and objects To be able to guarante safety To make correct timing of MR&R actions To be able to evaluate MR&R costs To be able to combine optimised actions into MR&R projects To be able to prioritise between candidate MR&R projects To make annual repair and reconstruction programmes To have sufficient budget control To be able to make Residual service life analysis To be able to make Analysis of the structural capacity To be able to make Economic and ecological life cycle analysis

Table 7. Users, Stakeholders and Main Task Goals cont.

Users, Stakeholders and Main Task Goals	
System name: *Lifecon LMS* *(Life cycle Maintenance and management planning System for concrete structures)*	
USER GROUPS/ STAKEHOLDERS	MAIN TASK GOALS
Group 3: Repair consultants	To be able to plan, program and describe MR&R projects
Other stakeholders Service providers	
Purchasers:	?
Installers/Customer design: User organization IT staff	To be able to modify parts of the system as the bank's corporate needs evolve.
Maintenance staff: User organization IT – Maintenance	To be able to maintain the system so that system running can be maintained for at least 20 hours per day.
Others:	

4.4 User characteristics

The characteristics of the end user group identified within section 4.3 (e.g. Chief managers, Central administration, local administration, maintenance engineers and repair consultants) generate inputs to the requirements specification.

The user group characteristics are expressed either for users of the current system or users of the future system.

Relevant characteristics include: age range, gender, culture, education, language, physical attributes, frequency of use, discretion to use, experience of system, general IT experience or training (Table 8).

Table 8. User group characteristics

User group characteristics		
System: *Lifecon LMS* **User group:** *End users e.g. Chief managers, Central administration, local administration, maintenance engineers and repair consultants*		
CHARACTERISTICS	POTENTIAL SYSTEM REQUIREMENTS	REF.
SKILLS AND KNOWLEDGE		
Training and experience in the processes and methods which the system supports *Ranging from non to experienced*		
Experience in: **a) using current systems** *Will be first time user* **b) using other systems with similar main functions** *10 % of end users will have used other LMS systems*	*Try to make the system conform with any accepted ad hoc standards for similar systems.*	UReq. 1.
c) using systems with the same interface style or operating system *Some technologies may be unfamiliar to user e.g. touch screens, PDA.*	*Ensure that clear instructions are provided for input devices that users may not be experienced with.*	UReq. 2.

Table 9. User group characteristics cont.

User group characteristics		
System: *Lifecon LMS* **User group:** *End users e.g. Chief managers, Central administration, local administration, maintenance engineers and repair consultants*		
CHARACTERISTICS	POTENTIAL SYSTEM REQUIREMENTS	REF.
SKILLS AND KNOWLEDGE		
Knowledge or training in: **a) Tasks supported by the systems main functions** *Variable, assume none.* **b) Using the systems main functions** *No formal training. In most cases a few minutes informal instruction may be given.* **c) Using other systems with similar main functions** *In most cases no formal training.* **d) Using systems with the same interface style or operating system** *Variable, assume none.*	*Use highly supportive interface with logical, clear structure* *Make system as intuitive and self explanatory as possible.*	UReq. 3. UReq. 4.
Education/Qualifications *Any level of ability*	*Design to attract people who may have few skills in use of the system.*	UReq. 5.
Relevant input skills *Variable, assume normal skills in using computers*		
Linguistic ability *May be several native languages, reading difficulties.*	*Use English language, simple terminology, diagrams and pictures.*	UReq. 6.
Background knowledge/IT Knowledge *Variable, assume normal office skills.*	*Use very supportive dialogues to make user feel comfortable.* *Develop attractive interfaces.*	UReq. 7. UReq. 8.

Table 10. User group characteristics cont.

User group characteristics		
System: *Lifecon LMS* **User group:** *End users e.g. Chief managers, Central administration, local administration, maintenance engineers and repair consultants*		
CHARACTERISTICS	POTENTIAL SYSTEM REQUIREMENTS	REF.
PHYSICAL ATTRIBUTES		
a) Age range *20 to 65 years.* **b) Typical age** *25 to 60 years.* **Gender** *Both*		
PHYSICAL ATTRIBUTES		
Motivations a) attitude to job and task *Assume positiv*		
b) attitude to the system *May be reluctant to use.*	*Make it appear attractive to use.*	UReq. 9.
c) attitude to information technology *Assume positiv*		
d) employees attitude to the employing organisation *Assume positiv*		

Table 11. User group characteristics cont.

User group characteristics		
System: *Lifecon LMS* **User group:** *End users e.g. Chief managers, Central administration, local administration, maintenance engineers and repair consultants*		
CHARACTERISTICS	POTENTIAL SYSTEM REQUIREMENTS	REF.
JOB CHARACTERISTICS		
Job function *Section not applicable* **Job history** *Section not applicable*		
Frequency of use *Ranging from first-time users or very infrequent to daily. May return to system*	*Use supportive dialogue - easy to learn and remember.*	UReq. 10.
Discretion to use *End users have to use the produc* *End users may not ignore system or abandon for any reason.*	*Make attractive and easy to use.* *Ensure that results can be achieved quickly.*	UReq. 11. UReq. 12.
Other relevant features *Wish to attract casual users who may be short on time.*	*Make as attractive and simple as possible to attract casual users.* *Ensure that results can be achieved easily.*	UReq. 13. UReq. 14.

5 User requirement

More than 170 potensial user requirement have been identified to the Lifecon LMS, covering the following areas (Table 8 - Table 28):

- User group characteristics
- General

- Data input
- Startup and logon
- Finding objects
- Map functionality
- Presentation of objects
- Condition Assessment included inspections
- Output
- Analysis
- User Documentation
- System documentation
- Interface Requirements
- On-screen reference
- Consistency
- Shortcuts for experienced users
- Make it difficult to make an error, but easy to correct one
- Provide useful feedback, prompts and messages
- Reduce memory load
- User control
- Miscellaneous
- Network-level analyses
- Project-level analysis
- Works programming
- Inventory
- Determination of fund needs
- Selecting candidate management segments when funds are constrained
- Determine the impact of funding decisions on the future condition and fund needs

- Impact analysis and presenting results to decision-makers
- Generated reports
- Feedback System
- Condition survey
- Condition indexes
- Prediction models
- Selecting the best maintenance strategy
- Quantifying benefits of treatments
- Technical specifications
- Hardware Interfaces
- Software Interfaces
- Communications Interfaces

Table 12. Potential User Requirement.

System: *Lifecon LMS* **User group:** *End users e.g. Chief managers, Central administration, local administration, maintenance engineers and repair consultants*		
CHARACTERISTICS	POTENTIAL SYSTEM REQUIREMENTS	REF.
General	The application should have a help-file containing at least the same information as the user guide	UReq. 15.
	All methods referred to in the LMS Handbook, D1.1. should be included	UReq. 16.
	The tool should be capable of being operated at at least three levels: Basic, Expert and Information	UReq. 17.
	Three levels of investigations should be supported: Overview / risk assessment (desk study), Simple investigation, and Detailed investigation and analysis	UReq. 18.
Data input	Data entry relating to objects, modules and components should be as simple as possible.	UReq. 19.
	There should be the ability to copy a 'template' of information between records for individual components.	UReq. 20.
	Existing information from databases should be possible to import to and export (convert) from the Lifecon Database.	UReq. 21.
	The import of information from excisting databases should be done in a way that conservs or improves the consistency in the information.	UReq. 22.
	The IT-tool should contain or link to different "Initial" data set reprrsenting different types of object and degredation type.	UReq. 23.
	”Default" values for important parameters described in D1.1 - The LMS Handbook, should be available	UReq. 24.
	The Lifecon Database and data-handling methods should be as compatible as possible with other major applications/formats (e.g. Access, Excel, Paradox, SQL...)	UReq. 25.
Startup and logon	Each user of the system must have an unique user identification (user-ID) and a password that is required to log on to the system	UReq. 26.
	Users should be divided in different access classes (User, Admin and Guest?), where only the Admin-class can update library-tables	UReq. 27.

