HELPMATE

ESPRIT Project Number 25282

Odense Lindø

Acknosoft

Multicosm

IT Innovation Centre

D7.3 Definition of Best Practice

Version 1

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EXECUTIVE SUMMARY

Through the application of an HELPMATE-like system, best practice is demonstrated both in the fields of knowledge elicitation and hypermedia documentation management, and as well in the area of usability of this information at the point of use, operators' training to maintenance and repair procedures and improvement of the feedback loop between the technicians and the specialists.

The commercial application of an HELPMATE-like project is improved as well. In order to reliably plan and cost proposed projects, IT Innovation has improved the baseline practice for project definition and developed a planning template that can be adapted in response to the particular situation of each prospective client.

CONTENTS

About This Document **1**

1 Introduction **1**
1.1 General Industrial Maintenance Issues 1
1.2 Issues for the Maintenance of High Technology Machinery 2

2 The HELPMATE Best Practice Approach **2**
2.1 Introduction 2
2.2 The INRECA methodology 3
2.3 Collecting Knowledge Information in the Form of Structured Cases 3
2.4 Acquiring and Standardising Multimedia Documentation 6
2.5 Linking Pieces of Knowledge Information to the Accurate Pieces of Documentation 7
2.6 Providing Accurate Technical Information at the Point of Use 9
2.7 Training the Operators to Maintenance and Repair Procedures 10
2.8 Improving the Feedback Loop between the Technicians and the Specialists 11

3 Commercial Best Practice for Project Planning **12**
3.1 Introduction 12
3.2 Baseline Planning Template 13
3.3 Resourcing Estimates 14
3.4 Example Project Plan 15
3.5 Conclusions 17

4 Conclusion **17**

5 References **18**

LIST OF FIGURES AND TABLES

Figure 1. The methodology terminology 3
Figure 2. Solving problem procedure before HELPMATE..... 4
Figure 3. Diffusion of the information before HELPMATE 4
Figure 4. Case acquisition after HELPMATE 5
Figure 5. Solving problem procedure after HELPMATE..... 6
Figure 6. Acquiring documents to be linked 7
Figure 7. Creation of links between knowledge information and documents 8
Figure 8. Overview of the system development 9
Figure 9. Consultation of the system with links displayed 10
Figure 10. Displaying links during the CBR consultation 10
Figure 11. Learning process 11
Figure 12. Information flow for knowledge management based on technical facts..... 12
Figure 13. High level project structure and key milestones 13

Table 1. Time estimates for documents acquisition..... 7
Table 2. Time estimation for authoring links depending on the document type..... 9
Table 3. Detailed task breakdown and roles..... 14
Table 4. Timings for information resource acquisition and linking 14
Table 5. Timings for consultation to docuverse linking and linkbase pruning 15
Table 6. Timings for knowledge base creation..... 15
Table 7. Estimated effort for docuverse creation and linking 16
Table 8. Estimated effort for knowledge base creation 16
Table 9. Example resourcing plan 17

About This Document

The partners in the HELPMATE project - AcknoSoft, IT Innovation, Multicosm and OSS - have implemented, operated and evaluated a novel fault resolution support system for maintainers of complex production equipment. The application developed in HELPMATE and installed at OSS's shipyard in Odense is called Freya.

This publicly available document is targeted to potential users of the HELPMATE approach who want to evaluate the amount of work they will have to invest in such a project. Installing a system like Freya in a new environment may not be such an easy task. This is why this document summarises all the steps required for such an installation and demonstrates the benefits of applying the proposed methodology for building similar applications.

The working best practice starts with the collection of the cases and the related documentation. Then, it is necessary to link them together. The next step is to deliver the integrated system to the end-user and provide training. Finally, the last step for best practice is to evaluate the results of a HELPMATE-like system.

Section 2 of this document recalls some general maintenance issues and the related limitation of applying such a best practice in an industrial environment like the OSS shipyard. In section 3, we present the methodology used to accomplish the different steps required for delivering a HELPMATE-like system. We compare this method with the initial methods used in the shipyard before HELPMATE. Section 4 describes the commercial approach for best practice of the IT Innovation Centre in the context of delivering a HELPMATE application.

The methodology used in this document is based on the INRECA2 methodology created by the INRECA consortium in the scope of the INRECA2 Esprit project.

1 Introduction

1.1 General Industrial Maintenance Issues

Reliable, effective maintenance support is a vital consideration for users and suppliers of modern industrial machinery. Maintenance is now a strategic issue that brings competitive advantages for equipment manufacturers. Companies frequently gather extensive data to track the history of their machines, with many using this data in some form to aid troubleshooting. The issues associated with the maintenance of complex machinery are many and complex:

- periodic overhauls and checks can often disrupt production timescales, or not happen when the plant is running to capacity,
- maintenance instructions are often communicated through paper, which is either lost, or filed with so much other information so as to render itself effectively lost,
- diagnostic information is often too bulky to be carried by technicians and is therefore not used,
- diagnostic information becomes out of date quickly after local repairs and customisation,
- maintenance work varies in complexity and nature from the replacement of simple mechanical parts to electrical and software work,
- maintenance work is carried out by a variety of people, departments and organisations depending upon the time of the failure and the nature of the work, communication of problems and remedies between these people is essential.

1.2 Issues for the Maintenance of High Technology Machinery

The use of high technology production facilities requires systematic maintenance practices. The main purpose of these practices is to keep the production cost at a minimum, by ensuring the reliability and the quality of the machinery. Also the system should keep the maintenance cost to a minimum.

An obvious way of keeping the maintenance cost to a minimum is to develop a system which enables the operator to carry out a greater part of the maintenance tasks, thereby minimising the time wasted in waiting for maintenance specialists. By allowing the operator to carry out more maintenance tasks, the sense of responsibility is also increased; this mode of operation is referred to as *operator-minded maintenance.*

The activities involved in operator-minded maintenance can be divided into two broad categories:

- breakdown maintenance, and
- Preventive maintenance.

Breakdown maintenance cannot be avoided. The downtime associated with breakdowns can be high, as the outages are unplanned and can have a number of knock-on problems throughout the plant. Operator minded breakdown maintenance has to support the operators in getting the machine working as quickly as possible, either by continuing to run the machine at reduced speed, or by fixing the problem or by referring to the expert.

