Fraunhofer Institut System- und Innovationsforschung

# FAZIT Schriftenreihe

**Forschungsbericht Band 6**
**- English Version -**

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## Future Information Technology for the Health Sector

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# Executive Summary

Information technology in the health sector will (continue to) be an important topic in the oncoming years. This offers interfaces for new market potential for IT companies. However, which information technologies bring about change? This was the initial question for the Delphi study at hand in the context of the FAZIT project (research project for current and forward-looking information and media technology and its use in Baden-Wurttemberg). In order to find answers to this question, information technological developments were identified, which could become relevant during the next 20 years. Literature was sought, experts were consulted and a workshop was organised to generate the theses, focus on them and to phrase each individually.

During the selection period of the theses there was a first curious finding: The task instructed to phrase technical theses, which could have a beneficial effect on the health sector. However, those developments which have a strong impact on cost cutting and solving of problems cannot always be assigned to technical areas, they are moreover closely correlated to the German health care system, regulatory issues and organisational challenges. Correspondingly one finding of this study describes that although technical obstacles are a major hindrance, other obstacles play a significant role as well, e.g. the acceptance by parties involved and users, too.

To answer further questions on technological methods and their use, in a two-step online Delphi survey, the theses phrased in detail were evaluated by experts from scientific research organisations, companies, healthcare facilities and societies respectively associations in terms of the theses' importance, feasibility, desirability and obstacles.

In the first round 203 persons filled out the questionnaire completely or partially, in the second round, this was accomplished by 86 persons. This way, the results are fairly significant. Among the persons answering there were seven percent females, which resembles the share of the gender among researchers and technological developers in Germany. Differences in the answers between gender or age could not be detected.

Many of the technical solutions described in the theses which can lead to new markets consist of low-profile unspectacular developments. Some of the theses consist of scenarios that employ the use of a technology that, already today, is in use, e.g. telemonitoring of risk patients. However, it has turned out that, although there have been tests and first applications, monitoring on a closely-meshed base in the sharpened phrasing of the Delphi study as a "standard" this is not yet reality. In the overview all theses – near-future realisations as well as later ones – are expected to evolve around the year 2025, which means that future developments of individual theses display very different dynamics.

Theses which capture the industry's interest, e.g. technologies that can be applied to other sectors as well, should be more closely observed in the future. They are the important and interesting issues of the study: In the evaluation of realisation time and importance they are not among those expected in the near future, but are rather located in the chronological higher respectively early mid-table and are all considered desirable by most of the Delphi participants.

On the other hand, theses which employ applications which "get under the skin" are very controversial. In the Delphi study at hand all theses that involve implantation (e.g. retina implants, artificial kidneys, electrodes in the brain in order to prevent epileptic seizures, artificial heart and lung implant etc.) as well as transdermal intervention (e.g. biopsy robots) are considered desirable, however, desirability does not extend to the stage of other theses. Besides ordinary technical problems data integrity and data protection or acceptance by the persons concerned are often stated as obstacles.

For new markets in the sector of ICT-based health applications topics such as proteomics, telemonitoring, expert systems and databases, voice entry as documentary means or external data access are especially interesting and they receive the highest rating with respect to their importance in cost cutting, improving the healthcare system or the quality of healthcare. The topic "ambient intelligence" will particularly contribute to improving the quality of life.

All theses with high market potential for the IT industry are extremely knowledge-intense in their development and realisation. Correspondingly, some of the theses are to be found in the topic areas of the Federal Government's high-tech strategy (BMBF, 2006b and 2007). The few controversial theses of the Delphi study at hand refer to a higher investment risk for developers and manufacturers.

Many of the theses are not strictly limited to the health sector, but are rather important in other sectors in the future, too. Nearly all the phrased theses are considered feasible; nevertheless, experts see obstacles in their development in certain fields. Technical problems are predominantly mentioned. These are foremost in developments such as retina implants, artificial organs, micromachines and implantable minimal systems, voice recognition or genome analysis as standard health care applications. For other theses, they concern issues of data protection and data safety and thus regulative issues, which still need to be adapted to, e.g. radio frequency identification (RFID) or ambient intelligence. In a few cases, e.g. when considering surgery-executing micromachines, there are other, legal, questions (liability etc.).

Very often, high expenditure (initial investment or maintenance costs) is mentioned as an obstacle for realisation. For certain theses, on the one hand expenditure is considered an obstacle, on the other hand technology is rated as important for cost cutting. This, for instance, can be applied for ambient intelligence for monitoring patients at home or for non-invasive long-term blood pressure sensors. In these cases the odds must be weighed as to whether or not investing in the future is worthwhile. The Delphi results merely deliver starting points for further going discussion or measures.

All in all, it can be said that chances for the realisation of many of the phrased theses in the upcoming 10 to 15 years are not bad. While technical obstacles cannot be disregarded, they are, however, surmountable. New markets for ICT in healthcare applications are especially expected in the areas of voice recognition, virtual reality and simulations, databases, sensors, Radio Frequency Identification (RFID) or new management and planning systems.

# 1. Information Technology for the Health Sector: Which are the technical challenges?

Information Technology will (continuously) alter the Health Sector strongly in the coming years. But in how far? And which technologies will be those evoking these alterations? This was the core question for the study about Information Technology in the Health Sector at hand. Where and in which way can Information and Communication Technology contribute to improving or economising the Health System? What is, though technically possible, not desirable?

By means of the Delphi Study at hand about "Information Technology in the Health Sector" it has been analysed which specific contributions by Information Technology at all can improve the Health Sector, when they can be realised and which obstacles need to be overcome on the way towards realisation.

In order to answer these questions, the IT developments relevant for the next 20 years were identified and phrased in the form of theses. A two-step survey was conducted, during which experts evaluated the theses according to their importance, feasibility and desirability.

Even during the time of identifying the theses it became apparent, that although technology can indeed contribute to the sustainability of the Health System, the success of the technological innovations is strongly related to such factors as costs, acceptance, regulation or organisational alterations.

The study at hand represents a part of a larger project called FAZIT (Forschungsprojekt für aktuelle und zukunftsorientierte Informations- und Medientechnologie und deren Nutzung in Baden-Württemberg – research project for current and future information and media technology and its use in Baden-Wurttemberg), which is facilitated by the state of Baden Wurttemberg. Since the beginning of 2005, in the context of FAZIT the demand and applicability for innovative information and media technology has been analysed and long-term drivers, which lead to new market opportunities for ICT in Baden-Wurttemberg, are identified. The project is supported by the MFG Foundation Baden-Wurttemberg, the Centre for European Economic Research (Zentrum für Europäische Wirtschaftsforschung – ZEW), Mannheim and the Fraunhofer Institute for Systems and Innovation Research (Fraunhofer ISI) partner it.

A multi-step foresight process in the framework of the project, conducted by the Fraunhofer ISI, identifies the research and development units which are important for the innovation potential of the state of Baden-Wurttemberg. As this phenomenon reflects social as well as economical trends, a combination of foresight methods is applied. Social and technological developments are screened in three Delphi studies and are evaluated by experts regarding specific criteria such as their importance or their realisation time. The results enter a scenario process, in order to assess the future viability of Baden-Wurttemberg in the ICT sector and in order to delineate selected market segments.

The report at hand describes the second Delphi study of the project including the conduct of the survey and its method. Subsequently, the third chapter gives an overview of the results of

all theses. Detailed evaluations for each thesis and the results are described in chapter 4. The report is concluded with a short glimpse into the future.

## 1.1. Why and how to look into the future?

The FAZIT research project is scientifically embedded in the research approach of regional innovation systems, which understands innovation as an evolutionary and cumulative process that delivers feedback. Innovations can only be realised in economic and social interaction of various regional players and result in technological, organisational and social changes (Koschatzky, 2001). This, on the one hand, emphasises the social angle of innovation in the sense of a collective learning process and, on the other hand, the high relevance of involving all players of the region. The approach of regional innovation systems leads to the conclusion, that the future viability of Baden-Wurttemberg depends especially on the fact, how successfully knowledge is generated, newly associated and implemented in products. The key factor to successful innovation in the regional context is an institutionalised network between enterprises, universities and organisations as well as the social structure of innovations in the field of Technology Push and Market Pull (Leydesdorff, 2005).

Especially long-term research, long-range technological development or the influence of social mega trends brings about new products and profitable markets. In order to be able to outline long-term perspectives and design stable future prospects and not merely gain short-term vantage points, FAZIT combines various methods of future research. It is the aim, to embed the results globally, however, to focus on the location Baden-Wurttemberg and to point out specific local respectively regional challenges, in order to enable new strategies or to adjust and re-align existing strategies. The so-called “regional foresight” approach thus facilitates strategic decision-making on behalf of all players in the innovation system. The players are involved in the process of future research.

Future prospects should be linked to today’s decision processes. This way, they can, today, facilitate appropriate decisions and trigger acts, which are aligned according to a common future.

When designing future prospects one is very well aware of the fact, that the future is not predictable. However, there are certain developments, which can in fact be taken into consideration, especially in the fields of science and technology. When applying foresight methods, experts are primarily interested in those things, which are, above all, on the agenda. For this reason, foresight is a systematic glance into the future in terms of economy, science and society with the aim of identifying those fields of strategic research and new technology, which will most probably have a strong impact on economy and the well-being of human beings (see Martin, 1995 and Cuhls, 2003, respectively).

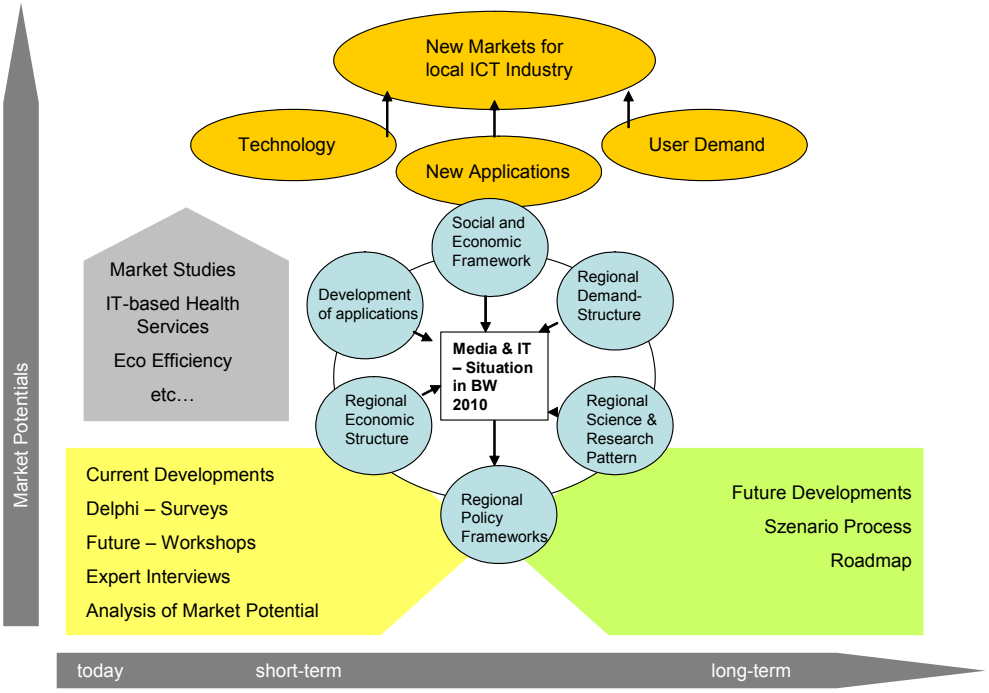
## 1.2. What is the Delphi Method?

The Delphi Method was developed in the 1950s by the Rand Corporation, Santa Monica, California, as a method of “operations research” (a type of system research, which uses statistics, mathematical models etc. for decision-making) for military research. In Japan, it has

been applied in national, civil context ever since the beginning seventies and has become an element of foresight processes throughout Europe since the beginning nineties (compare Blind/Cuhls/Grupp, 1999; 2002). The Fraunhofer Institute for Systems and Innovation Research conducted some of the first German national Delphi surveys for the Federal Ministry of Research and Technology (today Federal Ministry of Education and Research, Bundesministerium für Bildung und Forschung – BMBF). Ever since then, the method has been internationally refined together with a Japanese partner (Cuhls/Kuwahara, 1994; Cuhls/Breiner/Grupp, 1995). Thanks to new possibilities of electronic surveying, especially in the European and Asian context, the Delphi Method has gained more and more popularity (e.g. EUFORIA, FISTERA, Delphi of the Millennium Project; NISTEP, 2005; MOST, 2003 and 2005).

Delphi processes are generally surveys conducted in two or more rounds or "waves". As from the second round, feedback is given on the first round. The topics to be evaluated are generated through different sources, desk research or group processes. The interviewees are mostly professionals, often decision-makers from sectors such as the economy, research, but also associations or other organisations. During the second round, each interviewee can consider whether he or she will take the given evaluations of all questioned experts into account and be influenced by them (Häder/Häder, 2000).

**Illustration 1:** FAZIT Methodology and procedure of futurology




The three Delphi studies in the FAZIT context represent a demand-oriented Delphi regarding the question "How will we make use of information and communications technology in the year 2020" (by Oertzen/Cuhls/Kimpeler, 2006) as well as two technology-related Delphi surveys. The Delphi study at hand relates to the question, which specific forward-looking contributions information technology can make towards solutions in the Healthcare sector.

Which technologies are to be expected? What is technically feasible? What is desired and what is not desired? How important are the developments? In how far are there obstacles for the realisation? These are the questions which the experts are asked in the Delphi study.

The results are collected in the FAZIT scenario process (see illustration 1). In the third and final Delphi those technological theses are seized, which, from the scenario-development point of view, require further evaluation. A combined method of scenarios and Delphi processes offers the contentual added value that information concerning specifically detailed theses can be compiled and coherent future prospects can be delineated. Theses and developments can thus be treated in the context of these future prospects (Kinkel/Armbruster/Schirrmeister, 2006).

The discussions initiated through the FAZIT project and respectively the Delphi process with experts and decision-makers need to be continued. Several results can and should be enlarged upon, so that the resume of FAZIT clearly shows, where new markets can evolve and how facilitating measures at the location Baden-Wurttemberg can be enforced.

# 2. Procedure for the Delphi survey

For a Delphi survey theses, which are to be evaluated according to a grid of criteria, are phrased. This is why a Delphi study begins with the theses-finding phase and the phrasing of the assembled theses, the so-called theses generation. After that follows the questionnaire design. At the same time, participants for the survey are identified. The Delphi study concerning information technology for the Health Sector is a two-step internet-based survey.
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## 2.1. Theses generation

This second FAZIT Delphi study involved an internal workshop during which developments in information technology on the one hand and possible fields of application on the other hand were compiled together. They were entered in a mind map (for information on working with mind maps, see Buzan/Buzan, 1993) in order to display the topic in a structured way (see illustration 2). This structure was expanded and enlarged step by step.

Studies with regard to medical technology and information technology in the Health Sector were screened (e.g. Hornschild/Raab/Weiss, 2005; BMBF, 2005; Jackson, 2002). Long-term developments, which could be classified in the sense of "future technological problem-solving" were selected and evaluated regarding whether or not they could be of any importance to the state of Baden-Wurttemberg. They, too, were integrated in the mind map, so that the mind map in the end consisted of two completed levels. Illustration 3 shows a branch of the mind map. This level was not only important for the structuring process of the topic; moreover it helped selecting those topics, which could be of importance in the future. The accurate phrasing of the theses took place at a later point of time, based on these guiding principles.

Based on the framework of this first overview, experts on the topic were invited to a workshop in Karlsruhe on 5 April 2006, in order to assist in

- Assessing the overview, updating it, completing it and respectively re-phrasing, as well as
- Elaborating in phrasing detailed theses.

**Illustration 2:** Basic structure (mind map)

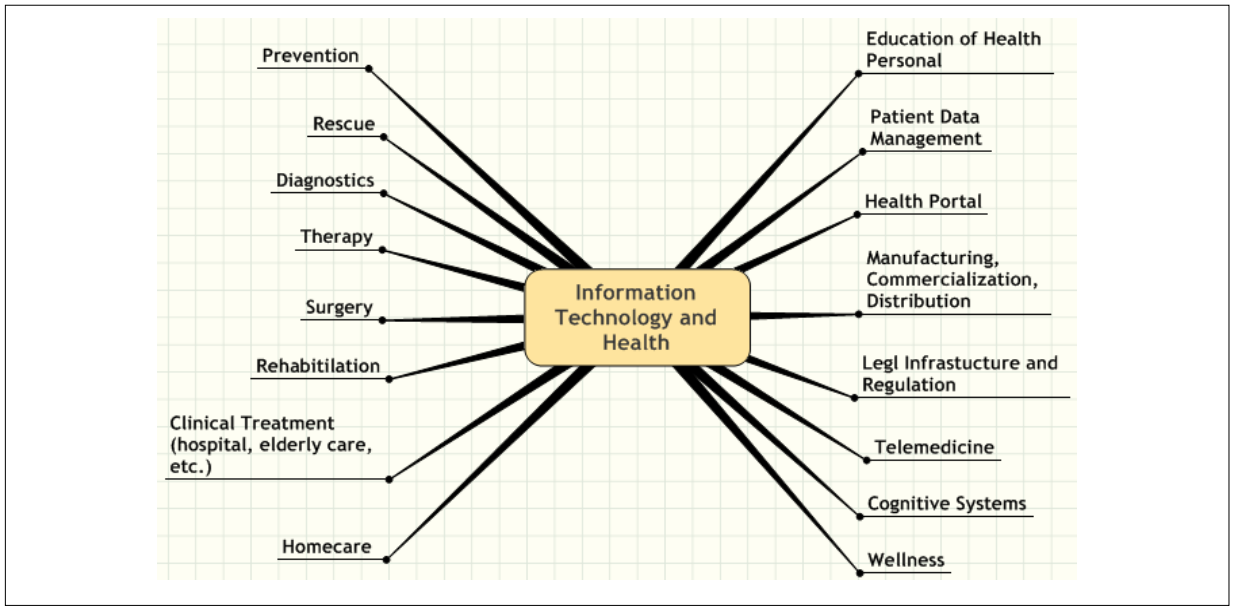
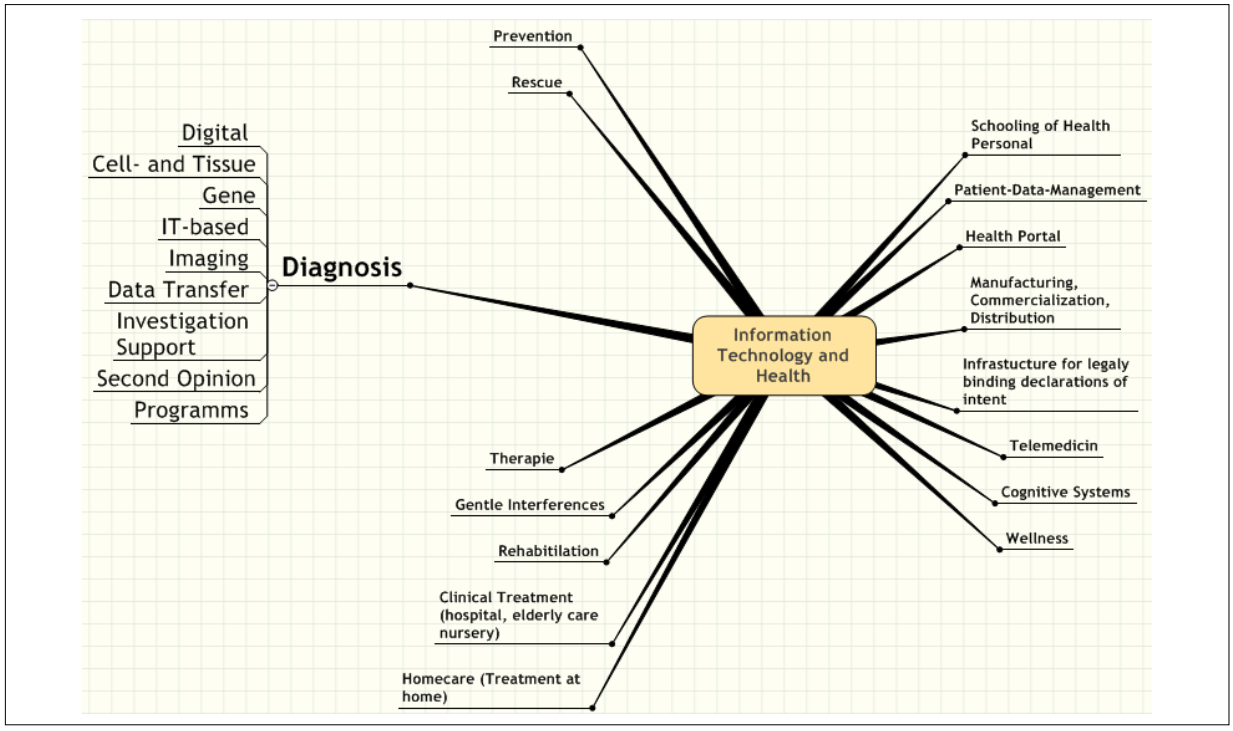



**Illustration 3:** Exemplary path of mind map for thesis generation (excerpt)




Experts from applied sciences, the economic sector as well as from a physicians' association and a health insurance took part in this workshop. Even after it, they were available for revisions and consulting.

The theses for the Delphi study were supposed to meet the following requirements:

- include a technological challenge.
- be realisable by the year 2030.
- be associated with the health system (contribute to cost reduction or better quality of healthcare etc.)

- be phrased in a positive way, in order to include a desirable excerpt of the future.

It transpired that the actual challenges are not so much seen in the technological field, moreover in organisational changes of the health system, of applicable regulations and acceptance of the technology. This is why often-discussed topics such as the electronic patient data card were considered as a challenge, but dismissed as a Delphi thesis. According to experts, the patient data card yet requires technical upgrading (in terms of data storage capacity, standardisation, adjustment to infrastructure etc.) and there still are various technical obstacles before it can be used, these problems, however, could all be solved according to requirement within a relatively short period of time. Initially, decisions need to be made, such as: What information and how much information will the data chip card contain? Will it contain the whole patient record or merely excerpts? Or does the card simply represent a key to a decentrally organised total system? Which infrastructure is necessary and how is this infrastructure organised? Who has access under which conditions? The thesis regarding the patient data card was therefore not considered. On the other hand, around 50 other theses were phrased.

The 36 theses considered most interesting and most promising were selected, focused on for the survey and phrased accurately.

## 2.2 Questionnaire design

After a trial phase the Delphi questionnaire was made available exclusively via the internet and tested. Following the phase of topic selection, the specific theses were elaborated in two feedback rounds by participants of the workshop and other external experts. For this, participants were assigned access codes, so that each person could work on his/her personal questionnaire sheet and interrupt it, retrieve it and add to it at another time. The first phase began on 16 May 2006 and ended on 10 June 2006. The second round, which began directly after this ended on 19 July 2006. A reminder email was always sent out after about three weeks, motivating the participants to deliver their feedback.

In the second round, only those participants were contacted via email, who had taken part in the first round. For this, during the first round email contact addresses and various pieces of personal information had been asked for.