	Any input to the system should be logged with date and user	UReq. 28.
	A unique number should identify every object	UReq. 29.

Table 13. Potential User Requirement, cont..

System: *Lifecon LMS* **User group:** *End users e.g. Chief managers, Central administration, local administration, maintenance engineers and repair consultants*		
CHARACTERISTICS	POTENTIAL SYSTEM REQUIREMENTS	REF.
Finding objects	There should be possible to find a specified object by choosing the object by its unique number	UReq. 30.
	There should be possible to find a specified object by selecting it from a list of objects	UReq. 31.
	There should be possible to find a specified object by searching for it based on a specific set of criteria's	UReq. 32.
	There should be possible to find a specified object by searching for it through a map interface	UReq. 33.
Map functionality	Add and remove map-themes (raster or vector)	UReq. 34.
	Select color, style and symbol for map-themes	UReq. 35.
	Zoom all, zoom in, zoom out, zoom to objects	UReq. 36.
	Pan	UReq. 37.
	Print map to printer, file or clipboard	UReq. 38.
	Choose one or several objects by point at them or drag at polygon around them	UReq. 39.
	Show themes with graduated color, style or symbol (type and size) dependent on properties in each theme	UReq. 40.

Table 14. Potential User Requirement, cont..

System: *Lifecon LMS* **User group:** *End users e.g. Chief managers, Central administration, local administration, maintenance engineers and repair consultants*		
CHARACTERISTICS	POTENTIAL SYSTEM REQUIREMENTS	REF.
Presentation of objects	It should be possible to present the objects in several ways	UReq. 41.
	Primarily the objects should be presented as a 2D-drawing of the objects base	UReq. 42.
	If several levels/floors exists and the base for higher floors diverge, several different drawings for each floor shuold be possible	UReq. 43.
	It should be possible to show the objects in scale	UReq. 44.
	Symptoms connected to objects should be possible to list	UReq. 45.
	Symptoms connected to the drawing should be possible to see on the drawing	UReq. 46.
	The symptoms should be possible to acsess both from drawings and lists	UReq. 47.
	When a symptom is selected, further information regarding the symptom and evaluations should be shown.	UReq. 48.
	Other documents connected to the object should be shown in a separate list	UReq. 49.
	Documents, who are linked to the drawing, should be marked on the drawing.	UReq. 50.
	The different object-parts registered on the object should be shown in a separate list/tree-view, marking the relation between them	UReq. 51.
	When the object-parts are linked to the drawing they should be marked on the drawing	UReq. 52.
	Information like documents and object-parts should be possible to turn on and off in the drawing.	UReq. 53.
	It should be possible to add new symptoms when viewing the object.	UReq. 54.

	It should be possible to add new object-parts when viewing the object.	UReq. 55.
	It should be possible to add new documents, spreadsheets and photos when viewing the object	UReq. 56.

Table 15. Potential User Requirement, cont.

System: *Lifecon LMS* **User group:** *End users e.g. Chief managers, Central administration, local administration, maintenance engineers and repair consultants*		
CHARACTERISTICS	POTENTIAL SYSTEM REQUIREMENTS	REF.
Condition Assessment included inspections	Field inspections should be performed using a portable computer or a PDA	UReq. 57.
	The inspection-application should have its own database, being a subset of the main database.	UReq. 58.
	Requirements for logon will be as for main application	UReq. 59.
	Information about users etc. should be downloaded to portable computer before inspection starts of accsessed online in the field	UReq. 60.
	Information about object, damage atlas etc. should be downloaded to portable computer before inspection starts or accsessed online in the field	UReq. 61.
	The application should have high priority on ease-of-use	UReq. 62.
	Symptoms should be possible to mark directly on the drawing and should be given a unique ID	UReq. 63.
	Additional identification of location of symptoms should be possible	UReq. 64.
	List of possible should be possible to predefine and made available as lookup menyes	UReq. 65.
	Each symptoms should have a separate set of predefined questions and/or information which the user can fill out	UReq. 66.
	Additional information should be possible to give in form of free-text (comments)	UReq. 67.

	Digital photos should be linked to an object, a specific object-part, symptom or map	UReq. 68.
	Each object should have a predefined list of attributes that can be updated/added while doing the inspection	UReq. 69.
	After completion of inspections, the inspection-data should be automatical uploaded to the main database if not online	UReq. 70.
	A list of object-parts should be possible to add/update during the inspection	UReq. 71.
	Object-parts should be possible to link to the drawing	UReq. 72.
	Symptoms should be possible to link to an object-part in stead of, or in addition to the drawing	UReq. 73.
	It should be possible to set up a plan, program for inspections, register the inspectionresults and condition.	UReq. 74.

Table 16. Potential User Requirement, cont..

System: *Lifecon LMS*

User group: *End users e.g. Chief managers, Central administration, local administration, maintenance engineers and repair consultants*

CHARACTERISTICS	POTENTIAL SYSTEM REQUIREMENTS	REF.
Output	The tool should allow a variety of ways to view the results (like MS Project can show information on e.g. schedule, costs, staffing, etc.).	UReq. 75.
	At network level, the output should include an overall plan, with the ability to 'burrow' down to detailed information on each individual project, including staff numbers and categories.	UReq. 76.
	The schedule of projects should exist in a form where it is possible to be translated/transferred to other project management applications.	UReq. 77.
Analysis	The tool should allow the user to 'play' with various possible, studying their effects and relative benefits, without "damage" to the original dataset (What-if analysis).	UReq. 78.
	Network-level optimisation should be based on Markov statistic or MADA methods or both as appropriate; guidance on the method to be used should be given.	UReq. 79.

	Optimisation of projects and within projects would probably be by MADA methods.	UReq. 80.
	The 'Basic' version of the tool should use the "quick" versions of the equations describing the progress of degradation (depth of carbonation, chloride ingress, etc.).	UReq. 81.
	The 'Expert' version would probably use more complex methods like Duracrete models routinely, but should also be able to use the "quick" equations too, when there is insufficient data or the system is being used to carry out an overview.	UReq. 82.
User Documentation	User manuals should be provided	UReq. 83.
	On-line help should be available	UReq. 84.
	Tutorials should be available	UReq. 85.
System documentation	Documentation of the system architecture incl. Requirement to application environment should be available	UReq. 86.
	Documentation of database incl. Safety copying, reestablising and tuning should be available	UReq. 87.
	Documentation of the interface between other applications should be available	UReq. 88.
	Documentation of the network and communication should be available	UReq. 89.
	Documentation of faultseeking should be available	UReq. 90.

Table 17. Potential User Requirement.

System: *Lifecon LMS* **User group:** *End users e.g. Chief managers, Central administration, local administration, maintenance engineers and repair consultants*		
CHARACTERISTICS	POTENTIAL SYSTEM REQUIREMENTS	REF.
Interface Requirements	The IT-prototype should have good usability by providing a well-designed inductive user interface (IUI).	UReq. 91.

	The features of the application should be self-evident and self-explanatory.	UReq. 92.
	Users must be able to find a feature every time they need it, and must be able to use that feature every time they want to use it.	UReq. 93.
	The application should provide pages who are simple and task-based focusing on a single task per page and providing navigation forward and backward through pages.	UReq. 94.
	The application should provide inductive navigation which starts with focusing the activity on each page to a single, primary task.	UReq. 95.
	The interface should use consistent screen templates	UReq. 96.
	The interface should Provide screens for starting tasks	UReq. 97.
	The interface should make it obvious how to carry out the task with the controls on the screen	UReq. 98.
	The interface should provide an easy way to complete a task and start a new one	UReq. 99.
	The interface should make the next navigational step obvious.	UReq. 100.
On-screen reference	Each step should include an on-screen reference to the relevant section of the Generic Handbook, to allow the user to look up the Handbook to check what s/he should be doing on that screen.	UReq. 101.
Consistency	Sequences of actions should generate the expected response, identical terminology and abbreviations should be used throughout, prompts should always appear in the same place.	UReq. 102.
Shortcuts for experienced users	Shortcuts in order to reduce the number of interaction steps and to speed up the interaction process should be available (e.q. macro facilities, special key combinations and fastpaths). Their presence should not interfere in any way with the dialogue as presented to a novice user.	UReq. 103.

