Deliverable 7.1 Impact assessment framework and methodologies, including outcome assessment and project evaluation

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D 7.1 Impact assessment framework and methodologies, including outcome assessment and project evaluation

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1. Executive Summary

1.1 Scope

This deliverable describes the framework for evaluation and assessment of the project DebugIT and the outcomes of the project. This includes impacts on society, science, technology, and life sciences, as well as clinical impact and socio-economic effects that will guide the potential exploitation of outcomes. The first part of the report addresses the evaluation of the project as such, with focus on the period of its duration. The second part deals with impact assessment studies and methodologies, which will allow informing decision makers about the potential to bring to market tools developed by DebugIT.

1.2 Problem being addressed

The report provides a framework for assessment. A significant problem it addresses is the easy confusion between different kinds of assessment, different purposes of evaluation, and different types of impact. The main differentiation is between project evaluation and outcome assessment. Project evaluation concerns the achievements of DebugIT as a research activity. In contrast to outcome assessment, this part of the evaluation work focuses exclusively of the processes during the project lifetime. The relevant comparison constant is a state of the world in which the DebugIT project does not exist. Outcome assessment deals with those project results that are expected to have an impact after DebugIT has ended. The relevant comparison constant is a state of the world in which the three DebugIT tools do not exist. The tools are a knowledge discovery tool, the decision support tool, and the monitoring tool. How these project outcomes come into life is a secondary question within this part of the evaluation and assessment framework.

The project evaluation is divided into five themes, which are scientific impact, impact on life sciences, technology impact, expected society impact, and impact on the project team. The report defines these themes and explains how they can be measured.

The outcome assessment framework starts with defining the three tools that are expected to emerge from DebugIT and continue to exist after the project's termination. Then the clinical impact assessment matrix is presented. It specifies 18 different studies that can be performed, resulting from combinations of tools, prime users, and level of performance of the tools. The levels are divided into target, defined by users' wishes, maximum, defined by use under perfect conditions, and actual performance, defined as the performance observed in routine operation. The socio-economic impact assessment builds on the results on the clinical impact studies and expands the analysis to all stakeholders and also into the business direction.

1.3 Scientific approach

Given that evaluation is a non-RTD activity, no advancing over the state of the art in evaluation methods is required, or indeed constructive. The work resulting in this report reflects the completion of the challenging task to identify the best-fit evaluation and assessment methodologies and approaches, and adapting them to the needs of DebugIT.

1.4 Work undertaken

The assessment framework is the result of a thorough literature review, analysis of the current status deliverables, discussions with consortium members, as well as the experience and expertise of the evaluation team.

The reviewed literature comprises publications on several topics including infectious diseases; antibiotics treatment; resistance patterns; clinical and economic impact of the above; technology assessment; socio-

economic impact assessment; business analyses; scientific, technology, and social impact; risk and uncertainty in evaluation; project evaluation; and empirical methods. The deliverable review included all currently available project reports. The framework was discussed with consortium partners informally, as well as in a formal meeting and exchange between empirica and HUG. Available tools that facilitate the analysis of impacts and presentation of outcomes were further developed, in particular with respect to dealing with uncertainties in the quality of data and in going forward in time.

1.5 Achievements

This report reflects the framework in which evaluation and assessment work will be performed. It is not the evaluation or assessment itself. It only provides a structured presentation of the scope of evaluation work and the methods that will be used. The actual evaluation is going to take place in years 3 and 4 of the project, as planned and described in the Description pf Work.

1.6 Relationship to the rest of the project

This report has drawn heavily form the achievements of the first two project years. The evaluation and assessment work is an accompanying activity to the RTD workpackages. Thus, their input is critical to the success. Input in the reverse direction, from evaluation to other workpackages, is only meaningful and planned for the late stages of the project.

1.7 Next steps

The immediate next steps in the evaluation and assessment work are to convert the conceptual framework presented in this document into a pragmatic set of tools for gathering relevant information and performing the required analyses. This includes detailed questionnaires and interview guidelines for the project evaluation, finalisation of plans and design of clinical impact studies, and to further understand the realistic expectations for the functionalities and usability of the DebugIT tools. This task, to be addressed mainly through bilateral exchange with the project-internal clinicians, but also utilising the clinical advisory board, will lead to a robust hypothesis model of the socio-economic impact to be ready by M 36.

1.8 IPR

As a non-R&D activity, evaluation is not expected to produce new IPR protected content. The methods and tools presented in this report are existing and proven methodological approaches, the sources of which are referenced as appropriate. Consequently, no specific IPR issues arise from this report.

2. INTRODUCTION

2.1 Purpose

The purpose of this report is to delimitate the scope and features of the evaluation and assessment work in the DebugIT project. A further goal is to provide insights on the selected methodologies and approaches.

2.2 Scope and context

This deliverable describes the framework for evaluation and assessment of the project DebugIT and the outcomes of the project. This includes impacts on society, science, technology, and life sciences, as well as clinical impact and socio-economic effects that will guide the potential exploitation of outcomes.

At this stage of the project, the subjects of evaluation are slowly becoming clearer in the details. This concerns in particular the functionalities, options, and design of the three tools, for knowledge discovery, decision support, and monitoring. These are important for outcome assessment. The process of revealing details also applies to several project-internal achievements, like the work on ontologies and technical interoperability, which are important milestones and subject of the project evaluation.

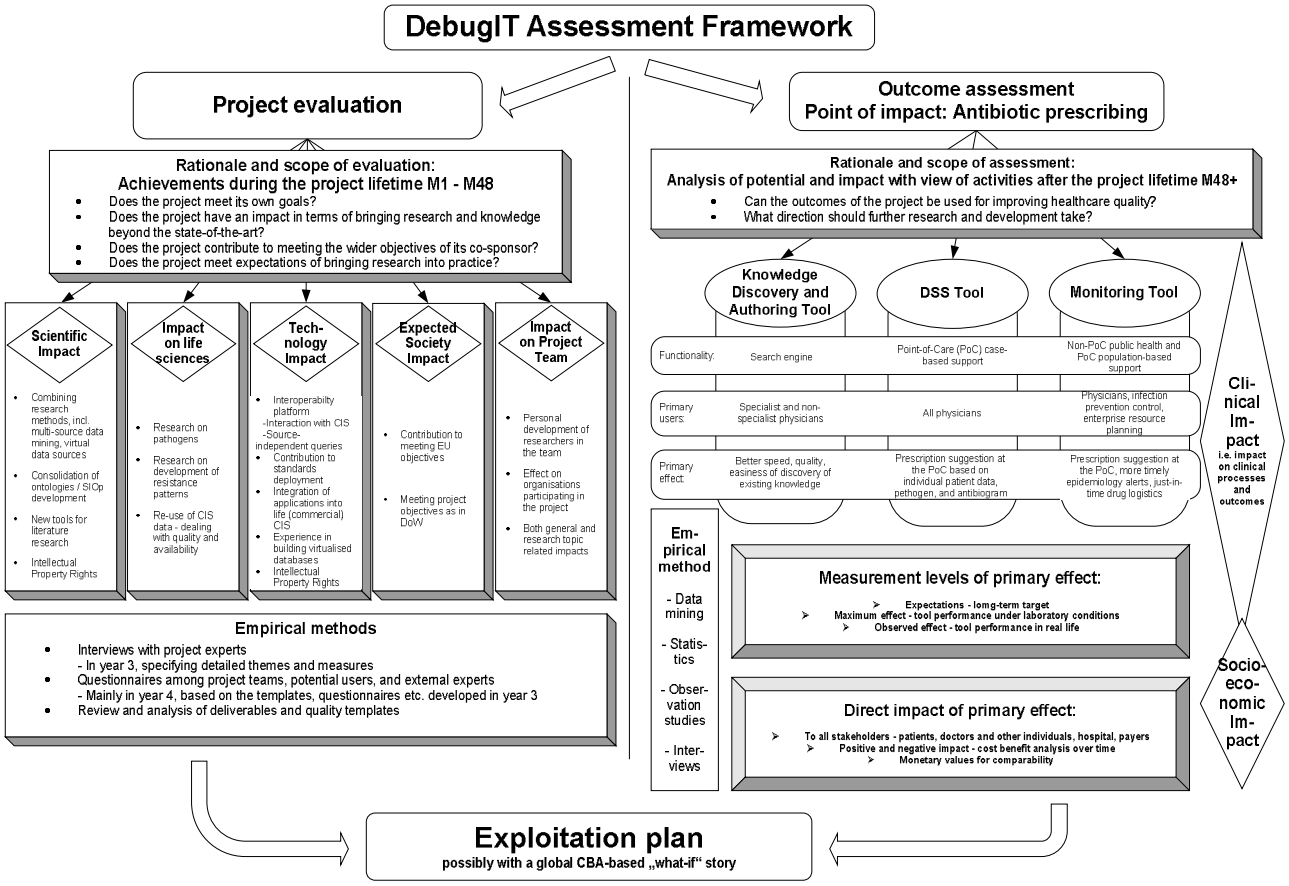
2.3 Definitions, Acronyms and Abbreviations

AB	Annual Benefit
AC	Annual Costs
CAB	Clinical Advisory Board
CBA	Cost-Benefit Analysis
CIS	Clinical Information System
CPD	Continuing Professional Development
DCO	DebugIT Core Ontology
DoW	Description of Work
EHR	Electronic Health Record
ERA	European Research Agenda
FP7	Seventh Framework Program
HPO	Health Services Provider Organisations
ICT	Information and Communication Technology
ICU	Intensive Care Unit
IPR	Intellectual Property Rights
NB	Net Benefit
NPV	Net Present Value
PoC	Point of Care
PV	Present Value
QALY	Quality Adjusted Life Years
R&D	Research and Development
RTD	Research and Technological Development
SAB	Scientific Advisory Board
S&T	Science and Technology
SER	Socio-Economic Return
SIOp	Semantic InterOperability
SMEs	Small and Medium-sized Enterprises
WHO	World Health Organisation
WTP	Willingness to Pay

2.4 Overview

The first part of the report addresses the evaluation of the project as such, with focus on the period of its duration. The second part deals with impact assessment studies and methodologies, which will allow informing decision makers about the potential to bring to market tools developed by DebugIT. These are the two main lines of evaluation and assessment work for the DebugIT project. Exhibit 1 below shows an overview of the whole framework. The details are elaborated upon in the rest of the document.

Exhibit 1: DebugIT assessment and evaluation framework – overview

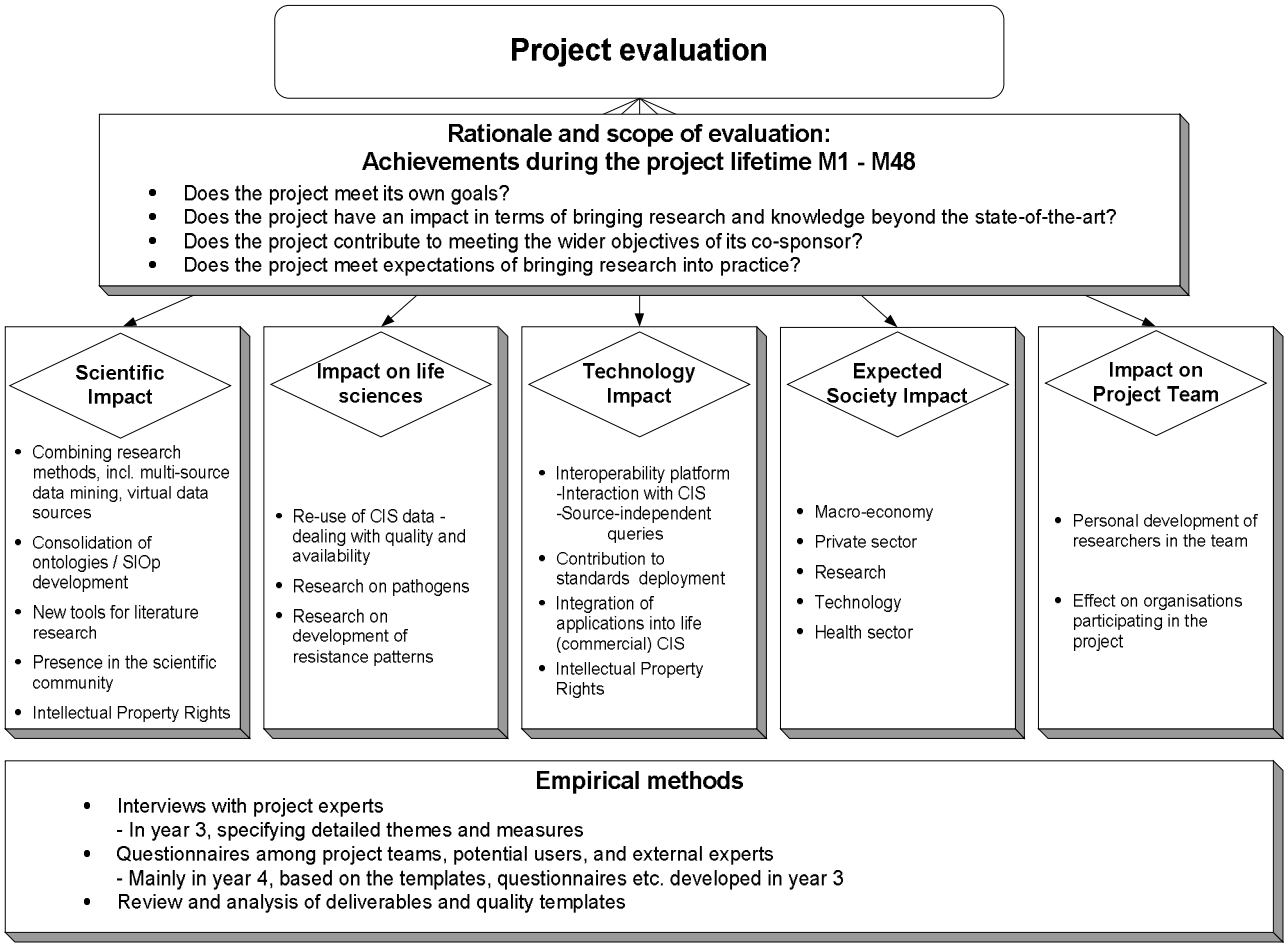


Source: DebugIT / empirica 2009

3. Project evaluation framework

The project evaluation concerns the achievements of DebugIT as a research activity. In contrast to outcome assessment, this part of the evaluation work focuses exclusively of the processes during the project lifetime. The relevant comparison constant is a state of the world in which the DebugIT project does not exist. Exhibit 2 shows the five themes that comprise the DebugIT project evaluation framework. They are discussed in detail in the remainder of this section.

Exhibit 2: DebugIT project evaluation framework



Source: DebugIT/ empirica 2009

3.1 Goals

The overarching goal of project evaluation is to determine whether, and to what extent, the project meets its own objectives. More specifically, the evaluation aims to identify how and by how much the project carries research and knowledge beyond the state-of-the-art. A primary objective of DebugIT is to bring research into practice, ideally faster than conventional translational cycles. Accordingly, special attention is given to this issue. Last but not least, the project evaluation must investigate whether the project contributes to meeting the wider objectives of its main funding organisations. The impact of DebugIT on meeting EU and EC objectives is particularly important in order to justify the use of public finance. The evaluation will also give insights on what future initiatives are likely to be of sufficient social value to deserve taxpayers support.