The questionnaire design during the second round resembled that of the first round, however, each thesis' results compiled of a recapitulation of all participants' feedback, so that the experts could consider them when evaluating the answers again. The survey was conducted – as usual for Delphi – anonymously, so that nobody would lose their face when changing their opinion. In fact, several participants changed their points of view.

According to the purpose of the study, it was the aim to find out which specific forward-looking contributions information technology can add to solutions in the health sector. Which technologies are there? How will their application in the health sector work? Where and how can information and communication technology contribute to an overall improvement of the health system, to healthcare, to a higher quality of care or to cost reduction? What is technically realisable and when? Is the application of the technology desirable? In how far is

the thesis important? Where can one see obstacles for the realisation? These are the exact questions that were presented in the Delphi study.

This is what the questionnaire looks like (an example sheet of the second round is supplied in the annex): The question about which technologies are to be expected was treated during the phrasing phase of the theses. Subsequently, the questionnaire begins with the **naming of the thesis**. Questions regarding the thesis follow. The first question concerns a self-evaluation of expertise. This is followed by the question, as to when the topic can be realised (in five-year steps), respectively whether or not it will ever be realisable. Directly after this, desirability of the topic is evaluated: Do you consider the realisation of the thesis altogether desirable? Here, the answer options “yes”, “no” and “do not know” can be marked.

The question regarding the importance of the thesis is subdivided into importance regarding

- cost saving
- better health provision
- quality of healthcare
- technological progress
- higher quality of life
- environmental safety and sustainability as well as
- others (naming possible).

Appropriately this question may be (multiply) marked. The following questions refers to the fact, as to which other sectors apart from the health sector the technological development mentioned in the thesis may be applicable, too. Stated in the questionnaire are the following:

- product development
- Management
- Industry and production
- logistics
- sales
- environmental management
- traffic, mobility
- other sectors (naming possible).

Here, too, multiple marking is allowed.

The last question regards the obstacles, which may obstruct the realisation of the thesis. Multiple naming and marking is allowed. The assumed obstacles are:

- technical problems
- research & development infrastructure
- research financing
- costs

- acceptance by those concerned
- user acceptance
- data safety, data security
- standards
- regulations
- influence of interest groups
- (higher) education, as well as
- others (naming possible).

The questionnaire design allows for free commentary. If desired, the participants can merely read the thesis and use the "forward" button to skip to the next thesis. Selective filling out of each thesis is possible, too.

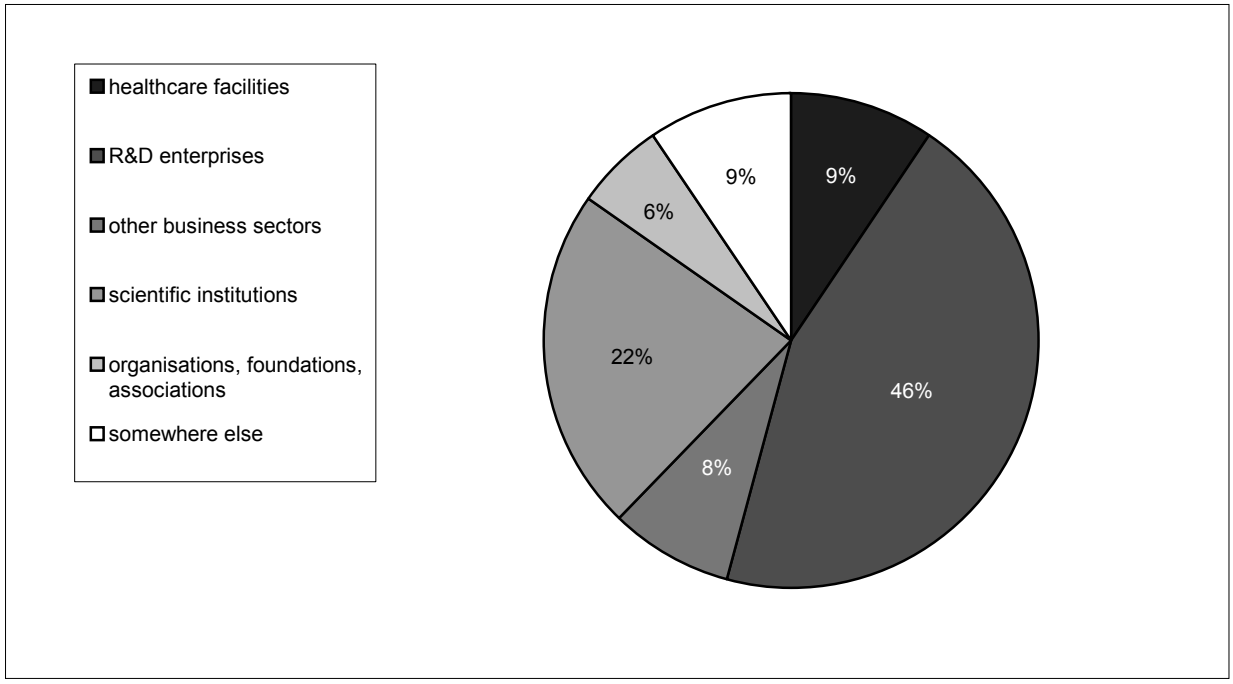
## 2.3. Sample of participants

The selected participants of the Delphi study are recruited from scientific research institutions, enterprises, and organisations and associations of the healthcare sector (see illustration 4). Their addresses were filtered from publicly accessible databases. Since the survey requires expertise on both sectors, healthcare and information technology, the participants were selected accordingly. Additionally participants were recruited from patent databases, if they had applied for a patent in the respective classification during the last three to five years.

The procedure of using patent databases for address research is new for this kind of survey, however, it does bring about problems. The prospect of patent applicators actually answering a questionnaire was not assumed to be as high as the response ratio among other participants, especially since patents are applied for giving home addresses, which can frequently change. On the other hand these persons have a high expertise. Many of the contacted had moved away from the known address, the contact letters were returned. Others phoned back upon receiving our mail, enquiring where we had their private home address from. The latter ones could often be convinced of the advantages of participating in the survey. A couple of recipients were pensioners who unfortunately perceived themselves too old to take part in a futurology study.

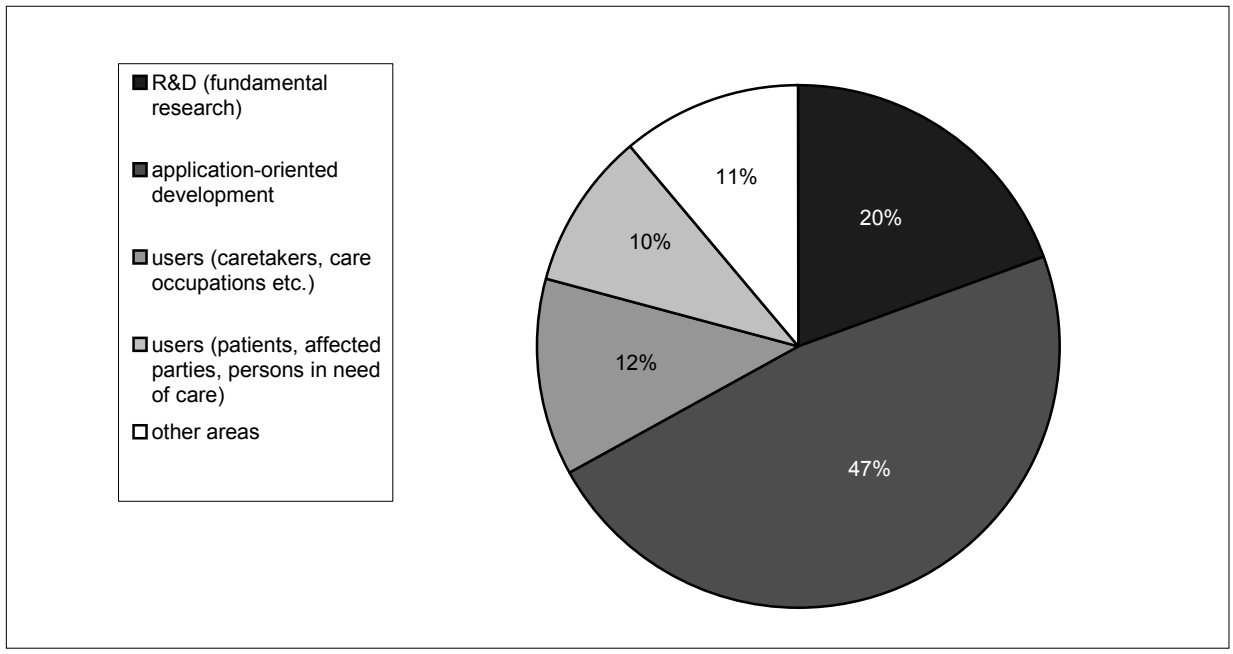
In the first round 203 participants answered the questionnaire completely or in parts, in the second round this was accomplished by 86 persons. Among those seven percent were females, reflecting their share in research and technology development in Germany.

**Illustration 4:** Where do participants come from? (second round of survey)



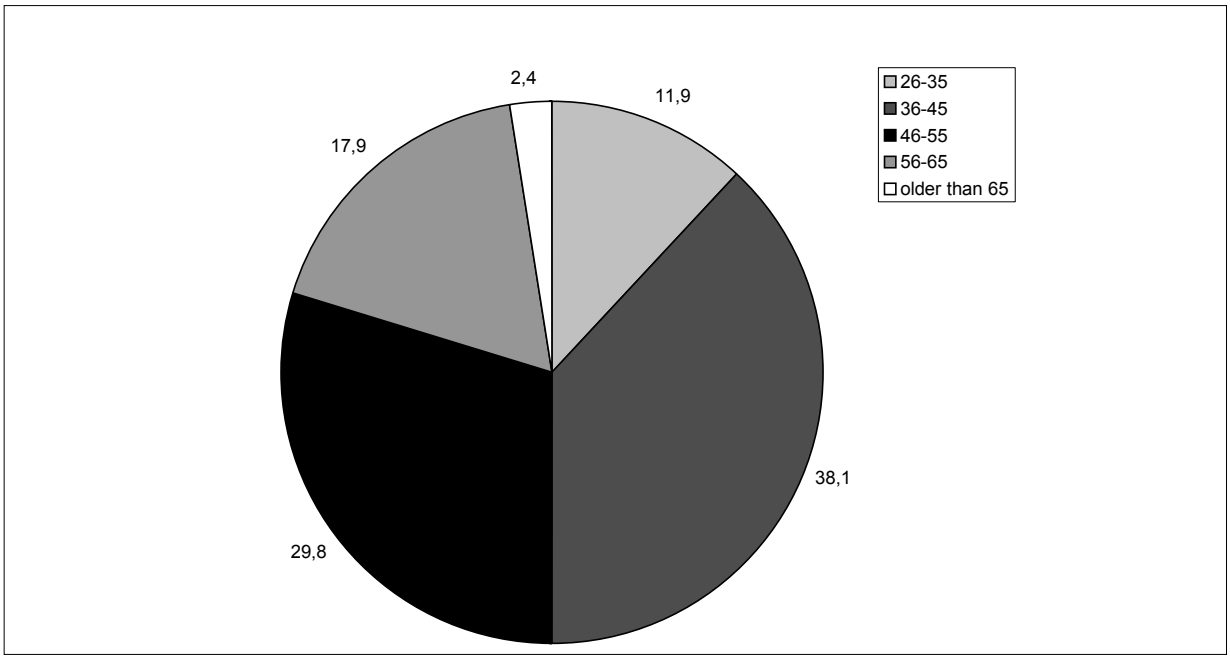

Most Delphi experts are from company research and development departments (46 percent). A further share of 22 percent works for scientific institutions (22 percent). The other participants can be divided into other business sectors (industry) and organisations, foundations and associations. Around nine percent of the participants work "somewhere else". Nearly half of the participant group work on application-oriented developments (illustration 5), nearly 20 percent work in research and development (fundamental research), 12 percent are users (caretakers, care occupations etc.) and around 10 percent are users in the sense of a patient perspective or that of an affected party or in need of care. 11 percent are from other areas.

**Illustration 5:** Shares of participants with respect to research areas



The age distribution (illustration 6) is relatively even, with persons aged below 25 or above 65 providing no or hardly any share.

**Illustration 6:** Age distribution of participants




The number of answers received in the Delphi study at hand is sufficient for statistical evaluation, even though the feedback ratio (percent share of responses in relation to mailings) is lower than response rations for traditional postal surveys (generally between 70 and 85 percent). Especially during the second round participation dropped in comparison to what experience in other traditional postal surveys (especially Delphi surveys) lead to assume.

Evaluation was rated according to differences in the answering habits of the participants, according to age and respective expertise. The mean of all data shows no grave differences in age, expertise or expertise, which could lead to clues for divergent opinions. There are, however, differences to be identified for specific theses (see chapter 4). Worth remarking is the fact that the *mean ratio* shows no grave differences between participant groups in terms of the selected topics for the health sector, references to certain topics, however, are deducible.

# 3. Overview of Results

## 3.1. When are the theses considered feasible?

The timeframe for realisation was not polled exactly, moreover in five-year steps, since nobody knows exactly what lies in the future. This is shown with a median and the quartiles Q1 (25 percent step) and Q2 (75 percent step). Exactly half of the participants give answers that are located between the ratios of Q1 and Q2. One quarter gives evaluations that are ranged below this timeframe, one quarters' evaluations range above it. This way a range of opinions can be described. If the lower (Q1) and upper quartile (Q2) are very close to each other, half of the participants (generally even the majority) are consistent in their evaluation. If they are further or far separated, there is no or hardly any consensus or there may be large precariousness about the time of realisation. Table 1 shows when participants expect the realisation, for all theses. The theses are sorted according to the median, meaning the 50 percent mark, ranging from early realisations to later ones. The median can be calculated by help of a complex formula (compare Cuhls/Kuwahara, 1994; BMFT, 1993). There is an easier way to calculate it, as well: The answers are sorted according to the five-year steps from 2006 to 2010, from 2011 to 2015, from 2016 to 2020, from 2021 to 2025, from 2026 to 2030 and "later". Afterwards, the number of answers is counted, divided by two and claried as to where the answer is located (assuming an even distribution within each marking box). Example: 100 persons answered, each box received 20 marks, and nobody marked "later". This means, the 50$^{th}$ respectively 51$^{st}$ person's answer is located in the exact middle of the box ranging from 2016 to 2020, the year being 2018. This is the median.

**Table 1:** Realisation of all 36 theses sorted by year of realisation (early to late)

| Theses | Year of realisation (50 percentage point) |
|---|---|
| Expert systems and databases, which monitor customised medications for individual patients with respect to undesired medication interactions and recommendations for a pharmaceutical therapy with reduced adverse reactions and side effects, are tested in pilot experiments. | 2010 |
| Patients in hospitals are directed by an EDP-supported planning system, so that waiting periods, e.g. at admission, diagnostic procedures (X-ray, CT, endoscopy, etc.), operation are minimised and at the same time the overall efficiency of hospital facilities is enhanced. | 2010 |
| Regional microwave hyperthermia can be ideally planned with a computer simulation of the biothermal conduction. | 2012 |
| A computerised system exists, which allows practice-based physicians to access all information at hand about the patient (cryptographically secured) via a terminal of their choice during house calls. | 2012 |
| Virtual reality is a standard in training of medical staff (e.g. virtual surgery, practising of minimally invasive interventions, endoscopy, rescue practices, patient interviews etc.). | 2012 |
| A non-invasive long-term blood pressure sensor has been developed. | 2012 |
| Documentation tasks in hospitals are routinely performed via voice entry. | 2013 |

| Theses | Year of realisation (50 percentage point) |
|---|---|
| Telemonitoring, i.e. close-meshed monitoring of patients (at risk), evaluation of the generated information in and by medical facilities and, if necessary, alerting the treating physician, has become a standard. | 2013 |
| Wireless rechargeable implanted defibrillators are used, which convey their measured data to a control unit, which then conveys its data to a service centre for a check up and for an emergency report, if necessary. | 2013 |
| Ambient Intelligence in a house allows monitoring of patients at home (via camera, thinking carpet, furniture equipped with sensors, immobility sensors), reporting irregular features to an emergency call centre. | 2013 |
| An implantable data carrier has been developed, storing all data of a patient necessary for treatment and administration. | 2013 |
| Labs-on-Chips are broadly applied for "point of care" diagnoses of clinically relevant parameters such as proteins, antibodies, hormones, bilirubine, cholesterol, urea as well as enzymes in blood and urine. | 2013 |
| Computer-supported planning of biologically adaptive resonance therapy (ART), which allows an individual adaptation of the therapy to heterogeneous tissue, is possible. | 2013 |
| Voice recognition and correct relation of a voice to the person speaking is so accurate, that surgeons are able to navigate instruments through voice commands and are thus effectively relieved. | 2013 |
| Electrodes in the brain detect a beginning epileptic seizure and prevent it through specific electrical stimulation patterns. | 2013 |
| Expert systems are routinely appointed to recommend specific advice for diagnoses and therapies to the healthcare staff. | 2014 |
| A wireless label system (RFID) is introduced to common households, allowing patients who easily and often forget things (due to dementia, Alzheimer's disease etc.) to find anything and be attentive to things of importance. | 2014 |
| Technologies are applied in research, which allow forecasts on biological activity of proteins and their functional domains via information as to their spatial configuration. | 2014 |
| Interactive electronic logopaedics trainers are a standard. | 2014 |
| Fully functional robot systems have been developed and tested for transdermal intervention (e.g. biopsy robots). | 2014 |
| Valid diagnostic test procedures based on functional Magnetic Resonance Imaging (MRI) are clinically used for diagnoses with mental diseases (e.g. manic-depressive diseases) and diseases of the central nervous system (e.g. Alzheimer's disease). | 2014 |
| Routine whole-body scanning with functional imaging is a standard procedure after accidents. | 2014 |
| Protein-chips for "Point of Care" diagnostics have been developed and tested. | 2014 |
| Histological diagnosis of tissue in vivo is possible with the help of spectroscopic, microscopic laser scanning methods. | 2014 |
| Clinically applicable systems consisting of implantable glucoses sensors, actuators and insulin reservoirs as well as corresponding control software have been developed, allowing an optimum fine-tuning of diabetes patients. | 2014 |
| In emergency cases, in order to be able to identify a person very soon after an accident, a quick genetic test is completed and the data is matched with a profile database. | 2016 |
| Due to IT approaches (simulations, virtual animal models), 80% of all animal testing in medical and pharmaceutical research becomes redundant. | 2016 |

| Theses | Year of realisation (50 percentage point) |
|---|---|
| Methods for quick analysis of the genome, e.g. DNA Chips, high-speed sequencing or genetic mapping are applied in healthcare routine. | 2017 |
| Vital parameters (blood pressure, blood levels, antibodies, hormones) can be deciphered via implanted chips. | 2017 |
| Blind persons can orient themselves within a room with a retina implant. | 2018 |
| Standardisation and processing of the large mass of data delivered through proteomics has developed a predictive and integrative biology, consisting of techniques for visualising results, automatic matching with other genome-comprising data records as well as the integration of additional "-omics" (genomics etc.) approaches. | 2018 |
| Many hospitals employ robots for difficult and standard procedures in nursing (e.g. putting someone into another bed, changing of bedclothes) in order to relieve the nursing staff and enable them to have more time for personal attentiveness towards the patients. | 2018 |
| Retina implants improve dramatically and thus become ready for use through combination of functional and morphological data, the evaluation of the data by expert systems and the cross linking of the various systems. | 2019 |
| Surgeries within the body, which are conducted by a remote-controlled micromachine, equipped with sensors and actuators, are possible. | 2019 |
| Entire artificial kidneys have been developed. | 2022 |
| An artificial heart and lung implant receives marketing approval. | later |

The scale of evaluations in the questionnaire ranges up to the year 2030, which means that it is not possible to give an exact estimate for evaluations dated after this, the table simply lists "later". The estimate "never" was calculated by percent and only mentioned when the ratio is very high.

The realisations expected later are either very specific (proteomics, retina implants, for better understanding see chapter 4), extremely controversial, as "operations conducted via micro machines", respectively "nursing robots", or they pose technical and technological challenges, like the two theses concerning artificial organs "fully artificial kidneys are developed" and "an artificial heart and lung implant receives market approval"). Correspondingly, such theses can only become reality at an earlier stage if there are measures taken into consideration, which promote them. Approaches referring to this are to be found in chapter 4.

All theses are considered feasible, only a small minority marked "never" realisable for the categories – which will be explained at a later stage – "desirability" and "importance" of the theses considered most controversial (see also following chapter). These are the five theses:

1. Many hospitals employ robots for difficult and standard procedures in nursing (e.g. putting someone into another bed, changing of bedclothes) in order to relieve the nursing staff and enable them to have more time for personal attentiveness towards the patients. (nearly 24 percent say "never")

2. Due to IT approaches (simulations, virtual animal models), 80% of all animal testing in medical and pharmaceutical research becomes redundant. (12 percent say “never”)
3. An implantable data carrier has been developed, storing all data of a patient necessary for treatment and administration. (12 percent say “never”)
4. Voice recognition and correct relation of a voice to the person speaking is so accurate, that surgeons are able to navigate instruments through voice demands and are thus effectively relieved. (10 percent say “never”)
5. In emergency cases, in order to be able to identify a person very soon after an accident, a quick genetic test is completed and the data is matched with a profile database. (nearly 10 percent say “never”)

## 3.2. Nearly all selected theses are desirable

In this Delphi study the desirability of the theses was directly determined. The questioned posed was: Do you personally find the realisation of this thesis altogether desirable? Nearly all topics open for discussion were considered desirable (mostly more than 90 percent). There even are theses, which gained 100 percent approval, they are:

- Entire artificial kidneys have been developed.
- Virtual reality is a standard in training of medical staff (e.g. virtual surgery, practising of minimally invasive interventions, endoscopy, rescue practices, patient interviews etc.).
- Blind persons can orient themselves within a room with retina implants.
- Computer-supported planning of biologically adaptive resonance therapy (ART), which allows an individual adaptation of the therapy to heterogeneous tissue, is possible.