Table 18. Potential User Requirement, cont.

System: *Lifecon LMS* **User group:** *End users e.g. Chief managers, Central administration, local administration, maintenance engineers and repair consultants*		
CHARACTERISTICS	POTENTIAL SYSTEM REQUIREMENTS	REF.
Make it difficult to make an error, but easy to correct one	The user should not be able to damage the LMS system or make serious error. Destructive commands such as deleting a directory or erasing all memories should be structured such that the user is made to confirm his action.	UReq. 104.
	Inapplicable commands should leave the system state unchanged. Ideally, any action should be undoable or reversible, so that a user does not fear learning by experimentation, though this is often difficult to implement.	UReq. 105.
	Abbreviations should be analysed for inconsistency or ambiguity.	UReq. 106.
Provide useful feedback, prompts and messages	Every operator action should elicit some system feedback. At its simplest this might be a click to confirm a action following.	UReq. 107.
	The application should give feedback at the end of a sequence or operations to give the user the satisfaction of reaching task closure.	UReq. 108.
	Messages should be constructive and give guidance for using the system in a courteous way. All messages should be part of the system design and available in the user manual.	UReq. 109.
Reduce memory load	Displays should be kept simple and users should not be required to 'carry-over' information from one display to another.	UReq. 110.
User control	The user should feel that they are in control and that the system is responding to his or her actions, not vice versa.	UReq. 111.
	Users should have control over the amount of information they receive at different points of the interaction.	UReq. 112.
Miscellaneous	Make it convenient to change modes so that the user should not need to close down one activity in order to start another. Rest pauses	UReq. 113.

	Rest pauses should be considered in relation to the type of work, the types of fatigue to which a person is prone	UReq. 114.
	The application shuold have the ability to "save" the current state of any analysis	UReq. 115.

Table 19. Potential User Requirement.

System: *Lifecon LMS* **User group:** *End users e.g. Chief managers, Central administration, local administration, maintenance engineers and repair consultants*		
CHARACTERISTICS	POTENTIAL SYSTEM REQUIREMENTS	REF.
Network-level analyses	The analysis should cover all civil infrastructure objects and buildings owned by the organisation; typically represented as strata of structures or structures elements.	UReq. 116.
	The application should identify constraints from owner, user and the society	UReq. 117.
	The system should transform information of owner, user and the society constraints to technical and economical constraints by applying Quality function deployment (QFD)	UReq. 118.
	It should be possible to make analysis of different service life strategies for populations of objects owned by the organisation	UReq. 119.
	It should be possible to make optimisation of service life strategies for objects owned by the organisation	UReq. 120.
	It should be possible to prepare long term strategic service life plans and budgets	UReq. 121.
Project-level analysis	The analysis should cover single objects. The results from these analyses are descriptions of feasible service life strategies for the object including both inspection and maintenance plans. This should include modules for:	UReq. 122.
	The system should include a modul for condition survey	UReq. 123.

	The system should include a modul for condition assessment	UReq. 124.
	The system should include a modul for service life prediction	UReq. 125.
	The system should include a modul for life cycle analyses of feasible maintenance and reconstruction strategies	UReq. 126.
Works programming	Should cover all objects owned by the organisation; typically represented as strata of structures or structures elements.	UReq. 127.
	The results from the works programming should be tactical plans including prioritised working plans and programs.	UReq. 128.
	The development of prioritised working plans and programs should be based on multi attribute analyses following both the long term plans from network-level and taking into consideration the constrains from network-level, as well as the descriptions of feasible service life strategies for the object including both inspection and maintenance plans from project level	UReq. 129.

Table 20. Potential User Requirement cont.

System: *Lifecon LMS* **User group:** *End users e.g. Chief managers, Central administration, local administration, maintenance engineers and repair consultants*		
CHARACTERISTICS	POTENTIAL SYSTEM REQUIREMENTS	REF.
Inventory	In order to manage a network of objcts, the system have to keep track of the network inventory incl. Strata of this (information about the physical size of the facilities, locations and related basic information such as applied materials and systems).	UReq. 130.

	The system have to provide basic information about the location and inter-connectivity of each management segment.	UReq. 131.
	The system should be based on modularisation of the inventory.	UReq. 132.
	The minimum data required for each management segment generally includes: Identification, district, county, municipality, structural no., , fairway no., fairway cat., location, latitude and longitude, size, dimesion information, min. vertical clearance above high tide, functional classification (Fishing, industrial, municipal wharfe, ferry, defence, parallel structure, temporary structure, historic significance), type materials applied, age and service, year built, year reconstructed, type of service, main users, initial cost, previous maintenance projects, year, costs,…	UReq. 133.

Table 21. Potential User Requirement, cont.

System: *Lifecon LMS* **User group:** *End users e.g. Chief managers, Central administration, local administration, maintenance engineers and repair consultants*		
CHARACTERISTICS	POTENTIAL SYSTEM REQUIREMENTS	REF.
Determination of fund needs	One of the main tasks at network-level is to determine future fund needs for strata of structures based on the defined network after collection of inventory and condition data. Analysis of fund needs should include: – Identifying sections needing maintenance or reconstruction – Treatment selection – Cost determination	UReq. 134.
	The system should provide need analyses which identies management sections needing maintenance and reconstruction based on engineering analysis of the best treatment to apply without considering if funds are available to fund each structure.	UReq. 135.
	The system should enable assignment of treatment to the sections identified as needing maintenance or reconstruction based on analysis of: Least life-cycle costs and Benefit/cost and cost-effectiveness	UReq. 136.
	The need analyses from the system should provide the following from a life cycle view: – A listing of sections needing maintenance and reconstruction – The projected condition with and without the treatments identified as needed – The total costs needed to apply the maintenance based on a selected policy – Summarised needs for specific classes of treatments and facility types	UReq. 137.

Table 22. Potential User Requirement, cont.

System: *Lifecon LMS* **User group:** *End users e.g. Chief managers, Central administration, local administration, maintenance engineers and repair consultants*		
CHARACTERISTICS	POTENTIAL SYSTEM REQUIREMENTS	REF.
Selecting candidate management segments when funds are constrained	The systems selection of management segments when funds are constrained, should be based on optimisation procedures that identifies a list of candidate management sections and treatment cost categories for the available funding. The final selection of sections and treatments must be completed at the project-level.	UReq. 138.
	The optimisation should be based on information on: – damage measures – performance – equivalent uniform annual cost – net present value – benefit/cost ratio or cost-effectiveness	UReq. 139.
	When the system are doing optimisation, timing should be considered as well as selection of the sections and time of treatment.	UReq. 140.
	The optimisation procedures used by the system should be formulated as probabilistic models	UReq. 141.
	The system should enable optimisation by Markov processes or Markov chain models based on e.g. agreed damage levels. The Markov model should be calibrated against survivor curves.	UReq. 142.
Determine the impact of funding decisions on the future condition and fund needs	The system should show the performance of the structures by projecting the average condition of the structures over the defined analysis period with various levels of funding and various funding strategies, e.g. higher and lower percentages of funds directed at maintenance.	UReq. 143.
	The system should enable analysis of different scenarios describing the current quality of service being provided and discuss how the funding will increase or decrease the performance with an emphasis on the percentage of each type of facility, at one of performance levels.	UReq. 144.

Table 23. Potential User Requirement, cont.