Preventive maintenance effectively involves minimising breakdown operations, by replacing or repairing components before they break down. This has traditionally resulted in large increases in resources spent on components because of the calendar-time or production-time based replacement intervals. Also the use of calendar-time or production-time based checking procedures results in an increase in demand on maintenance resources.

2 The HELPMATE Best Practice Approach

2.1 Introduction

The HELPMATE project has tackled the area of breakdown maintenance by trying to empower operators to diagnose problems without recourse to an expert. The system supports operators by helping them diagnose the problem and suggesting how best to resolve it (sometimes it may be better to switch the system back on, but at a slower speed, or to call the expert to repair the system – these are valid solutions in the HELPMATE system). Thus breakdown maintenance is supported through the Freya application directly.

Preventive maintenance has been addressed by the HELPMATE project through the systematic logging and analysis of problems on the factory floor. A team (consisting of foremen, expert maintainer and maintenance manager) periodically analyses the problems that have occurred and the solutions that were found. With this information preventive maintenance schedules can be updated (by adding or amending existing procedures) or problems can be “designed out” by replacing components or modes of use of the equipment.

For both break-down and preventive maintenance, the HELPMATE project has improved the standard practices in the yard by introducing methods and tools for:

- Collecting knowledge information in the form of structured cases
- Acquiring and standardising multimedia documentation
- Linking the pieces of knowledge information to the accurate pieces of documentation
- Providing accurate technical information at the point of use

– Training the operators to maintenance and repair procedures

– Improving the feedback loop between the technicians and the specialists

This valuable experience has been reused in other applications, sharing similar constraints, by using the same methods if not the same tools. Therefore, the HELPMATE project has demonstrated an approach for best practice in the domain of maintenance of industrial equipment. It has demonstrated as well a potential return on investment for the yard, both for the quantitative and qualitative points of views.

The rest of this section details the different steps above and compares the new processes with the ones used before HELPMATE. The procedures described in these chapters are based on a methodology created by the INRECA consortium. In chapter 2.2 the basics of this methodology are explained, as well as the keys to understand the figures.

2.2 The INRECA methodology

This methodology describes all the different steps that should be performed in order to build and maintain a CBR application. This methodology is one result of the INRECA 2 Esprit project. The goal of this project was to create and diffuse a generic methodology for creating and maintaining application based on CBR.

In this document, we have refined this methodology to target the applications that encompass CBR and hypermedia documentation to give guidelines about how to develop a system like Freya. This methodology covers organisational analysis and technical application development by defining a set of methods involving processes.

The methodology is defined by a set of diagrams representing products. The products are the entry points as well as the output of methods (see Figure 1).

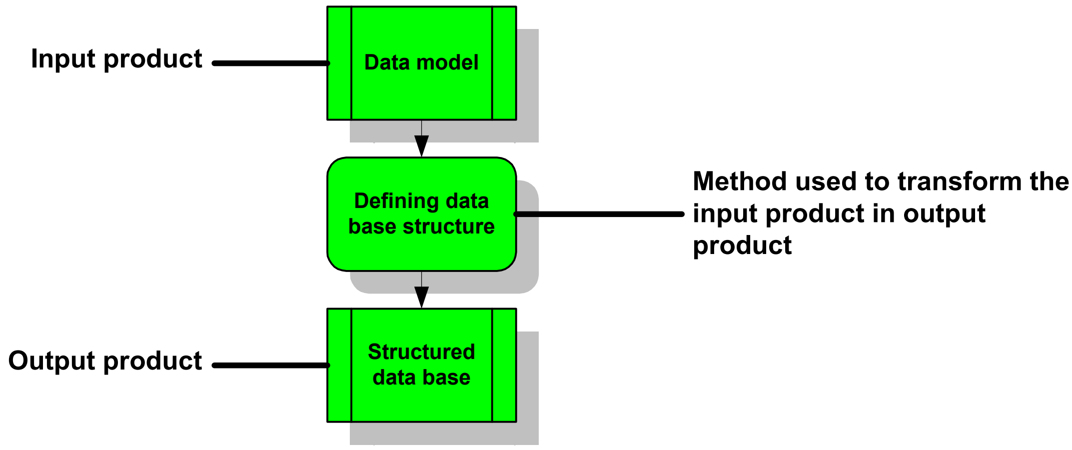

Figure 1. The methodology terminology

2.3 Collecting Knowledge Information in the Form of Structured Cases

Before the installation of Freya, OSS was collecting the information in a non-standardised way. Information could be found in reports, booklets, and other paper documentation. The operators had access to troubleshooting guides to help them diagnose the robots, and they would then issue reports on the repair action they had to perform. This process of reporting is time consuming, and can lead to some misunderstanding in the vocabulary used, or abbreviations… By using Freya, the operator automatically creates this report by going through the maintenance process. This report is structured, and formalised. The following figure shows the process of problem solving.

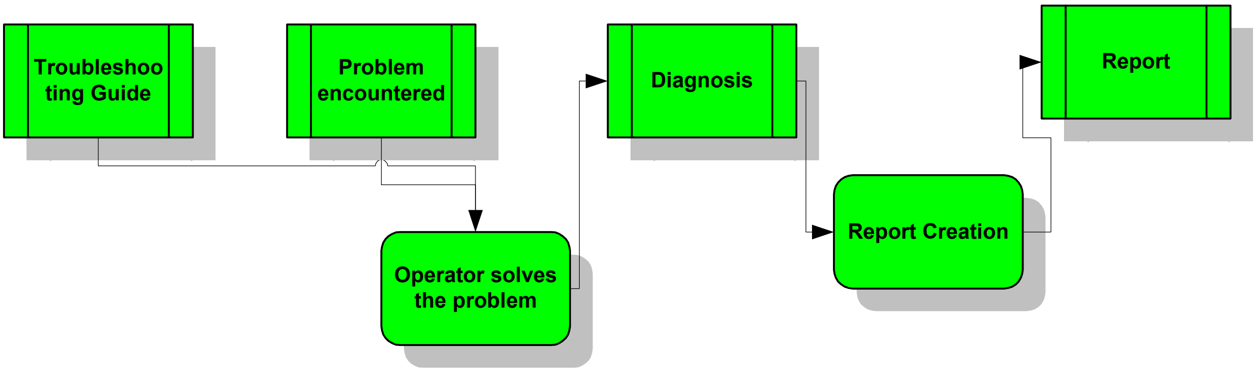

Figure 2. Solving problem procedure before HELPMATE

The limits of this procedure lie in the limits of the foreman to be always precise in the description he gives of the problem. Moreover, there is no loop in the gain of information: the person who solves a problem does not share his experience with the other foremen. The diffusion of information follows another chart:

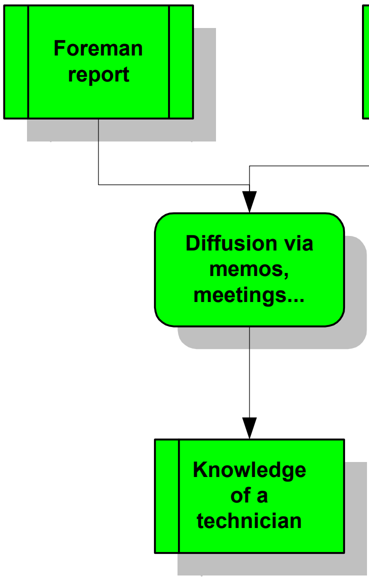

Figure 3. Diffusion of the information before HELPMATE

The limit of this knowledge exchange is time-related. This diffusion does not imply that the technician will retain all the information that has been diffused. If the technician actually retains the information, it is limited to a period of time and to the memory of the technician.

The other limit lies in the diffusion process: there is no loop; meaning that in order for all the teams to be aware of the information, the foreman has to proceed to many diffusions.

After the installation of Freya, the knowledge diffusion is done automatically. A case base was first created, using the INRECA methodology to improve the process:

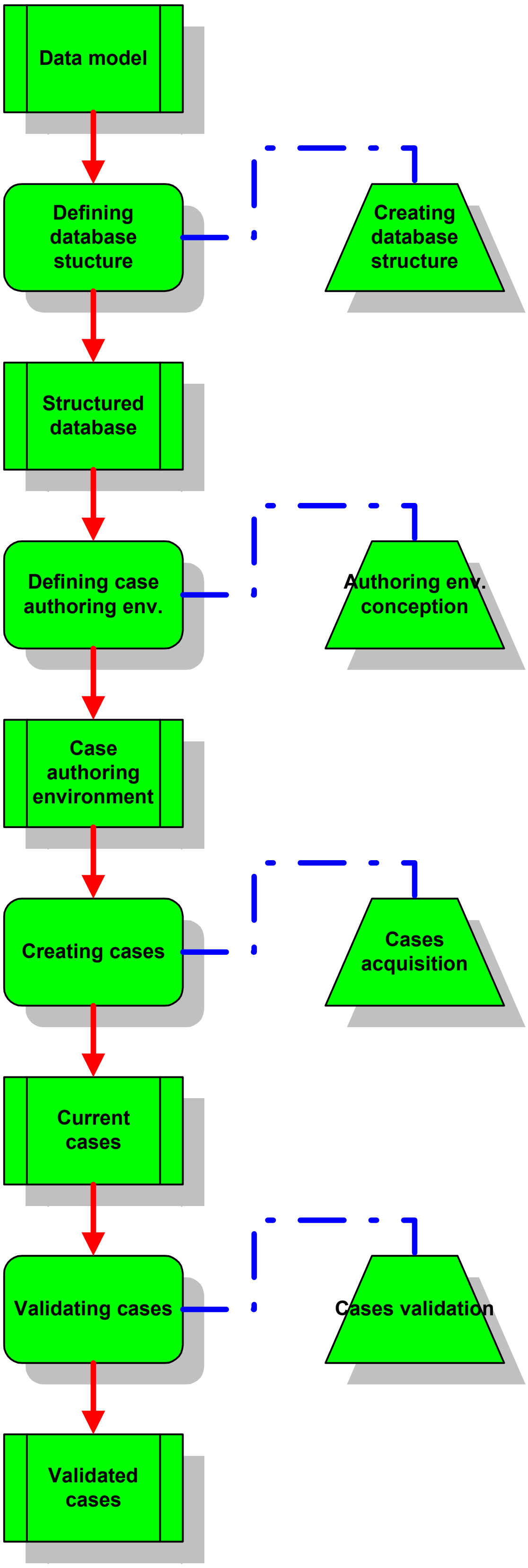

Figure 4. Case acquisition after HELPMATE

The validated cases are then used by the foremen to solve new problems, and then create new cases.

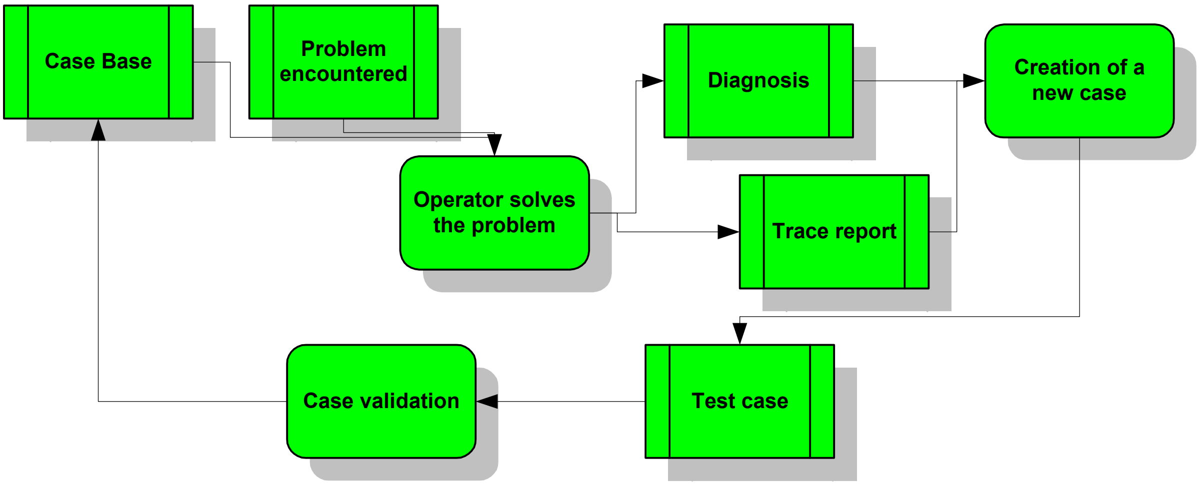

Figure 5. Solving problem procedure after HELPMATE

This figure shows that all the new knowledge that the operator gets from the system (for example a new case) is fed back into the system after validation. Then, the following user of the system will gain from the previous experience without having to go through a diffusion process.