Only for theses are controversial as to their desirability, i.e. their ratio for “desirability: yes” is far lower than the mean ratio, though still fairly high:

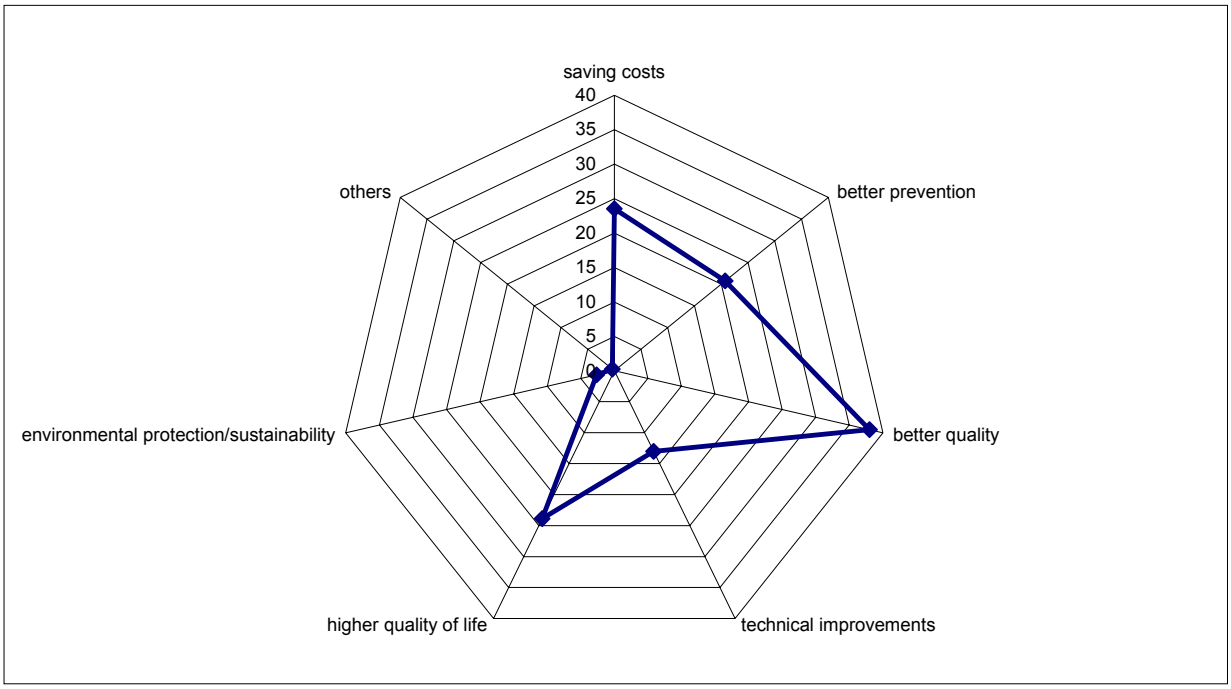
- An implantable data carrier has been developed, storing all data of a patient necessary for treatment and administration. (64 percent say “no”)
- Many hospitals employ robots for difficult and standard procedures in nursing (e.g. putting someone into another bed, changing of bedclothes) in order to relieve the nursing staff and enable them to have more time for personal attentiveness towards the patients. (54 percent say “no”)
- In emergency cases, in order to be able to identify a person very soon after an accident, a quick genetic test is completed and the data is matched with a profile database. (20 percent say “no”)
- Methods for quick analysis of the genome, e.g. DNA Chips, high-speed sequencing or genetic mapping are applied in healthcare routine. (14 percent say “no”, 14 percent say “do not know”)

Two of these theses, which are not necessarily desirable, show the highest ratios for "never realisable". Perhaps they will not be realised or only realised at a later stage, since, in their contemporary form, they do not belong to the desirable theses. Especially controversial, for many years now, are the "robots in nursing" (see also BMFT, 1993 or Cuhls/Blind/Grupp, 1998). Commentaries of participants indicate that they will become an inevitable necessity regarding the "healthcare crisis" and demographic change, which will probably aggravate problems in nursing and healthcare. Prototypes of such robots in fact, already exist (e.g. Care-O-Bot at the Fraunhofer Institute for Production Technology and Automation, IPA, 2006). Alternative solutions to robotised nursing need to be found on other levels apart from the purely technological one (attractiveness of nursing occupations, salaries etc.) The technology as such will surely be applied in other service areas, too – or even earlier.

## 3.3. Quality of Healthcare and importance of higher quality of life

The next question referred to the importance of the thesis, not so much overall, moreover on a cost reduction basis, technological progress, better healthcare provision, quality of healthcare, quality of living, environmental protection, sustainability or others. Evaluations by Delphi experts show that the importance of the averagely most often mentioned theses is laid upon a better quality of healthcare and higher quality of life for human beings. However, both were only marked by around half of the participants. The values are not very high, suggesting the ranking of the theses' mean importance not very high, either. Since multiple marking was allowed, the naming of topics is broadly distributed. In this manner, cost reduction, better healthcare provision and technological progress were marked as well, however, values varied between respective theses, which makes the average depicted in illustration 7 less convincing. As cost reduction was marked for one thesis and other categories more often for others, the marks spread out in the percentage analysis. More detailed ascertains are recorded in chapter 4.

**Illustration 7:** What are the topics important for?




The theses are not of importance for technological progress itself or environmental protection or sustainability. The latter is not surprising, since the topics dealt with concern application-related healthcare. The only thesis playing a major part in terms of environmental protection and sustainability is: “Due to IT approaches (simulations, virtual animal models), 80% of all animal testing in medical and pharmaceutical research becomes redundant.”.

However, what can be shown is the fact that even though the development of new information technology will be important for applications, it will not serve as a driver for technological progress as such. The only topic considered important for technological process by more than 80 percent of the experts is: “Standardisation and processing of the large mass of data delivered through proteomics has developed a predictive and integrative biology, consisting of techniques for visualising results, automatic matching with other genome-comprising data records as well as the integration of additional “-omics” (genomics etc.) approaches.”. Does information technological progress only provide such few impulses to the healthcare sector?

The following theses respectively are important for a better quality of healthcare, more than 90 percent of the participants considered them important:

- Computer-supported planning of biologically adaptive resonance therapy (ART), which allows an individual adaptation of the therapy to heterogeneous tissue, is possible.
- A computerised system exists, which allows practice-based physicians to access all information at hand about the patient (cryptographically secured) via a terminal of their choice during house calls.
- Patients in hospitals are directed by an EDP-supported planning system, so that

waiting periods, e.g. at admission, diagnostic procedures (X-ray, CT, endoscopy, etc.), operation are minimised and at the same time the overall efficiency of hospital facilities is enhanced.

- Telemonitoring, i.e. close-meshed monitoring of patients (at risk), evaluation of the generated information in and by medical facilities and, if necessary, alerting the treating physician, has become a standard.
- Histological diagnosis of tissue in vivo is possible with the help of spectroscopic, microscopic laser scanning methods.
- Expert systems and databases, which monitor customised medications for individual patients with respect to undesired medication interactions and recommendations for a pharmaceutical therapy with reduced adverse reactions and side effects, are tested in pilot experiments.
- Surgeries within the body, which are conducted by a remote-controlled micromachine, equipped with sensors and actuators, are possible.
- Regional microwave hyperthermia can be ideally planned with a computer simulation of the biothermal conduction.
- Virtual reality is a standard in training of medical staff (e.g. virtual surgery, practising of minimally invasive interventions, endoscopy, rescue practices, patient interviews etc.).
- Expert systems are routinely appointed to recommend specific advice for diagnoses and therapies to the healthcare staff.
- Valid diagnostic test procedures based on functional Magnetic Resonance Imaging (MRI) are clinically used for diagnoses with mental diseases (e.g. manic-depressive diseases) and diseases of the central nervous system (e.g. Alzheimer's disease).
- Protein-chips for "Point of Care" diagnostics have been developed and tested.
- Routine whole-body scanning with functional imaging is a standard procedure after accidents.

For better healthcare provision the following two theses were considered to be the most important by more than 80 percent of the Delphi experts:

- Labs-on-Chips are broadly applied for "point of care" diagnoses of clinically relevant parameters such as proteins, antibodies, hormones, bilirubine, cholesterol, urea as well as enzymes in blood and urine.
- A non-invasive long-term blood pressure sensor has been developed.

Six of the theses were considered to be especially important with reference to cost reduction; predominantly, with a share of more than 85 percent of the participants, naming systems with software solutions for data processing (the first three theses). The other three theses were named by more than 80 percent of the participants.

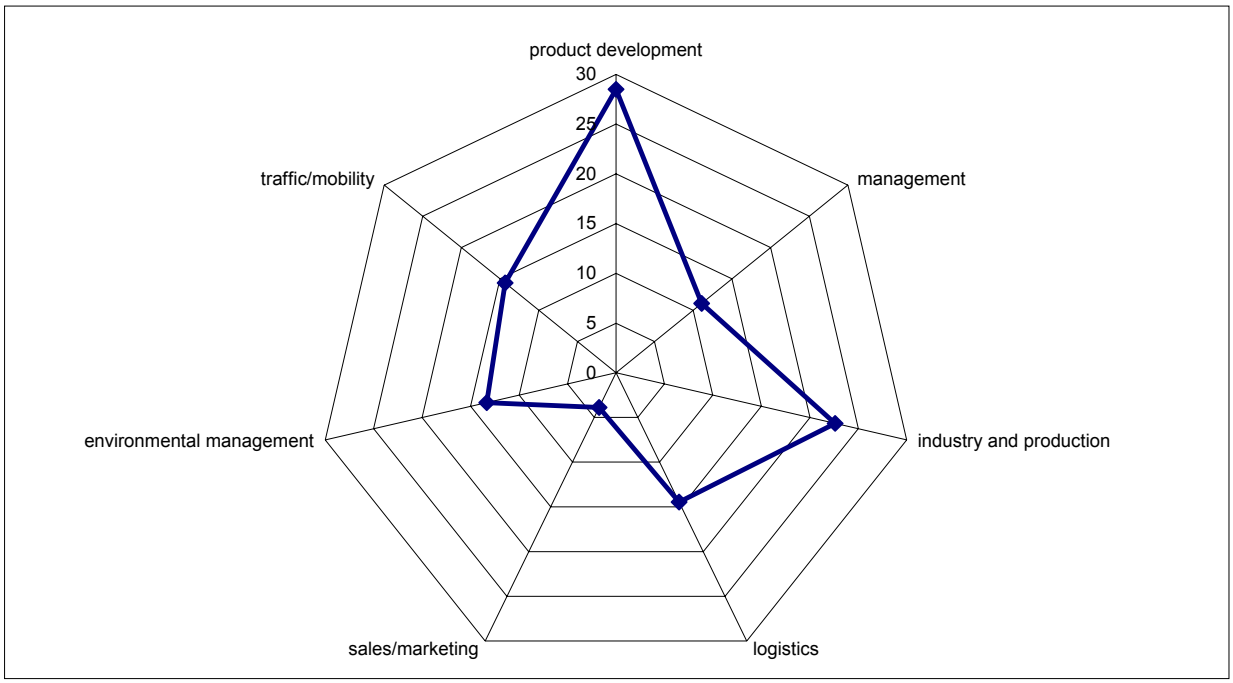
- Patients in hospitals are directed by an EDP-supported planning system, so that waiting periods, e.g. at admission, diagnostic procedures (X-ray, CT, endoscopy, etc.), operation are minimised and at the same time the overall efficiency of hospital facilities is enhanced.
- Documentation tasks in hospitals are routinely performed via voice entry.
- A computerised system exists, which allows practice-based physicians to access all information at hand about the patient (cryptographically secured) via a terminal of their choice during house calls.
- Virtual reality is a standard in training of medical staff (e.g. virtual surgery, practising of minimally invasive interventions, endoscopy, rescue practices, patient interviews etc.).
- Labs-on-Chips are broadly applied for "point of care" diagnoses of clinically relevant parameters such as proteins, antibodies, hormones, bilirubine, cholesterol, urea as well as enzymes in blood and urine.
- Due to IT approaches (simulations, virtual animal models), 80% of all animal testing in medical and pharmaceutical research becomes redundant.

## 3.4. Applicability in other areas

The named information technology theses are not only applicable in the health sector; many of the technologies can be applied to other areas. The choice offered the sectors product development, management, industry and production, logistics, sales, environmental management, traffic and mobility and "others" (see illustraion 8). Surprisingly, for each thesis different sectors were named, which means each of the technology approaches offered for discussion is applicable in another area. This demonstrates the objective of demonstrating how information technological approaches have been selected, which will not only concern the health sector, but be of interest to other "markets" as well.

The application named alternatively in most cases was product development. Even though the mean evaluation by the Delphi experts resembles 28 namings the ratio can be considered high, as so-called technological approaches were not estimated to be that diverse. None of the technologies in the theses is considered applicable for "none" of the named areas. "Other" areas than those offered could be named and phrased, this, however only took place rarely (average one mark), this is why they are not represented in illustration 8.

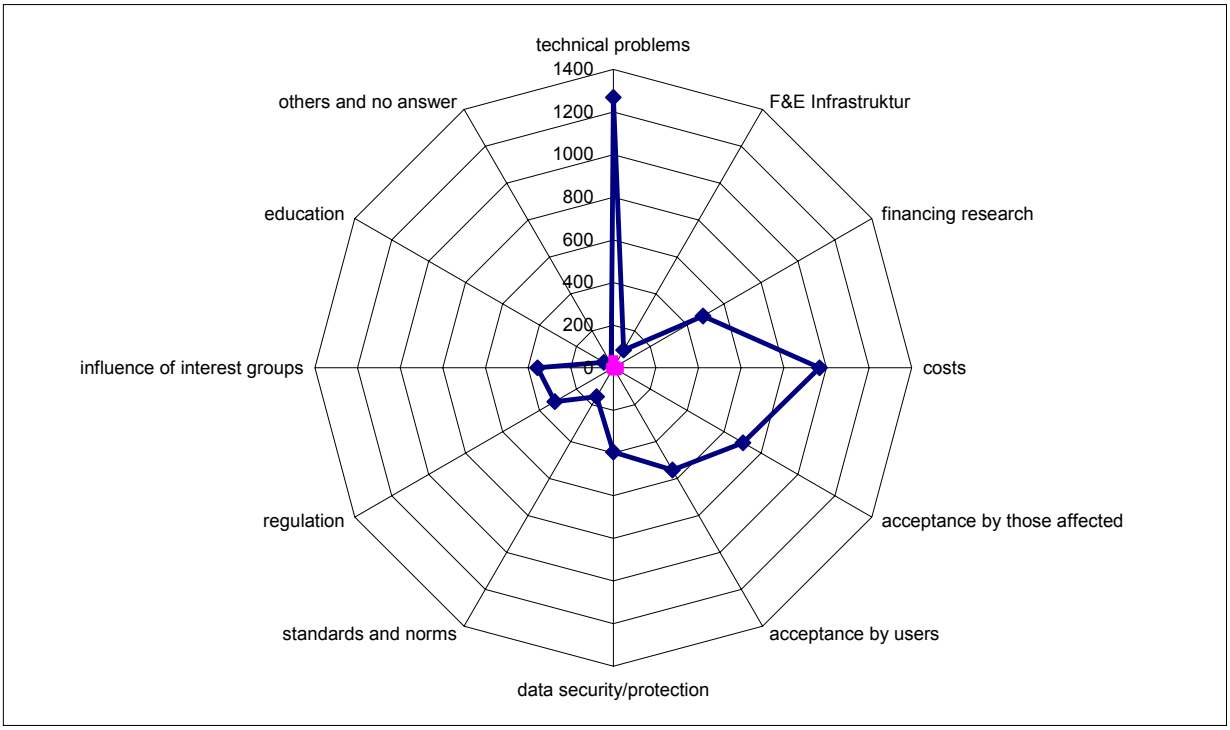
**Illustration 8:** Application of the technology of the theses in other areas




## 3.5. Technical problems are the main obstacle for realisation

Even though the participants in the Delphi study rated technical problems as the largest obstacle (see illustration 9, based on the number of namings) they believe problems are solvable. This precisely is the reason why the topics were included in the Delphi study: They should represent a technical challenge; on the other hand they need to seem realistic. Thus, the selected topics seem to be the "right" ones, particularly since they receive relatively high ratings in the evaluations on importance (see above).

**Illustration 9:** Obstacles for realisation




Note: All namings/markings were counted and divided by the number of theses in order to obtain a mean value. Multiple namings were possible.

35 participants among 86 participants in the second round marked “technical obstacles”. The 10 most-marked theses are presented in table 2. Respectively more than 90 percent of the participants marked a cross here.

The analysis of the “obstacles for realisation” shows, that, apart from technical problems, realisation of individual theses could fail due to the high costs. Overall costs were not mentioned often, but came second in the field of realisation problems – even if cost reduction may serve as a reason for realisation of the theses (see chapter 3.3). In singular cases, this contradiction is rare to be found (see chapter 4) and then generally refers to topics, which are connected to high investment expenditure and may only lead to long-term cost reduction and saving.

**Table 2:** Top 10 these posing the largest technical problems

| Theses | Namings in percent |
|---|---|
| Retina implants improve dramatically and thus become ready for use through combination of functional and morphological data, the evaluation of the data by expert systems and the cross linking of the various systems. | 100 |
| Entire artificial kidneys have been developed. | 95,5 |
| Computer-supported planning of biologically adaptive resonance therapy (ART), which allows an individual adaptation of the therapy to heterogeneous tissue, is possible. | 94,6 |
| Surgeries within the body, which are conducted by a remote-controlled micromachine, equipped with sensors and actuators, are possible. | 94,5 |
| Clinically applicable systems consisting of implantable glucoses sensors, actuators and insulin reservoirs as well as corresponding control software have been developed, allowing an optimum fine-tuning of diabetes patients. | 93,8 |
| An artificial heart and lung implant receives marketing approval. | 93,2 |
| Blind persons can orient themselves within a room with a retina implant. | 92,6 |
| A non-invasive long-term blood pressure sensor has been developed. | 91,8 |
| Voice recognition and correct relation of a voice to the person speaking is so accurate, that surgeons are able to navigate instruments through voice commands and are thus effectively relieved. | 91,4 |
| Methods for quick analysis of the genome, e.g. DNA Chips, high-speed sequencing or genetic mapping are applied in healthcare routine. | 90,7 |

In detail more than 80 percent of the participants marked costs as an obstacle for the following theses:

- Routine whole-body scanning with functional imaging is a standard procedure after accidents.
- Ambient Intelligence in a house allows monitoring of patients at home (via camera, thinking carpet, furniture equipped with sensors, immobility sensors), reporting irregular features to an emergency call centre.
- Telemonitoring, i.e. close-meshed monitoring of patients (at risk), evaluation of the generated information in and by medical facilities and, if necessary, alerting the treating physician, has become a standard.
- Patients in hospitals are directed by an EDP-supported planning system, so that waiting periods, e.g. at admission, diagnostic procedures (X-ray, CT, endoscopy, etc.), operation are minimised and at the same time the overall efficiency of hospital facilities is enhanced.
- Valid diagnostic test procedures based on functional Magnetic Resonance Imaging (MRI) are clinically used for diagnoses with mental diseases (e.g. manic-depressive diseases) and diseases of the central nervous system (e.g. Alzheimer's disease).

Obstacles which were named as well - even though not as frequently – are research funding as well as acceptance by those concerned and users. Data protection is a factor not to be underestimated in rare cases, either. However, it is interesting to note that research and development infrastructure, standards and norms, education and further education and other obstacles are not critical for the experts. A deeper insight is offered in the individual evaluations of the theses in chapter 4.

# 4. Evaluation of the individual theses

In the following chapter, the results for the individual theses (1 to 36) are reported, outlined by the questions of the questionnaire. The first thesis was evaluated by the most participants, the last thesis by the least. Apart from demonstrating how diverse expertise is among the Delphi participants and the difference in "degrees of difficulty" of the individual theses this also shows typical fatigue symptoms for following through the questionnaire. Indications as to different answers by gender difference can only be offered conditionally. The number of cases is mostly too low to be able to make ascertains, since only 7 percent of the participants are females. Differences can rather be attributed to individual mindsets.

Differences in terms of expertise are only mentioned in those cases, where conspicuous differences can be observed and where the number of those answering in the individual categories is resilient. This means, in cases where only two or three very competent persons did answer at all, the results ought to be evaluated more individually. Conclusions regarding expertise in these cases would be speculative.

Systematic differences in answers of individual cohorts are not observable. Thus, the age of the Delphi participants does not seem to be of influence on the contents of the answers. Aberrations for individual theses are thus only mentioned if it can be assumed, that no statistical artefact is on hand, i.e. the difference is only based on the low number of e.g. younger participants in the sample.

## Thesis 1: Electrodes in the brain detect a beginning epileptic seizure and prevent it through specific electrical stimulation patterns.

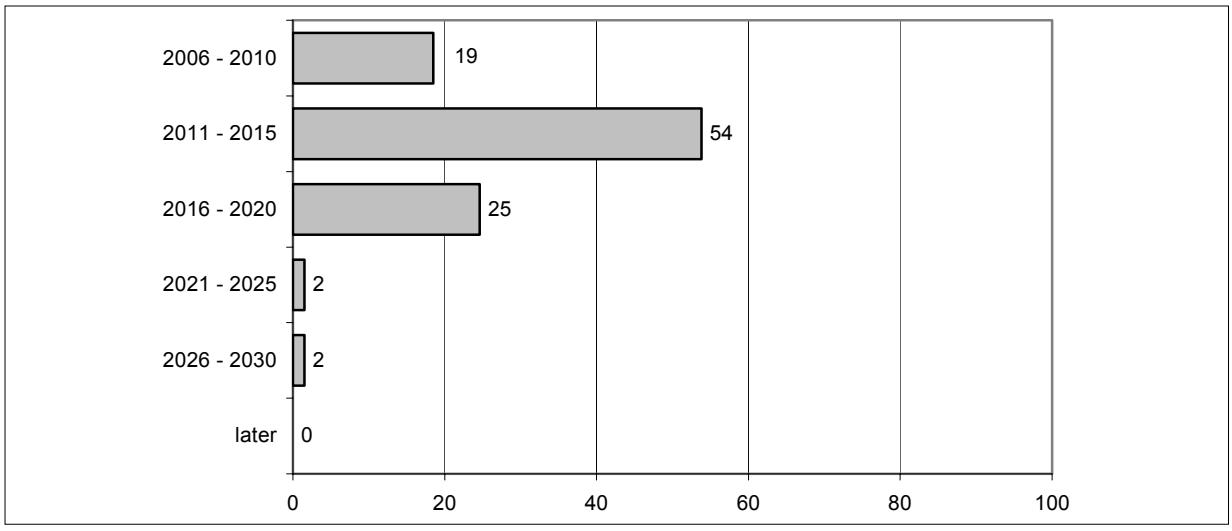
The technical groundwork of this thesis are specific sensors as well as electrical stimulation control. For this, interfaces in the brain need to be exactly determined (brain research) and they must be featured in a state which allows access to the areas relevant for epileptic seizures. Simulation of other areas must be excluded in order to prevent side effects, which can be dangerous in this case. Commentaries refer to possibilities of manipulating the brain via such electrodes and also to the fact that there have been applications as such since the year 1996. However, the existing project, for various reasons, has not been further elaborated on up to administration.

This thesis was evaluated by 70 participants. Of those, 10 percent estimated their expertise as high, 44.3 percent as medium and the others as low. For classification: Other Delphi theses were evaluated by more persons with high expertise.

**When do you expect the realisation of this thesis?**

The realisation of this thesis is expected around the year 2013 (median). Experts are fairly united in this estimate. The low quartile of the answering persons (Q1) is ranged at the mark for 2011, the high quartile (Q2) at 2016, showing relatively little variation in the answers (illustration 10). Nobody selected "never". Electrodes in the brain are thus a development, which is expected.