System: *Lifecon LMS* **User group:** *End users e.g. Chief managers, Central administration, local administration, maintenance engineers and repair consultants*		
CHARACTERISTICS	POTENTIAL SYSTEM REQUIREMENTS	REF.
Impact analysis and presenting results to decision-makers	The system should show the performance of the objects by projecting the average condition of the objects over the defined analysis period with various levels of funding and various funding strategies, e.g. higher and lower percentages of funds directed at maintenance.	UReq. 145.
	The system should also provide assistance in showing the impact of funding decisions by allowing the user to look at different funding scenarios and showing the projected impact.	UReq. 146.
	The system operator should be able to run the program for different funding options and compare the results.	UReq. 147.
	The system should show the impact of funding alternative segments compared to those recommended by the standard prioritisation procedure.	UReq. 148.
	One of the most important data types should be generated by the system is the projected condition of the infrastructure network with different funding levels. This projected condition can be for individual deterioration measures, deterioration indices, individual condition measures, or combined indices.	UReq. 149.
	The system should present the impact of funding decisions on the health of the network by presenting the change in backlog of funding needs	UReq. 150.
	The system should present the impact of financial projections on the health of the network by presenting the change in the deferred funding needs.	UReq. 151.
	The system should present the health of the network is as a function of the amount of funds spent on stopgap maintenance.	UReq. 152.
	The system should present the impact of different funding strategies as a function of the change in percent of network with different levels of remaining service life.	UReq. 153.

Table 24. Potential User Requirement, cont.

System: *Lifecon LMS* **User group:** *End users e.g. Chief managers, Central administration, local administration, maintenance engineers and repair consultants*		
CHARACTERISTICS	POTENTIAL SYSTEM REQUIREMENTS	REF.
Generated reports	The system should generate reports covering the following topics: – infrastructure condition – infrastructure performance (condition over time) – deficiencies – prioritised listings – predictions – strategies – treatments – costs – history – summary reports – summary reports showing the amount of infrastructure maintained, – trends of past performance and projected performance, – the amount of funds needed to maintain the current condition level and alternative condition levels, – changes in the amount of infrastructure in unacceptable condition for different funding strategies over some future period, – changes in the percent of infrastructure that has been backlogged for different funding strategies over some future period, – changes in the amount of deferred fund needs for different funding strategies over some future period, – distribution of categories of remaining life for different fund levels, and – changes in stopgap maintenance fund needs and the amount of infrastructure for which stopgap maintenance will be needed for different funding strategies over some future period.	UReq. 154.
Feedback System	The system should provide information on how reliable past estimates have been and should be a method to improve future estimates.	UReq. 155.

Table 25. Potential User Requirement, cont.

System: *Lifecon LMS* **User group:** *End users e.g. Chief managers, Central administration, local administration, maintenance engineers and repair consultants*		
CHARACTERISTICS	POTENTIAL SYSTEM REQUIREMENTS	REF.
Condition survey	The system should allow each element of an object to be rated to define: – overall condition – extent of degradation and deterioration – degree of degradation and deterioration – cause of degradation and deterioration	UReq. 156.
Condition indexes	The system should use Condition indexes for several purposes. The primary use is to develop a simple method of defining the condition of the infrastructure elements to communicate more easily information on condition. Once it is defined, the condition index should be used in quantifying changes in condition, to predict future changes in condition, and to establish level at which various should be completed. They also should be used to determine the long-term impact of various treatment alternatives.	UReq. 157.
Prediction models	The system should use prediction models to forecast condition during that analysis period with or without any treatment applied.	UReq. 158.
	The using the models, the system should show the impact of recommended maintenance and rehabilitation treatments and provide information to calculate the remaining useful life of the segment with and without the treatments. This remaining life information should then be used in life cycle cost analysis.	UReq. 159.
	The system should predisct the average condition of strata of infrastructure segments for network-level analysis, and the condition also should be predicted for individual elements and sub-elements. The condition information for individual sections should then combined together to show the condition of groups of structures.	UReq. 160.
	The system also should allow the predicted condition of the group to be weighted for the area or size of each section within the group.	UReq. 161.
	Since environmental loading is one of the most important factors that affect degradation of most element, it should be used by the system to develop condition prediction equations.	UReq. 162.

	The system should be based on infrastructure condition prediction models who at least forecast the condition in terms of one of the following different measures of condition: – Primary response – Structural performance – Functional performance – Degradation	UReq. 163.

Table 26. Potential User Requirement, cont.

System: *Lifecon LMS* **User group:** *End users e.g. Chief managers, Central administration, local administration, maintenance engineers and repair consultants*		
CHARACTERISTICS	POTENTIAL SYSTEM REQUIREMENTS	REF.
Selecting the best maintenance strategy	The system should give guideanse based on the results from analysis and at project level should the system define a series of alternative maintenance strategies. These maintenance strategies should be combination of maintenance products and systems that give the least life-cycle impact for the design period analysed while providing the desired service. This should also include delayed traffic cost and environmental impacts.	UReq. 164.
Quantifying benefits of treatments	The system should quantify benefits of treatment using net cost analysis taking owner cost, user costs and society cost, as well as cost related to the total environmental impact into consideration. This methodology should be applied into analysis of maintenance strategies at both network- and project level.	UReq. 165.
Technical specifications	The application should be running on Windows 2000 and later	UReq. 166.
	The application should have a three-layer architecture, alt. client/server	UReq. 167.

6 Design and Implementation Constraints

The documentation of the delivered software should be sufficient for the customer's organisation to be responsible for maintaining the delivered software.

Table 27. Potential User Requirement - 6 Design and Implementation Constraints.

System: *Lifecon LMS* **User group:** *End users e.g. Chief managers, Central administration, local administration, maintenance engineers and repair consultants*		
CHARACTERISTICS	POTENTIAL SYSTEM REQUIREMENTS	REF.
6 Design and Implementation Constraints	The documentation of the delivered software should be sufficient for the customer's organisation to be responsible for maintaining the delivered software	UReq. 168.

7 Assumptions and Dependencies

The Lifecon LMS tool should ideally not require links to many specialised commercial applications with expensive licence fees! The aim should be to keep it as simple as possible.

Dependencies:

- Import and export to existing inventory lists e.g. the Fareway list should bes possible
- The map functionality should be compatible with ESRI products

Table 28. Potential User Requirement - 7 Assumptions and Dependencies.

Potential User Requirement - 7 **Assumptions and** Dependencies		
System: *Lifecon LMS* **User group:** *End users e.g. Chief managers, Central administration, local administration, maintenance engineers and repair consultants*		
CHARACTERISTICS	POTENTIAL SYSTEM REQUIREMENTS	REF.
Assumptions and Dependencies	Import and export to existing inventory lists e.g. the Fareway list should bes possible	UReq. 169.
	The map functionality should be compatible with ESRI products	UReq. 170.
	The system should ideally not require links to several specialised commercial applications with expensive licence fees	UReq. 171.

8 Organisational design

The organisational design is done to understand the organisational basis for the LMS-concept. This should show at a high level how the users will interact with the system and communicate with other people as part of the work process or operating environment. It should also show how information will flow through the system.

The organisational design is not a part of D1.3 User requirement.

9 Technical specifications

10 System Architecture

10.1 Introduction

This document specifies the application structure of the Lifecon LMS IT prototype. It describes in detail the dependencies between components and modules of the system. One central requirement for the IT prototype is that it should be generic. This requirement is fulfilled by a modularized structuring of the system and a completely generic database structure. A common application framework (Café) has been developed which enables the system to flexibly handle both the different modules as well as different databases.

Table: Main achievements of the IT prototype

Before Lifecon	**Lifecon IT prototype**	**Exploitation/Use**
Reactive Maintenance	Predictive Maintenance	
Specific data model	Generic data model	User configurable data models (expert user)
Function centric	Data Centric (Object oriented)	
Specific functions	Generic functions	
Specific GUI	Generic GUI	
Pre-programmed models	Generic model editor	User-specific models (expert user)
Specific system integration	Generic system integration	User-specific system integration (IT expert)
Object type specific	Configurable object types	Configuration (normal user)

As you will see from the table, the Lifecon LMS IT prototype has been designed to be generic and modular. It is thus possible to use the system for a multitude of object types and model types. It is, however, important to be aware that effective and relevant use of the system presupposes an adaptation of the to the specific user environments. This adaptation may be done by normal users, expert users and in some instances by IT experts.