2.4 Acquiring and Standardising Multimedia Documentation

The multimedia part of Freya enables the B4 operators to find quickly the documents that correspond to a repairing action or a maintenance job without leaving the shop floor.

The first phase for this process is to target the documents that have to be included in the tool. This implies interviewing the experts to select the documents that best represent a case or maintenance procedure. The foremen and the operators also have to be interviewed to find which extra information could be included in the tool to make it more useful. Therefore, ones can include documents that do not relate to maintenance procedures, but also general documentation on the robots that can be consulted anytime.

The documentation that was made available in the Freya system was related to maintenance procedures and parts. This means that before Freya, the only way to find an information was to use the index of catalogues, or browse the maintenance manuals. This procedure was time-consuming and did not follow a precise methodology.

A methodology had to be used in order to create the proper documentation that could be inserted in the tool. The documents were of many types including images, videos, sound files, and text.

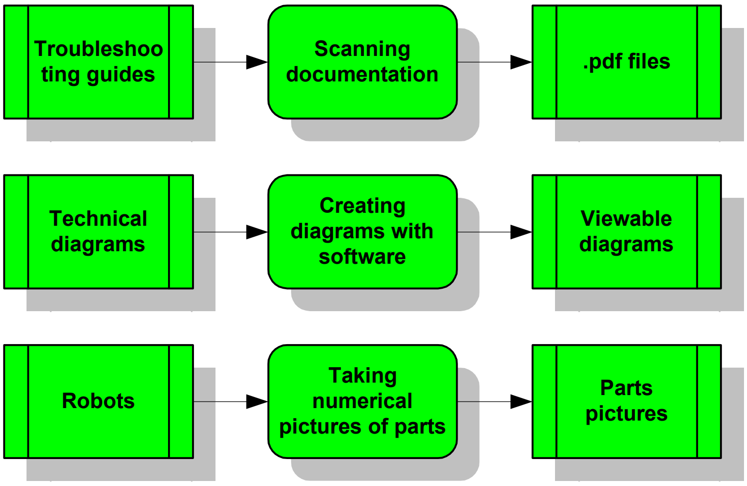

Figure 6. Acquiring documents to be linked

The following table shows the estimation of IT Innovation concerning the effort required to acquire such data (see Section 3.3).

Document type	**Time to acquire (mins)**
A4 pages	10
Word documents	15
Technical diagrams	60
Photographs	25

Table 1. Time estimates for documents acquisition

Some documents do not require too much effort and can easily be standardised. This is the case of A4 pages from authorised maintenance guides that have to be scanned to be displayed by a viewer such as Acrobat Reader. The other types of documents have to be formatted to be viewable by the software available (such as Word documents). Paper technical diagrams, particularly if these are A3 size or larger are more complex types of documentation to acquire since they need to be scanned in segments and then merged electronically. Most electronic technical diagrams can be used in their native format.

2.5 Linking Pieces of Knowledge Information to the Accurate Pieces of Documentation

Multicosm used a multimedia and hypermedia information management technology to create data bases of links between the documents. These data bases are called "link bases".

The following graph shows the process of creating and editing a new link through "link base filters". The documents to be inserted have been acquired through the process defined in Figure 5.

Please note that before HELPMATE, there was no link between a current situation and a piece of documentation but in the head of the foreman. The basic action then consisted in asking him or browsing the HiROBO Manual.

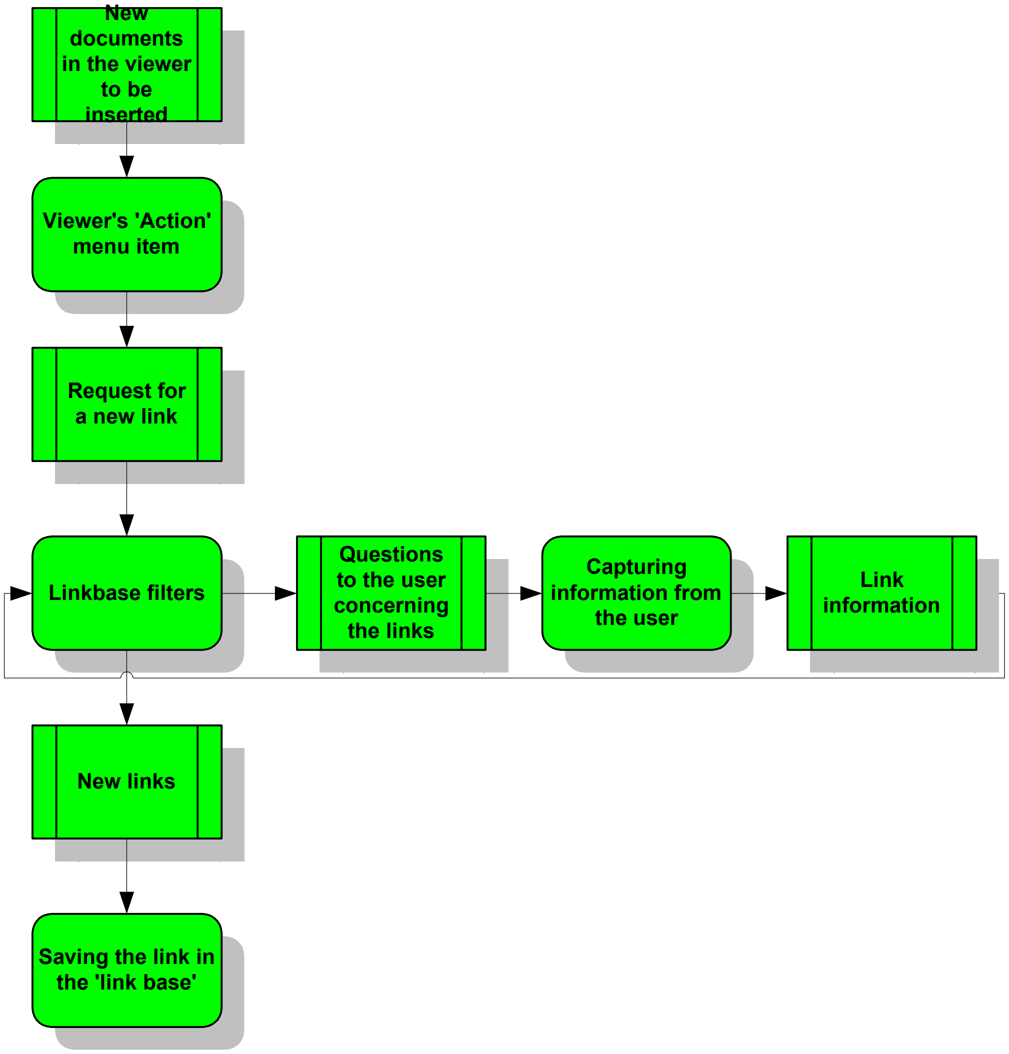

Figure 7. Creation of links between knowledge information and documents

One way of linking the information to documentation is by using "Generic links". These links are associations between a phrase, the source selection, and a destination that may be in any document. But rather than applying just to a single occurrence of the phrase in a given document, a generic link applies to any occurrence of the phrase anywhere in the document set. Consequently the link has to be authored only once, but is effective from any number of documents. In the Freya application, the generic link idea in taken further to be adapted to the CBR environment: this is called "linking by reference".