**Illustration 10:** Realisation time for thesis 1, distribution of answers in 5-year steps (in percent)

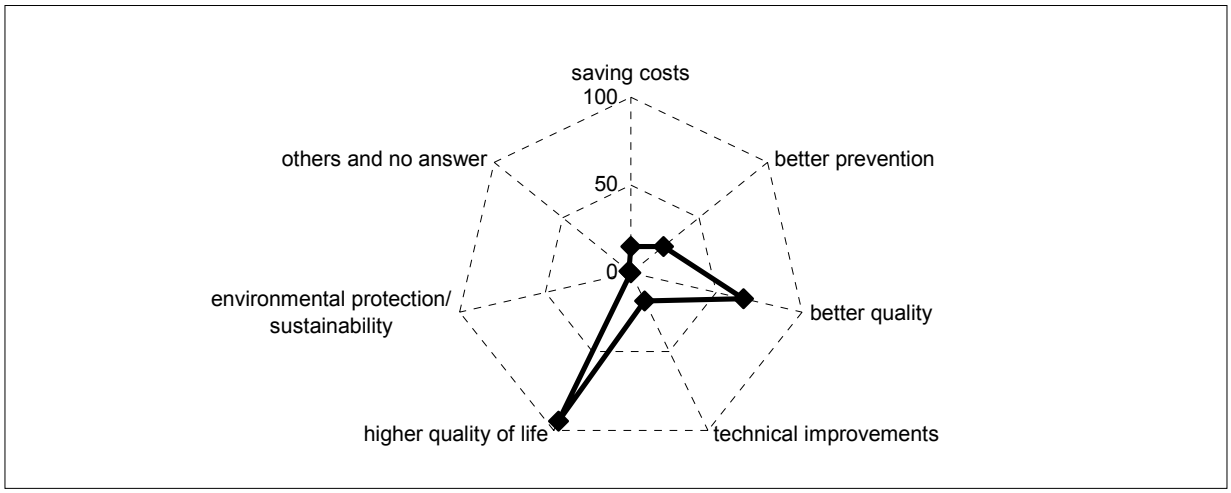



**All in all, do you personally consider the realisation of this thesis desirable?**

98 percent of the Delphi experts consider the topic desirable, only respectively one percent say "no" or "do not know".

**What is the realisation of the thesis important for?**

**Illustration 11:** Importance of thesis 1 (in percent)

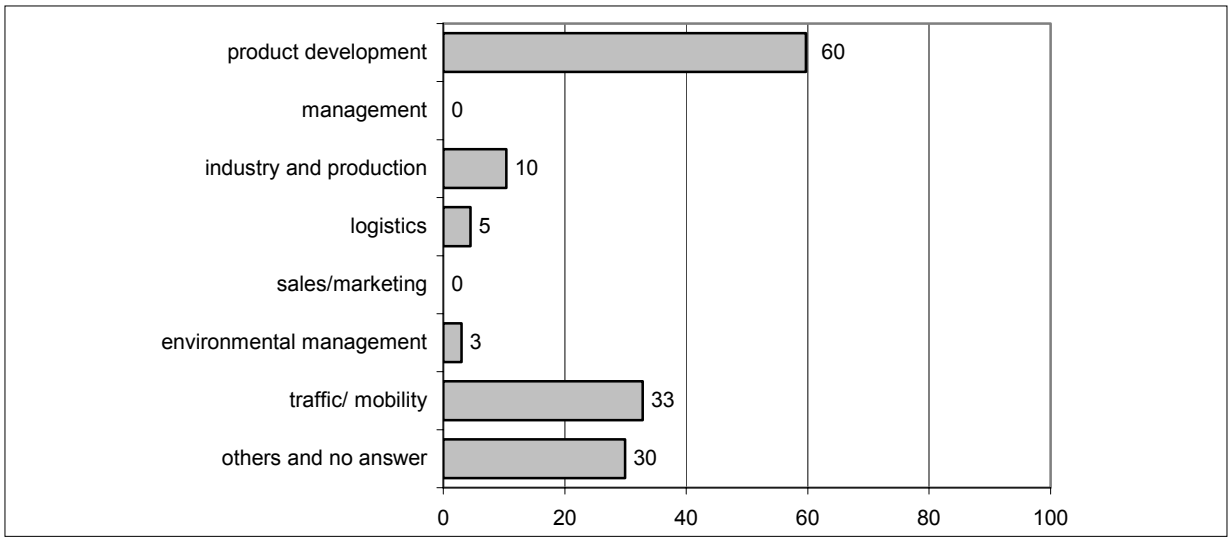



This topic is especially important for a higher quality of life, however, namings also include better care (illustration 11).

**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

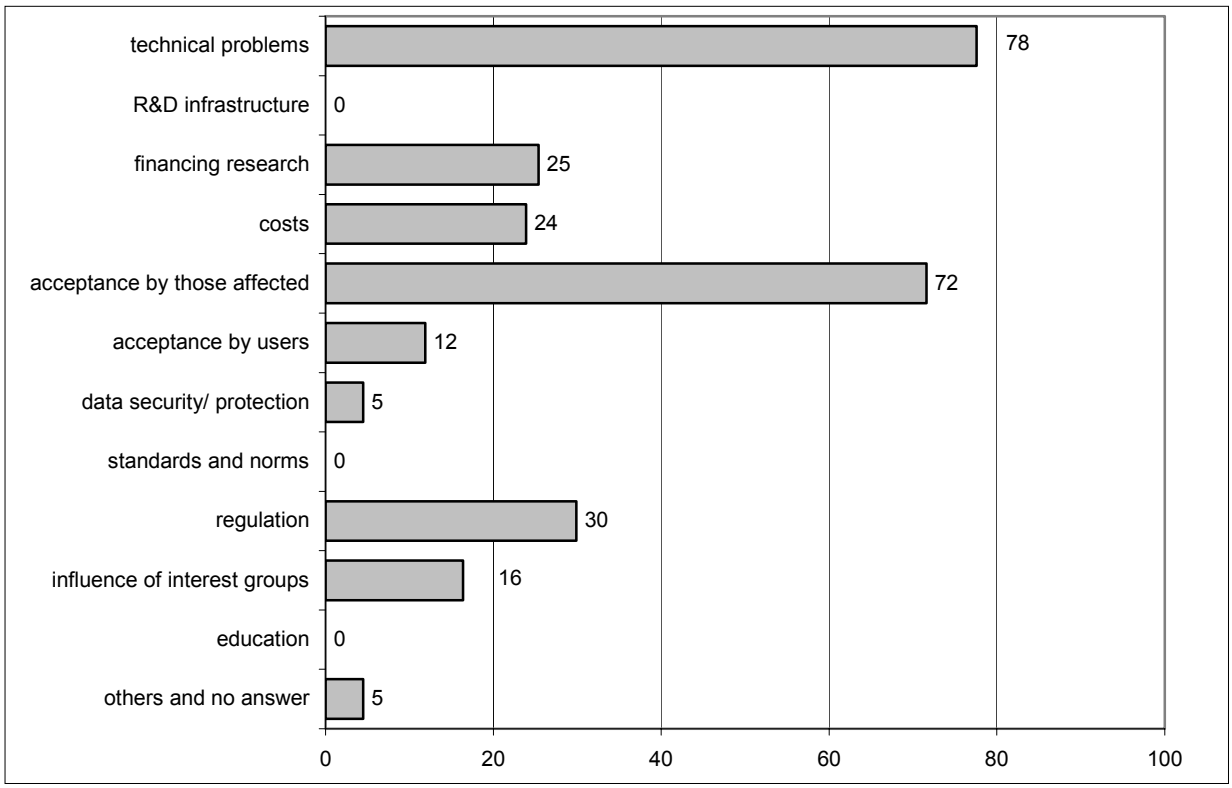
Apart from the health sector the technology could be applicable in product development as well as traffic and mobility (illustration 12). Commentaries refer to further application possibilities in the military sector, in physician practices and brain research. Commentaries also warn of misapplication possibilities, e.g. remote controlling of human behaviour.

**Illustration 12:** Thesis 1 – Applicability in other areas (in percent)



**Where do you see obstacles for the realisation of the thesis?**

**Illustration 13:** Obstacles for the realisation of thesis 1 (in percent)




Obstacles for realisation are especially technical problems and acceptance by those concerned (illustration 13). Brain surgery, for many of those potentially concerned, signify overcoming a barrier, as they not only provide possibilities for positively stimulating the brain, but the danger of (unintentional or intentional) manipulation of the concerned person's behaviour. Even "side effects" on other brain areas cannot be excluded. Then, who wants to be in danger of being remote-controlled? In cases of illness, on the other hand, the technology can serve as a blessing and, in cases of major epilepsy, will surely not fail on account of acceptance, or the timeframe for realisation would be differently evaluated. Stimulators for Parkinson patients even today show good progress and, in case of being affected, are accepted as a "minor resent".

The participants with high expertise often name the lack of research funding (67 percent) and the costs (67 percent, too) as obstacles, a ratio far above the average (24 respectively 25 percent). Other obstacles worth naming cannot be found in the evaluation.

**Prospect**

This thesis is very controversial, as, apart from technical challenges, it tackles low acceptance by those concerned. However, nearly all experts consider a realisation desirable and feasible during the coming ten years. Further development is designed in an interdisciplinary way: Without new findings in brain research it will not be possible for information technology and electrical engineering to press ahead with development. Basically the technologies involved can be applied in other areas, as well. However, epileptic seizures are very particular. What is more, indications also lead to potentials for misapplication (manipulation of personality, military use). This will more likely evolve through basic findings with simulations in other fields of application.

## Thesis 2: Due to IT approaches (simulations, virtual animal models), 80% of all animal testing in medical and pharmaceutical research becomes redundant.

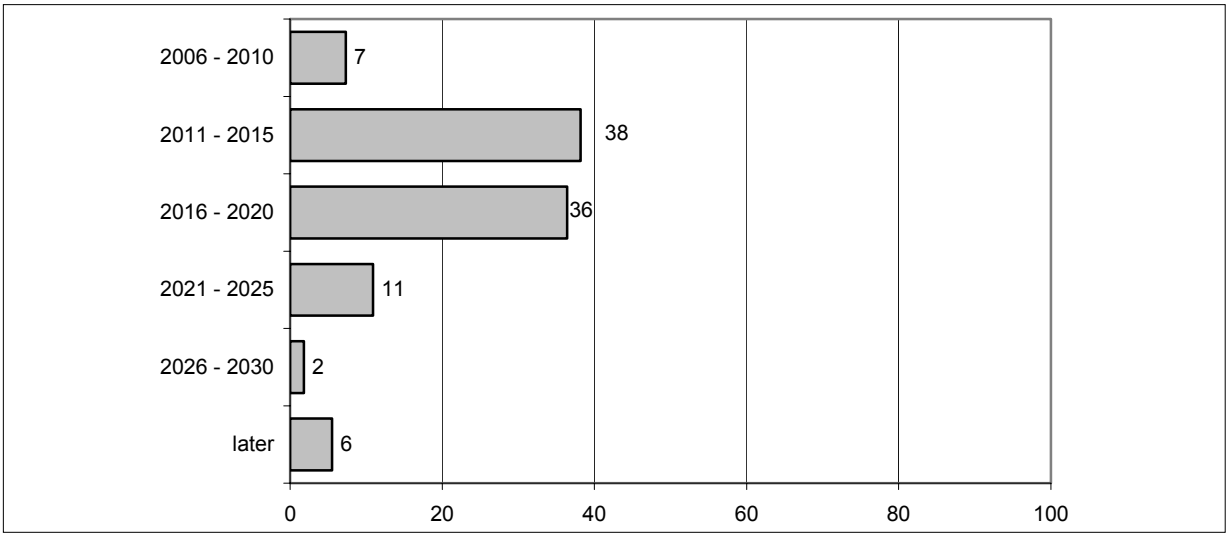
Even nowadays there are several approaches which make animal testing in medical and pharmaceutical research redundant, partly because of legislation (Omoe, 2006). However, to make 80% of all animal tests unnecessary is a high aspiration. Right now, funding and facilitating is slipping into gear in order to avoid as many animal tests as possible (BNN, 2006). For this reason, commentaries referred to both points of view which can be adopted: On the one hand the topic is important in terms of animal protection, on the other hand drawing comparisons for testing results with reality would become difficult. One expert remarked that "the complexity of living creatures is so high, that even animal tests lead to errors in transferring and applying results to the human being." Arguments of many animal protectors, stating that animal test results are only seldomly directly valid for human beings are supported by new studies (Roberts, 2006, see also Gericke et al., 2005 or www.aerzte-gegen-tierversuche.de), but are yet controversial. This is why a technological and technical alternative would be of importance.

This thesis was evaluated by 66 participants, 9.2 percent of them estimated their expertise as high. Exactly half of those who answered estimated their expertise as medium.

**When do you expect the realisation of this thesis?**

The realisation of this thesis, i.e. 80% percent of all animal testing becoming redundant due to IT approaches, is considered feasible only at a very late stage. The median (50 percentage points of answers) is estimated for the year 2016, with a variation directed towards a later point of time (Q1: 2013, Q2: 2020). Illustration 14 shows the distribution of answers. 12.1 percent of the participants answering even say "never".

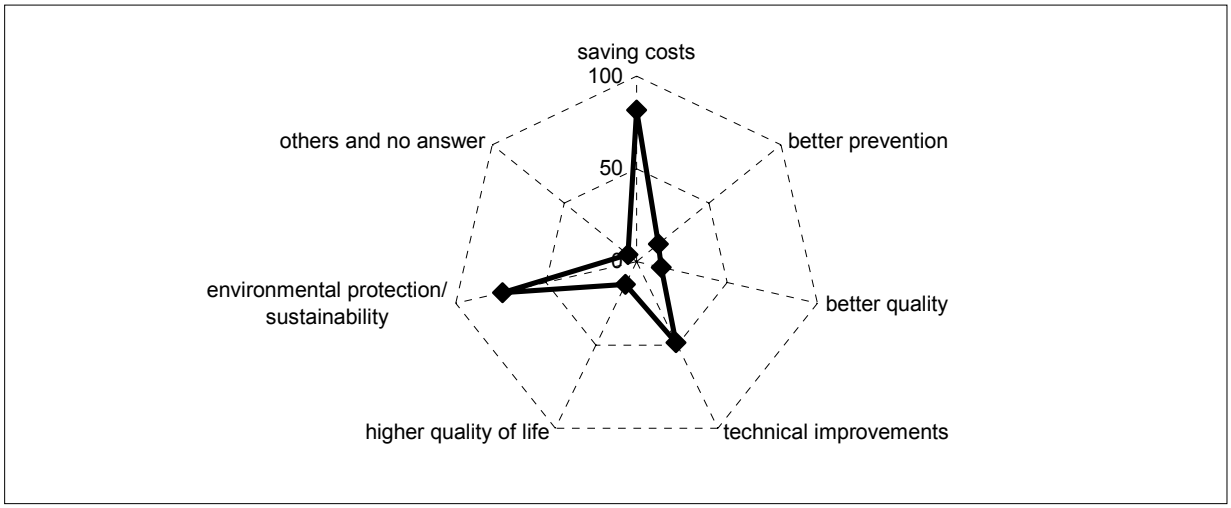
**Illustration 14:** Realisation time for thesis 2, distribution of answers in 5-year steps (in percent)



**All n all, do you personally consider the realisation of this thesis desirable?**
97 percent of those answering signalise that the topic is desirable, only three percent do not consider it desirable. Among those participants with high expertise (self evaluated), however, only 83 percent consider the topic desirable.

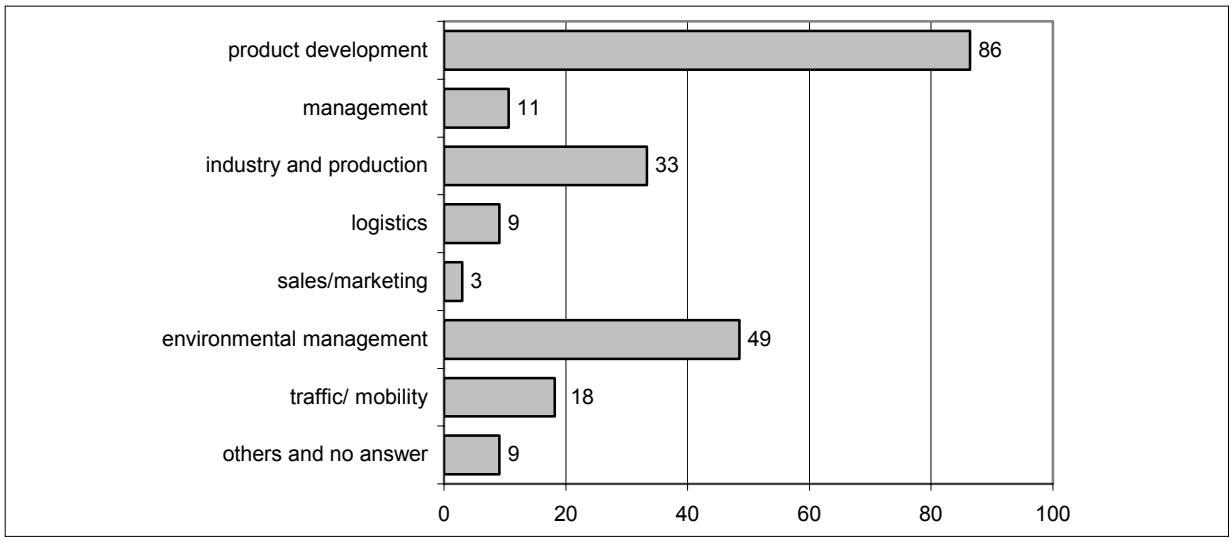
**What is the realisation of the thesis important for?**
The development is important for cost reduction (illustration 15), as animal testing has a high expenditure figure. Of all theses in the Delphi study at hand, this thesis is the only one considered extremely important in terms of environmental protection and sustainability. In a certain sense, this topic can contribute to technical and technological progress – according to the experts. The interesting point is, that persons with high expertise relativise the topic as to its importance for cost reduction: only 67 percent opposed to the average of 82 percent consider it important in this sense. And in terms of environmental protection and sustainability, too, the experts on the matter relativise the result (only 50 percent of namings instead of 74 percent). This probably represents a "statistical artefact" due to the poor female stake, however, those females participating consider the topic more important than male participants (especially for the quality of healthcare), the only exception being cost reductions, which are considered more important by male participants.

**Illustration 15:** Importance of thesis 2 (in percent)



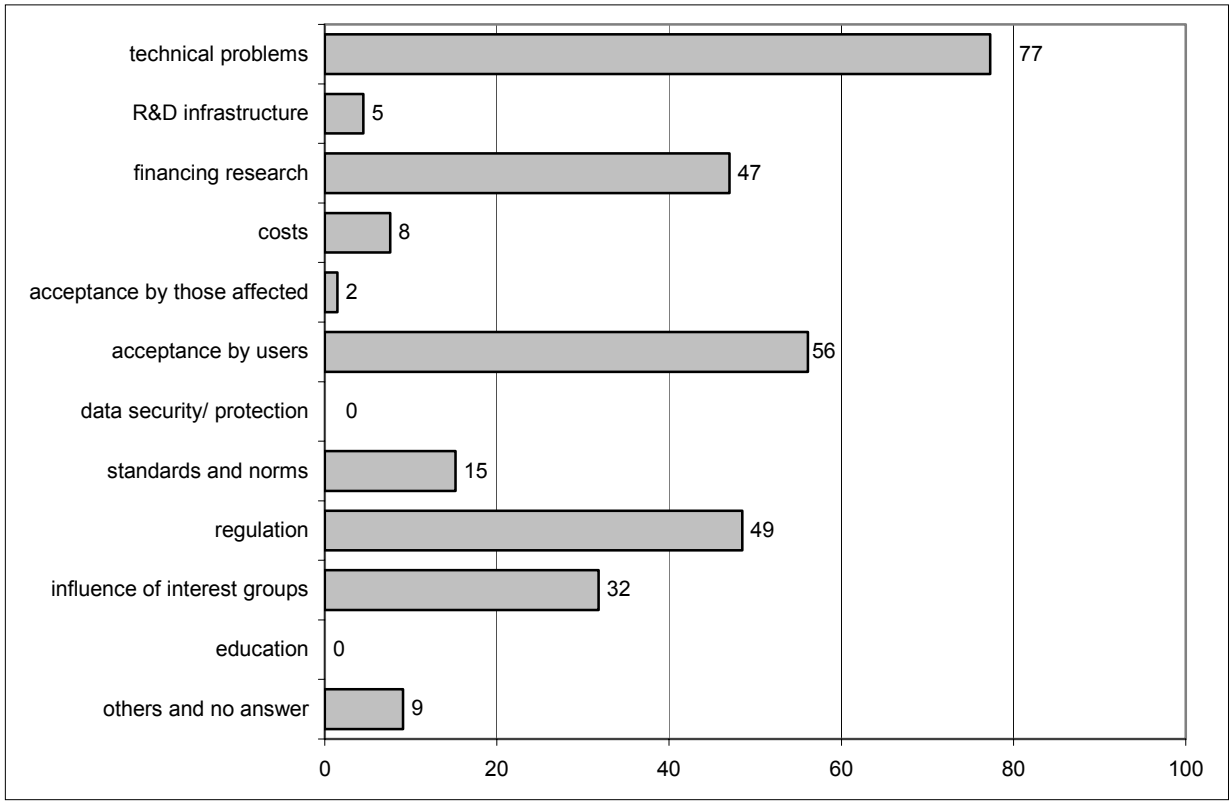

**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**
Technologies for simulation and model designing can find application in product development, environmental management as well as industry and production (illustration16). In this, al participants agree, even if persons with high expertise see an even larger potential in logistics.

**Illustration 16:** Thesis 2 – Applicability in other areas (in percent)




## Where do you see obstacles for the realisation of the thesis?

**Illustration 17:** Obstacles for the realisation of thesis 2 (in percent)




Obstacles for realisation are especially seen in the technical area (illustration 17). Second come acceptance by users (referring to doctors, pharmaceutical industry, researchers and developers etc.), regulations as well as research funding. The obstacle named third seems to be influence from sides of interest groups. The different groups of participants are in agreement with each others' evaluations.

**Prospect**

To make animal testing redundant can not only pose a technological and technical challenge, moreover it can fail due to acceptance by users. To make 80 percent of all animal testing redundant, is an ambitious goal which only seems realisable to many participants at a later stage (around the year 2018, with great uncertainty), even though it is considered highly desirable. At the same time, experts are aware of the fact that it is difficult to transfer results from animal tests to human beings. It will be even more difficult to collect data for such simulations and models through IT approaches and define causalities.

## Thesis 3: Virtual reality is a standard in training of medical staff (e.g. virtual surgery, practising of minimally invasive interventions, endoscopy, rescue practices, patient interviews etc.).