10.2 Overall functionality and shortcomings

In the Lifecon project, generic modules have been developed to handle:

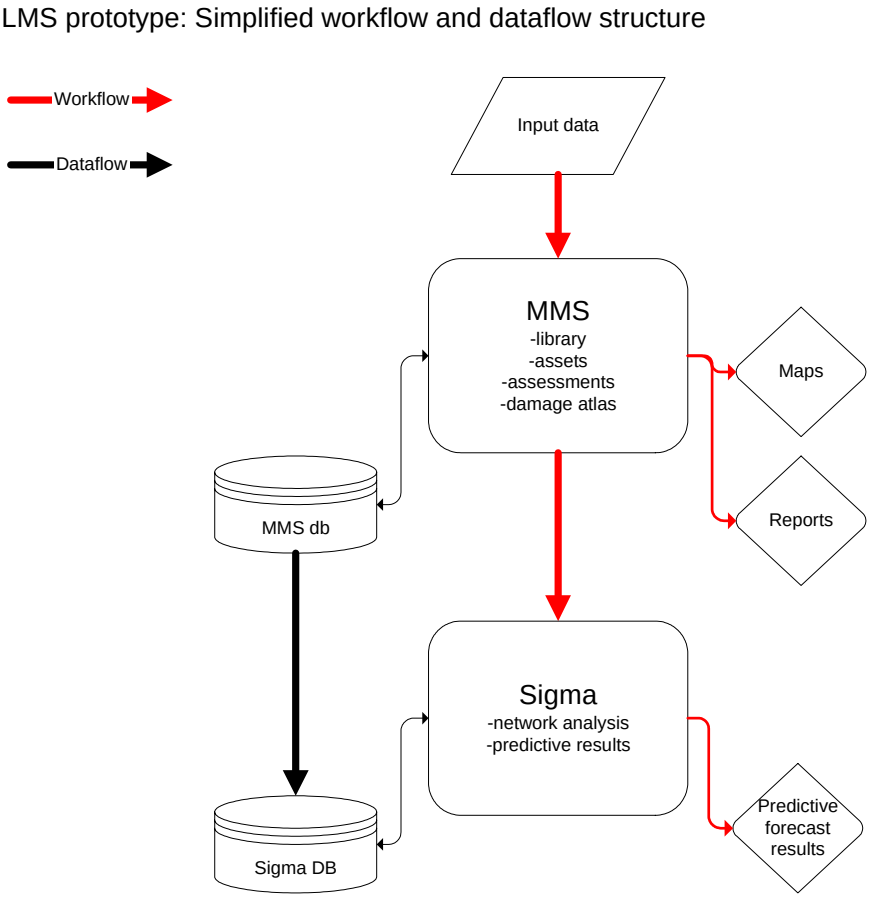
- Photos
- Maps
- Documents
- Drawings

Generic and flexible Assets and Condition Assesment modules that enables the users to enter descriptive and analytical condition information on all levels for buildings, installations and civil infrastructure systems, as well as their sub-parts

A generic and flexible network analysis module to enable flexible scenario analysis on all levels for buildings, installations and civil infrastructure systems

A full integration between the object and the network levels giving flexible fetching of aggregated data to the network level analysis

The following figure shows the main parts of the IT prototype and the interactions between the main components. In the following chapters we will describe the system in more detail.



Lifecon LMS: Simplified workflow and dataflow structure

The making of the IT prototype builds on D1.1 "Generic Technical Handbook for a predictive Life Cycle Management System of Concrete Structures" as well as the user requirements formulated in this document. The IT prototype may be considered as a concretisation of these requirements. It has, however, not been possible to fulfill all functionality in an overall, integrated IT prototype. The IT prototype will thus be dependent on input from functions external to the core system specified and described in other deliverables. The main shortcomings of the IT prototype are:

- Optimisation: It has been impossible within the timeframe of the project to integrate optimisation functionality in the core IT prototype. The users will therefore be dependent on using Excel sheets external to the system for optimisation purposes. Our investigations showed that the solver functions in Excel did not have a defined API. The main rival to the Microsoft dominance of office solutions, Openoppfice, does not have solver functionality. It was therefore impossible to use source code from Openoffice as an alternative API for the IT prototype. The fact that Openoffice lacks solver functionality also shows that this functionality represents a heavy workload to implement.

- Decision trees: The IT prototype lacks functionality for decision analysis at object level. This should not be difficult to implement, but it

In the next chapters we will describe the functionality that the IT prototype **do** have. We will firstly present a typical work flow to use the Lifecon LMS IT prototype, and will then proceed to present in more detail the functionality covered.

11 Lifecon LMS Workflow

The Lifecon LMS system is not trying to implement some specific users way of working. This is also impossible because our everyday working tends not to be common and systematic but individual and leads to various degree of chaos.

Therefore the new way of doing computer assisted Maintenance Management will need more or less education dependent on the users' previous computer experience.

In this way the Lifecon LMS IT prototype is not only a system. It represents a new way of working.

The point of Lifecon LMS will be to build an experience database over time that enables the user to do better and better maintenance planning. As the database grows, the accuracy and control increases. Hopefully the system users will see that planned proactive maintenance is better than reactive maintenance.

11.1 Create MMS user site database

The first thing to do is to create a user specific database of the generic data model. This is an advanced task though, but should be possible to do by advanced users who have received education on the topic.

User site specific object and object part properties in addition to the generic data properties will together suit the user site data storage needs. Both assets and condition assessment specific data structures will be possible to be extended by object oriented inheritance with the Dacl DataBase ManageMent tool (DDBMM).

11.2 Configuration

The object part types must then be configured with the general Data Explorer in Norgit Cafè. This general purpose editor of database objects is suitable for this task since no aditional information is required for this type of data. The most important configuration data fields will be:

- Measurement unit for Object Part type
- Value per unit and condition index
- Upgrade cost per unit and condition index
- Degrade/upgrade transition matrix

The calculation of the data to insert must of course be done by corrossion experts on the selected object part types.

11.3 Register your assets

With a completed user site data structure and a completed object part hierarchy the assets can be registered, both the objects and their object parts.

Connect objects to Maps

After registering the objects it will be possible to position them on maps as object points.

Connect object parts to drawings

After registering the object parts it will be possible to position them on different drawings appended to the objects.

Connect any database object to photos and/or documents

Each object and object part will be possible to connect to multiple photo and document added to the database.

11.4 Make a plan and program for your inspections

This is an optional task that will be possible to do in the condition assessment module.

A LMS program is to select what building parts to inspect for an object.

11.5 Do condition assessment

Register the object part conditions after the inspections.

11.6 Do an integrated network analysis on the registered conditions

The network analysis of the condition assessment data will enable the user to forecast consequences of maintenance actions for the years to come. This includes condition index consequences but also cost and value consequences.

The result of this analysis can be overall maintenance plans that shows possible consequences of budget restrictions for Maintenance Management. Based on the degraded condition over the years many different key issues can get indexed and used for decision making.

12 The MMS system functionality

12.1 Assets

The Assets module will contain all inventory data of objects and object parts.