For this latter kind of linking, the source selections are the classes, slots, and values of the cases. This implies that links for a given diagnostic question becomes independent of a local language. When a case base is translated into a different language, the classes, slots and values do not move, so that class1 slot5 values3-6 are still expressed as c1 s5 v3-6. Although questions and comments vary depending on the language, the hypermedia links do not have to be re-authored.

The other asset of this linking mode is that it can be more precise insofar as a link can be specific to a particular class, slot, or value, or even a combination of these.

The following graph shows the method used for developing such a system, and the position of the links creation in the whole process.

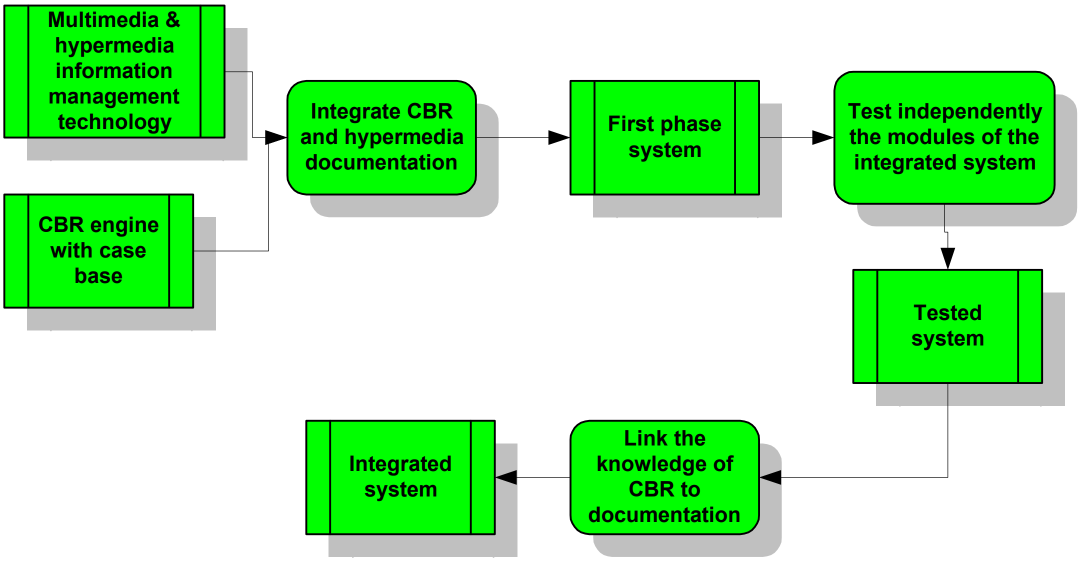

Figure 8. Overview of the system development

It is interesting to evaluate the time that is required to link the documents. Depending on the type of the documents, the process length may vary. IT Innovation provided a table that summarises the average time (in minutes) to author each link. The number of link required for each type of document shows that more effort and time is required to link word documents, than to link photographs or A4 pages (see Section 3.3).

Type of document	Number of links	Time per link (mins)
A4 pages	5	5
Word documents	15	5
Technical diagrams	10	5
Photographs	2	5

Table 2. Time estimation for authoring links depending on the document type

2.6 Providing Accurate Technical Information at the Point of Use

The information displayed to the operator can be found throughout the whole process of using Freya. This was the main applicative goal of the HELPMATE project.

- All the documents are indexed and can be found in a Help page available anytime and from all the screens of the system.
- Documents that are related to questions or values of a case are available during the consultation. When the operator is asked a specific question related to *part X* of the robot, a link is available on this *part X*. Also, if the possible answers of the question are *answer a*, *answer b*, or *answer c*, some links may exist to illustrate an answer.
- Then, at the end of the consultation, the retrieved cases, and therefore the retrieved solutions offer links to explain the repair procedure.

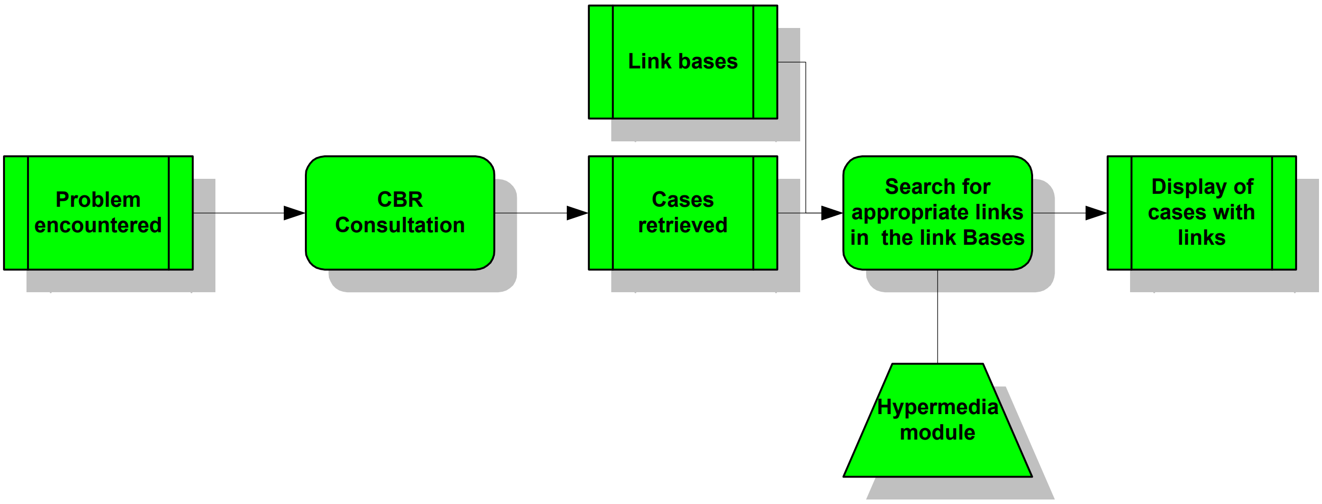

Figure 9. Consultation of the system with links displayed

The CBR consultation process is described in the following figure:

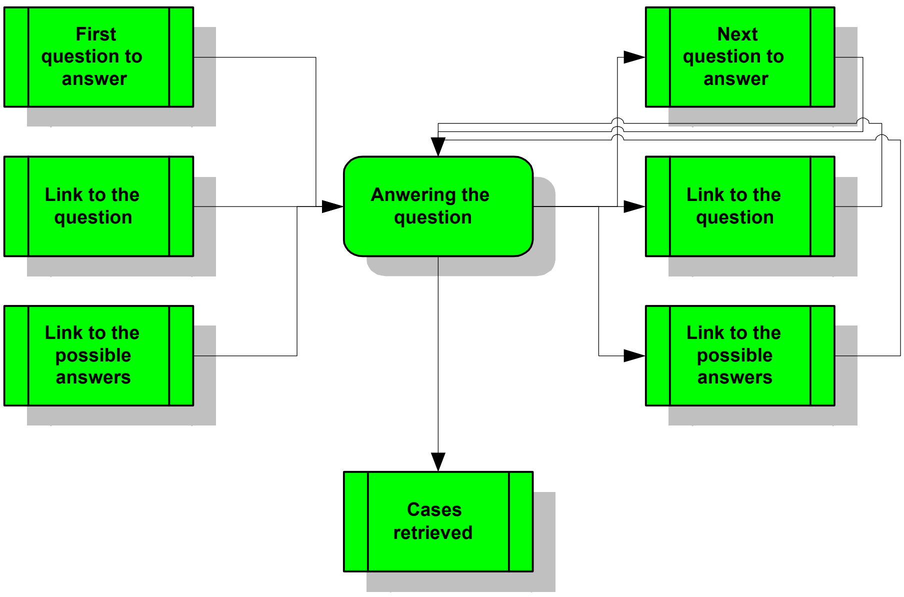

Figure 10. Displaying links during the CBR consultation

2.7 Training the Operators to Maintenance and Repair Procedures

Before the installation of Freya, the procedure for training a new operator was not structured. The foreman who is in charge of his team would train the operator during his first day. Since all kind of problems that can occur did not happen during that day, training came down to basic maintenance procedures, more than repair ones. To support this training, the troubleshooting guides were used, as well as technical diagrams represented on A0 sheets of paper.

The limit of this procedure lies in the fact that when faced with a new problem, the operator has to:

- go to the troubleshooting guide and find the corrective action, sometimes after a long search

- ask another operator how to fix the repair, thus monopolising the second operator's time.

In the following figure, the process called 'consultation of the system' recalls figure 8.

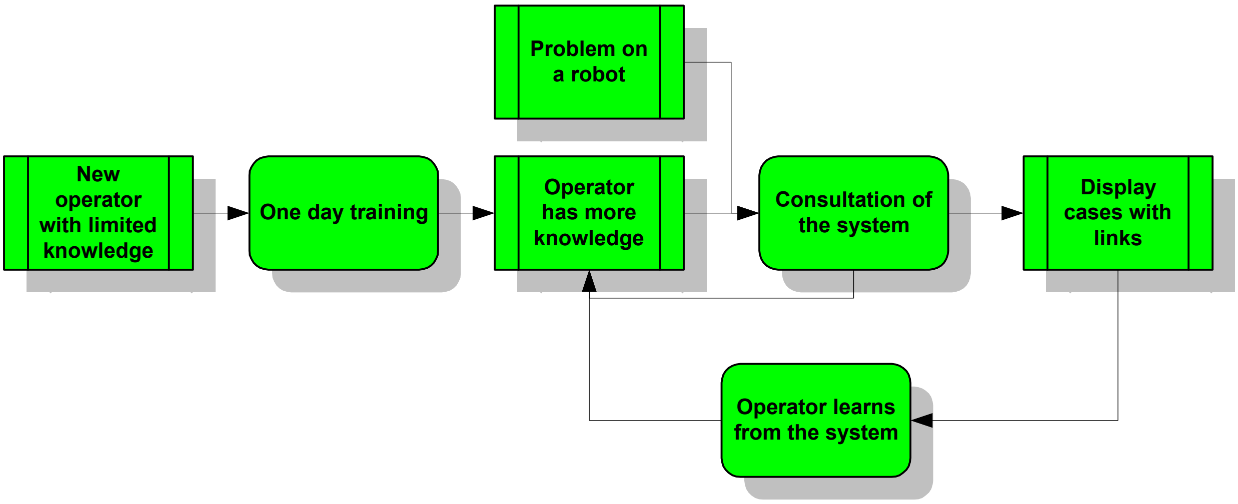

Figure 11. Learning process

By following this procedure, the operator gains knowledge:

- when consulting the system. Thanks to the links to the questions, the operator gets to learn about the robot parts and how to detect defaults.
- At the end of the consultation. The cases displayed to the operator teach him the conditions that can lead to a problem. Of greater importance for the training phase, the repair procedure to be undertaken is explained to the operator.

2.8 Improving the Feedback Loop between the Technicians and the Specialists

One of the most important assets of a HELPMATE-like system is the fact that it allows all the departments of the yards to get some relevant information. Figure 11 represents the flow of information that is either an input or an output of the knowledge management system.