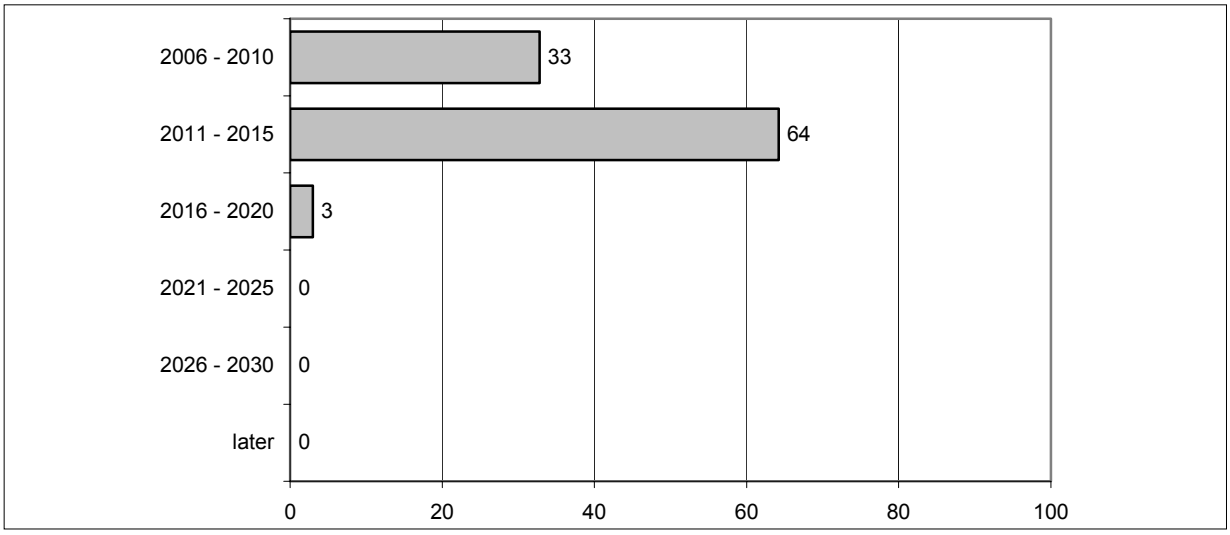
Good training of professional medical staff is essential. There, virtual reality will gain a greater importance. Like flight simulations, which today are a standard, surgical simulations will be part of medical training – say the experts – and agree on this in their evaluations. One commentary, however, points out that "simulations cannot substitute reality, but they allow more intensive training (see pilot training)" in various application fields, such as surgery, minimally invasive interventions or even patient interviews.

This thesis on virtual reality during training was evaluated by 67 participants, and 23.1 percent of them estimated their expertise as high, while 56.9 percent of them estimated their expertise as medium. Thus, the answers are very profound.

**When do you expect the realisation of this thesis?**

The topic is considered realisable around the year 2012 (low quartile: 2009, high quartile: 2014). The opinions only vary slightly, as shown in illustration 18.

**Illustration 18:** Realisation time for thesis 3, distribution of answers in 5-year steps (in percent)



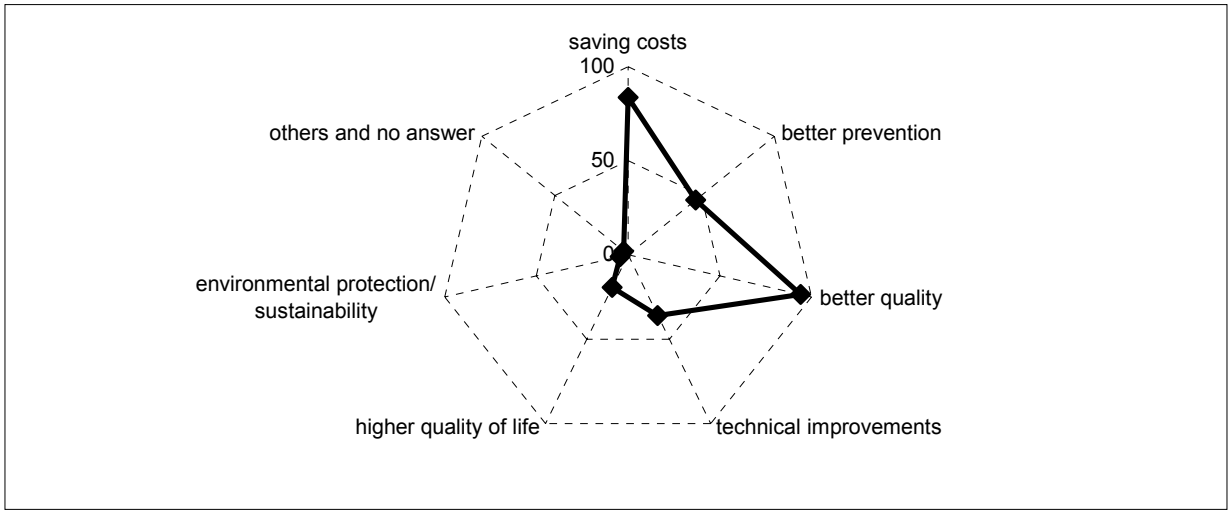

**All in all, do you personally consider the realisation of this thesis desirable?**

For this topic, realisation is considered desirable by all those answering (100 percent).

**What is the realisation of the thesis important for?**

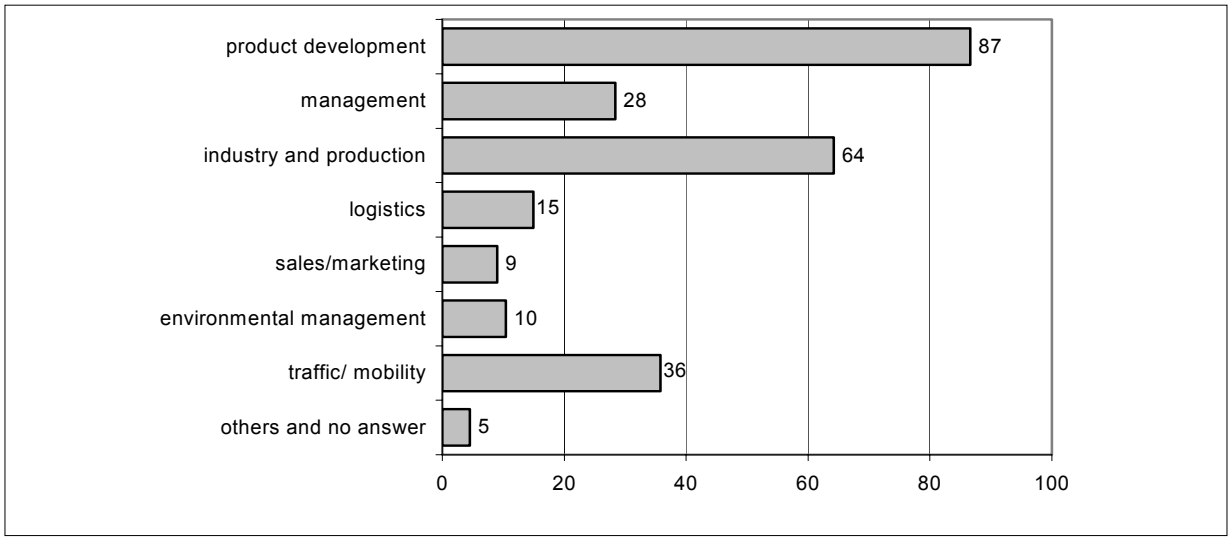
Virtual reality during training is considered important mainly because of cost reductions and for the quality of healthcare, but also for better healthcare provision and even technical and technological progress (illustration 19).

**Illustration 19:** Importance of thesis 3 (in percent)




**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

**Illustration 20:** Thesis 3 – Applicability in other areas (in percent)

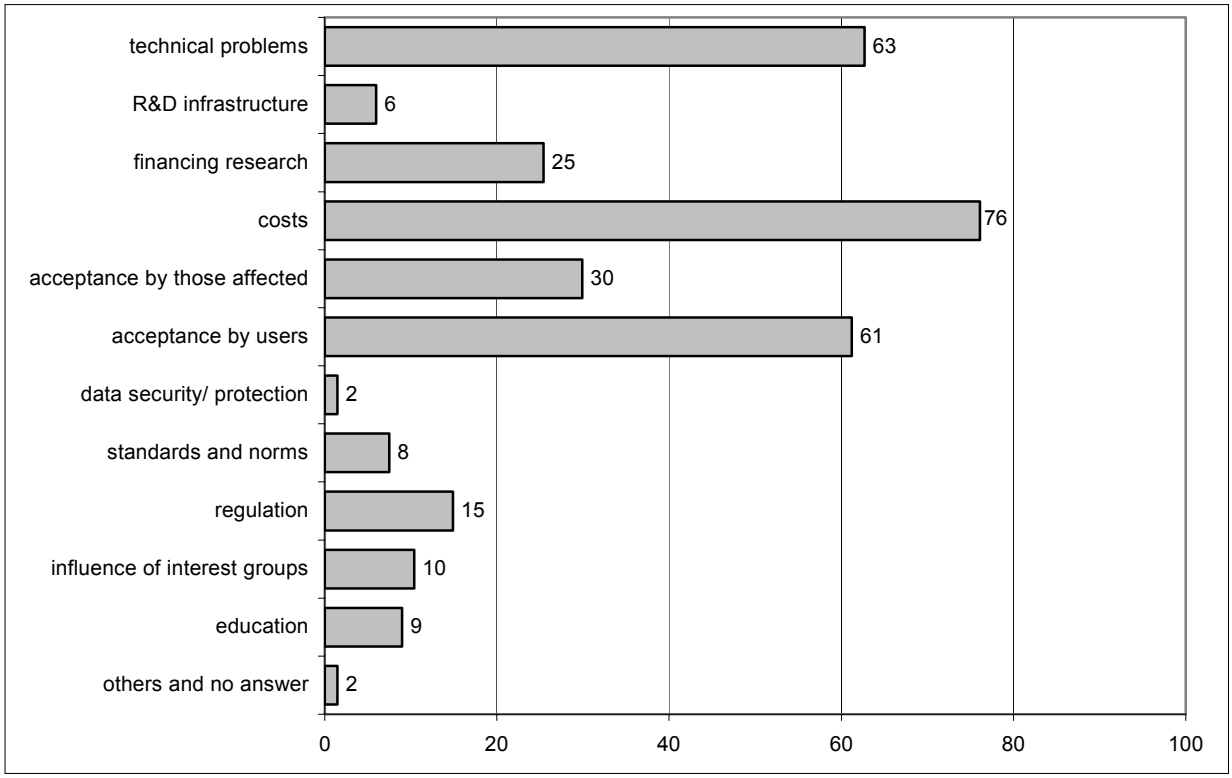



Virtual reality can find many areas of application. Most namings refer to product development, followed by industry and production. Traffic and mobility as well as management were also marked a couple of times (illustration 20).

**Where do you see obstacles for the realisation of the thesis?**

The largest obstacle to be considered are the costs, but technical problems and acceptance by users is also mentioned (illustration 21). Acceptance is attributed to a lesser degree by those concerned and research funding as well as matters of regulation.

**Illustration 21:** Obstacles for the realisation of thesis 3 (in percent)




Participants with expertise see fewer technical obstacles than the average of those answering. On the other hand, this group expects larger problems for acceptance by users, for regulations and problems due to the influence of interest groups as well as obstacles in further education and training. Other differences in evaluations cannot be found.

**Prospect**

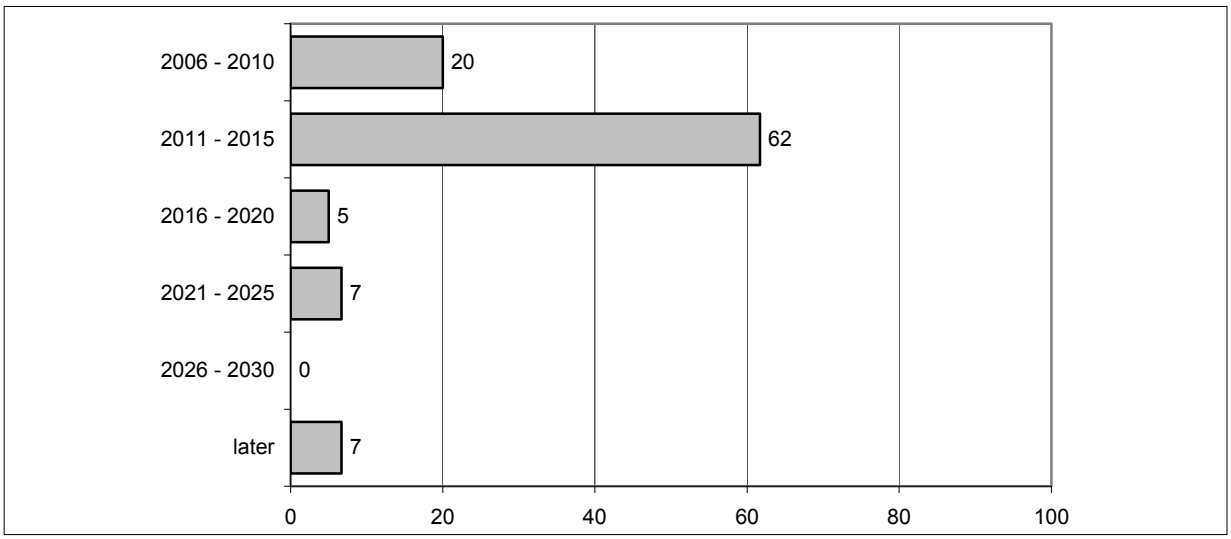
Virtual reality in training will become more of a topic during the coming ten years, not only in the health sector, moreover it will be applicable in many areas, in order to reduce education and training expenditure. Technical problems, costs and acceptance issues seem soluble.

## Thesis 4: An implantable data carrier has been developed, storing all data of a patient necessary for treatment and administration.

While this study is being conducted, for the first time in Germany, electronic patient data cards are tested as a storage carrier. Even this topic is controversial. An implantable data carrier may be safer on the one hand, on the other hand it does carry further risks. This is reflected by the Delphi participants' commentaries: "There is no necessity for such a carrier", "George Orwell 1984", "Control and surveillance", they warn against "personal control" and advise on "the protection of personal information". They also doubt that the use of implantation is higher than other procedures.
This thesis was evaluated by 69 participants. Of those, 29.9 percent estimated their expertise as high and 56.7 percent of them estimated their expertise as medium. This adds up to a large share of participants with expertise.

**When do you expect the realisation of this thesis?**
The realisation of this thesis is considered possible around the year 2013 (low quartile 2011, high quartile 2015). However, nearly 12 percent of the participants state that there will "never" be such a data carrier. Thus the distribution of answers (see illustration 22): Either realisation will take place at a relatively early stage, or after 2030 – or not at all "12 percent "never"). A relatively high percentage of participants (7 percent) consider the thesis realisable only after the year 2030.

**Illustration 22:** Realisation time for thesis 4, distribution of answers in 5-year steps (in percent)



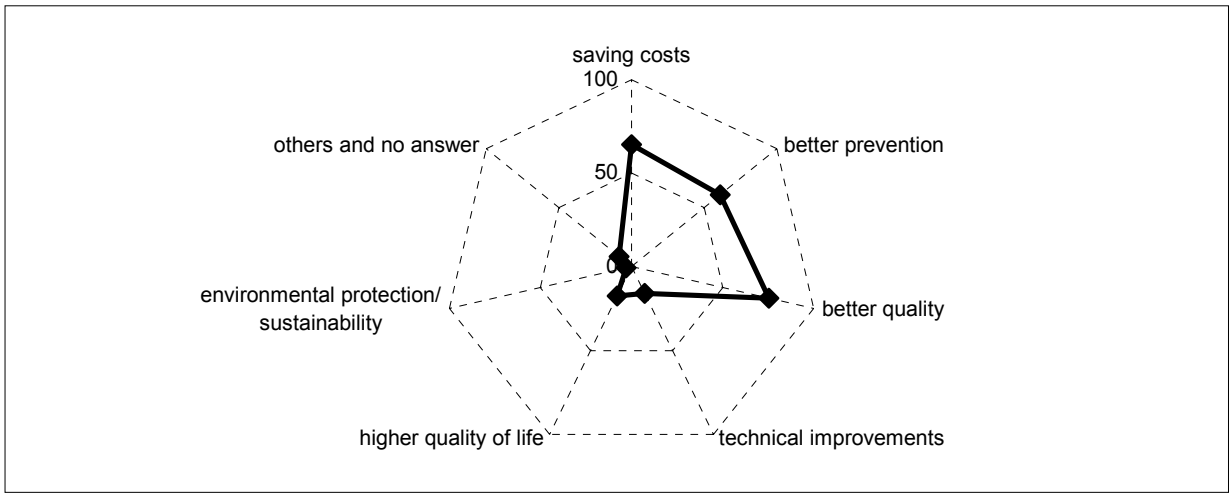

**All in all, do you consider the realisation of this thesis desirable?**
This thesis is fairly controversial. While nearly all these are clearly evaluated as desirable, in this case 64 percent do not find development in this area desirable and 7 percent say "do not know". Nevertheless, 29 percent do in fact agree upon desirability of the issue. To have a data carrier directly implanted, seems to make persons feel "queasy", and being even more supervisable. This corresponds with evaluations by 12 percent of the Delphi experts, a high

share when comparing to other theses, stating the realisation of the thesis will "never" take place. Most probably doubts regard the actual use of this implantable data carrier, not so much its technological development.

**What is the realisation of the thesis important for?**

The overall development is important for the quality of healthcare, better health provision and cost reductions (illustration 21). Persons with high expertise rate the importance even higher. Albeit, namings in all categories are not very prevalent. This probably reflects the low desirability of the thesis compared to the other theses.

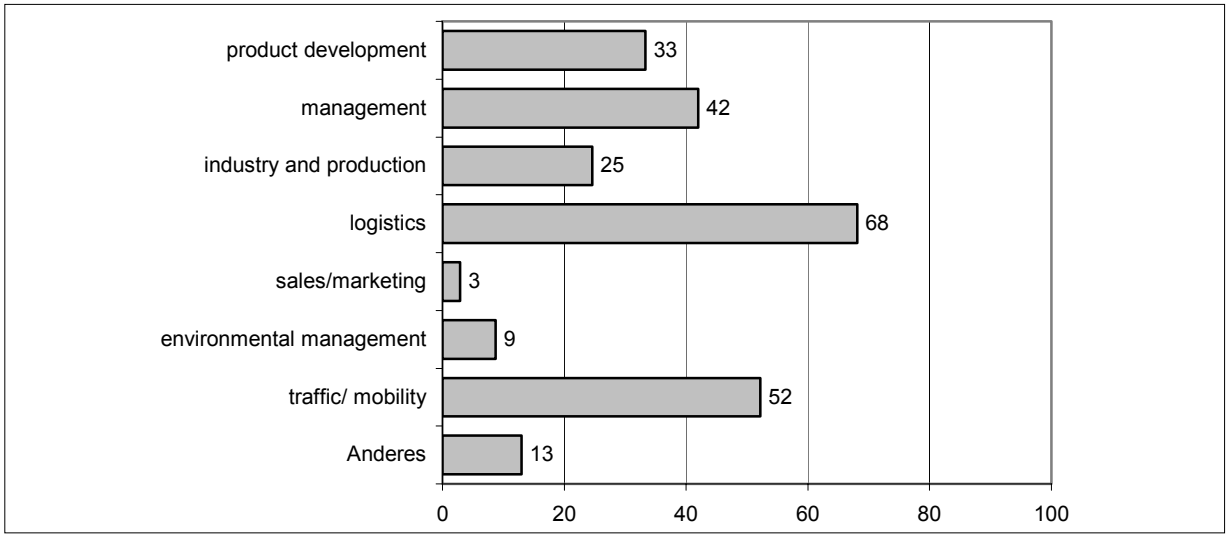
**Illustration 23:** Importance of thesis 4 (in percent)




**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable?**

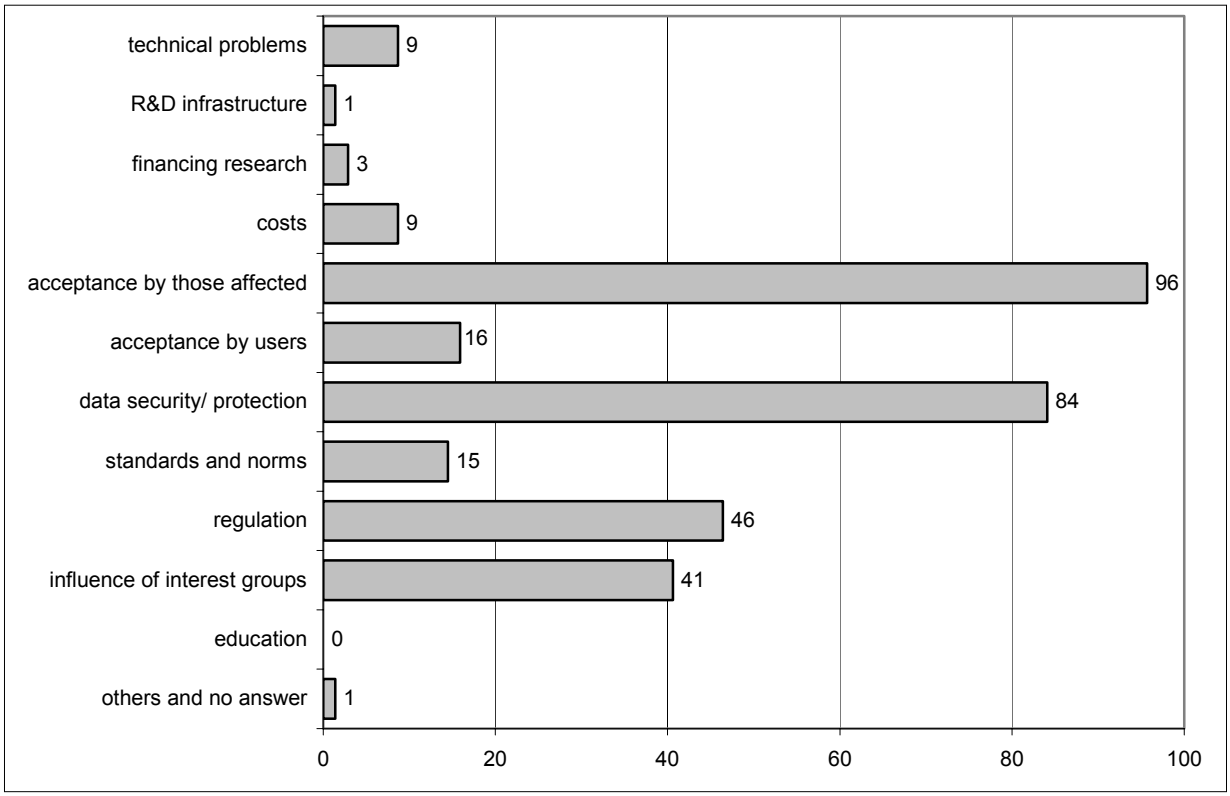
Implantable data carriers will also be applicable in the logistics sector. Traffic, mobility, management and product development as well as industry and production are also frequently marked (illustration 24). The participants with high expertise mark exactly these sectors with crosses more frequently than the average participant.

**Illustration 24:** Thesis 4 – Applicability in other areas (in percent)




## Where do you see obstacles for the realisation of the thesis?

**Illustration 25:** Obstacles for the realisation of thesis 4 (in percent)




Since many participants do not consider the thesis desirable, they correspondingly consider the number of obstacles as high. Nearly everybody names acceptance by those concerned and data protection as large obstacles (illustration 25). Regulations and the influence of interest groups could obstruct the introduction of an implantable data carrier. Acceptance by users and standards and norms are only considered a problem by a few.