12.1.1 Kernel dependencies

Assets are dependent of the following kernel components:

GUI: for the Assets add-in to get access to interface elements such as menus, toolbars, status bar etc. This is necessary to be able to add menu items for the add-in on the application menu bar etc.
MDI: to open Assets window as modeless MDI child
GIS: to select objects position from map
Geography Manager: to add geographic object for object (to be displayed on map) and object parts (to be displayed on drawing)
Look-up Manager: to edit look-up tables
NLS: to ask the kernel what language is selected for the application
Help: to display a reference to the add-ins help file on the Help menu
Add-in Manager: used to install/uninstall, load/unload add-in

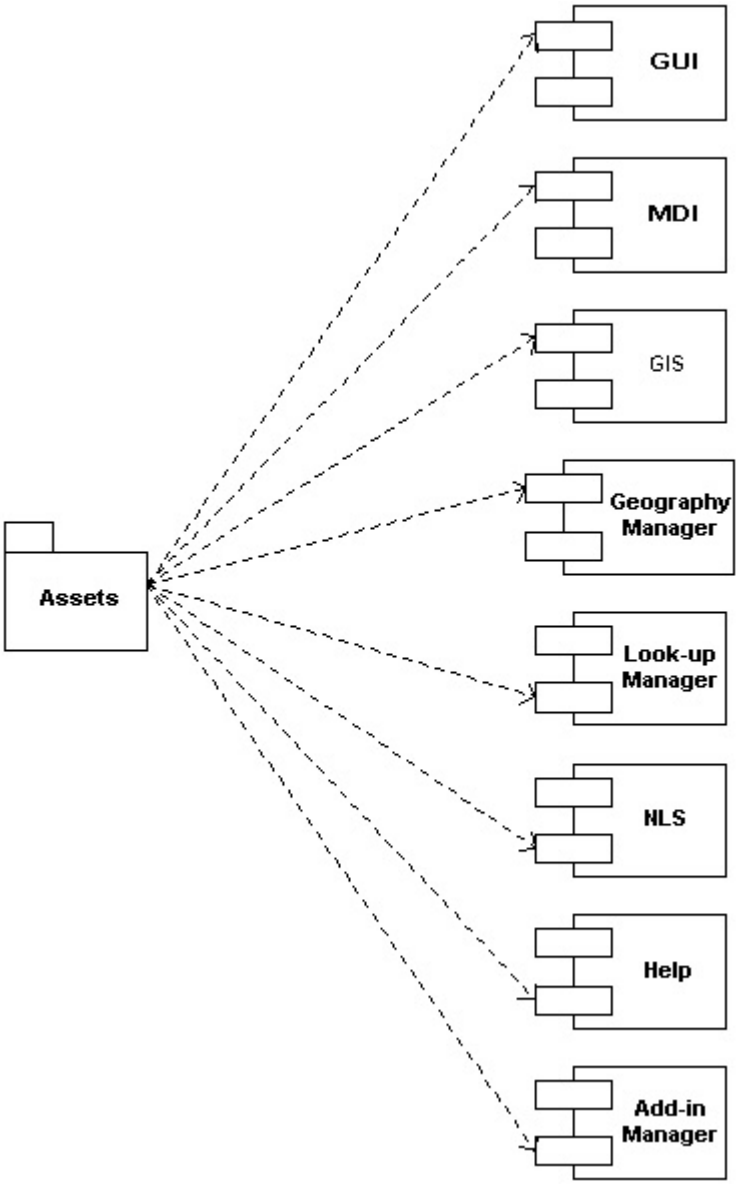


Figure 1 Assets - dependencies to kernel components

12.1.2 Dependencies to other add-ins

Drawing: to add drawings for one or more of the floors of a object and to select position/area for object part when adding it as geographical object.
Photo Server: to add/display images connected to object or object part
Document Manager: to add document reference to object and open document

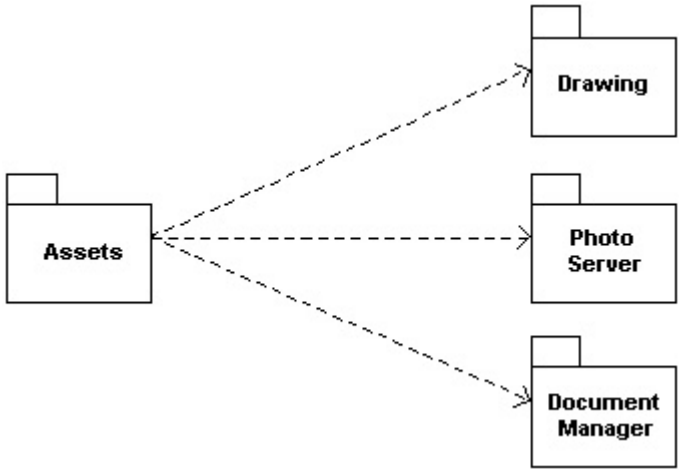


Figure 2 Assets - dependencies to other add-ins

12.1.3 Dependencies to other add-ins DB classes

The Assets is not dependent of any other add-ins DB classes.

12.1.4 Dependencies to 3rd parties components

The Assets is not dependent of any 3rd parties components.

12.2 Condition Assessment

The Condition Assessment module handles all functionality related to set up plan and program for inspections and registering the inspections and conditions

12.2.1 Kernel dependencies

GUI: for the Condition Assessment add-in to get access to interface elements such as menus, toolbars, status bar etc.

MDI: to open the Condition Assessment window as modeless MDI Child

GIS: to select object(s) to inspect

Geography Manager: to add geographic object for condition (to be displayed on drawing)

NLS: to ask the kernel what language is selected for the application

Help: to display a reference to the Condition Assessment help file on the Help menu

Add-in Manager: used to install/uninstall, load/unload add-in

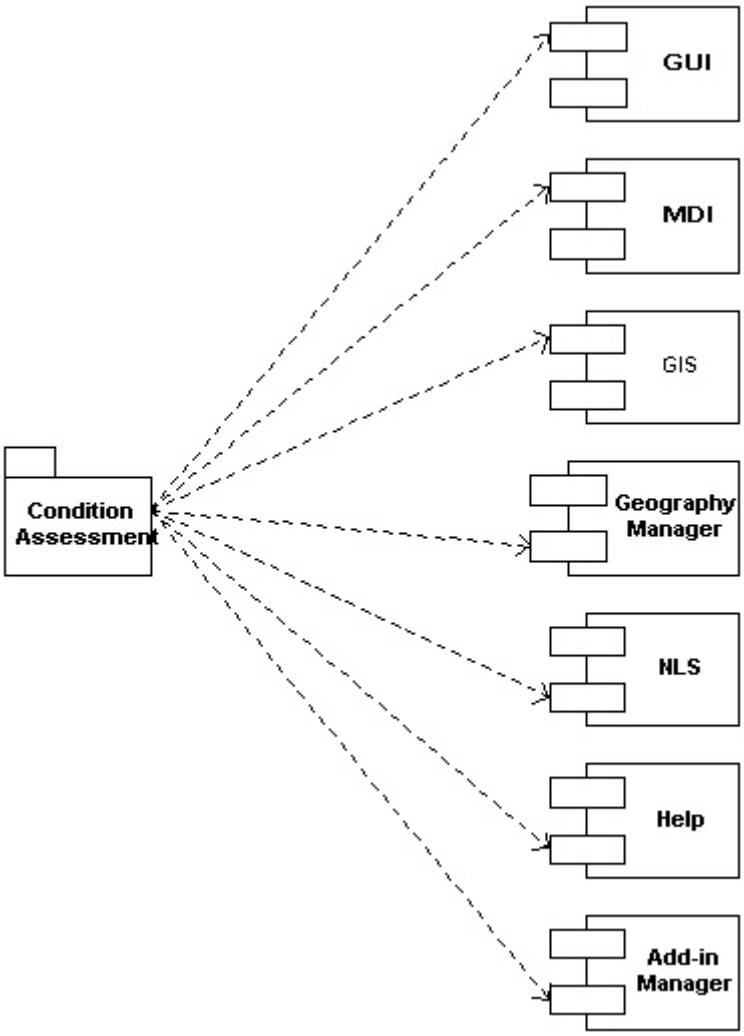


Figure 3 Condition Assessment - dependencies to kernel components

12.2.2 Dependencies to other add-ins

Drawing: display drawings connected to object for the user to be able to select position/area for geographical object connected to object part or condition

Photo Server: to add/display images of conditions.