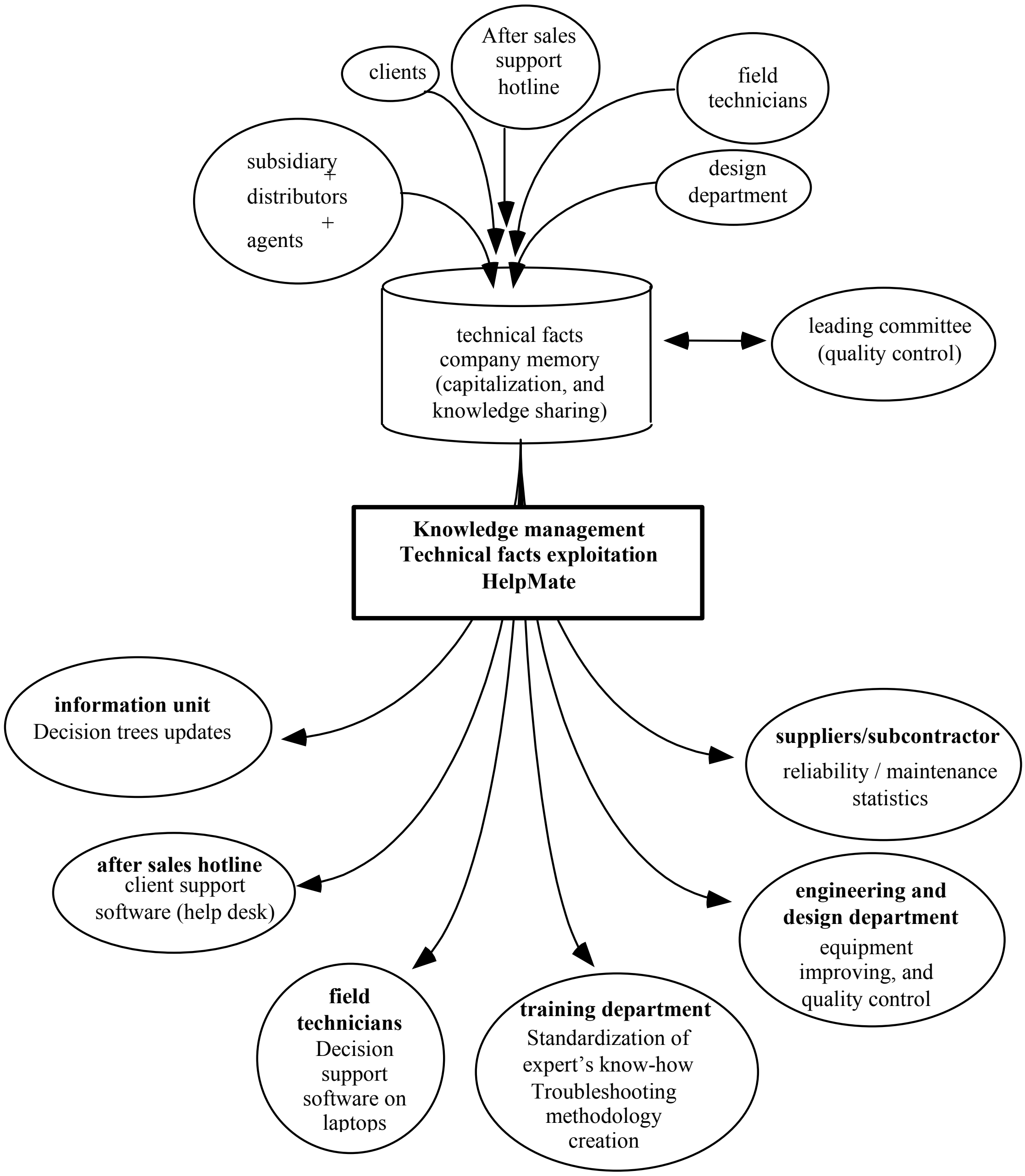

Figure 12. Information flow for knowledge management based on technical facts

3 Commercial Best Practice for Project Planning

3.1 Introduction

During the last six months, IT Innovation has developed a sales campaign for Freya-like systems based on the results of HELPMATE.

In order to reliably plan and cost proposed projects, IT Innovation has developed a baseline planning template that can be adapted in response to the particular situation of each prospective client.

This section of the report describes IT Innovation's baseline planning template and some of its underlying assumptions.

3.2 Baseline Planning Template

Figure 12 shows the high level project structure developed by IT Innovation, together with key project milestones. The task duration shown in Figure 13. *High level project structure and key milestones* are indicative only.

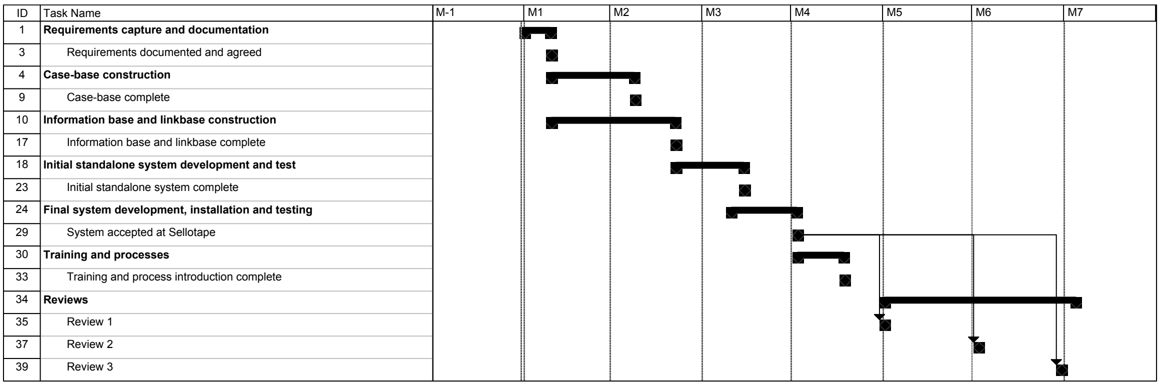

Figure 13. High level project structure and key milestones

Table 3 shows a detailed task analysis together with the roles required for task execution.

Four distinct roles have been identified. These are:

- Project manager. The planning template assumes that project management effort is required at 10% x the total of other effort.
- Consultant. The consultant is primarily responsible for knowledge acquisition tasks.
- System developer. The system developer is responsible for developing the information repository and for configuring, testing and installing the system platform.
- Hardware/networking specialist. The hardware/networking specialist supports the system developer in configuring, testing and installing the system platform.