**Prospect**

Hardly anyone really wants an implantable data carrier, which registers all data of a patient necessary for treatment and administration, especially for reasons of data protection and personal protection reasons. However, there is only little controversy about the actual realisation of the carrier. Obstacles are not seen in the technology, moreover the acceptance by those concerned and data protection issues. Whether or not a large market will develop, cannot be evaluated here, even if a theoretically broad range of application (for all patients and furthermore in other sectors) is mentioned.

Thesis 5: A computerised system exists, which allows practice-based physicians to access all information at hand about the patient (cryptographically secured) via a terminal of their choice during house calls.

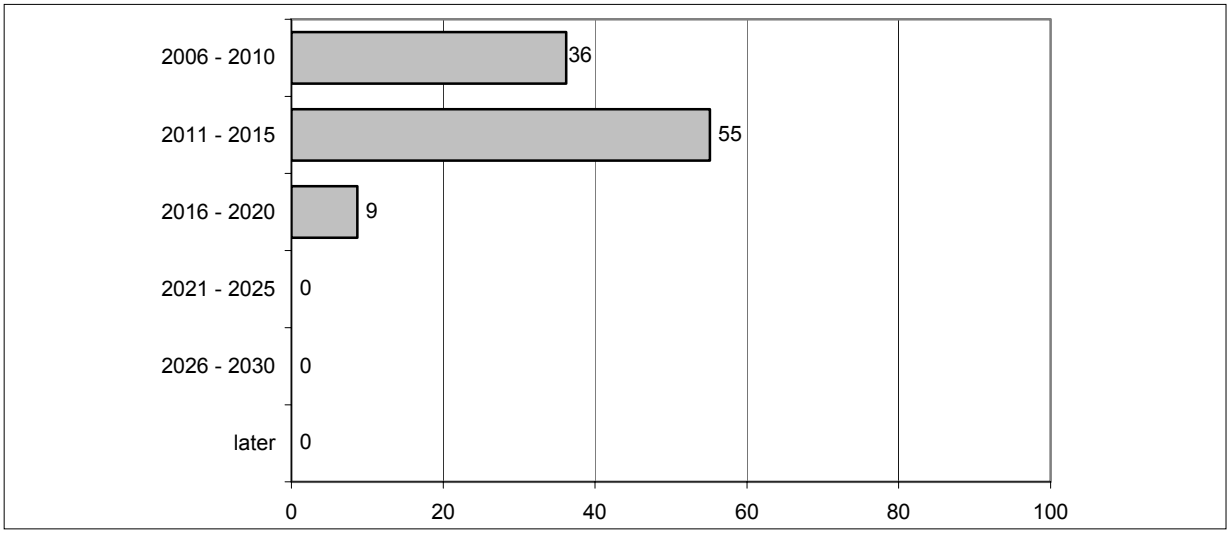
On house calls doctors often do not have sufficient information of their patients on hand. The idea behind this thesis is, that data need not necessarily be available at a certain location, moreover one must be able to access certain pieces of centrally stored information from a terminal elsewhere. Of course, this requires adequate data securing (cryptography). The availability would not only serve the purpose of quick data access and thus possibly faster – and in the most serious case, life-saving – diagnosis, but also facilitate many administrative processes, e.g. direct data entry.

For this reason, many of the participants expect workload relief (see also PriceWaterhouseCooper, no year) from such a system, even though there are warnings regarding – similar to the other cases with data protection issues – surveillance and "tracking" possibilities of patients, and also physicians are among those who warn.

This thesis was evaluated by 69 participants, nearly half of them (44.8 percent) estimated their expertise as very high. Only 9 percent of the participants estimated their expertise for low, the others estimated it as medium, which means this thesis has been evaluated with very high expertise.

**When do you expect the realisation of this thesis?**

**Illustration 26:** Realisation time for thesis 5, distribution of answers in 5-year steps (in percent)

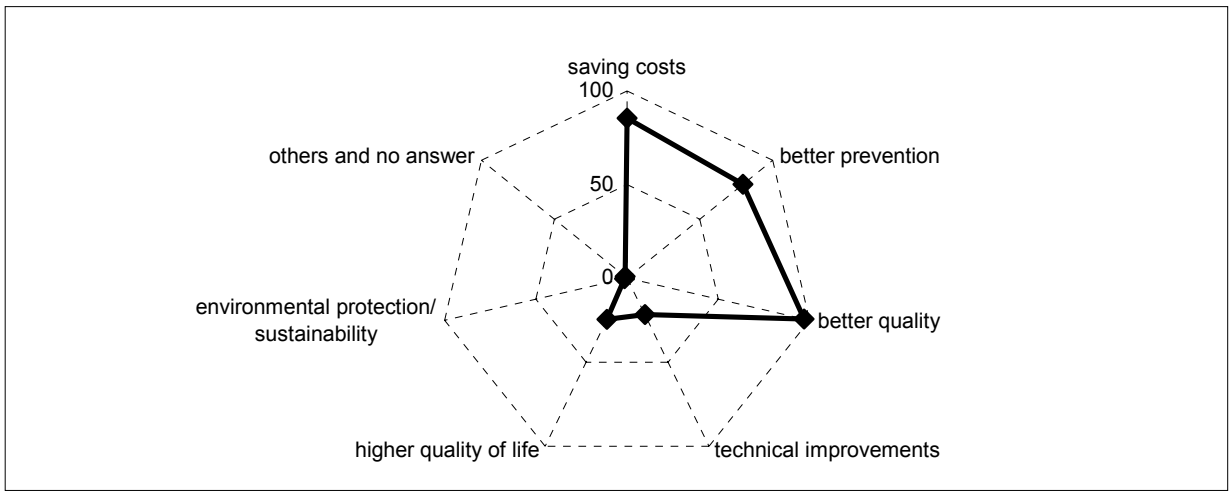



There was a fairly general agreement on the timeframe for realisation. The median lies in the year 2012 (Q1: 2009, Q2: 2014). Illustration 26 shows clearly, that nobody expects the system later than the year 2020. Also, nobody says "never". This makes the topic a very probable one, with safe statements as to the time of realisation.

**All in all, do you personally consider the realisation of this thesis desirable?**
92 percent of the Delphi experts consider the computerised system desirable. Only four percent respectively say “no” or “do not know”.

**What is the realisation of the thesis important for?**

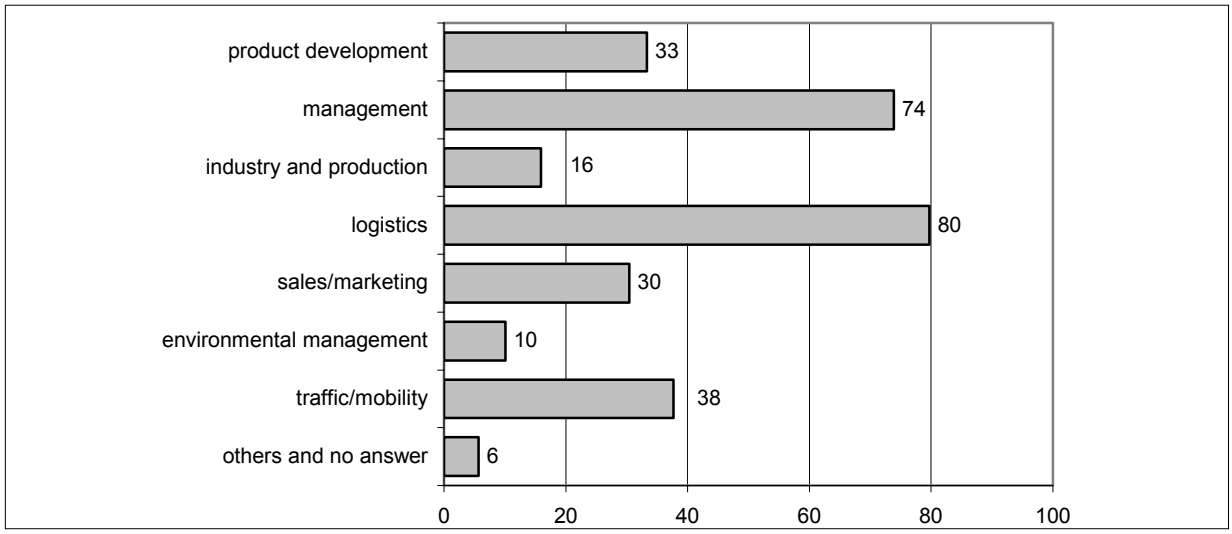
**Illustration 27:** Importance of thesis 5 (in percent)




The computerised system for house calls is extremely important regarding cost reduction, a better health provision and higher quality of healthcare (illustration 27). Other namings were only seldomly made. Persons with high expertise consider the mentioned issues even more important.

**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

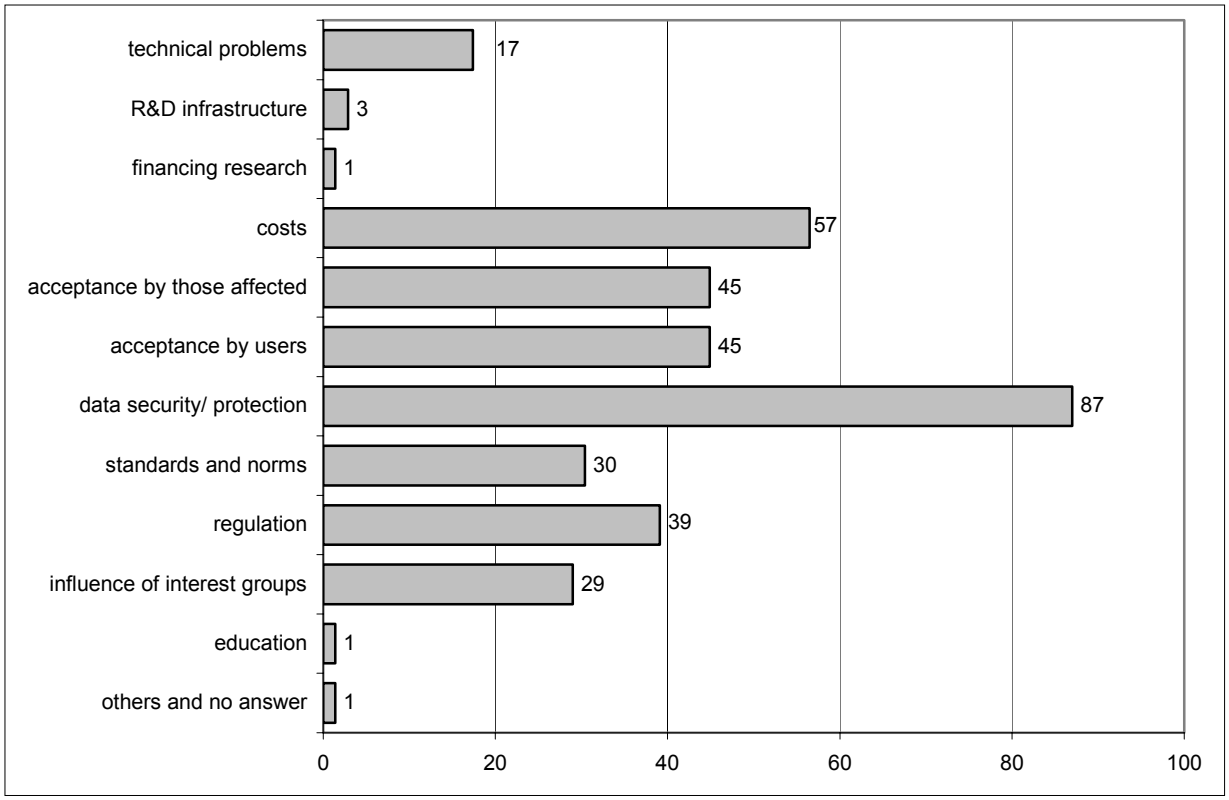
**Illustration 28:** Thesis 5 – Applicability in other areas (in percent)




A similar system will surely be applicable in logistics and management, as well (illustration 28). A minority also speaks of its application in product development, in sales and in traffic and mobility.

**Where do you see obstacles for the realisation of the thesis?**

**Illustration 29:** Obstacles for the realisation of thesis 5 (in percent)




Obstacles for the realisation are not necessarily of a technological type, as "technical problems" are only named by 17 percent of the participants. Data security and data protection take up a top position among the obstacles, followed by costs and questions as to acceptance, by those concerned and users (illustration 29). Also named, though not as often, are regulations, standards and norms as well as the influence by interest groups.

**Prospect**

The computerised system in the health sector, with secure data accessible from everywhere, will become reality in a future not too far away. Obstacles are issues concerning acceptance and data protection, however, the experts are of the opinion that these obstacles can be overcome. For manufacturers of simple terminals which are compatible with such a system or software developers there can be potential for a large market. The challenge lies in the systemic character of the topic including the design of an infrastructure.

Thesis 6: In emergency cases, in order to be able to identify a person very soon after an accident, a quick genetic test is completed and the data is matched with a profile database.

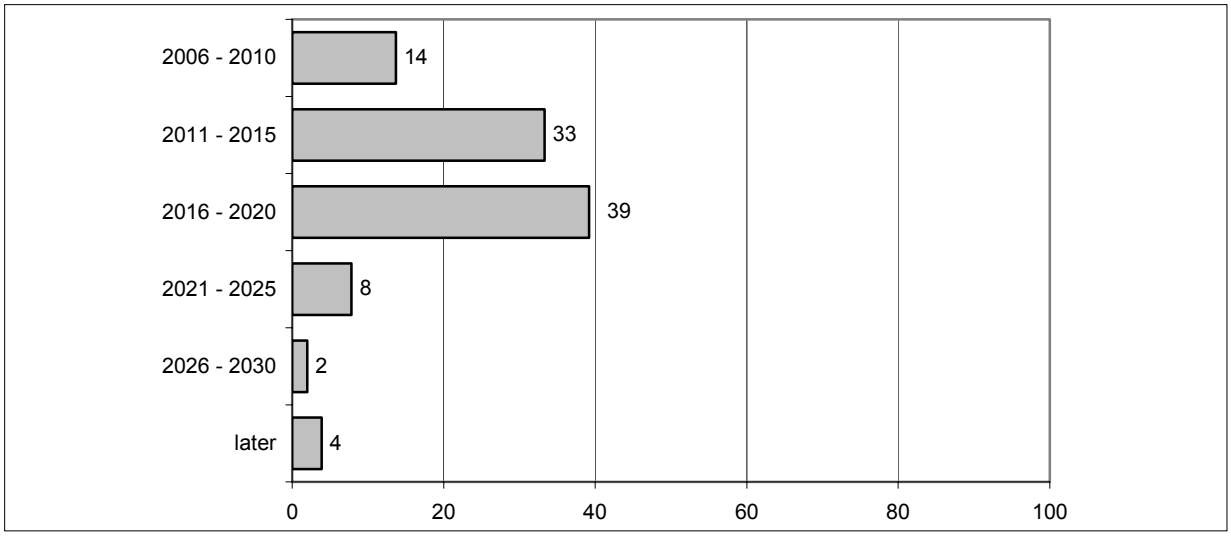
In certain cases it can be helpful to identify someone in an emergency, only then one can know whether or not this person requires special medical treatment (ranging from chronic illnesses to past bone fractures). This was the initial issue behind the Delphi thesis. The technical issue concerns the quick on-the-spot completion of a genetic test and IT-matching of the results with a person profile database, an extremely large amount of data. However, first of all such a database needs to exist.

Several Delphi experts point out in commentaries that the necessity to identify a person quickly after emergencies is rare in reality. In an acute case of emergency, priority is unquestionably stabilising the patient. To run a genetic test and then also match data to a database seems too far-fetched for most of the participants. Correspondingly are the commentaries by the Delphi experts: Phrased this way, the thesis seems like an approach for “totalitarian systems”, “with dubious necessity” and better applied in “criminalistics” respectively “surveillance”. The results in this thesis are therefore very clear.

This thesis was evaluated by 63 persons, 12.7 percent estimated their expertise as high. 39.7 estimated their expertise as medium and the other 47.6 percent claimed they had little expertise.

**When do you expect the realisation of this thesis?**
Quick identification in a case of emergency by means of a genetic test and matching with a profile database is expected to be possible around the year 2016. The low quartile lies at the year 2012, the high quartile ranges in the year 2019. The variance of answers is thus relatively large, also depicted by illustration 30. Only 3 percent of Delphi experts consider the topic for feasible “never”, a very low ratio, compared to the commentaries and critical doubts, which are noted.

**Illustration 30:** Realisation time for thesis 6, distribution of answers in 5-year steps (in percent)

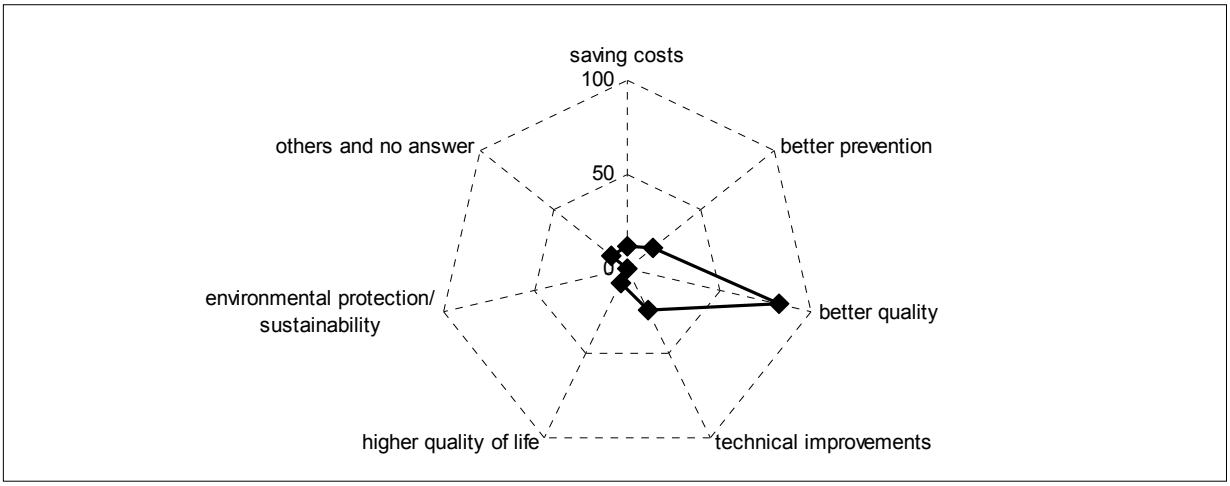



**All in all, do you personally consider the realisation of this thesis desirable?**

The thesis is controversial. Considering the mean value of answers, it is even clearly declined. 70 percent of the participants do not consider quick identification of human beings through a genetic test desirable, even in emergencies, and 10 percent, a comparatively large share in relation to other theses, are not sure. Only averagely 20 percent consider the thesis desirable – compared to other theses this is a low ratio. There are large differences between age cohorts: Among younger persons (aged 26 to 35 years) desirability is attested by 43 percent. By those aged between 36 and 55 years it is a mere 4 respectively 6 percent; among those older than 65 years the thesis is considered in a positive way. Discomfort here does not arise on account of the quick identification, even though it is stated that primary stabilisation of a patient must come first before identification (commentary), moreover it is the database behind the testing that causes discomfort, the knowledge that personal data incorporated could also be used for criminal investigations, insurances etc.), if not adequately secured.

**What is the realisation of the thesis important for?**

**Illustration 31:** Importance of thesis 6 (in percent)

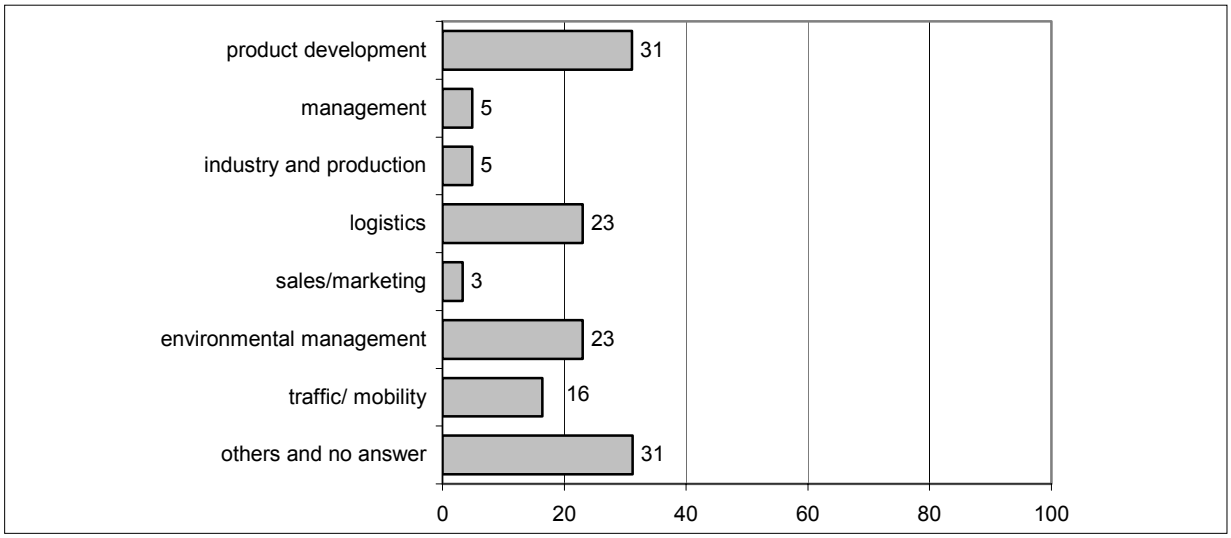



However, on the other hand quality of healthcare is something the thesis is important for (illustration 31). Other categories are hardly mentioned.

**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

In return, quick /genetic) testing respectively data matching is applicable in other areas (illustration 32). With large variance, the Delphi experts name product development, logistics and environmental management, all areas, however, do not receive high ratings. Participants estimating their expertise as high name these sectors more frequently than the average of participants. One of the categories marked most often is “other areas”: criminalistics and crime prevention, the safety sector and personal surveillance are mentioned, for instance for illegal immigrants. How the latter is supposed to work in reality is yet unclear, since data it is not permitted to store data on illegal immigrants. An international database would make every person a “transparent immigrant” somewhere in the world.