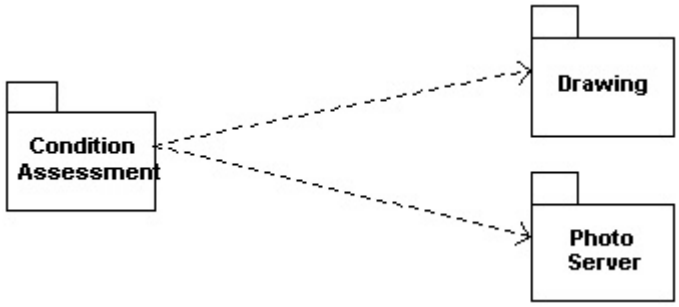


Figure 4 Condition Assessment - dependencies to other add-ins

12.2.3 Dependencies to other add-ins DB classes

Assets: to get access to regions, objects and object parts

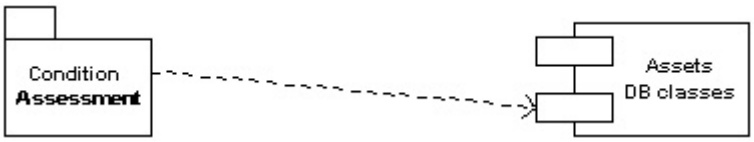


Figure 5 Condition Assessment - dependencies to other add-ins DB classes

12.2.4 Dependencies to 3rd parties components

Condition Assessment is not dependent of any 3rd parties components.

12.3 Drawing

The drawing module should be able to display drawings. It should provide common GIS functionality like display layers, zoom, pan etc.

12.3.1 Kernel dependencies

GUI: for the Drawing add-in to get access to interface elements such as menus, toolbars, status bar etc. This is necessary to be able to add menu items for the add-in on the application menu bar etc.

MDI: to add new document type and to open Drawing window as modeless MDI child

GIS: The drawings are bitmaps that are handled as maps.

Presentation Manager: Makes it possible to use a specific configuration for the drawing.

NLS: to ask the kernel what language is selected for the application

Help: to display a reference to the add-ins help file on the Help menu

Add-in Manager: used to install/uninstall, load/unload add-in

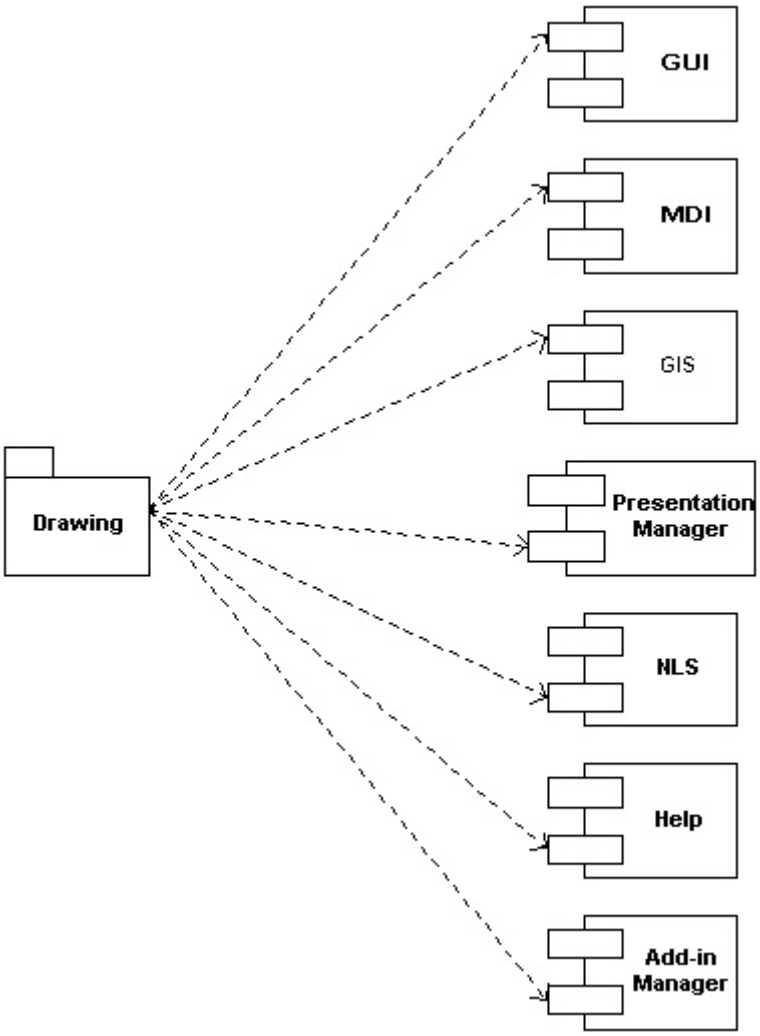


Figure 6 Drawing - dependencies to kernel components

12.3.2 Dependencies to other add-ins

Drawing is not dependent of any other add-ins.

12.3.3 Dependencies to other add-ins DB classes

Drawing is not dependent of any DB classes.

12.3.4 Dependencies to 3rd parties components

Drawing should use the NORGIT component SDMS that is dependent of MapObjects.

12.4 Photo Server

The Photo Server provides functionality to add/display images from digital camera or file system.

12.4.1 Kernel dependencies

GUI: for the Photo Server add-in to get access to interface elements such as menus, toolbars, status bar etc.

MDI: to add new document type and open Photo Server window as modeless MDI child

NLS: to ask the kernel what language is selected for the application

Help: to display a reference to the add-ins help file on the Help menu

Add-in Manager: used to install/uninstall, load/unload add-in

12.4.2 Dependencies to other add-ins

Photo Server is not dependent of any other add-ins.

12.4.3 Dependencies to other add-ins DB classes

Photo Server is not dependent of any other add-ins DB classes.

12.4.4 Dependencies to 3rd parties components

Photo Server is dependent of twain driver to import images directly from digital camera.

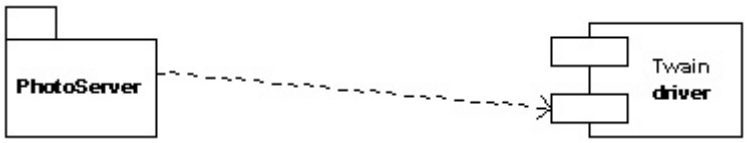


Figure 7 Photo Server - dependencies to 3rd parties components

12.5 Document Manager

The Document Manager provides functionality to add document link and open document in default application.

12.5.1 Kernel dependencies

GUI: for the Document Manager to get access to interface elements such as menus, toolbars, status bar etc.

NLS: to ask the kernel what language is selected for the application

Help: to display a reference to the add-ins help file on the Help menu

Add-in Manager: used to install/uninstall, load/unload add-in

12.5.2 Dependencies to other add-ins

Document Manager is not dependent of any other add-ins.

12.5.3 Dependencies to other add-ins DB classes

Document Manager is not dependent of any other add-ins DB classes.

12.5.4 Dependencies to 3rd parties components/applications

Document Manager is not dependent of any 3rd parties components.

12.6 Report Generator

General report generator to produce reports based on DACL and XML.

12.6.1 Kernel dependencies

GUI: for the Report Generator to get access to interface elements such as menus, toolbars, status bar etc.

NLS: to ask the kernel what language is selected for the application

Help: to display a reference to the Report Generator help file on the Help menu

Add-in Manager: used to install/uninstall, load/unload add-in

DACL: for read access to database objects

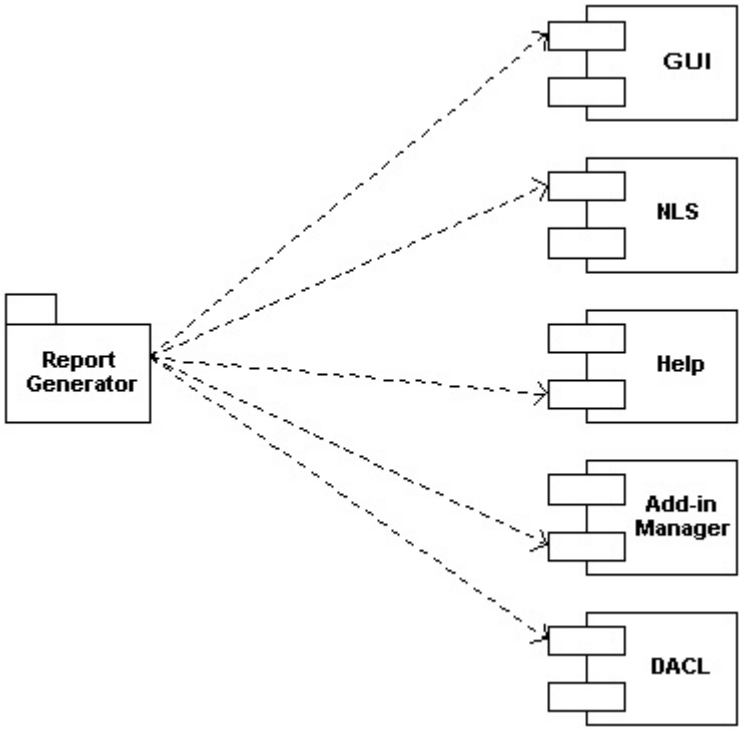


Figure 8 Report Generator - dependencies to kernel components

12.6.2 Dependencies to other add-ins

Report Generator is not dependent of any other add-ins.