3.2 Analysis questions

The analysis questions for the project evaluation are divided into five themes. The **scientific impact** of DebugIT concerns science in general, including scientific methods and tools, as well as ways to cope with the increasing amount of new scientific knowledge created every day. The potential **impact on life sciences** relates to possible discoveries within the field of infectious diseases, or bio-medical research in general. Any specific resistance patterns or new pathogen characteristics would add to the pool of life sciences knowledge. **Technology impact** evaluation deals with the degree to which DebugIT contributes to the developments in the IT community, with specific focus on integration and interoperability. The expected **society impact** of the project encompasses the contributions of DebugIT to societal objectives shared across the EU. These are defined through the various policy initiatives and documents published by the EC. The fifth theme is the impact that the DebugIT project has on the **participating researchers and their organisations**.

As they stand now, the concrete impact measurement questions depicted in each subsection serve the purpose of preliminary examples. They are a starting point, from which data collection tools, such as interview guidelines and later on questionnaires, will be specified. As they stand no, some project evaluation questions imply a search for yes or no answers. This will be refined to ones seeking the degree of contributions, for example by allowing a five-point scale in to the answers or a set of predefined responses.

3.2.1 Scientific impact

The scientific impact of the project relates to the new knowledge about the “state of the world” produced by DebugIT. This could be newly made observations, discovered causal relationships, patterns etc. These outputs exist only in an abstract way as concepts in contrast to technological outputs, which manifest themselves in more tangible ways. At this stage, three primary topics have been identified as showing a reasonable potential for impact. These are the combination of research methods, work on semantic interoperability, and coping with an exploding amount of new knowledge published in many scientific fields. Two further themes relate to what happens with the new knowledge about the “state of the world” produced by DebugIT. These are the presence in the scientific community and the clarification of IPR with view for future exploitation of insights gained through the project.

In the following paragraphs, the scientific impact themes are elaborated further, with specific indications about the possible measures to be applied.

3.2.1.1 Combining research methods, including multi-source data mining and virtual data sources

The standard approach to learning from multiple heterogeneous data sources relies on a preliminary integration step whereby the different initial sources are fused into a single data representation. Though conceptually clear, the approach is not as straightforward to implement as it appears, for data fusion involves intricate issues such as estimation of source credibility or adjudication of conflict[1]. Effective data integration often requires a high-level model of the data and consideration of user preferences. The resulting unified data representation can then be used with any standard learning algorithm. A drawback of this standard approach is that the research data is static. Any new data has to be fused into the single data representation, which can be cumbersome and time consuming.

In contrast to the standard approach described above, the DebugIT project is working on a novel approach called multi-source learning. In this approach, there are as many initial models as there are independent representations of data, and a single final hypothesis emerges either during learning or by aggregating the outcome of several learned models. Multi-source learning (or mining) is related to ensemble learning and multi-view learning, two research currents in the state of the art. However, it is distinct from both in its problem setting and its basic underlying approach. In DebugIT’s approach, data mining takes place on

[1] R.R. Yager. A framework of multi-source fusion. Information Sciences, 163:175-200, 2004.

multiple independent representations of training data, and pattern/model integration is performed either on the fly, as part of the learning process, or after learning, via a principled combination of multiple models.

The multi-source mining approach could potentially set up the theoretical foundation base for large clinical research projects based on the secondary usage of raw clinical data integrated across many health service actors in several countries. This would have an enormous effect on the way clinical research is performed, as well as on its costs. The main difference is that data do not need to be generated by very expensive randomised clinical trials, but become more and more available as organisation-centred, local, regional and national EHR systems diffuse across Europe. The impact of using a virtual data source that includes a wide range of real sources would be a serious modification of empirical research methods in the clinical domain.

This impact theme will become visible through the specific application of the approach within the DebugIT project work. In the project evaluation, we will be able to measure only the direct effect. This is the performance of data mining across the heterogeneous sources provided by different partners, with centrally designed research questions, and centrally delivered research answers[2]. DebugIT will only be able to demonstrate that such a distributed learning approach can work. The exploitation plan will deal with this wider and longer-term impact on scientific methods.

Impact measurement questions:

- Can the DebugIT tools provide answers to centrally designed questions by mining heterogeneous sources?
- Are the answers to basic research questions consistent with recognised knowledge?

3.2.1.2 Consolidation of ontologies / development of semantic interoperability

The DebugIT project is laid out in a way that intrinsically supports international development of semantic interoperability. One of the explicit operational objectives of the project is to logically combine medical and clinical data, information and images from different clinical information systems in a way that allows their meaningful use. This requires that data generated in one place must be not only readable, but also understood in the right way at any other place. Details of the current state-of-the-art in semantic interoperability can be found in D2.1 Information Model & Ontology Specifications.

To support the location-independent unambiguous identification of data and its meaning, the DebugIT team has chosen to work with ontologies. To the extent possible, existing ontologies, or parts of them, are used. This is in order to ensure a high level of replicability and re-use of the tools. The result of this work, the DebugIT Core Ontology (DCO) is already a tangible output of the project, even though it will have to be continuously refined and expanded, depending on the project's needs. The real impact from the perspective of project evaluation, however, will be the experience in consolidating different ontologies, each designed for a very specific purpose, into a framework that aims at different purposes. At this stage of the project, we expect the last version of the DCO within the project timeline to be of use for future work in the field of infectious diseases. As all ontologies, however, the DCO will be purpose-bound. Thus, the size of impact it generates depends on the ease with which it can be used as input for other ontologies. The latter is a consideration for the exploitation plan and shall be dealt with accordingly. The important measure for the evaluation is the extent to which the experience in putting together existing ontologies advances the state-of-the-art.

The measures for this impact theme are twofold. First, the joint use of disparate data with clear meaning will be the indicator for developments in the field of semantic operability. The second line of measurement will have to be a qualitative account by internal and external experts on the extent to which the experience in working with ontologies adds new knowledge to this scientific field.

[2] See D3.1 Requirement Analysis & Preliminary Data Mining for details

Impact measurement questions:

- § Is the meaning of the data used clear and unambiguous despite the disparate data sources?
- § Does the experience in working with ontologies add new knowledge to this scientific field?

3.2.1.3 New tools for literature research and knowledge discovery in general

The constantly and fast increasing amount of publications is a challenge to many research fields. New knowledge in medicine can take up to 30 years before it is fully integrated into clinical practice. Part of the difficulty is that healthcare professionals do not have the time to monitor all new literature in search for relevant publications. Even worse, researchers suffer from the same problem.

DebugIT's contribution towards meeting this challenge is twofold. As a specific, tangible result, DebugIT is in the process of creating an up-to-date, integrated, unified knowledge repository covering a wide variety of relevant sources of knowledge such as medical, workflow and public health knowledge. The other contribution, which is more relevant from a scientific impact perspective, is the knowledge discovery and authoring tool. The tool is being designed with the goal to automatically search different knowledge sources and produce a comprehensive overview of the most relevant knowledge available, yet within a manageable size. Knowledge sources include mainly literature, but also statistics and data mining results.

The scientific impact of DebugIT with respect to the discovery of existing knowledge will be measured by the demonstrated functionality of the knowledge discovery and authoring tool. Based on the specific example of research on a concrete topic in the field of infectious diseases, the tool will demonstrate how vast amounts of publications can be scanned and prioritised electronically. The performance will be analysed with respect to the usability of the tool for other topics as well, and the effort required for adaptation. Mostly qualitative accounts of the impact will be reported on, based on the judgement by project-internal users and experts.

Impact measurement questions:

- § Can the knowledge discovery tool scan a large number of articles, for example on PubMed, and automatically prioritise them to return a small number of high-relevance articles on infectious diseases?
- § Can the tool be used for topics other than infectious diseases?
- § Is the tool intuitive and easy to use?

3.2.1.4 Presence in the scientific community

The themes discussed above relate to contributions that DebugIT is likely to make to the state of the scientific world. These contributions, as well as all others discussed on the sections below, must be adequately presented to the scientific community. Otherwise, their potential will not be realised and their value will be low. Thus, a measure scientific impact is the presence of the project and its results in the community.

A quantitative measure of scientific output is the number of publications, conference presentations and papers, workshops, and the number of times DebugIT papers are cited by others. This is common practice for comparing research outputs. An additional factor is the elapsed time papers take to get into print and then to get discovered and cited. For this reason, we will have to account for submissions and acceptance notifications in addition to actual published material.

The main advantage of using number of publications as an indicator for scientific importance is that it is pragmatic and can be objective. The disadvantage is that the average number of publications varies significantly across scientific fields, can be influenced by researchers and consequently gives the researcher wrong incentives, such as focusing rather on quantity of publications than on quality. In addition, there is no clear reference for how many publications from an EU RTD project can be considered a success. These

disadvantages are considered to be of limited relevance, since this part of the project evaluation is entirely observational and better scores do not have immediate effects on the research teams.

The measures for presence in the scientific community are continuously provided by WP 8 in dissemination and exploitation.

Impact measurement questions:
§ How many publications are derived from DebugIT research?
§ How many conference presentations and papers are derived from DebugIT research?
§ How many paper submissions are derived from DebugIT research?
§ How many DebugIT submissions have been accepted for publication?
§ How many workshops build on DebugIT research?
§ How often is DebugIT cited in scientific papers?

3.2.1.5 Intellectual Property Rights (IPR)

Also on the borderline to exploitation activities, IPR arrangements are a sign of scientific impact. The DebugIT project develops a number of tools, instruments, and concepts, which can be utilised in different ways. All R&D reports of the project identify potential IPR issues that arise from the performed work. These reports will be analysed as part of the project evaluation work. The analysis will clarify which aspects of the work done add sufficiently to the state-of-the-art in order to generate IPR and thus have a scientific impact.

Impact measurement question:
§ Which aspects of the work done add sufficiently to the state-of-the-art in order to generate IPR?
§ What kind of IPR features were brought into the project a priori?

3.2.2 Impact on life sciences

The general scientific impact is the effect of the project on science in general, independent of the specific examples and use cases employed for development purposes. Further to those generic scientific contributions, the DebugIT project is also likely to produce a number of specific results related to its thematic orientation of use of routine clinical information in the fight against infectious diseases.

Three topics comprise the evaluation on the project's impact in life sciences. The first is a realisation of the long-waited-for opportunity to use existing information gathered as part of the clinical process for research purposes. The second concerns findings in the field of pathogen research. The third focus is on the research related to resistance development among pathogens.

3.2.2.1 Re-use of CIS data - dealing with quality and availability

Knowledge discovery in databases is an evolving field that provides analysis for extraction of implicit but potentially useful information from data. Many research efforts are focusing on the feasibility of adverse

events detection to increase the quality of care[3,4]. The ability to analyse routine data from electronic patient records in clinical information systems (CIS) would be a significant progress in this field[5].

The description of work (DoW) specifies the aim to identify, select and acquire relevant data relating to infectious diseases and their treatment from routine databases at partner sites. This data is being integrated into a comprehensive virtual clinical data repository allowing further research and analysis. This apparently easy objective is facing numerous important challenges in the implementation phase[6]. The data in clinical databases designed for daily healthcare activities often lacks sufficient quality for re-use in clinical research. In many instances, availability of some data items is also a problem.

By actually performing research on a set of clinical data sources from routine environments, DebugIT will have a significant impact. At the least, a successful demonstration will provide a strong argument against a general rejection of routine CIS data as a reliable source of data for life science research. The actual knowledge creation in the field of infectious diseases will provide an objective measure for this impact theme. Further impact indicators may be developed, depending on the observed results of work on re-use of CIS data.

Impact measurement question:

§ Do the insights drawn from mining routine CIS data lead to new and better understanding of infectious diseases?

3.2.2.2 Research on pathogens

Bacteria can be studied at population or subpopulation levels, such as specific strains and specific genotypes. In both cases, a desirable aim is to understand the way different pathogens work, and thus how best to approach them. It is too early to speculate on concrete new insights in this area resulting from the DebugIT project. We nevertheless include the topic in the evaluation framework in order to set the scene for later analyses. Results from data mining within the timeframe of the DebugIt project will be discussed with the clinical consortium partners, particularly the clinical lead, as well as with the clinical advisory board (CAB) members. The discussions will provide the details for measuring the size of the impact.

Impact measurement question:

§ Can DebugIT help understand the way different pathogens work, and thus how best to approach them?

3.2.2.3 Research on development of resistance patterns

Providing a global epidemiological vision and of resistance profiles of pathogens have become a top priority in public health, moving to become the third world challenge of WHO. DebugIt aims to identify events, issues and patterns that can help improve sustainable healthcare service delivery. New observations will include data about the status of resistance, as well as the relationships between antibiotics prescription and the probability of resistance building. Like with the general pathogen research, the project's scientific impact in the field of pathogen resistance will be documented as soon as results become available. The novelty and significance of the gained knowledge will be at the heart of the analysis.

[3] Murff H, Patel V, Hripcsak G, Bates D. Detecting adverse events for patient safety research: a review of current methodologies. J Biomed Inform 2003; 36: 131-143.
[4] Birkner B. Problems with the implementation of medical guidelines. MMW Fortschr Med 2006; 148: 26-28.
[5] See for example eMERGE (Electronic Medical Records and Genomics) Network https://www.mc.vanderbilt.edu/victr/dcc/projects/acc/index.php/About
[6] Ohmann C, Kuchinke W. Methods Inf Med. 2009;48(1):45-54., Future developments of medical informatics from the viewpoint of networked clinical research. Interoperability and integration

Impact measurement questions:

- § What evidence on the status of resistance is gained?
- § What insights does DebugIT contribute to the knowledge about the relationships between antibiotics prescription and the probability of resistance building?

3.2.3 Technology impact

The technology impact of a project manifests itself in some kind of tool that is capable of doing something with the purpose to serve human needs. This tool does not need to be a physical object, but also can be a new way of doing things. In mot cases, however, technology has two components. The hardware aspect consists of the tool that embodies the technology as a material or physical object. The software aspect consists of the information base for the tool.[7] Different technologies have different mixtures of the hardware and software component, so some technologies have only a software component.

The technology impact evaluation will uncover what tools the DebugIT project is contributing to the state of the world. A descriptive part of the evaluation will clarify the points of impact. Examples are the interoperability platform, the use and deployment of standards, and the integration of research applications into routine CIS and the healthcare service at the point of care. Each of them will be analysed with respect to the progress compared to the state-of-the-art.

3.2.3.1 Interoperability platform

The generic, scalable interoperability platform will be a major technology tool produced by DebugIT. Its impact is expected to be twofold. First, it will connect existing CIS to build a DebugIT demonstrator, feeding live data from CIS into other DebugIT tools such as the knowledge authoring, decision support, and monitoring tools. The second impact concerns source-independent queries. Pure data exchange is between systems is a necessary step, yet is not necessarily a significant improvement on the state-of-the-art. Processing the data from different systems towards a common goal and creating a consistent analysis result is the core innovation in the interoperability platform.