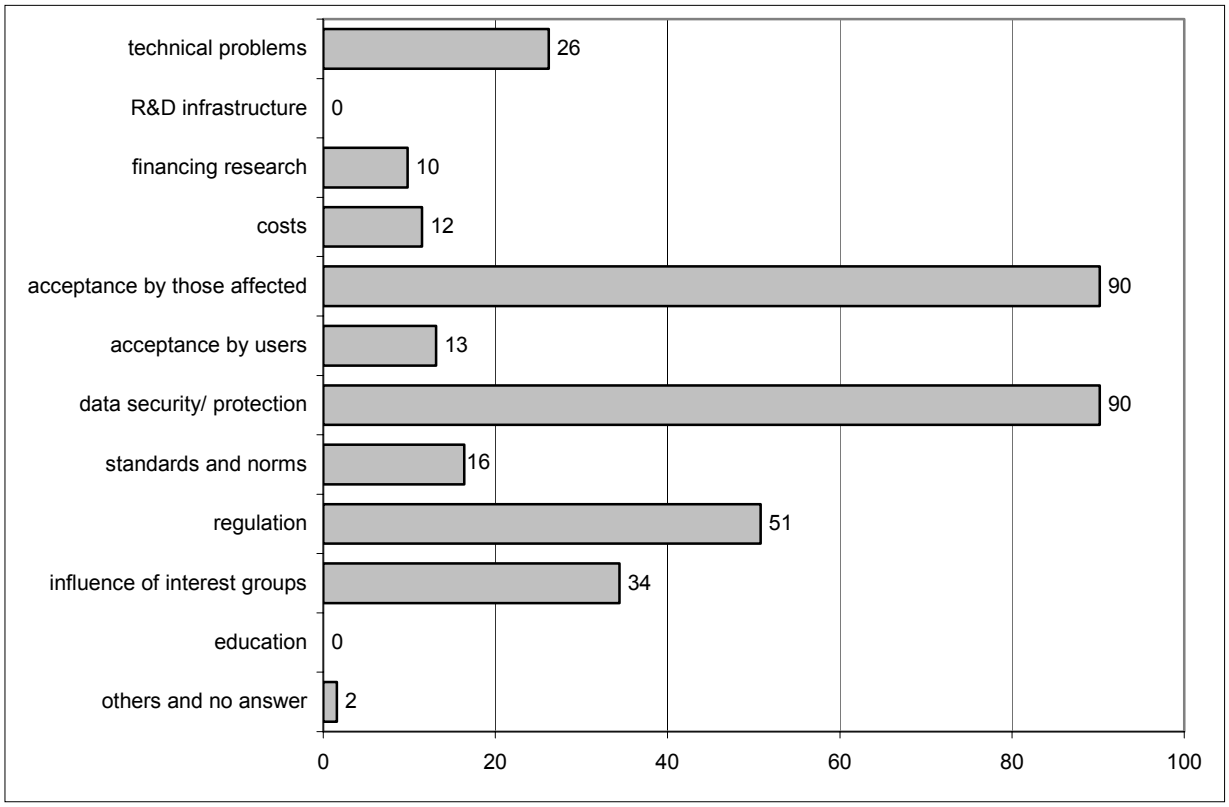
**Illustration 32:** Thesis 6 – Applicability in other areas (in percent)




**Where do you see obstacles for the realisation of the thesis?**

Following the above mentioned, nearly all participants name data protection and data security (illustration 33). Regulation, the influence by interest groups and technological and technical problems are mentioned, too. This makes the thesis a topic with relatively many obstacles on the way to realisation. This is reflected in the comparatively late estimated timeframe for realisation.

**Illustration 33:** Obstacles for the realisation of thesis 6 (in percent)



**Prospect**

Only the minority of participants desire a quick genetic test and match with a profile database – also for the reason that in an actual case of emergency, the priority of identifying somebody is not given. However, the application of the technology is considered feasible, even if not during the coming ten years. There are simply too many obstacles in the way. It is assumed, that genetic testing and database matching will be applied in other sectors at first. Here, criminalistics and person surveillance are the first to be mentioned.

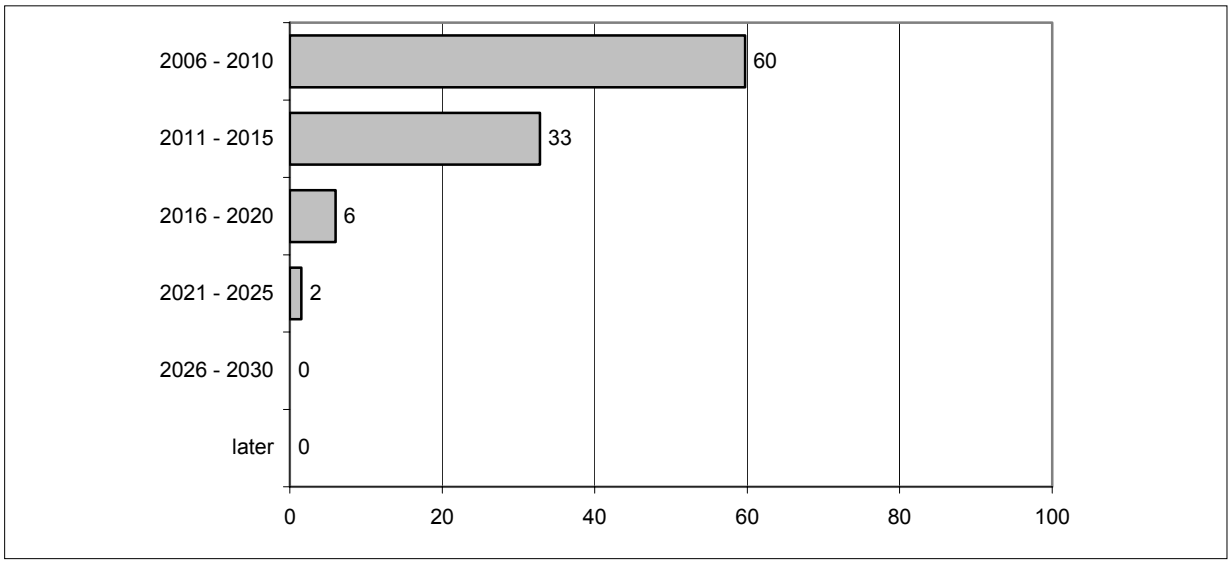
Thesis 7: Patients in hospitals are directed by an EDP-supported planning system, so that waiting periods, e.g. at admission, diagnostic procedures (X-ray, CT, endoscopy, etc.), operation are minimised and at the same time the overall efficiency of hospital facilities is enhanced.

Waiting periods in hospitals are tiresome and unpleasant for patients. For the hospital institutions, as well, long waiting periods involve irregular use of capacities – especially regarding personnel and thus add to costs and stress. An EDP-supported system could be helpful in directing the patients in such a way, that waiting periods be avoided. The Delphi participants' spontaneous reaction was: "But this system already exists!" Long discussions with the experts during the April 2006 workshop, consulting even more experts and further research have shown that there is no functioning complete system in use, which meets all requirements.

This thesis was evaluated by 69 participants. 46.2 percent estimated their expertise as extremely high, the highest rate registered in this survey. Only 9 percent estimated their expertise as low. The answers can be assumed to have been given by persons with expertise.

**When do you expect the realisation of this thesis?**

**Illustration 34:** Realisation time for thesis 7, distribution of answers in 5-year steps (in percent)

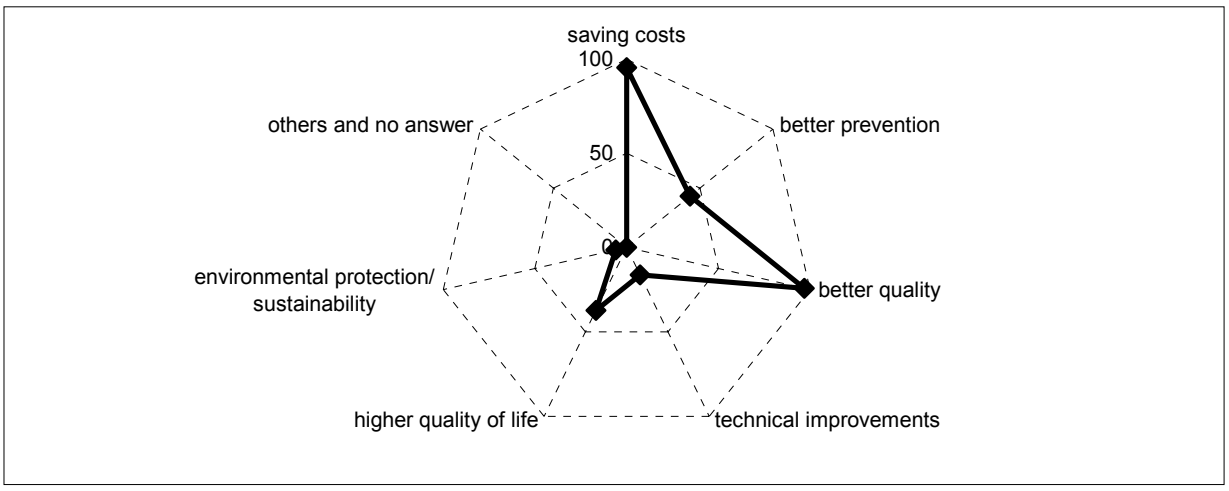



Expectations as to early realisation of the thesis are high. The experts are relatively united in the projection that the topic is feasible quite soon, nobody says "never". The year 2010 represents the median estimate, the lower quartile ranges at the year 2008, the high quartile at the year 2013, which means there is no large variance, also depictable from illustration 34. The development and implementation of such a system is thus awaited in the near future, if it has not already been realised – partly – by now.

**All in all, do you personally consider the realisation of this thesis desirable?**
98 percent of the experts, which means nearly all of them, consider this guiding system for patients desirable. Only respectively one Delphi expert does not find the topic desirable or is noncommittal.

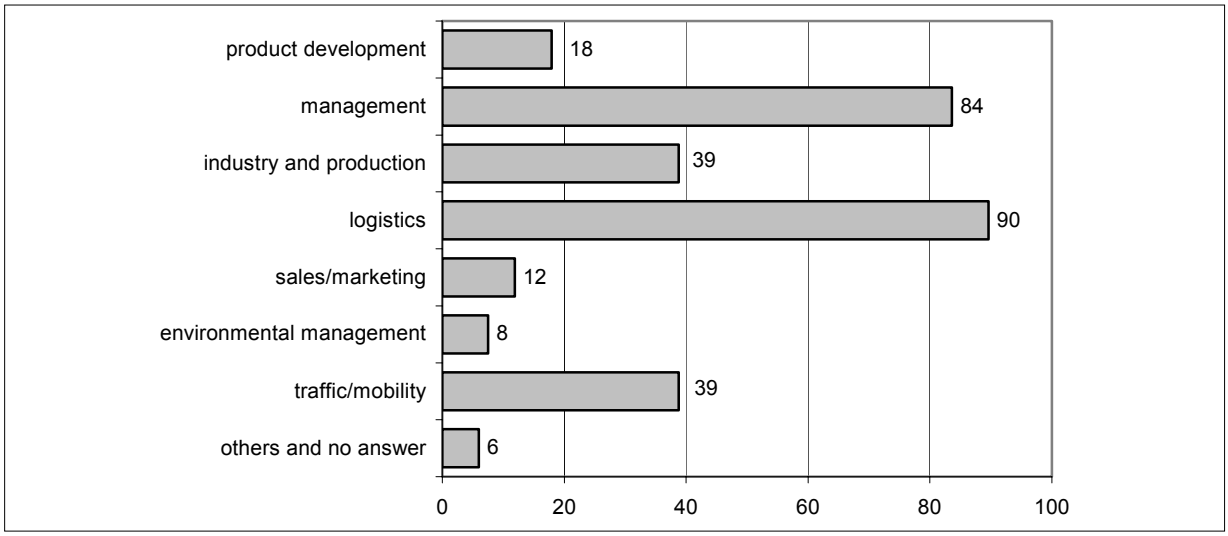
**What is the realisation of this thesis important for?**
As hinted in the thesis, expected cost reductions due to the implementation of an EDP-supported system are important. This is stated by all participants (illustration 35). However, further than mere EDP, the quality of healthcare can benefit through this development. Other than that, the system is considered important for better health provision, as easier access to health services and shorter waiting periods possibly lead to more people making use of preventive services. This thesis does not refer to shorter periods of waiting in physicians' practices; it only refers to waiting periods in hospitals.

**Illustration 35:** Importance of thesis 7 (in percent)



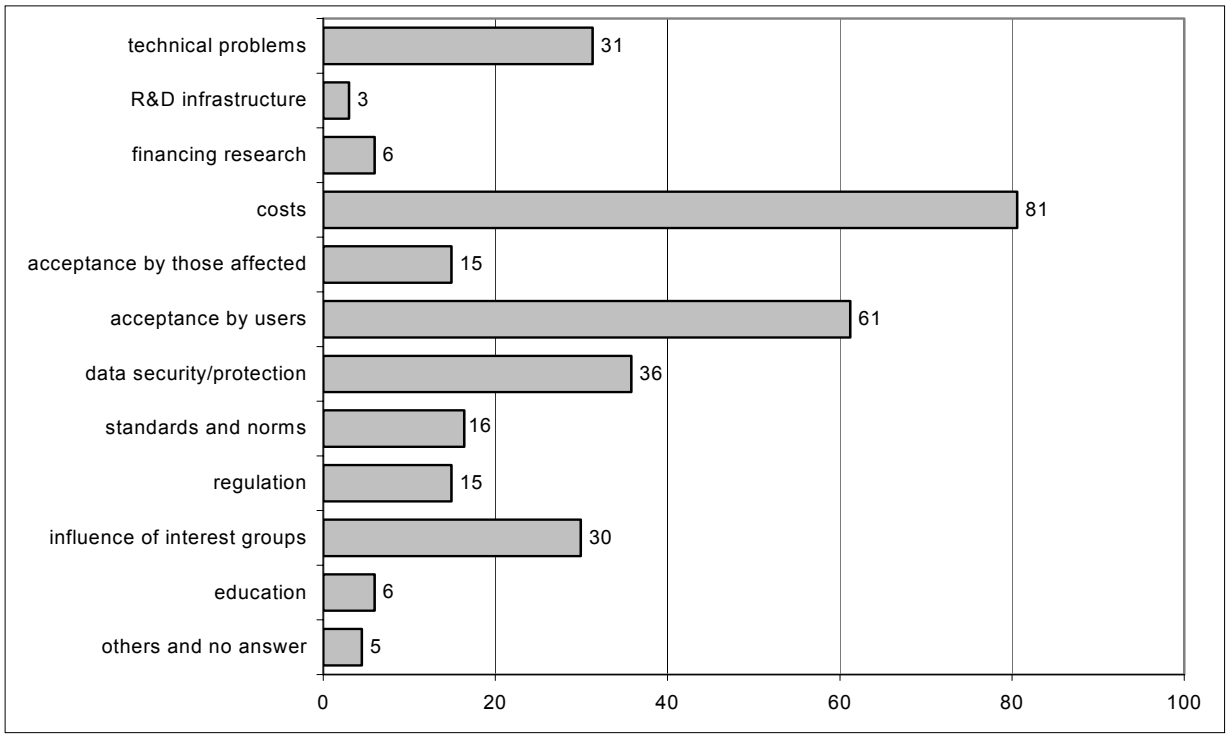

**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**
A system of such kind could not only guide patients, but many other things, such as goods or production-process parts in a modified version. According to many of the Delphi experts it could be applied in management and logistics (illustration 36), too. Also mentioned are the areas industry and production as well as traffic and mobility. Even product development, sales, environmental management and "others" are named – even if only by few.

**Illustration 36:** Thesis 7 – Applicability in other areas (in percent)




## Where do you see obstacles for the realisation of the thesis?

**Illustration 37:** Obstacles for the realisation of thesis 7 (in percent)




In spite of the participants' elation there are yet many obstacles considered on the way towards realisation (illustration 37). Firstly considered are the costs: They are firmly characterized by investment expenditure for the basic infrastructure necessary for the system. Also not neglectable: acceptance by users, meaning the hospitals, seems to be an obstacle, especially for cost reasons, probably also for time reasons. All other categories are named, especially data protection / data security, influence by interest groups as well as technical problems. Then, there is the acceptance by those concerned, the question whether they will adopt such a system and behave according to its purpose. 15 percent of the participants name this acceptance by those concerned as a probable obstacle.

**Prospect**

An EDP-supported guiding system for reducing waiting periods and making better use of capacities sounds like a sellout idea. And as a matter of fact, chances for realisation are good, as Delphi experts unanimously consider the project feasible during the coming ten years, especially regarding its importance for cost reductions. And yet, many obstacles are named on the way to realisation and implementation. A system of this kind could be applied in other sectors in the near future, leading areas are management and logistics.

Thesis 8: Telemonitoring, i.e. close-meshed monitoring of patients (at risk), evaluation of the generated information in and by medical facilities and, if necessary, alerting the treating physician, has become a standard.

Telemonitoring has been discussed for quite some time now and first trials are running (Der Spiegel, 2007), though, for various reasons, it is not yet a standard application. So far there is no existing infrastructure for such a system, even for chronically ill or risk patients. A system of this kind would allow many patients, who right now need to be observed in hospitals, to stay at home, with their treating physicians being informed in cases of emergency or if observed parameters are not okay.

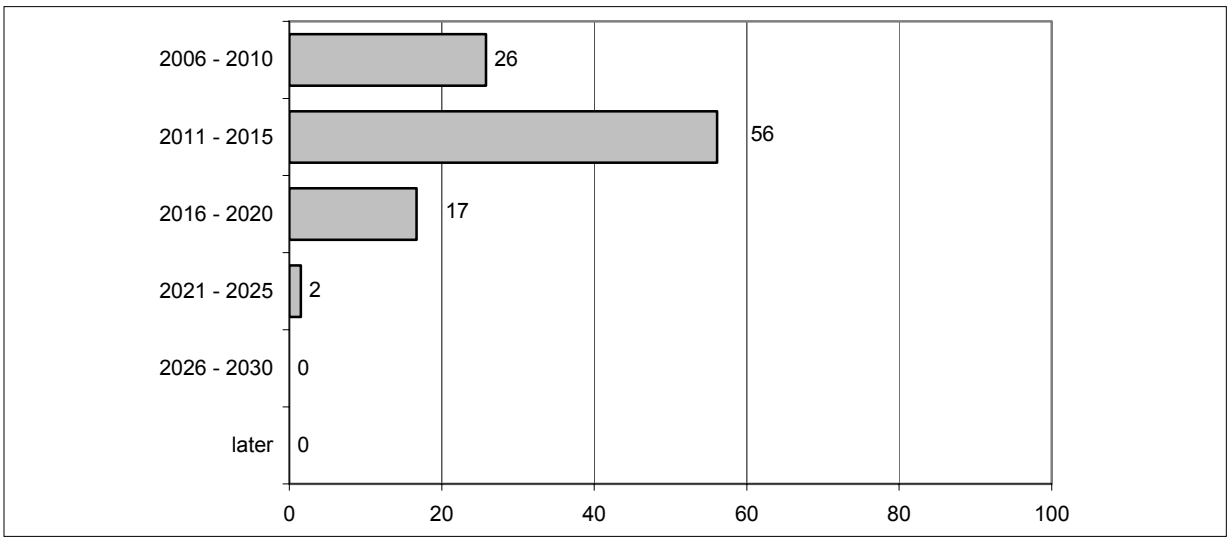
This topic has two facets: One the one hand the patients are more comfortable and in the long run costs (raised by in-patient stays) can be saved. On the other hand, in this context data protection and protection of privacy are issues highly discussed. The patients feel uneasy at the thought of permanently being under observation. Data protectors are afraid that persons become transparent are generally supervised. One commentary in the Delphi study at hand pointed out that, due to a shortage of doctors (even higher in the East German states than in Baden-Wurttemberg), which is expected and even beginning today, telemonitoring will become a necessity.

66 participants evaluated this thesis, 37.1 percent of them estimated their expertise as high – a high rate. Only 22.6 percent of the participants estimate their expertise as low, all the others have medium expertise.

**When do you expect the realisation of this thesis?**

As shown in illustration 38, telemonitoring as a standard is considered realisable around the year 2013, an estimate shared by the majority of participants (Q1: 2011, Q2: 2015). Everybody considers the thesis realisable. Initially, telemonitoring will only be used for patients at risk, e.g. chronically ill persons. Only after the costs have been reduced and an infrastructure has developed will such a system be used for more persons. When telemonitoring has become a standard and long-term stable bio-sensors are available, more and amore patients are able to stay at home.

**Illustration 38:** Realisation time for thesis 8, distribution of answers in 5-year steps (in percent)

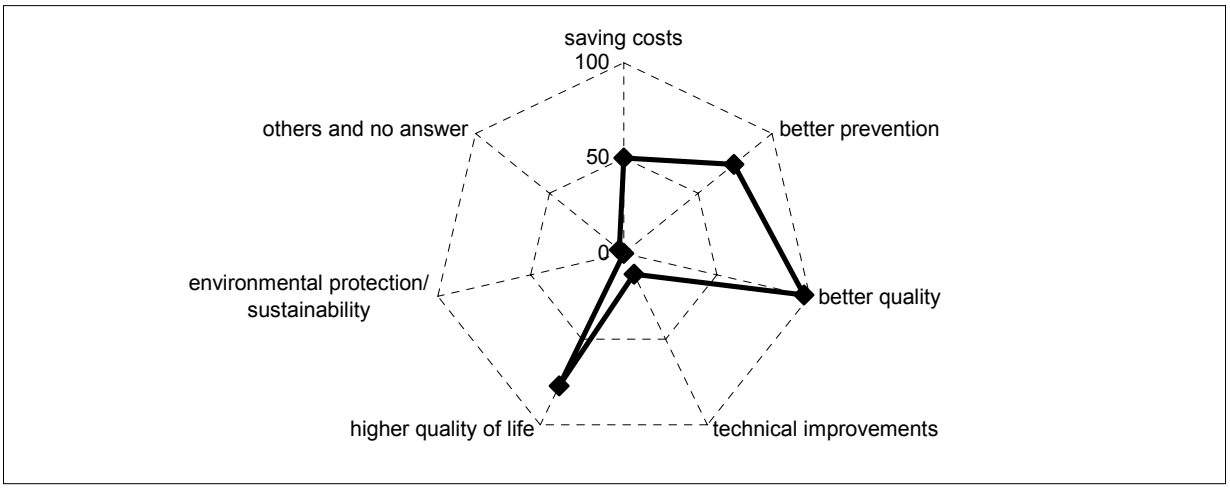



**All in all, do you personally consider the realisation of this thesis desirable?**

Also for the question as to desirability of the thesis the participants share their opinion: Telemonitoring of patients (at risk) is considered desirables by 89 percent of the answering participants. 9 percent do not know, 2 percent do not consider the topic desirable. Objections are made regarding possibilities of misapplication as well as costs. Very probably many of those answering would not like to be supervised around the clock – also if it is a benefit to their own safety in case of an illness. Certainly emotional considerations play a major role in this context.