12.6.3 Dependencies to other add-ins DB classes

The Report Generator is not dependent of any specific DB classes, but only reports on the classes found in database.

12.7 Import

Import data from Main application.

12.7.1 Kernel dependencies

GUI: for the Import add-in to get access to interface elements such as menus, toolbars, status bar etc.

NLS: to ask the kernel what language is selected for the application

Help: to display a reference to the Import help file on the Help menu

Add-in Manager: used to install/uninstall, load/unload add-in

DACL: for read access to database objects

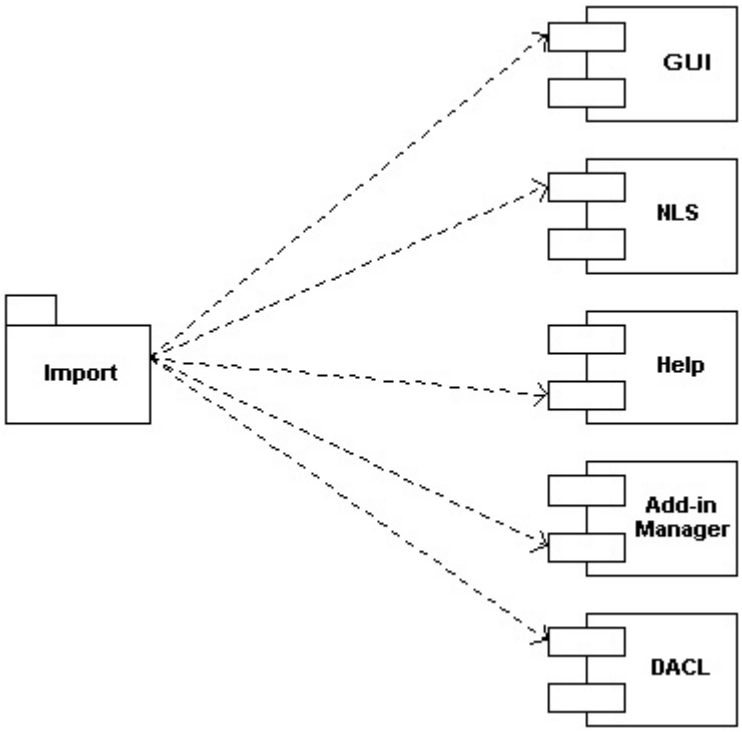


Figure 9 Import - dependencies to kernel components

12.7.2 Dependencies to other add-ins

Import is not dependent of any other add-ins.

12.7.3 Dependencies to other add-ins DB classes

Assets: to import objects and object parts

Condition Assessment: to import inspection data

12.7.4 Dependencies to 3rd parties components

Import is not dependent of any 3rd parties components.

12.8 Export

Export data to Main application.

12.8.1 Kernel dependencies

GUI: for the Export add-in to get access to interface elements such as menus, toolbars, status bar etc.

NLS: to ask the kernel what language is selected for the application

Help: to display a reference to the Export help file on the Help menu

Add-in Manager: used to install/uninstall, load/unload add-in

DACL: for read access to database objects

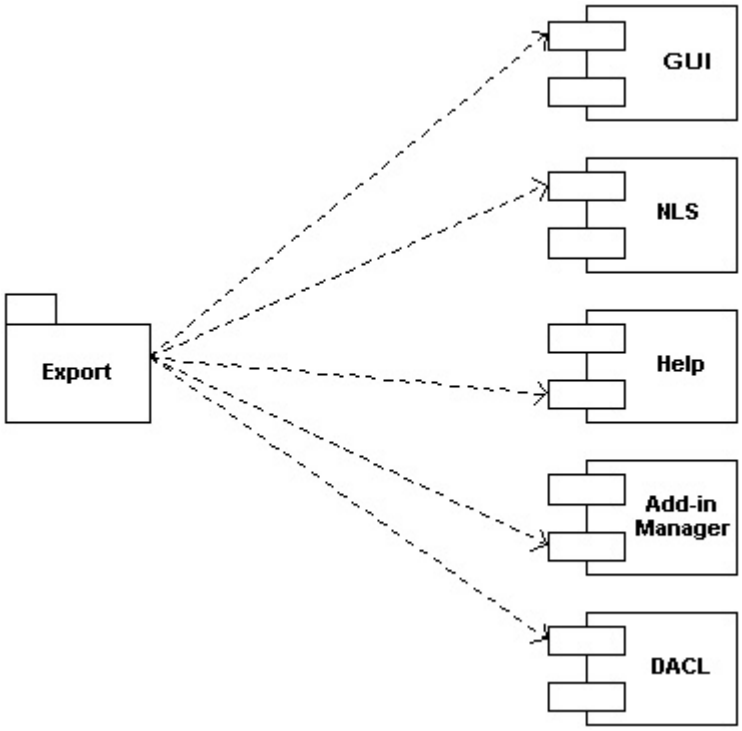


Figure 10 Export - dependencies to kernel components

12.8.2 Dependencies to other add-ins

Export is not dependent of any other add-ins.

12.8.3 Dependencies to other add-ins DB classes

Assets: to export regions, objects and object parts

Condition Assessment: to export inspection data

12.8.4 Dependencies to 3rd parties components

Export is not dependent of any 3rd parties components.

13 MMS generic database

The generic database structure of MMS will be possible to explore with the DDBMM tool.

The generic structure contains no information for specific kinds of object parts, but contains what is needed to do a forecast on the condition of any kind of object part.

14 The Sigma functionality

Sigma shall be able to read and aggregate object data from the MMS database.

Then it shall be able to do a predictive forecast according to the condition index data and transition matrixes for the project years selected.

Sigma will have a flexible math engine able to do matrix calculations, and a project and a dataset window to adjust both input data and to display the forecast results. Cut and paste to and from other applications will be possible from the dataset window. The dataset window will also be able to manipulate the look of the datasets by drag and drop of columns to rows and vice versa.

A math model editor will assure easy change of the math models. This way experts can make many different math models based on the LMS Lifecycle forecasting principles.

15 Conclusions

The Lifecon LMS IT prototype has been carefully examined from a user perspective giving expected performance and functionality in a requirements analysis. The functional and technical specifications have been deduced from these user requirements within the confines of available resources. The Lifecon LMS IT prototype has been realized meeting the overall requirement to be generic, modular and functional.

16 Proposals for further development

Some drawbacks still exists which calls for further developmental and integrational actions. Further actions will depend on the overall validation of the prototype, concerted agreements on the need for adjustments and fundings – either by expected market opportunities or by future adaptational projects.

17 References

[i] ISO 13407:1999 Human-Centred Design Processes for Interactive Systems
[ii] Lifecon Deliverable D1.1 Generic technical handbook for a predictive life cycle management system of concrete structures (Lifecon LMS)
[iii] Lifecon Deliverable D2.1: Reliability based methodology for lifetime management of structures
[iv] Lifecon Deliverable D2.2 Statistical condition management and financial optimisation in lifetime management of structures
[v] Lifecon deliverable D3.1 Prototype of condition assessment protocol
[vi] Lifecon Deliverable D3.2 Probabilistic service life models for reinforced concrete structures