The technology impact of the DebugIT interoperability platform will be evaluated in a qualitative manner by consulting domain experts about the innovation and usefulness values of the new tools. The account will be supported by quantitative metrics proving the functionality of the tools. Such metrics include the number of data items exchanged between different CIS, and between CIS and DebugIT tools, as well as the number of source-independent queries performed during the course of the project.

Impact measurement questions:

- § How innovative is the interoperability platform developed by the project?
- § Does it make sufficient use of existing, proven technology?
- § How useful is the interoperability platform beyond the needs of the DebugIT project?
- § How many data items are exchanged between different CIS?
- § How many data items are exchanged between CIS and DebugIT tools?
- § How many source-independent queries are performed during the course of the project?

[7] Diffusion of innovations EM Rogers - 1995 - Free Press THE FREE PRESS A Division of Simon & Schuster Inc. 1230 Avenue of the Americas New York, NY 10020 Copyright © 1995 by Everett M. Rogers Copyright © 1962, 1971, 1983 by The Free Press A Division of Simon & Schuster Inc. All

3.2.3.2 Contribution to standards deployment

This project will promote existing European technology standards in the domain of health and health information technologies by actively implementing them. A secondary endpoint of the project will lead to useful contributions to the work on these standards, both at the conceptual level and at the operational level, such as creating or adapting archetypes with typical use, such as patient safety issues, drug treatment, and pathogens descriptions.

The use of standards is being continuously documented by the respective technology teams. The important question for this technology impact theme is the extent to which standards have to be amended or adapted in order to fit the needs of the project. The less adaptation needed, the higher the impact on standards promotion. In addition to the account by technology developers about the use of standards, the technical transferability of DebugIT's tools to other settings will provide an objective measure of the impact. Other settings may include other medical spheres or other eHealth services.

Since it takes a while to gain a critical mass of interest to launch a new Work Item, the DebugIT lifetime may not be sufficient for unambiguously detecting impact on standards development. Consequently, a set of proxies might be needed, such as contributions to any relevant active Work Items or DebugIT potential contributions to future standards.

Impact measurement questions:

- Which standards are the most relevant for in the DebugIT context?
- To what extent are standards employed in the IT components of DebugIT with and without adaptation?
- Can the tools be easily transferred to other settings, such as connecting CIS from other hospitals complying with the used standards?

3.2.3.3 Integration of applications into life (commercial) CIS

One of DebugIT's goals is to foster the transfer of R&D results into daily life. From a technology perspective this means not only the use of life CIS data for research purposes, but also the reverse link of feeding research results into clinical routine. In other words, the tools developed by the project must work with and support the CIS.

The measure for evaluation purposes will be the deployment and integration of the knowledge authoring, decision support, and monitoring tools into CIS applications of participants. Ideally, integration to systems that are not part of the initial development and test sites can be achieved. A successful integration of the tools into systems in Bulgaria and the Czech Republic will prove transferability of the project tools. The size of technology impact will depend on the demonstrated integration into life information systems.

Long term commercial adoption cannot be realistically expected by the end of the DebugIT project. The demonstrations will serve as a proof of concept, which can be the basis for signals for commercial interest and possibly commitment.

Impact measurement questions:

- Are the DebugIT tools implemented and integrated to CIS at lead partner sites?
- Are the DebugIT tools implemented and integrated to CIS at non-lead partner sites?
- Do the commercial partners in the project show commercial interest for further exploitation of tools in their products?
- Do the commercial partners in the project show signs of commitment for further exploitation of tools in their products?

3.2.3.4 Intellectual Property Rights

A possibility to measure technological outputs is to count patents, copyrights, trademark, and other IPR based protection registrations. If this is meaningful for DebugIT is being investigated, as an explicit focus on open-source technological development goes against the principle of registered protection. Further, these measures are more suited for assessing outputs of larger entities, such as firms and universities, over an extend period of time. In comparison, DebugIT is a relatively short project with a relatively narrow focus.

3.2.4 Expected society impact

In this section we explore how the project can impact on society at large. As a proxy for the relevant themes in the European context, we focus on the scientific and technological objectives of the EU and how DebugIT contributes to achieving them. First, we describe the relevant goals of the EU set in different Plans/Programs and then we explore how the project is related to them. Relevant documents are the Lisbon Agenda, the Seventh Framework Program (FP7), the Lead Market Initiative, the plan to build the ERA (European Research Agenda) and the eHealth Action Plan. In this report, we present a short sketch which serves as an example of how the final analysis will look like. A more detailed analysis of the relevant documents will follow in the final deliverable at the end of the project. The thematic topic of social impact relates to public health themes.

We have divided the objectives of the EU into the five categories to which DebugIT is expected to have an impact:

3.2.4.1 Macro-economy

It is unlikely that a single project in itself will have a significant, or indeed measurable, impact on the macroeconomic performance of the EU. Nevertheless, addressing some goals laid out in the Lisbon Agenda and in FP 7 would indicate support in this respect. Under the aim to aid the transition to a knowledge-based economy, specific objectives that can be supported by DebugIT are:

- Stimulate investment in research and development.
- Increase the uptake and use of new technologies.
- Facilitate innovation.

Impact measurement questions:

§ Can the use of a DebugIT-type Decision Support System in medicine be interpreted as a switch to a knowledge-based medicine and thus also as a step towards a knowledge based-economy?

§ How does the financing of DebugIT by the EC stimulate any further investment into research and development, for instance by producing outputs that are usable by other projects or increasing the research capacity of the project-partners or other researchers?

3.2.4.2 Private sector

By not only undertaking world-class RTD, but also by preparing for the implementation and diffusion of the new knowledge generated into clinical and public health practice, the project supports improved competitiveness and productivity of European healthcare organisations, SMEs and industry in the fields of eHealth systems and solutions. Specific impacts on partner organisations are addressed in the next sub-section. The following list includes the EU goals that can be supported by DebugIT:

- Enhance innovative capacities of firms.

- Improve knowledge transfer between public research and private research.
- Accelerate the exploitation of research outcomes.
- Strengthen the role of SMEs.
- Involve industry and SMEs directly in co-operations with public research.

Impact measurement questions:
§ Does DebugIT increase the innovative capacities of the participating private sector project partners?
§ How do the participating project partners profit from the co-operation with public research partners within the project?

3.2.4.3 Research

Research objectives relate to improving the position of the EU as a research power and support certain types of research. Specific goals of relevance to DebugIT's project evaluation are to:

- Support translational health research related to drug resistance – the translation of clinical research outcomes into actual clinical practice.
- Foster multidisciplinary and cross-thematic approaches between science and technology.
- Improve access to knowledge and dissemination of new scientific results by exploiting the potential of ICT.
- Cooperate at the European level to keep pace with soaring research costs.

Although it is rather obvious that DebugIT, as a research project of the EC, relates to these goals, it is still interesting to evaluate the extent to which it does so. A primary input for this will be the analyses of scientific impact, discussed above.

Impact measurement questions:
§ To what extent and how does DebugIT support the EU objectives relating to:
o the translation of clinical research outcomes into actual clinical practice?
o multidisciplinary and cross-thematic approaches between science and technology?
o access to knowledge and dissemination of new scientific results?
o cooperation at the European level?

3.2.4.4 Technology

This European social objective relates to stimulating the development of new technologies. The EU has set the goal in the Lisbon Agenda to take over the leadership in key science and technology (S&T) areas in order to create a long-lasting first mover advantage for its industries. Through the Lead Market Initiative, eHealth has been established as one of those key areas. The FP7 program also identifies European health-related industries and businesses as a key area. Means of how to achieve the goals are:

- Create a competitive advantage of EU industry.
- Stimulate creativity, excellence and frontier research.
- Enhance research and innovation capacity.

Impact measurement questions:
§ Do the technology tools developed by DebugIT have the potential to help build a competitive advantage?
§ Has frontier research been conducted?
§ How have research and innovation capacities been influenced by DebugIT?

3.2.4.5 Health sector

At the generic level, this project will strongly contribute towards modernising public services and tackling emerging challenges in areas such as health, ageing, inclusion – cornerstones of the i2010 Initiative to achieve the renewed Lisbon agenda[8]. Fighting infectious diseases and improving patient safety with respect to antibiotics can have an impact on the struggle against global challenges faced in this field. Of specific social relevance are improving the quality, effectiveness and efficiency of public services, here healthcare. In this respect, the EU has set special goals related to health-technology and eHealth. We have identified three most relevant to DebugIT:

- Switch to knowledge based healthcare.
- Establishment of health-networks for epidemiological research and for surveillance purposes of communicable diseases.
- Interoperability of eHealth applications.

Impact measurement questions:
§ Does DebugIT improve the application of new medical knowledge by physicians through its knowledge base?
§ To what extent are the interoperability platform and the data-mining tools usable for the establishment of larger health-networks?
§ Are the clinical ontologies and the interoperability platform developed by DebugIT transferable to other eHealth applications?

DebugIT aims to build new monitoring systems that help hospital infection prevention, public health policy makers, and industry in their ability to provide and foresee adequate answers to the fight against infectious pathogens. The project will demonstrate that the continuous, real-time secondary use of large amounts of clinical data can become a key base to improve direct patient care in hospital, as well as in ambulatory settings, and indirectly also the quality of healthcare systems through better monitoring of diseases. This will be of great benefit for all European citizens.

3.2.5 Impact on project team

Apart form the impact of the project on different field of science, technology, and society, we regard it as important to analyse the effect the project has on the participating people and organisations.

3.2.5.1 Personal development of researchers in the team

Individual team members are gaining experience in conducting research, exchange knowledge with each other, and work in an international environment. The views on the overall value of the project for each individual will provide a measure of the performance of DebugIT in terms of building a good research atmosphere, as well as expanding professional and private networks. Further to that, personal career

[8] "i2010 – A European Information Society for growth and employment", COM(2005) 229

advances may be observed, such as completed PhD, or other academic papers leading to progress in the relevant research field.

Another impact is expected in the fields of science and professional education and continuing professional development (CPD) through the training activities in WP 10.

3.2.5.2 Effect on organisations participating in the project

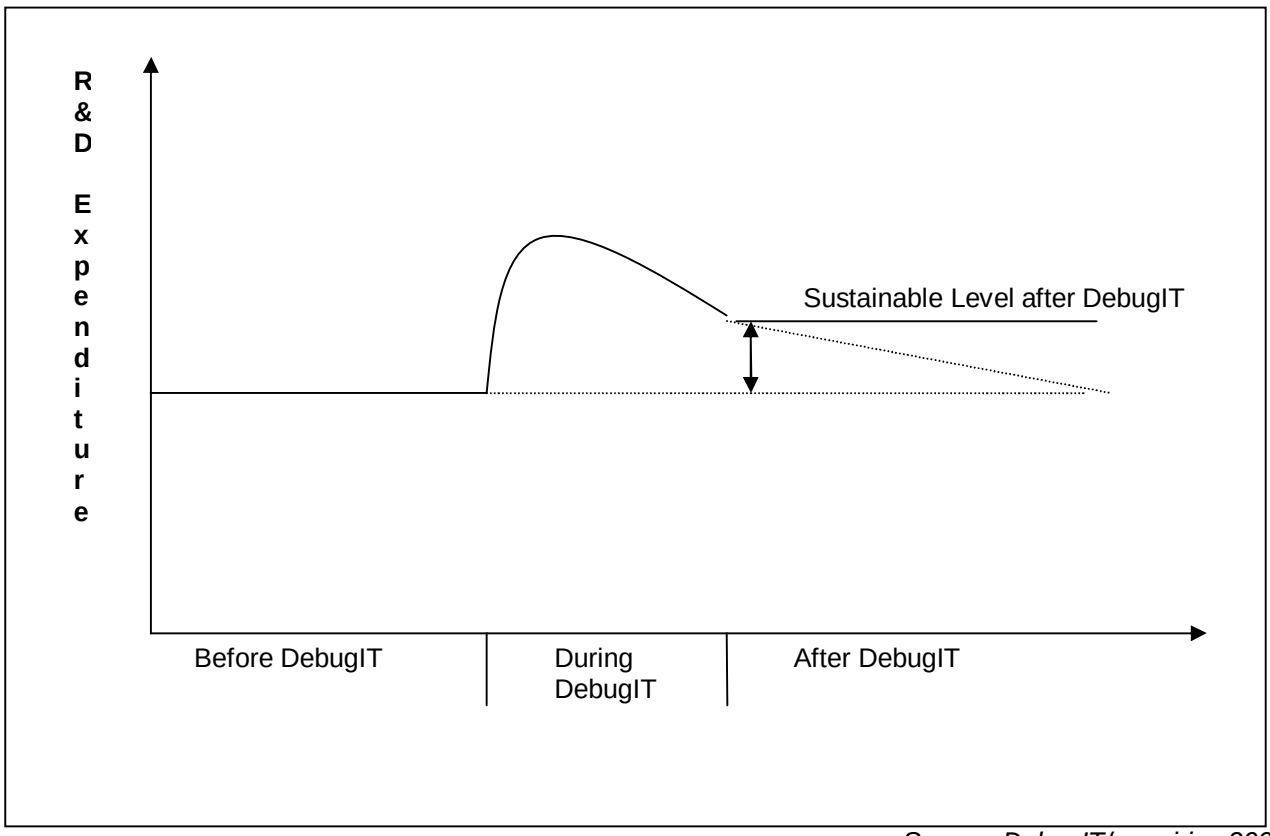
The impact on participating organisations includes changes in the capacity or ability to conduct future scientific and technological research activities. These impacts can be categorised into:

- **Input for future research by participants**: Some project outputs can be important inputs for other future research activities by the participants.
- **Organisational knowledge**: Contribution the projects makes to the knowledge base inside the participating organisations, which can be used for future or ongoing activities like other research projects.
- **Knowledge sharing and transfer**: Some knowledge exchanged between participating organisations can be used for research outside the project.
- **Effectiveness of future research**: Through its work on the foundations of a large clinical research project based on the secondary usage of raw clinical data integrated across many heath service actors in several countries, DebugIT may increase the effectiveness of future research. Data from EHR systems can be directly used for research purposes, which would complement or even replace expensive randomised clinical trials. Apart from the generic scientific impact this presents, the skills and knowledge are also specific assets for participating organisations.
- **Networking**: Creation of links between universities and industry, cooperation between public research and industry R&D within the project may stimulate future co-operations of that type for other projects.
- **Market development**: The tools developed by the project are expected to serve as a demonstrator for the opportunities they create. Ideally, this will draw the attention of an audience beyond the already convinced pioneers and stimulate demand for ICT in healthcare.
- **Commercial impacts**: Bringing a result to market is the ultimate goal of private R&D investment. Public efforts also have a wider impact when results make their way through the markets. Effects on some organisations can provide early indications about a potential commercial impact of the DebugIT project. Details will be followed and explored in WP8 on exploitation, but the following topics will be investigated as part of the project evaluation activities:
    - Ability to carry out new activities or enter new areas, access to new markets;
    - Ability to produce or deliver new products, processes or services;
    - Reputation and image, competitive position, market share;
    - Turnover, profitability, productivity;
    - Employment gains through increased business, employment losses through enhanced productivity;
    - Improved commercial links with other organisations, formation of new business entities such as spin-offs and special purpose vehicles.