Activity	Who?
Requirements capture and documentation	
Requirements capture and documentation	Consultant
Case-base construction	
Semi-structured interviews with client personnel	Consultant
Initial case-base development	Consultant
Cross-check initial case-base with client personnel	Consultant
Modify case-base	Consultant
Information base and linkbase construction	
Identify, capture and scan paper documentation	System developer
Identify and capture electronic documentation	System developer
Develop initial information repository	Consultant
Develop initial information repository	System developer
Develop information repository internal links	System developer
Linkbase pruning with client personnel	System developer
Develop case-base to information repository links	Consultant
Initial standalone system development and test	
Initial system build and test @ IT Innovation	System developer
Initial system installed on single PC at client	System developer
System testing jointly by client and IT Innovation	Consultant
System testing jointly by client and IT Innovation	System developer
First introduction session with 1 or 2 maintenance personnel	System developer
Final system development, installation and testing	
Hardware configuration at IT Innovation	Hardware/networking specialist
Software and information loaded at IT Innovation	System developer
Testing at IT Innovation	System developer
Installation and testing at client	System developer
Installation and testing at client	Hardware/networking specialist
Training and processes	
Usage training for maintenance personnel	System developer
Establish processes for system maintenance and development	Consultant
Reviews	
Monthly reviews in first 3 months	Consultant
Reviews follow-up	Consultant
Project management	
Project management @ 10% of other effort	Project manager

Table 3. Detailed task breakdown and roles

3.3 Resourcing Estimates

Table 4 shows the average time (in minutes) assumed for the acquisition of different information resource types, the average number of links assumed for each information resource type, and the average time required to author each link.

Docuverse and links				
		time to acquire (mins)	**number of links**	**time per link (mins)**
	A4 pages	10	5	5
	Word documents	15	15	5
	Technical diagrams	60	10	5
	Photographs	25	2	5

Table 4. Timings for information resource acquisition and linking

Table 5 shows the average time assumed for authoring consultation to docuverse links and for the process of linkbase pruning with a client expert. For estimation purposes, it is assumed that the number of consultation to docuverse links is 2 x the number of cases in the case-base. For estimation purposes, it is assumed that the time required for linkbase pruning is proportional to the total number of previously authored links.

Docuverse and links		
		time per link (mins)
	Consultation to docuverse links	5
	Linkbase pruning	1

Table 5. Timings for consultation to docuverse linking and linkbase pruning

Table 6 shows the average times assumed for the interviewing, case-base generation, review and case-base reworking tasks involved in creating a relevant case-base.

Knowledge base			
		time (mins)	
	Expert interviews	180	per interview
	Case base generation	60	per case
	Review	180	per review meeting
	Rework	10	per case

Table 6. Timings for knowledge base creation

3.4 Example Project Plan

The plan described in this section has been edited from a recent proposal document prepared by IT Innovation.

In this plan it has been assumed that there are:

- 140 A4 pages;
- 5 Word documents;
- 5 technical diagrams; and
- 5 photographs

to be incorporated into the docuverse.

It has also been assumed that there will be 52 cases in the case-base.

Table 7 shows the estimated effort for docuverse creation and linking.

Docuverse and links		Input					Output			
		number	time to acquire (mins)	number of links	time per link (mins)		time to acquire (mins)	time to link (mins)	total (mins)	person-day effort
	A4 pages	140	10	5	5		1400	3500	4900	13.61
	Word documents	5	15	15	5		75	375	450	1.25
	Technical diagrams	5	60	10	5		300	250	550	1.53
	Photographs	5	25	2	5		125	50	175	0.49
	Video clips									
	Consultation to docuverse links			104	5			520	520	1.44
	Linkbase pruning			939	1			939	939	2.61
	Total						1900	5634	7534	20.93

Table 7. Estimated effort for docuverse creation and linking

Table 8 shows the estimated effort for knowledge base creation.

Knowledge base		Input			Output	
		number	time (mins)		total (mins)	person-day effort
	Expert interviews	2	180		360	1.00
	Case base generation	52	60		3120	8.67
	Review	2	180		360	1.00
	Rework	52	10		520	1.44
	Total				4360	12.11

Table 8. Estimated effort for knowledge base creation

Using the estimates from Table 7 and Table 8 together with the baseline template the resourcing plan shown in Table 9 can be constructed.

Activity	Who?	Effort (p-d)	Subtotals (p-d)
Requirements capture and documentation			*2*
Requirements capture and documentation	Consultant	2	
Case-base construction			*12*
Semi-structured interviews with client personnel	Consultant	2	
Initial case-base development	Consultant	6	
Cross-check initial case-base with client personnel	Consultant	1	
Modify case-base	Consultant	3	
Information base and linkbase construction			*21*
Identify, capture and scan paper documentation	System developer	5	
Identify and capture electronic documentation	System developer	2	
Develop initial information repository	Consultant	1	
Develop initial information repository	System developer	3	
Develop information repository internal links	System developer	4	
Linkbase pruning with client personnel	System developer	3	
Develop case-base to information repository links	Consultant	3	
Initial standalone system development and test			*11*
Initial system build and test @ IT Innovation	System developer	5	
Initial system installed on single PC at client	System developer	1	
System testing jointly by client and IT Innovation	Consultant	2	
System testing jointly by client and IT Innovation	System developer	2	
First introduction session with 1 or 2 maintenance personnel	System developer	1	
Final system development, installation and testing			*11*
Hardware configuration at IT Innovation	Hardware/networking specialist	2	
Software and information loaded at IT Innovation	System developer	2	
Testing at IT Innovation	System developer	3	
Installation and testing at client	System developer	2	
Installation and testing at client	Hardware/networking specialist	2	
Training and processes			*7*
Usage training for maintenance personnel	System developer	1	
Establish processes for system maintenance and development	Consultant	6	
Reviews			*6*
Monthly reviews in first 3 months	Consultant	3	
Reviews follow-up	Consultant	3	
Project management			*7*
Project management @ 10% of other effort	Project manager	7	
TOTALS		**77**	**77**

Table 9. Example resourcing plan

Ideally this plan (excluding the monthly reviews that follow system acceptance) would be executed during an elapsed time of between 70 and 90 days.

3.5 Conclusions

The baseline planning template is an important element in IT Innovation's promotion of fault diagnosis support solutions. However, it has yet to be verified through the process of project implementation.

4 Conclusion

HELPMATE has demonstrated an improvement of the daily working practice in the Yard for:

- Collecting knowledge information
- Acquiring multimedia documentation and linking it to the knowledge information
- Providing accurate technical information at the point of use
- Training the operators to maintenance and repair procedures
- Improving the feedback loop between the technicians and the specialists

Additionally, it has enable to define accurate processes for commercial development of HELPMATE-like system.

We believe that many other similar applications can beneficiate of such an approach, independently from the tools being used in this particular Freya system. The deliverable D8.1a describes a list of customers of the project partners whose the Freya system have been presented to. Some of them have already been convinced by the approach and have developed similar systems.

5 References

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