A further measure, which also shows the influence EU funding has on research in Europe, is the impact of the project on R&D expenditure by the consortium partners. This concerns expenditure levels during the project lifetime as well as forecast levels for the future. Possible effects are an increase in spending, a decrease in spending because of co-financing by the EC, no impact, or preventing reductions in R&D budgets since the project obligations ensure long-term commitment.

A desired impact is illustrated in Exhibit 3 below. The chart shows a short-term boost in R&D spending during the project lifetime, with a subsequent expenditure staying above the pre-project level.

Exhibit 3: Project impact on R&D expenditure



Source: DebugIT/ empirica 2009

3.3 Empirical methods

The methods for data collection comprise three pillars – desk research, interviews, and questionnaire surveys.

3.3.1 Desk research

The desk research consists of review and analysis of **deliverables and quality templates**. The presented thematic framework already reflects the current status of project deliverables.

3.3.2 Interviews

Input from **project experts** will allow the evaluation team to refine the structure, themes, and measures presented above. Target interview partners are WP leaders and key internal experts, as proposed by the leads. **Members of the CAB and the scientific advisory board (SAB)** will also be approached to discuss topics of their expertise.

The outcome of the interviews will be survey tools tailored to the projects evolution over its lifetime. This may include stressing some features and accounting for the fact that others may turn out to be dead ends. This will ensure that the surveys to be conducted in year 4 are relevant.

3.3.3 Questionnaire surveys

The survey tools developed in the basis of this evaluation framework and the input from project experts will be utilised **among project teams, potential users, and external experts**. This will increase the objectivity of evaluation results.

The questionnaires will be distributed to the main target groups in electronic format. The use of online survey tools will be considered. In addition, paper-based questionnaires can be used for ad-hoc feedback from attendants of DebugIT workshops at conferences.

3.4 Next steps

The preceding sections laid out the framework for the project evaluation activities. This framework is based in the project's progress over its first 22 months, so the aim is to provide a structure of relevant themes that need to be considered in the evaluation. We have already provided indications on specific measures. The further the project progresses in its R&D work, the more precise these measures can become. This is the task during year 3 of the project, which will be devoted to further deskwork and to project expert interviews.

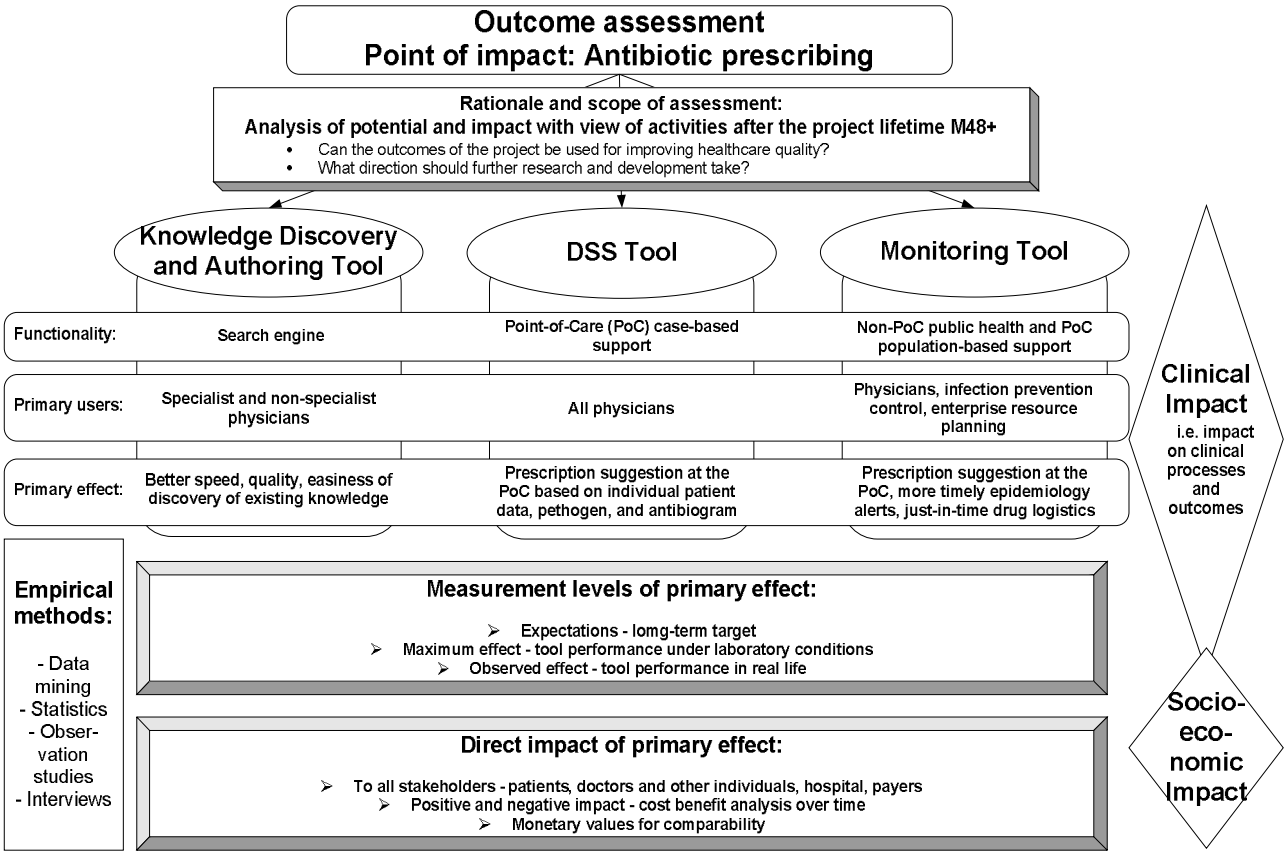
The surveys will be conduced mainly in year 4, when sufficiently advanced project results allow a meaningful judgement. Comparisons to initial project goals and analyses of discrepancies in either way have to be done in an ex-post manner, near the end of the project.

4. Outcome assessment framework

While the project evaluation concerns the achievements of DebugIT as a research activity, outcome assessment deals with those project results that are expected to have an impact after DebugIT has ended. The relevant comparison constant is a state of the world in which the three DebugIT tools do not exist. The tools are a knowledge discovery tool, the decision support tool, and the monitoring tool. How these project outcomes come into life is a secondary question within this part of the evaluation and assessment framework.

Exhibit 4 shows the DebugIT outcome assessment framework, discussed in detail in the remainder of this section.

Exhibit 4: DebugIT outcome assessment framework



Source: DebugIT / empirica 2009

The primary process affected by the DebugIT outcomes is the process of antibiotics prescribing. Details of this process are presented in D3.1 Requirement Analysis & Preliminary Data Mining. Here we summarise the steps in a simplified way, with the aim to make references to the process clearer. The three main steps are

- empirical diagnosis and prescription, based on symptoms and the doctor's knowledge and experience
- laboratory examination of the culture, identifying the pathogen responsible for the disease, which can lead to a change in prescription, and
- antibiogram, which proves that a given antibiotic is effective in fighting the pathogen.

At each stage of the process, the prescription should be reviewed and if necessary adjusted.

4.1 Goals

The goal of outcome assessment is to analyse whether the tools created by DebugIT have the potential to achieve sufficient benefits in term of healthcare quality. Sufficient means that the benefits exceed costs. Ultimately, the results of the assessment will be used as input for the exploitation plans to be generated by WP8. They will be supporting decisions on whether to invest further in the diffusion of the tools and their refinement, or whether to abandon some ideas and concentrate on ones that are more promising.

4.2 Defining project outcomes

As a technology R&D project, DebugIT is likely to create a number of technology instruments, such as algorithms for data mining, interoperability enabling software, and user interfaces. Other discoveries in the field of life sciences and science in general can also be various, yet were already addressed in the project evaluation framework. These achievements at sub-project level will be examined in the exploitation work.

The outcome assessment deals with the tools that eventually could become products and enter the healthcare IT market. These are defined as the final stage of development of DebugIT tools. Thus, all sub-project level achievements are only included as part of the final, potentially marketable outcomes.

The three tools that fit the criteria are defined in terms of their functionality, their primary users, and their primary effect on the provision of health services, including public health. The technology details are subject to other reports of the project.

4.2.1 Knowledge discovery and authoring tool

The knowledge discovery and authoring tool is de facto a search engine. Its function is to find relevant information according to criteria defined by the user. The source of information can be literature, such as publications available on the PubMed and Medline databases, or the DebugIT knowledge repository, where new insights gained form data mining are stored.

One target user group of the tool are specialists, who actively keep up-to-date with the latest developments in their fields of expertise. This requires them to monitor vast amounts of new literature. Given the DebugIT focus on infectious diseases and antibiotic treatment, specialists in this case are infectiologists. The second target user group are non-specialist physicians, who need some special information for a specific reason. This can be the case when they are about to decide on a diagnosis, but want to check with the literature whether the symptoms can be attributed to more than one disease. Another example is looking for state-of-the-art best practice in prescribing.

The expected primary effect of the knowledge tool is better speed, quality, and easiness of discovery of existing knowledge. For example, it is likely to be able to reduce the number of articles a doctor has to manually screen for relevance from 20 million to just a few thousands. Ideally, with good search criteria, the engine can reduce the number to about 20 to 50 publications, thus saving a lot of user's time. In many cases, manual screening of all 20 million publications is impossible and the probability of finding all 20 to 50 most relevant publications are low. Thus, the knowledge tool is expected to increase the quality of knowledge search as well.

4.2.2 Decision support tool

The decision support tool is planned to provide case-based assistance at the point of care. Its algorithms work with information specific to the concrete case. Three situations are expected to be handled allowing improvements to the decision ability at the point of care:

- Providing the caring physician a tool specialised in providing good information for clinical practice. This is a specialisation of the authoring tool. It will help answering questions such as “what is the best antibiotic to treat a urinary infection in a pregnant woman”.
- Using population-based information to help case-based decision. For example, at a given season, for children of a given age, coming from a given region, showing the probability of germs for each samples type according to their relative frequency in that population at that time in that sample.
- Using specific patient and germ data, such as comparing the actual antibiogram with the actual antibiotherapy and proposing the best-suited antibiotherapy.

Target users for the decision support tool are all prescribing physicians. Depending on the chosen level of integration, they can either actively ask for advice, or are given a suggestion for the medication therapy, which they can accept, alter, or completely decline.

A prescription suggestion at the point of care is the primary effect of this tool. Because of the case-based input information, these suggestions are expected to be very precise. The combination with knowledge automatically drawn from the knowledge discovering and monitoring tools will provide a new way to bring knowledge to the point of care. This primary effect has two lines of impact. First, the individual patient receives a treatment suggestion. Second, the tool facilitates the incorporation of new medical knowledge into clinical practice. A side effect is the increase in transparency, since the logs can be used to discover incompliance with current best practice. Investigating the reasons for incompliance can uncover malpractice on the one hand, but can also lead to the conclusion that guidelines are outdated and need replacement.

4.2.3 Monitoring tool

Infections, treatments regimes, and their outcomes are expected to be analysed automatically by the monitoring tool. The analysis consists of identification of patterns. These can in turn trigger alerts, or support prescribing based on population information, usually the population of pathogens.

The monitoring tool has three core user groups. Firstly, physicians can receive support at the point of care, at the second stage in the antibiotic treatment process, when the culture of the pathogen is known, yet the antibiogram is still missing. The tool compares the pathogen with previously prescribed drugs and the respective outcomes. The result is a suggestion based on the pathogen population, not guaranteeing effectiveness, but at least alerting on potential risk of resistance.

The second user group are members of the infection prevention control team. They use the tool to identify any potentially dangerous increase in the number of infections at an early stage. In this way, action can be taken earlier than in cases where infection monitoring is done by hand, possibly avoiding costly epidemia.

A third target user group are the enterprise resource planning teams. They are not directly concerned with the clinical effectiveness of drugs, but can draw useful information regarding demand for different types of antibiotics. For example, an increase in the number of a particular infection can indicate an expected increase in demand for the respective drugs. An identified emerging resistance can possibly be prevented from developing further by reducing the availability of certain antibiotics at the hospital pharmacy. Drug logistics moves towards a just-in-time model. This ensures appropriate stock levels and reducing waste compared to uninformed just-in-case stock holding, where expired medications are a common phenomenon.

4.3 Analysis questions

The analysis of the outcome assessment activities focus on two related topics – clinical impact and socio-economic impact. Clinical impact refers to the influence on different clinical processes and outcomes. Socio-economic impact assessment provides a measure of the overall effect from using the three tools from the perspective of all stakeholders, including society as a whole. Clinical impact is the direct primary effect of using the tools. The socio-economic perspective deals with the impact this effect has on patients, other citizens, health professionals as individuals, health service provider organisations, payers, industry, and

public health authorities. The socio-economic analysis includes assigning monetary values to all impact signs, including clinical effects, in order to enable comparability between positive and negative impacts.

In the following sections, we describe the framework for assessing the clinical and the socio-economic impacts, including the conceptual settings and the methodologies we will use.

4.3.1 Clinical impact assessment

The impact of using ICT tools in healthcare can, and should, be measured on three levels. The first level is the ideal situation in which technology and healthcare processes merge into realising the maximum positive effect. It is difficult to define this maximum impact, as in many cases it requires a balance between reflecting what users can imagine they want, and what technology can provide them with. In some cases, the imagination of users is more limited than the opportunities of technology. The DebugIT tools, however, are meant to fully support users in their activities and are clear in the type of support they can provide. Thus, the target performance can be derived from surveying users about their opinion on what a tool should be able to do in a best-of-all state of the world. The analyses of the target impact will take place as formal evaluation by eventual users.

The second level of measurement concerns the best performance of technology. It reflects the impact of an existing tool when implemented under perfect conditions. The gap between the target performance and the maximum performance indicates demand for further technology development. The analysis requires a controlled observational assessment setting, in which users are well trained and comfortable with the technology and the technology is perfectly tuned to the task it is tested on. Most pilot studies and trials focus exclusively on this level of impact measurement, claiming either explicitly or implicitly that the results are representative. This practice has recently been rightly criticised by the US Congressional Budget Office[9].

In order to avoid the bias of assessment under perfect condition, DebugIT tools will also be evaluated in routine practice. This is the third level of measurement, which needs observational studies in real life and provides a measure of the real effect of a tool. The gap between the real effect and the maximum performance indicates a need for fine-tuning the technology and more training for users.

The assessment of clinical impact will have the scope defined by the DebugIT outcomes. These are the three tools discussed above. With some tools having more than one target user group, and accounting for all three measurement levels, this yields an assessment framework with 18 potential studies to be performed. They are depicted in Exhibit 5.

[9] Congress of the United States (2008): Evidence on the Costs and Benefits of Health Information Technology. Paper by the Congressional Budget Office

Exhibit 5: DebugIT clinical impact assessment matrix

Tool	Knowledge tool		Decision support tool	Monitoring tool		
Primary users	Experts/ specialists	All physicians	All physicians	All physicians	Infection prevention control	Enterprise resource planning
Target – ideal performance of tool	√	√				
Best fit – maximum performance of the existing tool under perfect conditions			√			
Real performance – observed under daily business conditions	√	√	√	√	√	

Source: DebugIT 2009

The shaded area represents assessment studies of particular difficulty, as the tools to be assessed need to actively interact with the local clinical information system. In particular, the needed link to real-time EHR information presents three challenges. First, the performance of the DebugIT tool depends to a large extent on the performance of the EHR system. This can dent the assessment results, as flaws and virtues of the latter can be wrongly interpreted as attributes of the DebugIT tool. Secondly, the use of real-life patient-identifiable clinical data requires green light from the respective organisation's ethical committee. The third challenge is safety accreditation, the scope of which has to be determined in due course. These challenges may delay true adoption into large-scale routine care, so usability testing in a shadow-live environment can be considered a possibility. Although consisting of a limited number of users, a shadow-live environment is still a form of routine operation setting.

The ticked boxes indicate empirical studies already in the preparation stage at HUG. As clinical lead and primary project partner regarding clinical impact assessment, HUG paves the way to spreading studies to other DebugIT sites.

The DebugIT tools are currently in the stage of development. The precise research questions for the studies in the assessment matrix can only be defined once the functionalities and characteristics of the tools have reached a next-to-final stage of development. The themes of interest will differ. Here we provide some initial indications, which must be seen as provisional and illustrative.

- **Knowledge discovering and authoring tool:**
  - How many relevant articles can the knowledge tool identify within a given time limit?
  - Are the publications suggested by the tool really the most relevant ones?
  - How long would it take a specialist who is familiar with the subject to identify the same number of comparable articles?
  - Does the tool provide better quality information to specialists and non-specialists compared to conventional search engines, accounting for the restricted time professionals have at their disposal?

- **Case-based decision support tool:**
  - How often does the tool suggest a different medication than the doctor would prescribe without it?
  - How often does the physician judge the suggestion by the decision support tool to be inappropriate?
  - Can patients leave the hospital faster because of better prescribing practices?
  - It there a reduction in the number of adverse events because of more focused prescribing?
- **Monitoring tool:**
  - How often does the tool suggest a different medication than the doctor would prescribe without it?
  - How often does the physician judge the suggestion by the support tool to be inappropriate?
  - Can patients leave the hospital faster because of better prescribing practices?
  - It there a reduction in the number of adverse events because of more focused prescribing?
  - How do the answers compare to those for the decision support tool?
  - How much quicker can an emerging resistance be identified?
  - Can the emerging of a resistance be avoided by changing the suggested medications?
  - Can the stock of antibiotics be reduced?
  - Can waste be reduced as fewer drugs are thrown away because they have expired?
  - Can shortages be avoided because of the predictive power of real-time infection monitoring?

4.3.2 Socio-economic impact analysis

4.3.2.1 Theory foundations

Our methodology draws its theoretical foundation from value theory, and in particular from the concept of value added. Value added in economics is the additional value resulting from transformations of factors of production into a ready product. At its simplest, it is the difference between the value of a product and the aggregate value of its individual components. Over the last decade, value added has been a widely used approach supporting investment decision making.

In the context of DebugIT, socio-economic impact can be defined as value added to society from the development, implementation and use of the three DebugIT tools. By definition, this equals the total value of health services provided with the tools less the total value of health services provided without them.

value added from DebugIT = value of health services with DebugIT tools – value of health services without DebugIT tools

In an ideal model of perfect competition and complete markets, this can be derived form market prices for healthcare. However, the health services sector is marked by market failures, partly for structural, and partly for historic reasons. Thus, the way to estimate the value added has to focus on change.

A number of health services will not be affected by the implementation of the DebugIT tools, so their value will be equal in both cases of the with/without comparison and will mathematically cancel out from the equation. This leaves us with the task to identify and focus on the services affected by DebugIT. We talk about positive effects, or benefits, when value is created, and about negative effects, or costs, when value is

destroyed. The total value added is the sum of positive and negative 'value added', or value added less value destroyed, also referred to as net benefit.

This gives us the equation for the socio-economic impact of DebugIT's tools at any given point in time:

socio-economic impact = social added value = value added – value destroyed

This is the basic equation of a cost-benefit analysis. Socio-economic impact is presented by net benefits. Applied to a dynamic context, as required by DebugIT, the overall socio-economic impact is net benefit over time. In a mathematical representation, impact (I) equals net benefit over time (NB), which is benefits (B) less costs (C) for each year in the evaluation period (n).

$$I = NB = \sum_1^n (B_n - C_n)$$

This equation is the guiding principle of our methodology. The next sections deal with the practicalities of putting this high level starting point into practice.

4.3.2.2 Stakeholder analysis

A critical point in evaluation and assessment is the perspective from which the analysis is being done. "In any single study, it is essential to keep the same perspective, whichever it may be. Analyses that mix the different points of view in assessment tend to confuse rather than clarify the problem and its extent. For example, the business viewpoint might value loss of effectiveness of a cheap antimicrobial agent as important when it leads to use of a more expensive agent for patient care. In contrast, the medical viewpoint might find loss of effectiveness of the cheaper drug of little consequence as long as other effective drugs are available."[10] In the current evaluation, we include all stakeholders and take the social planner's point of view. With view of the comprehensive exploitation plan to be developed later in the project, we need to analyse the business perspective as well as the medical viewpoint. In some cases, a benefit for one stakeholder will simultaneously be a cost to another.

The stakeholder analysis identifies the relevant groups which DebugIT is expected to have an impact on. The analysis consists of identifying the affected groups and sub-groups of people and organisations and an indication of how they might be affected. The analysis gives valuable insights on individual stakeholders' perspective. For the purposes of the socio-economic impact assessment of the DebugIT tools, we divide stakeholders into four major groups: 1) patients, carers, and other citizens; 2) healthcare staff; 3) health services provider organisations (HPO); and 4) third parties. The following sketch of the stakeholder analysis is a preliminary sketch. All the stakeholder categories will be refined and defined when the model is used.

- **Patients, informal carers, and other people**

Patients
All Patients with an infection that is treated with antibiotics have the potential to profit from DebugIT. In the short-run, they receive better therapy with a higher level of safety due to the decision support doctors are given. In the long run, overall levels of antimicrobial resistance are potentially affected positively by smarter use of antibiotics, which additionally improves outcomes of antimicrobial therapy.

Informal carers
Better outcomes of antimicrobial therapy results in a decreased need for care by family members and other informal carers.

Citizens
Healthy citizens of the relevant geographical area, i.e. living in the catchment area of a hospital using DebugIT tools, might either become patients themselves in the future or one of their family members might

[10] McGowan: Economic Impact of Antimicrobial Resistance

become a patient. They are thus affected in the same way as patients and informal carers, although only with some probability.

- **Healthcare staff**

Doctors
Doctors are the largest group of end-users. The desired impact on them is more comfort in decision making, general alleviation of work and increased work satisfaction. On the other hand, doctors can feel threatened by the increased transparency or by a feeling distrust in their professionalism.

Specialists
In addition to their role as doctors, infection experts will be affected positively by the support of the knowledge discovery tool, which will make their job of keeping up-to-date with the latest developments on medical research easier. Specialist will also have to invest some time and effort in ensuring the DebugIT tools are fit for purpose.

Infection prevention control team
The teams responsible for infection prevention and control are expected to see their work become easier with the DebugIT monitoring tool. More certainly over the status of infection and resistance patterns in the hospital will ensure they can do their job better.

Nurses
Patients with an infection with multi-resistant bacteria have to be treated with special hygienic procedures by nurses to prevent the spreading of such diseases. Lower levels of such infections might decrease the workload of nurses. Better outcomes of antimicrobial therapy and decreased mortality and morbidity associated with it might also have a positive emotional effect on nurses.

Technicians
Technicians in hospitals have to give support to the hardware infrastructure and to the end-users. This could result in an additional workload for them.

Enterprise resource planning
These are people responsible for the logistics of consumables and medications in the HPO. The monitoring tool can allow them to be better at predicting the demand for specific antibiotics, which would take some pressure off their job.

- **Health service provider organisations**

Hospitals could experience an improvement in the use of antibiotics, lower levels of resistance, and better outcomes of antibacterial therapy of their patients. These effects would translate in changes in the costs of treatment, the allocation of resources within the hospital, and potentially reimbursement levels. A fee-for-service reimbursement environment may provide a disincentive to improve the effectiveness of antimicrobial therapy and shorten the hospital stay of its patients.

- **Third parties**

Insurance companies
Insurance companies benefit from better outcomes of antimicrobial therapies resulting in better health of their clients. To which extent efficiency gains inside hospitals are also beneficial for insurance companies depends on specific reimbursement scheme.

Government and public authorities
Antimicrobial resistance is a major public health concern, and thus governments and public authorities should have an interest in technologies such as DebugIT's tool that target it. The European Commission has also to be included. Although almost by definition as a project funded by the EC, DebugIT has an impact on various EC objectives, as elaborated in the project evaluation framework.

Industry
Two industry branches that DebugIT might have an impact on are the medical technology industry and the pharmaceutical industry. The medical technology industry is directly involved in the project and possible benefits it has from participating in it are: a) development of a new product b) acquiring a competitive edge c) supply of equipment for DebugIT. These impacts are primarily subject of the project evaluation, discussed in section 3.2. In the outcome assessment, they will be reviewed again, even though specific quantitative measures are unlikely to be available at the end of the project.

The pharmaceutical industry is affected in the sense that the demand for antibiotics may changes. It remains to be analysed if this results in a total benefit or a cost. The ways the demand is likely to shift are:

- Less demand for broad-band antibiotics and more demand for narrow-band antibiotics, as one aim of DebugIT is to induce a shift towards more targeted antibiotic therapy
- The emergence of resistance against existing antibiotics is slowed down and they are effective for a longer period of time and consequently can be sold longer
- On the other hand, when existing antibiotics are effective for a longer period of time, demand for new antibiotics is delayed.

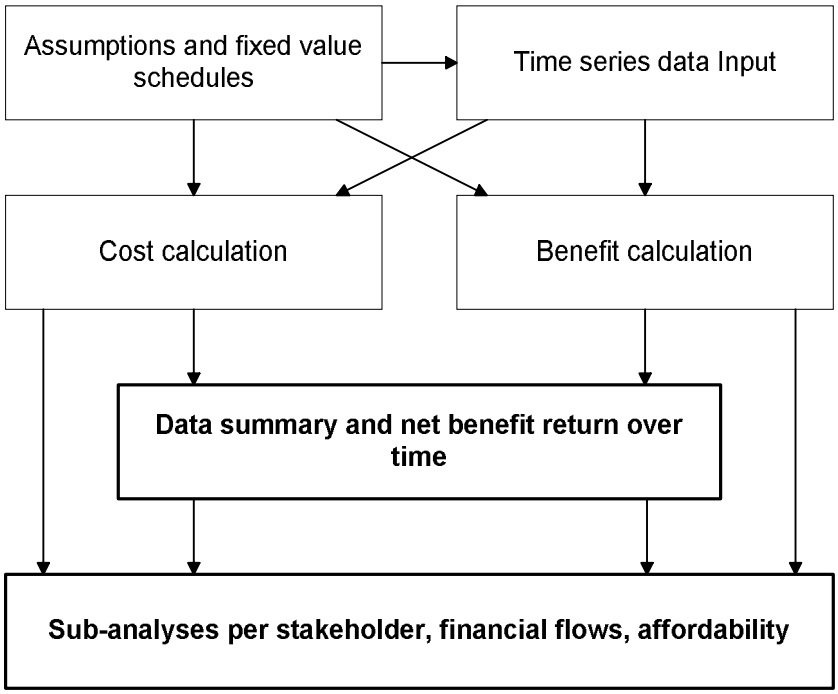
Research bodies
Research bodies can be of two types, research institutes and research organisations, such as pharmaceutical companies. Both types can benefit particularly from the knowledge discovery and authoring tool. Being able to identify the most relevant publications in large amounts of literature can accelerate research cycles. Research institutes may see the costs of research fall. Pharmaceutical companies have an intrinsic business interest in such developments, as they may lead to different product lifecycles.

4.3.2.3 Model structure

The evaluation model will operate at four levels, as shown in Exhibit 6:

1. Data input for populations, stakeholders, activity, staffing, unit costs, monetary values, and assumption schedules used for estimates where actual data is not available.
2. Cost calculation and benefits calculation showing combinations of data from the data tables to produce estimates for each stakeholder group, adjustment for contingencies, risk and discounting. Further analysis will include distribution of costs and benefits and categorisation of impact items into a financial perspective.
3. Data summary and net benefit return over time, showing overviews of the overall socio-economic performances.
4. Sub-analyses of the socio-economic and financial performance of each stakeholder, identifying affordability aspects, financial risks, and point of highest impact.

Exhibit 6: Structure of the socio-economic impact assessment model



Source: © empirica 2009

4.3.2.4 Generic mathematical representation

The mathematics behind the assessment methodology and model allows the conversion of data and qualitative insights into a quantitative set of results that can guide decision-making regarding further exploitation of project outcomes. The following is an illustration of the approach, focusing on the calculation of the socio-economic return over time.

The sets of permanent values, $p = (p^1, p^2, p^3, ...)$, and of time series values $s_t = (s_t^1, s_t^2, s_t^3, ...)$, provide the basis for calculating the monetary value of each benefit indicator b_i and each cost indicator c_j. Permanent values are gathered in the assumptions schedule, while series values are held in the data input box in Exhibit 6. The monetary values are functions of the variables p and s for the relevant year of calculation (*t*), and the contingency factor σ:

$$b_i(t) = f_i(s_t, p, s_i)$$
$$c_j(t) = g_j(s_t, p, s_j)$$

Specific functions have to be created for each individual indicator. The available techniques for estimating a particular benefit or cost indicator function are well known and widely used[11,12].

Table 1 provides an illustrative selection of variables relevant in the context of the DebugIT outcome assessment framework. Which of them are permanent values and which change significantly over time will have to be analysed in due course. The examples show the types of metrics that will be used in the analysis of clinical impact, discussed in section 3.3.3.1 above.

[11] Cf. Ministry of Health and Social Affairs in Sweden (2009): eHealth for a Healthier Europe. Opportunities for a better use of healthcare resources.
[12] Cf. Canada Health Infoway (2008): Diagnostic Imaging Benefits Evaluation. Final report

Table 1: Impact-relevant variables

Outcomes of therapy	Quality of therapy	Costs for therapy	Long-term impact
• Average recovery rate • Average mortality rate • Average morbidity rate • Activity level at discharge	• Length of hospital stay • Length of treatment with antibiotics • Drug dosage • ICU stay • Number of adverse events • Number of complications • Loss of functional time (missed work and activities)	• Number of antibiotic dosages • Use of redundant antibiotics • Use of broad-spectrum antibiotics • Application of prophylactic antibiotic regime • Microbiology cultures • Use of related resources, such as infusion equipment	• Expected future health status • Risk of future hospitalisation • Emotional impact • Prescribing behaviour • Resistance patterns

The value of Annual Benefit (AB) in year *t* is defined as the sum of the individual benefit indicators. The value of Annual Costs (AC) is derived correspondingly. For *n* benefit indicators and *m* cost indicators, the annual benefit and cost are:

$$AB = \sum_{i=1}^{n} b_i(t) \qquad AC = \sum_{j=1}^{m} c_j(t)$$

The Present Value (PV) of the Annual Benefit in year t of the initiative is the sum of the individual benefit indicators discounted by the discount rate *r*:

$$\text{PV of AB} = (1+r)^{-(t-a)} \sum_{i=1}^{n} b_i(t) = (1+r)^{(a-t)} \sum_{i=1}^{n} b_i(t)$$

Because the base year for discounting is the year of evaluation, say 2010, an additional variable (α) denotes the time to this year. α becomes negative when estimating future performance. The cost discounting works in the same way. The present value of the annual Net Benefit (NB) in year *t* is the discounted difference between the annual benefit and annual cost:

$$\text{PV of annual NB} = (1+r)^{(a-t)} \left(\sum_{i=1}^{n} b_i(t) - \sum_{j=1}^{m} c_j(t) \right)$$

The PV of the cumulative net benefit, or the Net Present Value (NPV) of the initiative, is the sum of discounted annual net benefits of each year, up to year k, the end of the horizon.

$$\text{NPV} = \sum_{t=0}^{k} \left[(1+r)^{(a-t)} \left(\sum_{i=1}^{n} b_i(t) - \sum_{j=1}^{m} c_j(t) \right) \right]$$

In the final step, the Socio-Economic Return (SER) of the investment is the ratio of discounted cumulative net benefits and cumulative costs:

$$\text{SER} = \frac{\sum_{t=0}^{k}\left[(1+r)^{(a-t)}\left(\sum_{i=1}^{n} b_i(t) - \sum_{j=1}^{m} c_j(t)\right)\right]}{\sum_{t=0}^{k}\left[(1+r)^{(a-t)}\left(\sum_{j=1}^{m} c_j(t)\right)\right]}$$

4.3.2.5 Example 1: Calculation of benefit from decision support tool

With the aim to make the approach as clear as possible, we provide an example of how a specific benefit function $b_i(t) = f_i(s_t, p, s_i)$ is defined. The example focuses on expected improvement of antimicrobial therapy through the use of DebugIT's decision support tool. The main variables are cost per patient, regarded as a permanent value, and the time series values for numbers of patients with infections:

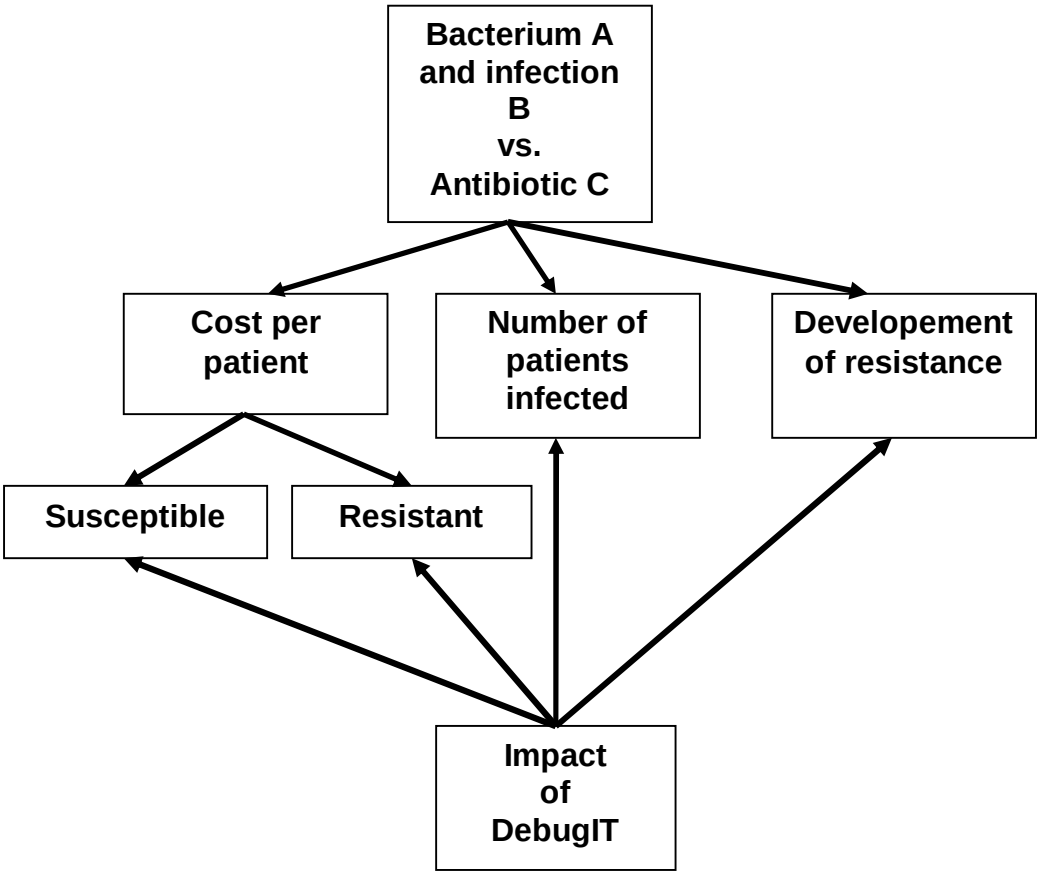
- **Cost of an infection per patient:** Each infection carries a wide range of negative consequences. These include inconvenience from necessary hospital stay, adverse effects associated with antimicrobial therapy, loss of work-time, diminished future health, and risk of mortality, extra costs for hospitals and insurance companies. We derive an average figure of cost of different types of infections based on indicators for the negative consequences associated with an infection and assess the potential of DebugIT to lower this cost.

- **Number of patients with infections:** This is the relevant population for which the costs apply.

- **Fraction of patients infected with a resistant strain:** A desired impact is to hinder the spread of resistant bacteria and to avoid adverse outcomes associated with decreased susceptibility to antimicrobial therapy.

Exhibit 7 shows the relevant detail variables that can be affected by the use of DebugIT's decision support tool.

Exhibit 7: Impact of DebugIT on different infection-related indicators



Source: DebugIT / empirica 2009

In order to evaluate the impact DebugIT will have, we need to define two scenarios:

- A **baseline scenario** without the introduction of DebugIT functions as a benchmark and consists of the current state plus a future without DebugIT.
- A **DebugIT scenario** includes a future with introduction of DebugIT tools.

Additionally, it would be easy to add further scenarios, such as pessimistic, normal, optimistic DebugIT impact scenarios which could be compared to the baseline scenario.

The net impact of a scenario is derived by comparing it with the baseline scenario. Table 2 illustrates the first step towards defining the benefit function for cost savings.

Table 2: Parameters of a cost saving benefit function

Scenario			Baseline	DebugIT
Number of patients for each year t			$P(t)$	
Fraction of patients with infection in each year t (of all patients)			$i_0(t)$	$i_D(t)$
Fraction of patients infected with resistant strain (of infected patients)			$r_0(t)$	$r_D(t)$
Average costs per patient	No infection		c^{NI}	
	Infection	Susceptible to antibiotic	c_0^S	c_D^S
		Resistant to antibiotic	c_0^R	c_D^R

The costs can be split into c^{NI}, the baseline costs for a patient without an infection, Δc^S the infection related increase in costs, and Δc_0^R, the resistance related increase in costs. The respective formulae are presented in Table 3.

Table 3: Cost of treatment per patient

	Baseline scenario	DebugIT scenario
No infection	c^{NI}	c^{NI}
Susceptible infection	$c_0^S = c^{NI} + \Delta c_0^S$	$c_D^S = c^{NI} + \Delta c_D^S$
Resistant infection	$c_0^R = c^{NI} + \Delta c_0^S + \Delta c_0^R$	$c_0^R = c^{NI} + \Delta c_D^S + \Delta c_D^R$

The absolute numbers of patients without infections, and with either susceptible or resistant infection is derived from the total number of patients per year $P(t)$ and the corresponding fractions for the patient groups $i(t)$ and $r\ (t)$, as shown in Table 4.

Table 4: Number of patients

	Baseline scenario	DebugIT scenario
No infection	$P_0^{NI}(t) = [1 - i_0(t)]\ P(t)$	$P_D^{NI}(t) = [1 - i_D(t)]\ P(t)$
Susceptible infection	$P_0^{S}(t) = i_0(t)\ [1 - r_0(t)]\ P(t)$	$P_D^{S}(t) = i_D(t)\ [1 - r_D(t)]\ P(t)$
Resistant infection	$P_0^{R}(t) = i_0(t)\ r_0\ (t)\ P(t)$	$P_D^{R}(t) = i_D(t)\ r_D(t)\ P(t)$

The number of patients for year *t*, $P(t)$, and the average cost per patient with no infection, c^{NI}, is constant in the different scenarios. The other variables vary across the scenarios, indicating the impact of using the DebugIT tool.

The next step is to calculate the total cost of treatment for each of the three patient groups. Table 5 shows the results.

Table 5: Total cost of treatment

	Baseline scenario	DebugIT scenario
No infection	$P_0^{NI}(t)\ c_0^{NI}$	$P_D^{NI}(t)\ c_D^{NI}$
Susceptible infection	$P_0^{S}(t)\ (c^{NI} + \Delta c_0^{S})$	$P_D^{S}(t)\ (c^{NI} + \Delta c_D^{S})$
Resistant infection	$P_0^{R}(t)\ (c^{NI} + \Delta c_0^{S} + \Delta c_0^{R})$	$P_D^{R}(t)\ (c^{NI} + \Delta c_D^{S} + \Delta c_D^{R})$

The total cost of treatment in a scenario is the sum of the total costs for individual patient groups. The benefit of the scenario under assessment is the difference between the costs in the baseline and the DebugIT scenario. The total benefit is the sum of these differences over the years. Table 6 shows the mathematical of calculating the total costs of treatment without and with DebugIT, which feeds into the formula for the benefit indicator. The last step of the process is discounting the result to present value, in order to account for the time value of money.

Table 6: Benefit calculation

Baseline scenario total cost	$$C_0(t) = P_0^{NI}(t)\, c_0^{NI} + P_0^S(t)\,(c^{NI} + \Delta c_0^S) + P_0^R(t)\,(c^{NI} + \Delta c_0^S + \Delta c_0^R) = P(t)c^{NI} + i_0(t)P(t)\Delta c_0^S + r_0(t)P(t)\Delta c_0^R$$
DebugIT scenario total cost	$$C_D(t) = P_D^{NI}(t)\, c_D^{NI} + P_D^S(t)\,(c^{NI} + \Delta c_D^S) + P_D^R(t)\,(c^{NI} + \Delta c_D^S + \Delta c_D^R) = P(t)c^{NI} + i_D(t)P(t)\Delta c_D^S + r_D(t)P(t)\Delta c_D^R$$
Benefit from DebugIT tool in year t	$$B(t) = C_0(t) - C_D(t) = P(t)(i_0\Delta c_0^S - i_D\Delta c_D^S + r_0\,\Delta c_0^R - r_D\Delta c_D^R)$$
Present value of benefit over time	$$PVB(t) = \sum_t (1-d)^{-t} B(t)$$

4.3.2.6 Example 2: Modelling resistance patterns

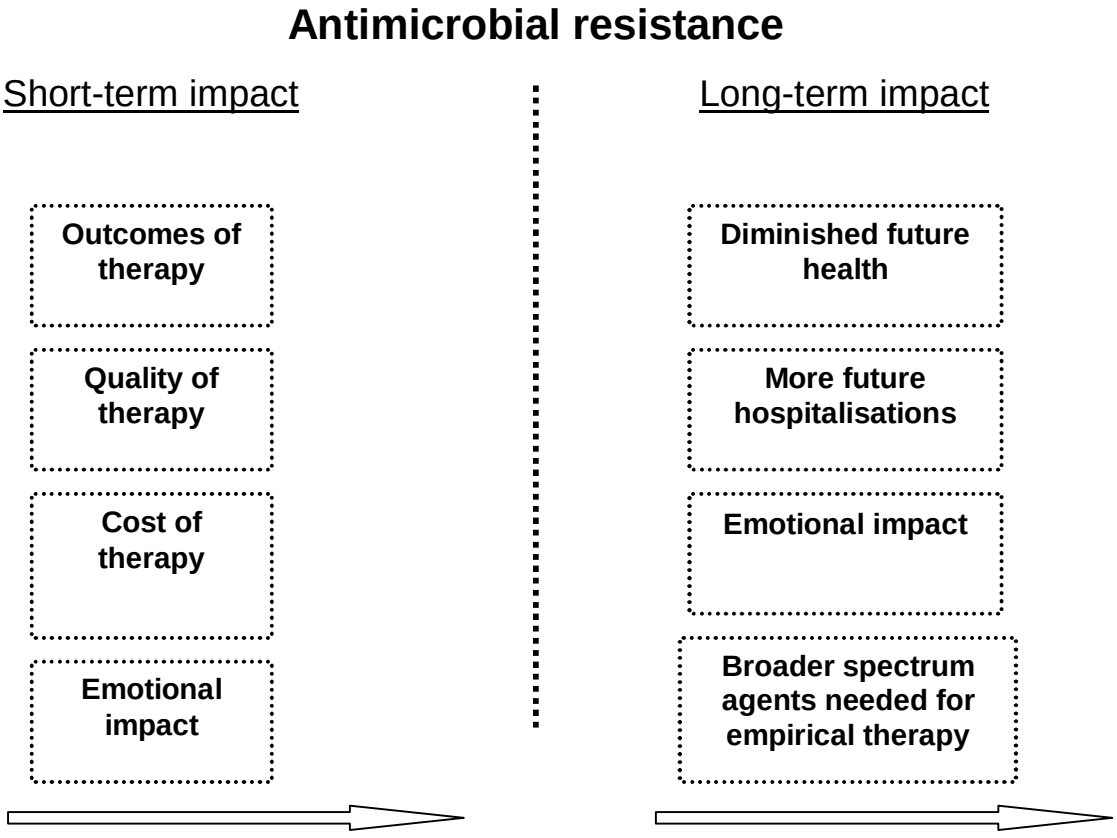
When assessing the impact of the DebugIT outcomes, the cost of treatments is an obvious indicator to expect an effect on. A similarly clear expectation is an impact on the resistance patterns of bacteria. Resistance of pathogens against commonly prescribed antibiotics has direct negative effects on the course of antimicrobial therapy. In this sense, the impact of decreased levels of resistance on success of therapy is similar to that of improved prescribing, namely on outcomes, quality and costs of therapy. However, it is different regarding the timing of the impact, the magnitude and the number of people affected.

Unlike treatment costs, however, antimicrobial resistance patterns are more difficult to model. This is due to the very nature of the problem, which is marked by long-term consequences, high levels of uncertainty and diverse effects. The development and spread of resistance is a complex process dependent on many factors, which are not yet fully understood[13]. Nevertheless, the literature provides some insights that can serve as a starting point.

Regarding the impact of antibiotic resistance, the majority of published studies have shown an association with adverse outcomes on the order of a 1.3–2-fold increase in mortality, morbidity, and cost for patients with resistant versus susceptible infections.[14] These can be regarded as short-term effects, which can be observed and measured even within the DebugIT pilot implementation phase. Additional to the direct effect of resistance on outcomes of antimicrobial therapy, there are indirect and long-term consequences of that have important implications and need to be included into the assessment.[15] Exhibit 8 shows several of the impacts.

[13] Coast et al.: Superbugs II: How should economic evaluation be conducted for interventions which aim to contain antimicrobial resistance?
[14] Yehuda Carmeli, MD; Nicolas Troillet, MD; Adolf W. Karchmer, MD; Matthew H. Samore, MD: “Health and Economic Outcomes of Antibiotic Resistance in Pseudomonas aeruginosa “
[15] Sara E. Cosgrove, Yehuda Carmeli “The Impact of Antimicrobial Resistance on Health and Economic Outcomes”

Exhibit 8: Impact of antimicrobial resistance



Broader spectrum agents needed for empirical therapy refers to an impact on currently healthy people. Increasing resistance rates among common pathogens means that if they do get an infection in the future, they will have to be treated with more powerful antibiotics with agents of a broader spectrum. These agents tend to be more harmful, less effective, and more expensive.

In order to model the rate of growth of the proportion of resistant pathogens over time, we use a logistic growth model. This type of model is commonly used to model growth of a population. Its use in the context of antimicrobial resistance has been suggested by Austin et al.[16]. The model is characterised by a first phase of slow growth, a middle phase of accelerated growth and a final phase were resistant pathogen population growth hits an upper bound, which represent an equilibrium proportion. The equilibrium proportion varies considerably between different pathogens and is determined by a number of factors such as relative fitness of resistant and sensitive strains, and the selection pressure. To take resistance to penicillin in the a hospital setting as an example, the initial lag phase would have occurred during the 1940s, the middle phase of accelerated growth would have started in 1947, and the final phase of equilibrium would have been reached in 1960.[17]

[16] Austin DJ, Anderson RM. Studies of antibiotic resistance within the patient, hospitals and the community using simple mathematical models. Philos Trans R Soc London 1999; 354: 721–738.
[17] Ashley DJB, Brindle MJ. Penicillin resistance in staphylococci isolated in a casualty department. J Clin Pathol 1960; 13: 336–338.

Denoting the fraction of infected patients with resistance to antibiotics in period *t* by $r(t)$, the fraction of infected patients with resistance to antibiotics in period 0 by r_0, and the maximal resistance, or equilibrium resistance by $r_{\max}$, the resistance function becomes the following:

$$r(t) = \frac{r_{MAX} r_0 e^{gt}}{r_{MAX} + r_0 (e^{gt} - 1)}$$

The additional variables are the growth factor, g, and time, t.

The actual parameters of the function can either be estimated by logistic regression if data is available, or have to be specified by estimates from clinical experts and literature reviews. If there is not sufficient data available and the shape of the curve needs to be specified without actual data, it is practical to specify the function in terms of r_0, $r_{\max}$ and $r(t) = c$, where *c* is the resistance after *t* years. The growth factor g can be obtained by the above formula:

$$g = \frac{\ln(c) + \ln(r_{MAX} - r_0) - \ln(r_{MAX} - c) - \ln(r_0)}{t}$$

This means the curve can be specified by asking three questions:

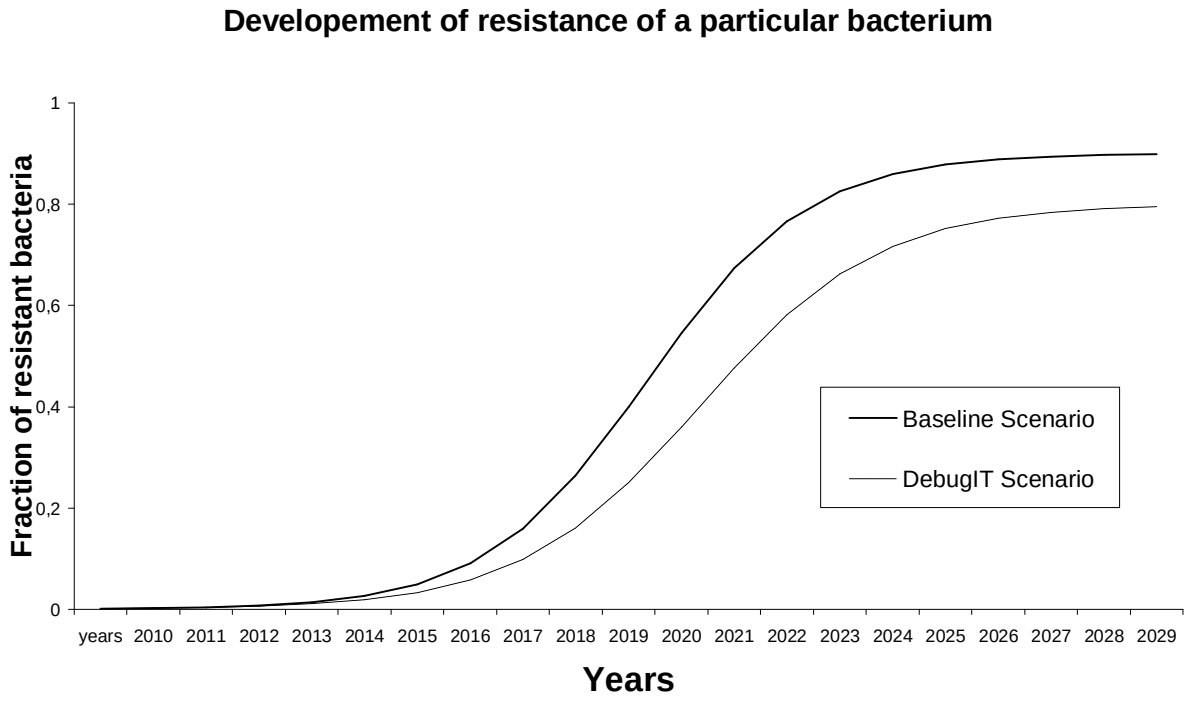
- What is the resistance now?
- What will be resistance in *t* years?
- What is the maximum or equilibrium rate of resistance?

In our context, it is imaginable that DebugIT might decrease the overall growth of the proportion of resistant pathogens. This would delay and slow down the middle phase of accelerated growth and decrease the final equilibrium proportion by decreasing selection pressure due to an environment with less use of antibiotics.

The figure below shows exemplary growth curves for a baseline scenario and a DebugIT scenario with following the specifications:

	Baseline	**DebugIT**
Resistance Now	0,001	0,001
Resistance in 10 years	0,4	0,25
Maximum Resistance	0,9	0,8

Exhibit 9: Illustrative model of resistance and the impact of using DebugIT tools



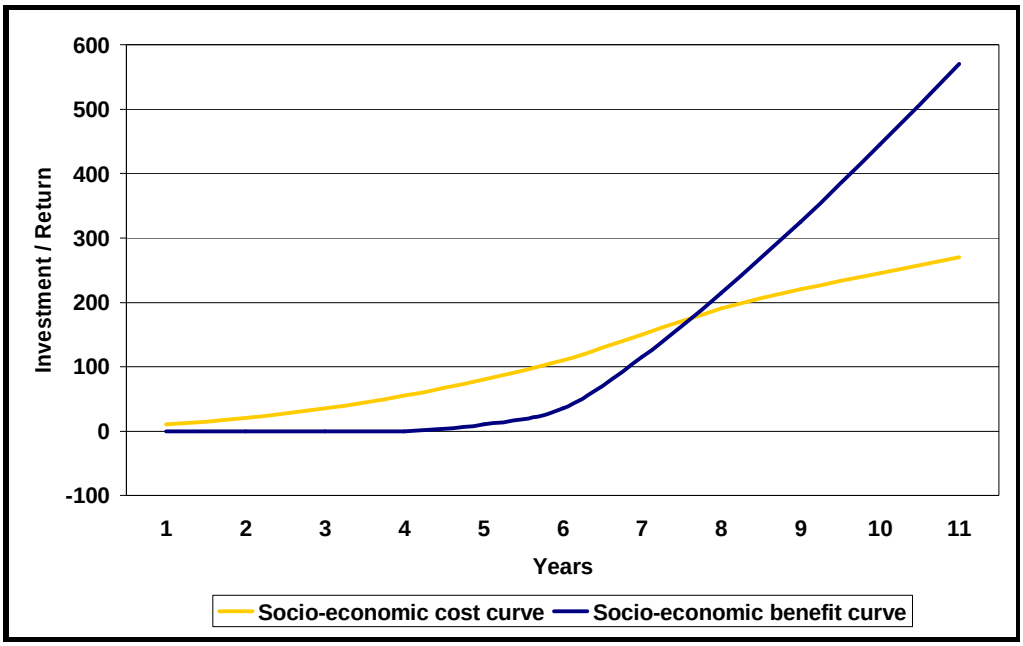
4.3.2.7 Performance measures

The proposed methodology provides a range of measures, which show different aspects of the expected impact of using DebugIT's outcomes during and after the project lifetime.

The socio-economic return, or net benefit to cost ratio over time, is a rate of socio-economic, not purely financial, return over a given period. A positive ratio indicates a worthwhile endeavour from a socio-economic perspective. A ratio of zero equals an implicit break-even point at which the overall socio-economic impact is zero.

Estimated monetary values of annual and cumulative benefits and costs show the estimated time it takes to realise net benefits and their scale. A generic example is show in Exhibit 10. Correlations of utilisation to benefits and to net benefits indicate whether the socio-economic impact is substantially achieved by increasing utilisation.

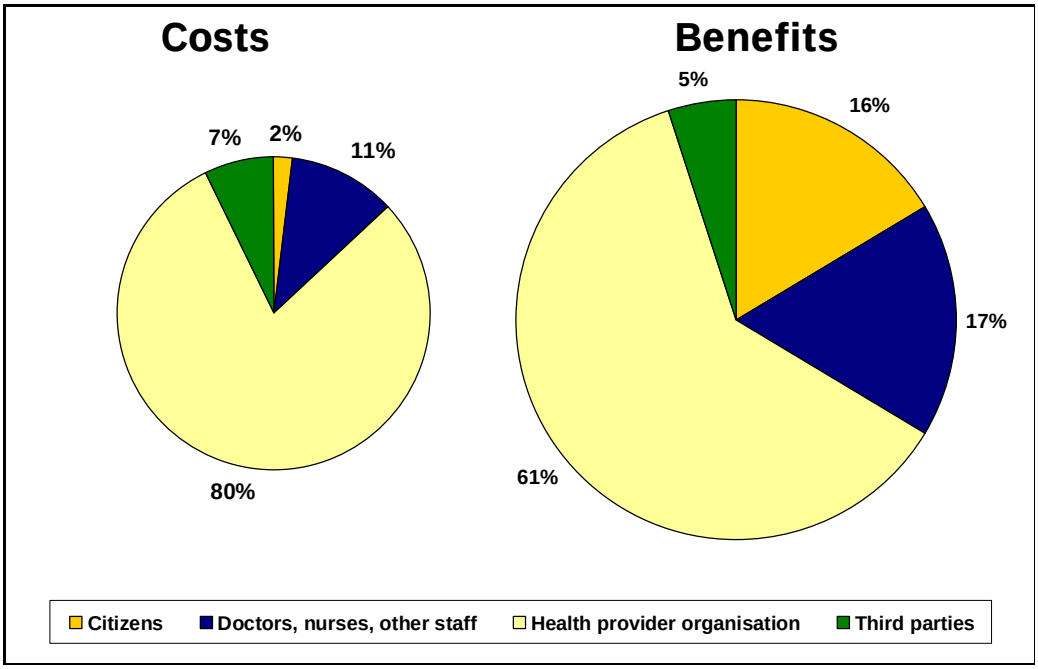
Exhibit 10: Generic value of socio-economic impact



Source: EHR IMPACT study (2009)

The cumulative estimates reveal the distribution of the costs and benefits between stakeholders, as depicted in Exhibit 11.

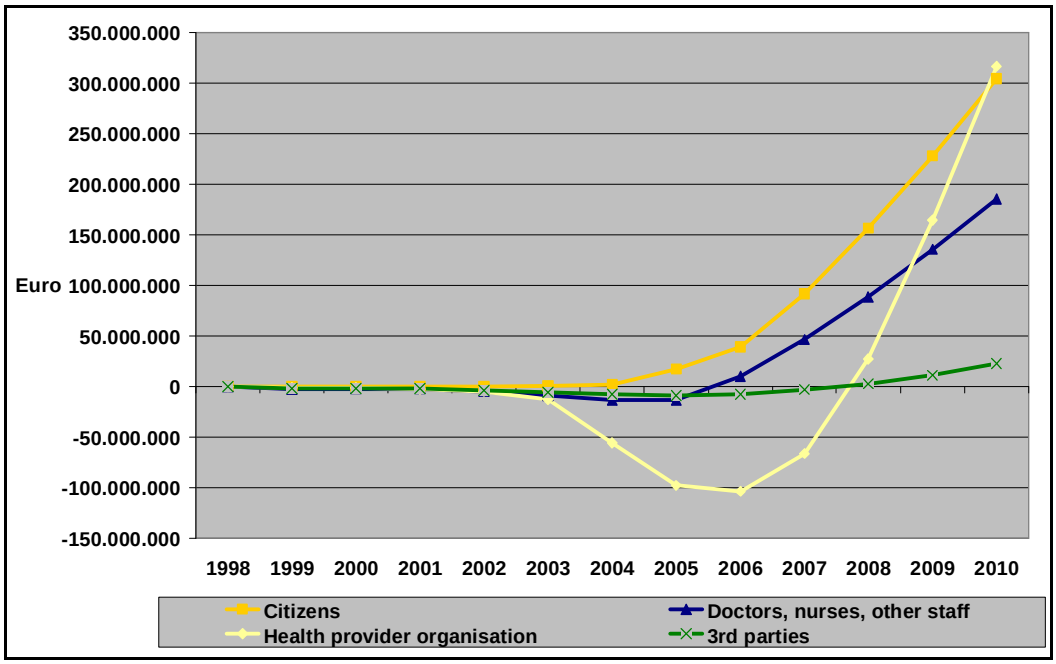
Exhibit 11: Example costs and benefits distribution by stakeholder groups



Source: EHR IMPACT study (2009)

One example of an outcome indicator when applying the proposed assessment framework is the cumulative net benefit for different stakeholders. In the following graph, we can see that a healthcare provider might have a long phase of net costs before the service becomes beneficial. This is an important feature for any exploitation efforts.

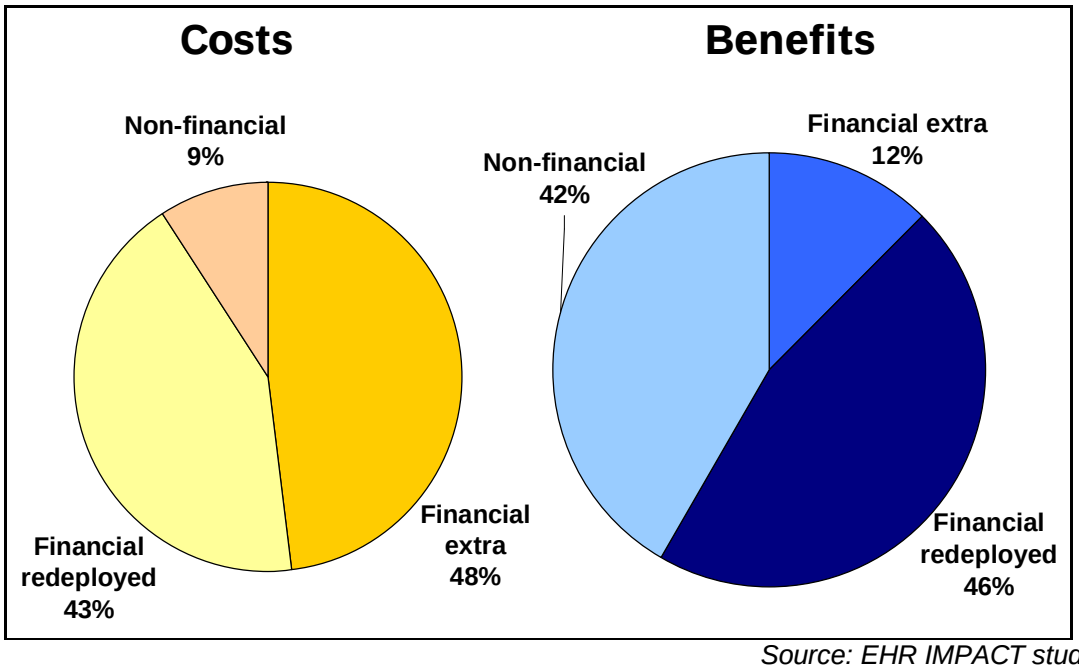
Exhibit 12: Example of cumulative net benefits to four stakeholder groups



Source: EHR IMPACT study (2009)

Two important features of the net benefit estimates need stressing. First, the net socio-economic benefit is a monetary measure of the net value of all positive and negative impacts, not a measure of financial returns and is not the same as return on investment. A separate analysis of the financial impact is part of the distribution of costs and benefits into the three different financial categories of extra finance, redeployed finance and non-financial. Exhibit 13 provides an illustrative distribution. Separate financial analyses for each stakeholder provide insights on the financial sustainability of potential business models.

Exhibit 13: Example types of costs and benefits distribution



Source: EHR IMPACT study (2009)

Another issue worth stressing is that although sustainability performance indicators are important for benefit realisation, they only measure if or to what degree an initiative is likely to perform well. This does not tell why or how the performance is achieved. This aspect is critical for a meaningful assessment of the future potential and will be part of the analysis in the exploitation plan.

4.3.2.8 Dealing with uncertainty - Monte Carlo simulation

In order to fully reflect the uncertainty regarding the future, we utilise the common risk modelling technique of Monte Carlo Analysis[18]. This method uses statistical sampling and probability distributions to simulate the effect of uncertain variables on model outcomes. The approach provides a systematic assessment of the combined effects of multiple sources of risk and uncertainty and known correlations between variables.

Whereas in non-probabilistic Cost Benefit Analysis, assumptions and variables are specified in terms of their expected values and outputs are provided as expected values, incorporating probability distributions as inputs gives the outcomes of the model as full distribution of possible outcomes. The probability distributions can be significant adjustments for this setting. They will have to reflect factors for risk and optimism bias in a prospective model and data, with long evaluation time scales of up to 20 or even 30 years.

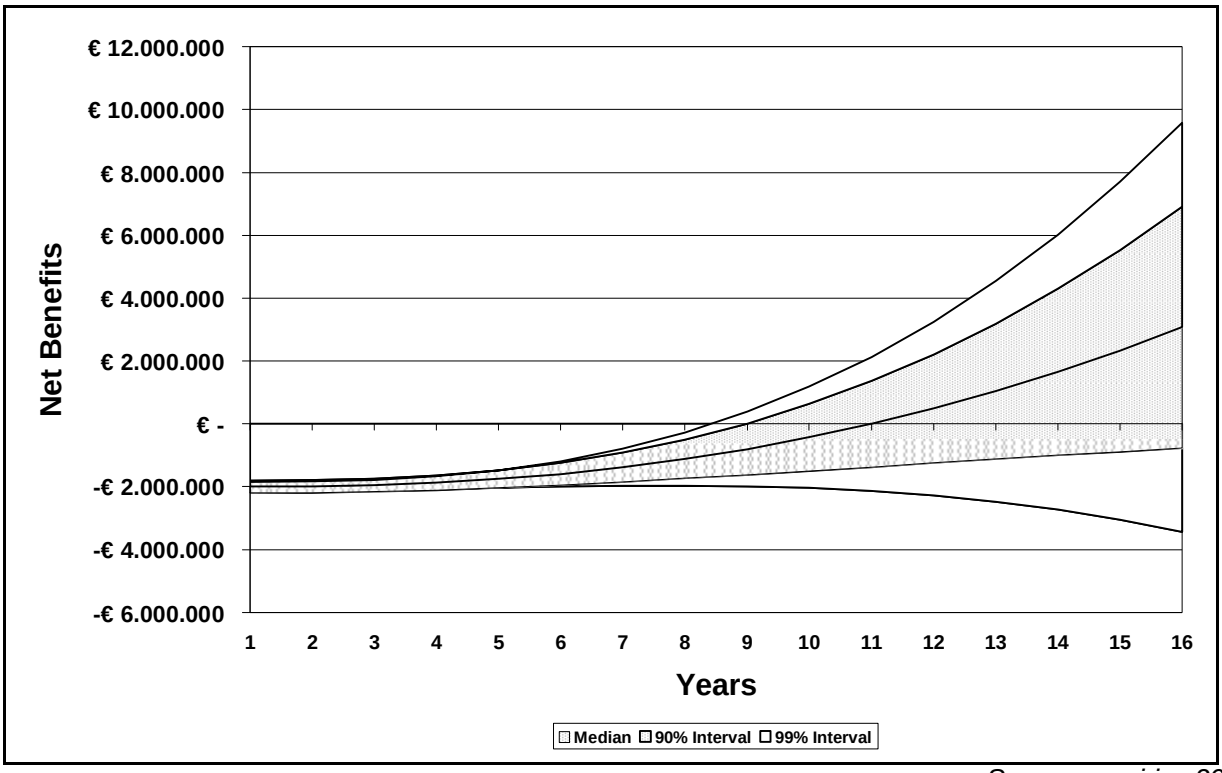
Monte Carlo Analysis will provide us with a representation of the relationship between input variables and assessment results and the range of variability of outcome variables, representing the combined effect of the multiple sources of uncertainty, optimism bias, and risk.

The process involves firstly the identification and assessment of the key variables. For each variable, a suitable probability or multivariate distribution is assigned that best describes the range of uncertainty around the expected value. For each variable being modelled, input values are generated randomly, sampled from the underlying probability distribution function. The computer model combines these inputs to generate an estimated outcome value, for example the present value of net benefits. The process is repeated thousands of times to generate a probability distribution of possible results. This distribution can be analysed to provide an indication of the variability or robustness of the analysis. The output of such analyses can have the form of statements like “there is an 86% chance that the net benefit in year five exceeds zero”. Other statistics of interest can include expected value, percentiles, and correlation coefficients.

Interpreting the outcomes of the evaluations should rely on their order of magnitude, not their absolute values. For this reason, the model will make use of Bayesian probabilities, which interpret the concept of probability as "a measure of a state of knowledge", in contrast to interpreting it as a frequency or a physical property of a system[19,20]. In combination with repeated random sampling following Monte-Carlo simulation methods, the result will be assessment outcomes in the form of ranges. The predictive power of a range is larger than the power of a specific point within that range. Exhibit 14 shows an example of a net benefit estimate over time with an increasing level of uncertainty in the result. A result range entirely in the positive indicates a robust positive impact, which is not sensitive to uncertainties in the estimations.

[18] New Zealand Treasury, “A Cost Benefit Primer”
http://www.treasury.govt.nz/publications/guidance/costbenefitanalysis/primer
[19] ET. Jaynes. Probability Theory: The Logic of Science Cambridge University Press, (2003)
[20] de Finetti, B. (1974) Theory of probability (2 vols.), J. Wiley & Sons, Inc., New York

Exhibit 14: Example net benefit over time range using a Monte Carlo simulation



Source: empirica 2009

Starting from an ex-post evaluation, the model extends into the future, facilitating investment decisions. The ex-ante, predictive features of the methodology, including adjustments for uncertainty and risk involved in forecasting, will be essential for the exploitation work in the project.

4.4 Empirical methods

Clinical impact assessment
The studies targeting the assessment of clinical outcomes will follow well-known methods of empirical data collection. Currently, trials are being prepared by formal and informal exchanges between the DebugIT technical teams and later users of the tools. This dialogue will be extended into a formative target-building exercise. Controlled studies under laboratory conditions, with a limited number of lead users, will provide the assessment of maximum performance. The real effect evaluation will be based on purely observational techniques and analysis of logs and other statistics relevant to the use and effects of DebugIT tools.

Socio-economic impact analysis
Statistics to be gathered as part of the socio-economic assessment include data about the population affected, the number of professional and end users, volumes of data transactions, and changes in healthcare activity and workflow. Metrics will include clinical results, based on the clinical impact studies, utilisation levels, costs of healthcare provision, and budgets.

Data should be made available by participating hospitals. Where such data do not exist, some estimation will be necessary. For cases where specific data are not available for input or for deriving accurate estimates, we will seek structured input for clinical experts within the project. We will make use of existing “tools to create and manipulate empirical statistical models using expert opinion (or judgment). Here, the latter expression refers to a specific body of techniques to elicit the distribution of a random variable when data is scarce or unavailable. Opinions on the quantiles of the distribution are sought from experts in the field and aggregated into a final estimate. The package supports aggregation by means of the Cooke, Mendel–Sheridan and

predefined weights models"[21]. The Cooke and Mendel-Sheridan models calculate a weight for each expert based on how correctly they estimated a "calibration" variable that is only known to the modellers. For our purposes, it might be sufficient to use the predefined weights model with equal weights to each expert. Instead of full calibration, a correction for optimism bias can be incorporated.

Monetary values of costs and benefits will usually be estimated at constant prices over the whole investment life cycle of design and development, engagement, testing, implementation, operation and change. All values will be based on prices for the current year of evaluation and for the country in which the service is provided. Only in countries where inflation is a major concern and would considerably bias these data, inflation-adjusted data will be used. Empirical evidence has shown that in recent years, inflation is no longer a major concern in most countries, and slight adjustments will have virtually no effect on outcomes.

Estimating the monetary value of impact applies several techniques. Time savings of citizens rely on estimates of the value of time. Savings in travel costs rely on available estimates of travel costs. Time savings of staff and numbers of tests can be estimated from unit cost calculations. Quality gains have the five categories of better-informed patients, timeliness of care, effectiveness of care, patient safety and streamlined care[22] . Some of these can be estimated using unit cost calculations, such as avoided hospital admissions. Intangible benefits, such as the value to patients and organisations, rely on willingness to pay (WTP) estimates inferred from stakeholder behaviour, usually with very small values for patients who enjoy a new benefit. The aim of WTP is to simulate a market by estimating how much users or beneficiaries will be willing to spend if they could receive the benefit, respectively avoid the negative impact, but only against payment. Where impacts cannot be readily measured and quantified, or prices determined from market data, the WTP can be determined by inferring a price from observations of consumer behaviour. This is a recognised approach used in CBA.

The same technique, combined with semi-structured interviews with healthcare professionals, can provide information to value the benefits to healthcare professionals. Valuing intangible negative impacts such as irritations and inconvenience can also rely on the same techniques. Intangible benefits for HPOs, such as reductions in risk exposure, are valued using insurance-based models. Benefits from efficiency gains are valued using estimates of the changes in unit costs from productivity improvements.

Quality adjusted life years (QALY), as a summary measure of benefits from a new medical intervention or a new medical device may be used in particular cases, according to data availability and the appropriateness of such a measure. QALYs are not an appropriate measure where the impact of using DebugIT tools in routine clinical settings concerns only the length and cost of acute (short duration) treatment. Generally, where eHealth applications improve citizens' experience of healthcare, but do not change the clinical outcome, QALY cannot be used as a measure for socio-economic impact. Similarly, QALYs are not helpful measures for the impact on carers, time savings, and improved productivity. However, where impacts include saving lives or reducing the risk of chronic illness or impairment, QALYs may be a good indicator for measuring the impact on patients. Whether QALYs will be used in the socio-economic outcome assessments will depend on the results of the clinical impact analyses.

4.5 Next steps

The next steps in outcome assessment will focus on investigating and planning the completion of the clinical impact assessment matrix depicted in Exhibit 5. It is important to make a realistic plan on how to fill in the missing boxes, or if not possible to complete the whole matrix, to analyse what this means for the quality of evaluation results. Also, the studies already in planning will be executed first at HUG, later prepared for other sites, based on HUG's experience.

[21] Modeling Without Data Using Expert Opinion by Vincent Goulet, Michel Jacques and Mathieu Pigeon http://journal.r-project.org/2009-1/RJournal_2009-1_Goulet+et+al.pdf

[22] eHealth is Worth it - The economic benefits of implemented eHealth solutions at ten European sites. Karl A. Stroetmann, Tom Jones, Alexander Dobrev, Veli N. Stroetmann. Luxembourg: Office for Official Publications of the European Communities, 2006 (56 pp. - ISBN 92-79-02762-X)

Regarding the socio-economic impact analysis, the immediate task for the third project year three are to further understand the realistic expectations for the functionalities and usability of the DebugIT tools. This task, to be addressed mainly through bilateral exchange with the project-internal clinicians, but also utilising the clinical advisory board, will lead to a robust hypothesis model to be ready by M 36. This model will also serve as input to the draft exploitation plan due in M 36.

5. Literature

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6. Contribution of the partners

The formal contributors to this deliverable are empirica and HUG. All other partners indirectly supported the work through their own achievements and reports, as well as fruitful informal exchanges.

6.1 Participants list

Nr	Partner	Name of representative(s)	Work performed
3	HUG	Christian Lovis, Patrick Ruch	Clinical impact studies conceptualisation and design
5	EMP	Alexander Dobrev, Karl Stroetmann, Dainis Zegners	Project evaluation and socio-economic impact assessment framework

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