**What is the realisation of the thesis important for?**

**Illustration 39:** Importance of thesis 8 (in percent)

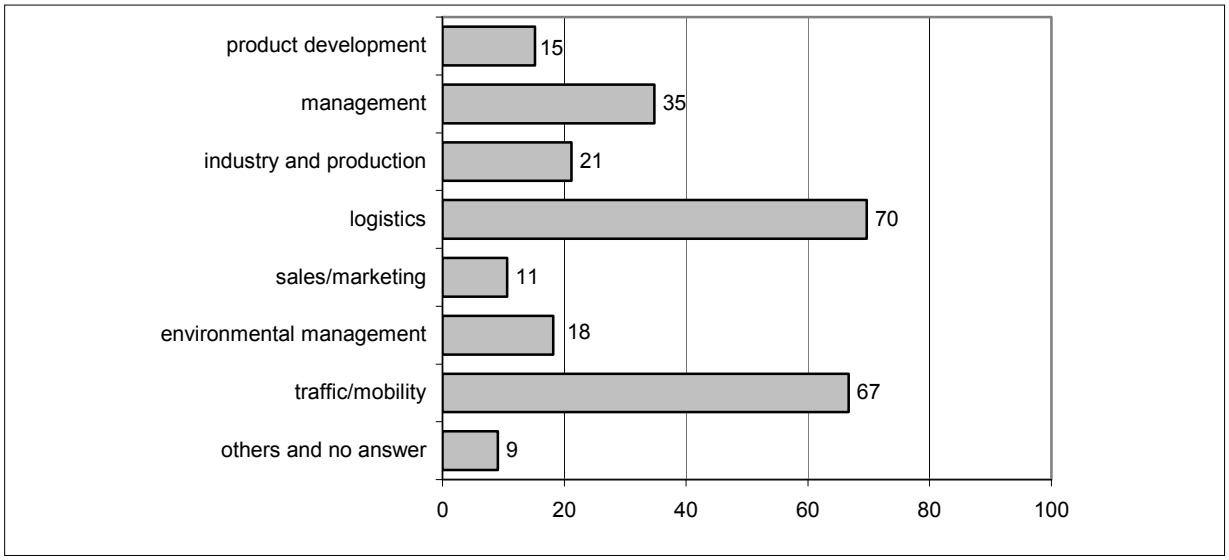



The development is very important for a better quality of healthcare, a higher quality of life and better prevention (illustration 39). The only alternative to telemonitoring in some cases proves to be going to a hospital as an inpatient – in so far this evaluation seems logical. By means of telemonitoring, patients can remain in their familiar environment, which leads to

higher quality of life and thus again to less stress evoked by getting accustomed to a new surrounding. This technology can also contribute to cost reductions.

**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

**Illustration 40:** Thesis 8 – Applicability in other areas (in percent)

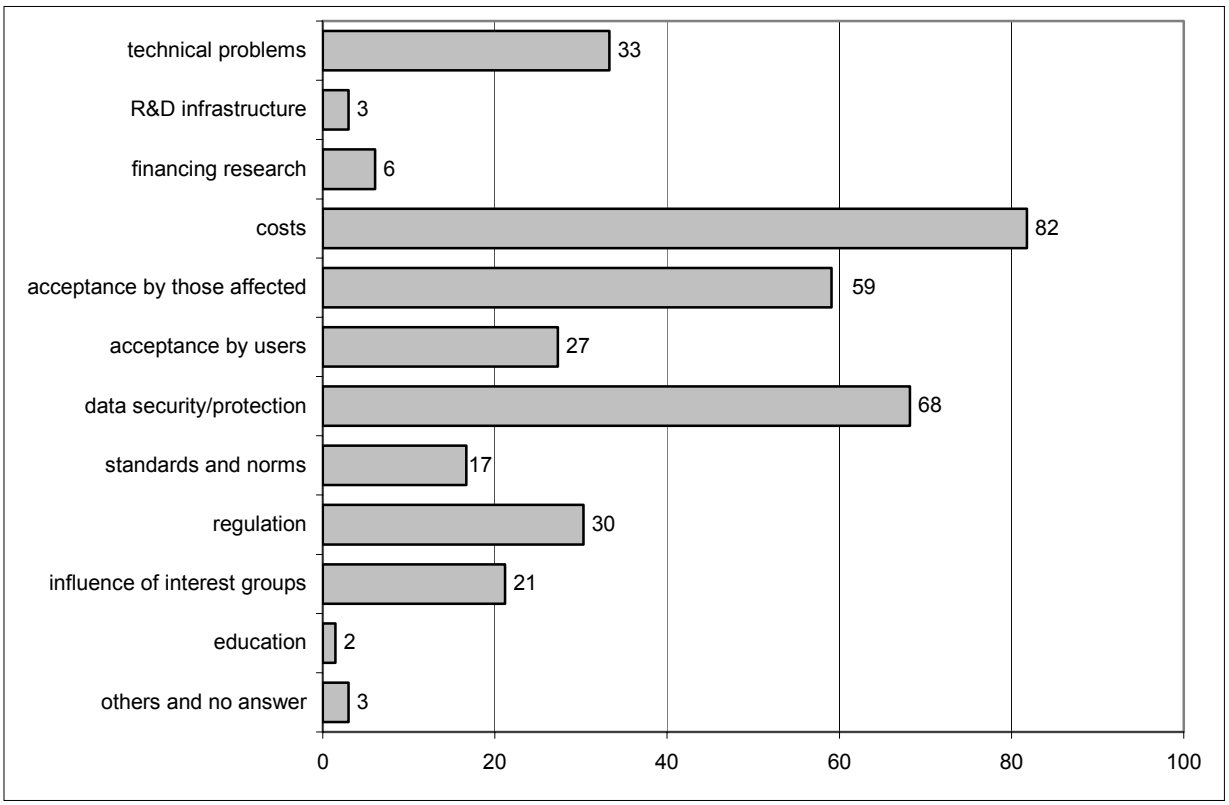



Especially logistics and traffic/mobility are areas named as application fields for telemonitoring (illustration 40). But also management, industry and production, environmental management or even sales are areas which could become fields of application.

**Where do you see obstacles for the realisation of the thesis?**

In spite of the very optimistic approach towards realisation times there are many obstacles mentioned to be lying on the way. These are especially characterised by the costs for such a system, most probably referring to both – initial investment expenditure and running costs for the full-time observation as well as the analysis of collected data. Mentioned second is data security and data protection, followed by the acceptance by those concerned – who, in fact, will be permanently watched. This acceptance issue is regarded more critically by the age cohort of 56 years and above than by younger Delphi participants. Also questions regarding regulation issues and several technical problems need to be solved. Here, too, the thesis is evaluated from angles depending on the participants' age: Persons younger than 45 years consider regulation as an obstacle (43 percent of the 26 to 35 year olds, 36 percent of the 36 to 45 year olds). The same applies to technical issues, which are considered a large obstacle by 43 percent of the 26 to 35 year olds with only 20 percent of those aged between 56 and 65 years. The medium age group of 36 to 55 year old persons evaluate approximately averagely (36 or 35 percent, respectively).

**Illustration 41:** Obstacles for the realisation of thesis 8 (in percent)




**Prospect**

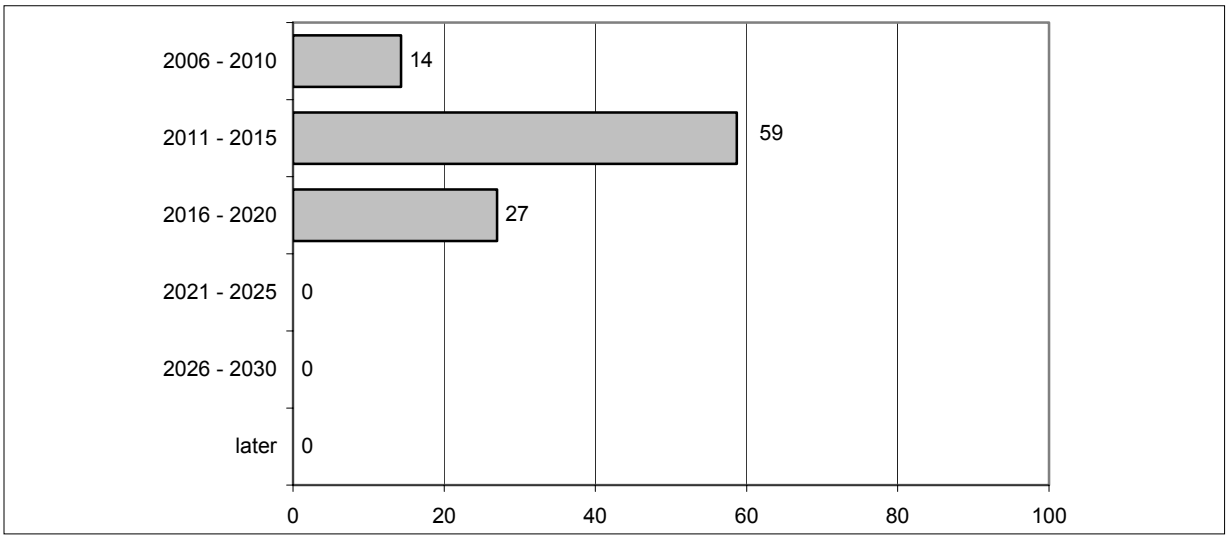
Telemonitoring in the sense of closely-meshed monitoring of patients will become a standard, Delphi experts agreed upon this. Also the timeframe of ten years from now on is indisputable. And yet, there are several obstacles to be taken, e.g. costs for building up and maintaining the system, which can lead to delays, as well as data protection and issues of personal rights, which need to be dealt with like all questions of monitoring persons.

## Thesis 9: Expert systems are routinely appointed to recommend specific advice for diagnoses and therapies to the healthcare staff.

Expert systems are expected to become increasingly "intelligent". This means, they will be able to draw contexts between pieces of data, sort them and filter though priorities according to specific criteria. The idea behind the thesis is the fact, that expert systems will be applied in the health sector, not only for the purpose of reference, but in order to offer specific advice. The power of decision, of course, lies with those actually treating the patient. One commentary points out that a "loss of decision-making competence" can be a consequence.
This thesis was evaluated by 65 participants, 27.7 percent of them – nearly one third – estimate their expertise as high. More than half (53.8 percent) estimate their expertise as medium.

**When do you expect the realisation of this thesis?**
With relatively low variance of the answers the topic is considered feasible around the year 2014. The low quartile Q1 is situated at the year 2011, the high quartile Q2 at 2016. Accordingly, the answers only range among the first three five-year steps (illustration 42). Only one person considered the topic "never" realisable. One remark was made, stating the system's technology was applied even today routinely, the problem was more the marketing and sales issue as well as interfacing all processes.

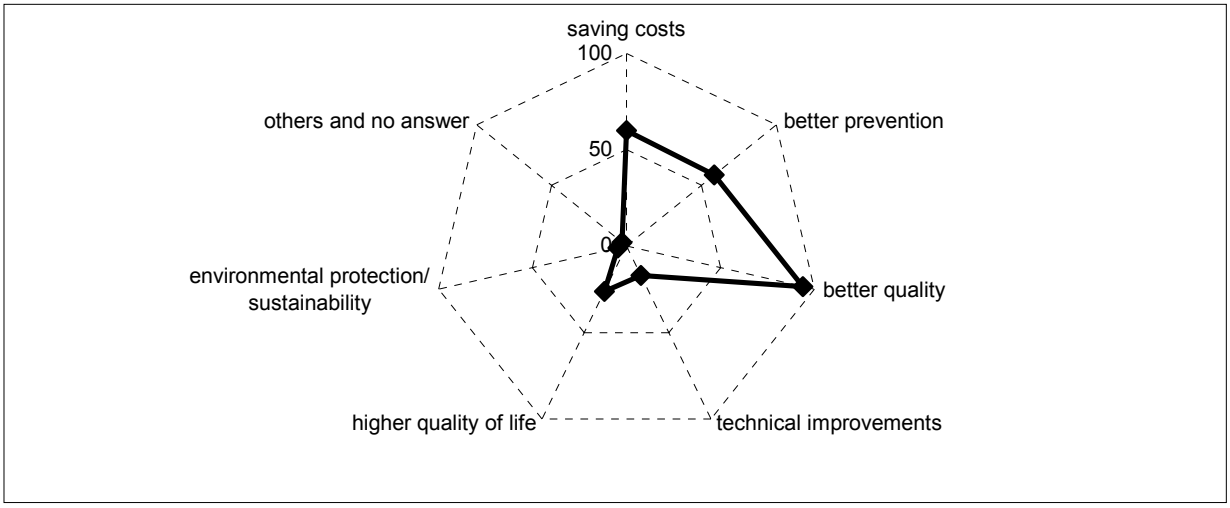
**Illustration 42:** Realisation time for thesis 9, distribution of answers in 5-year steps (in percent)



**All in all, do you personally consider the realisation of this thesis desirable?**
88 percent of the participants consider the topic desirable. Respectively 6 percent say "do not know" or that it is not desirable. Even before the survey (e.g. during the workshop) the topic was discussed, with the majority of participants stating that the expert systems were generally helpful. However, what happens in the case of recommendations which are "wrong" or imprecise or contrary to own treatment recommendations? The idea of machines substituting medical staff in making decisions about treatments was generally considered undesirable by workshop participants.

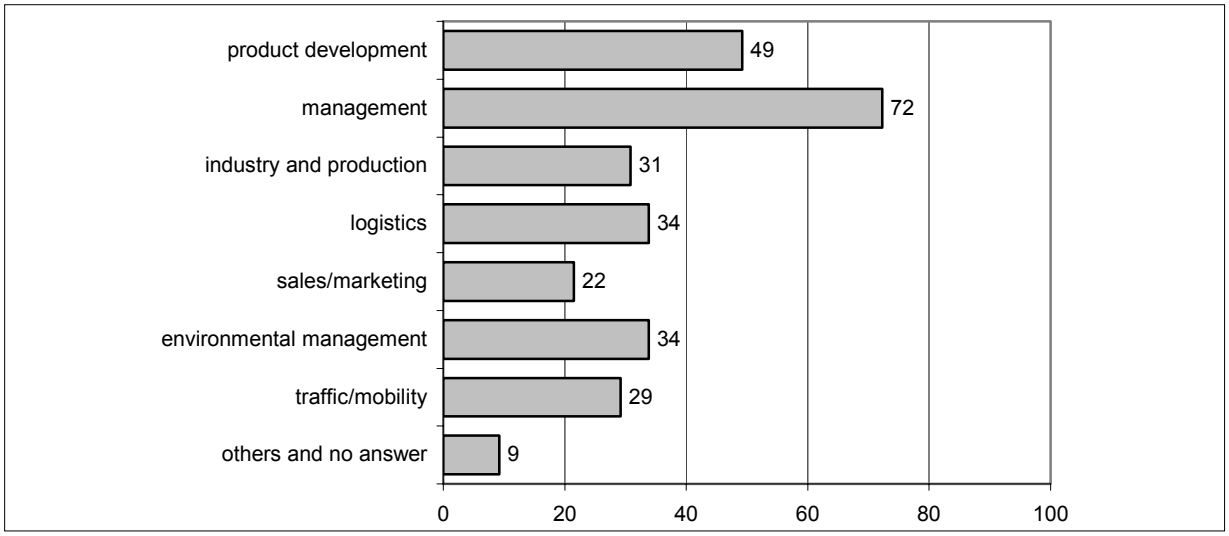
**What is the realisation of the thesis important for?**
The topic is definitely important for better quality of healthcare (illustration 43) and can possibly also contribute towards better prevention and cost saving.

**Illustration 43:** Importance of thesis 9 (in percent)



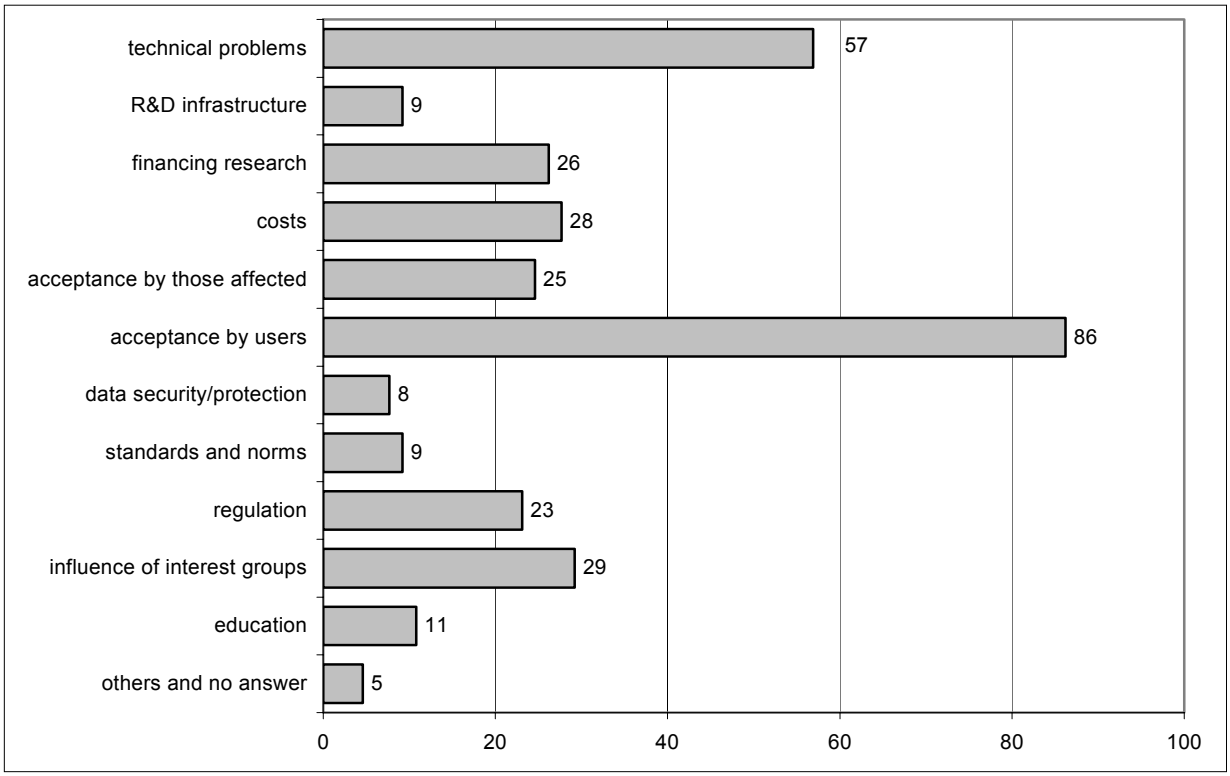

**Other than the health sector, in which other areas will the technological development mentioned in the thesis be applicable, too?**
Systems which offer recommendations for decisions can be applied in many other areas. Illustration 44 shows a large variance of answers. The most markings were made for the area management, followed by product development.

**Illustration 44:** Thesis 9 – Applicability in other areas (in percent)




## Where do you see obstacles for the realisation of the thesis?

**Illustration 45:** Obstacles for the realisation of thesis 9 (in percent)




Even though a system that offers recommendations for the medical sector is considered realisable the Delphi experts see the largest obstacle in acceptance by users. After all, who wants to delegate a share of decisions and only "nod to consent"? Technical problems such as access to organised databases, "intelligent" sorting and selecting of information, the use of large amounts of data in a short period of time etc. are also among those things which need to be figured out. But also other categories are mentioned – some of them often, some of them less often – costs, influence by interest groups, research funding, acceptance by users and questions of regulation are among them.

The expert commentaries show that there is apprehensiveness about staff needing to explain its actions or even having to carry the consequence if it – for good reasons – does not follow recommendations. What happens if doctors prescribe a treatment which does not follow recommendations and if there are negative consequences for the patient? What do legal proceedings look like and involve? Other commentaries point out that today's systems are still too inflexible and confined to (specific medical) domains. An adaptation to individual cases and requirements needs to take place; this is where standard rules and procedures do not always apply.

**Prospect**

The standard use of expert systems which even recommend decisions to the treating staff does not stand for the systems actually making the decision. This is pointed out various times, as the systems seem desirable to most of the Delphi experts and are to be realised – despite technical problems and issues of acceptance. Even today some already exist. The systems referred to in the thesis, however, will involve a number of legal questions, e.g. what happens if a recommendation is not followed? The other critical point is that such approaches can lead to "decision unwillingness" respectively "loss of decision power" and it is feared that medical staff, after a period of settling on, follows recommendations uncritically. This applies to the many other areas, too, which can make use of "intelligent expert systems".

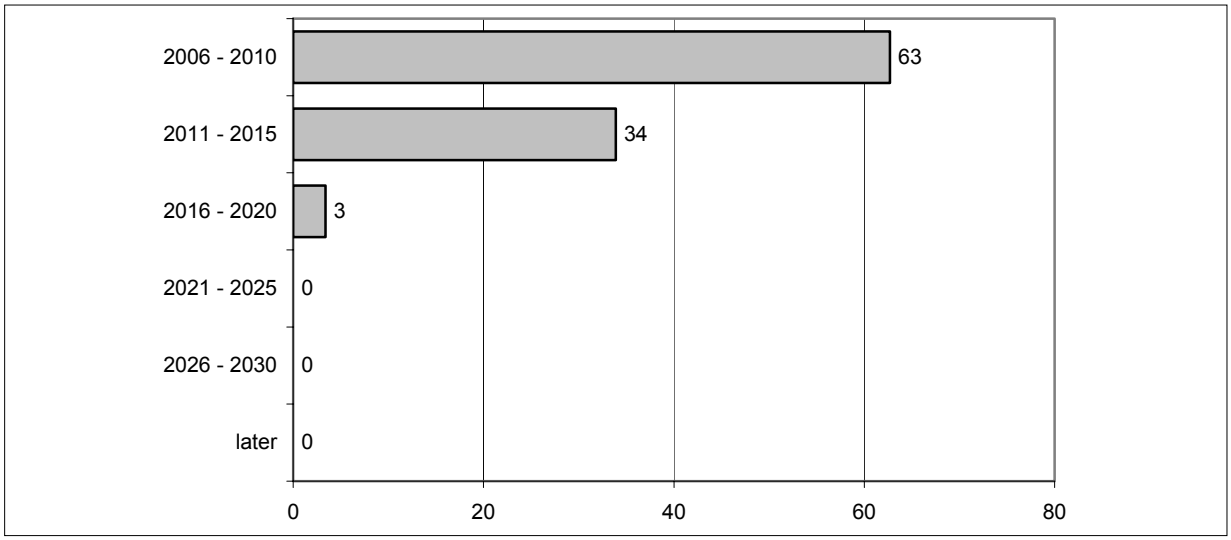
These 10: Expert systems and databases, which monitor customised medications for individual patients with respect to undesired medication interactions and recommendations for a pharmaceutical therapy with reduced adverse reactions and side effects, are tested in pilot experiments.

Unwanted drug interaction can cause great damage, even leading to a patient's death. Some of the unwanted drug interactions are caused by wrong doses or wrong administration by the patients themselves (so-called insufficient compliance, see Bührlen, 2003). Additionally, there is the fact that many patients are over-medicated for various reasons. This is why this thesis was selected. It offers a solution for these kinds of problems via expert systems and databases. Also, it is generally desirable to apply and prescribe a therapy with side effects as low as possible. However, the range of the phrased thesis does not go very far and "only" asks about testing in pilot experiments.

This thesis was evaluated by 60 Delphi experts. 25.9 percent – many of them – estimate their expertise as high, 44.8 estimate it as medium and 29.3 percent as low. For this thesis, some of the commentaries made for thesis 9 can be applied, as well.

**When do you expect the realisation of this thesis?**

**Illustration 46:** Realisation time for thesis 10, distribution of answers in 5-year steps (in percent)

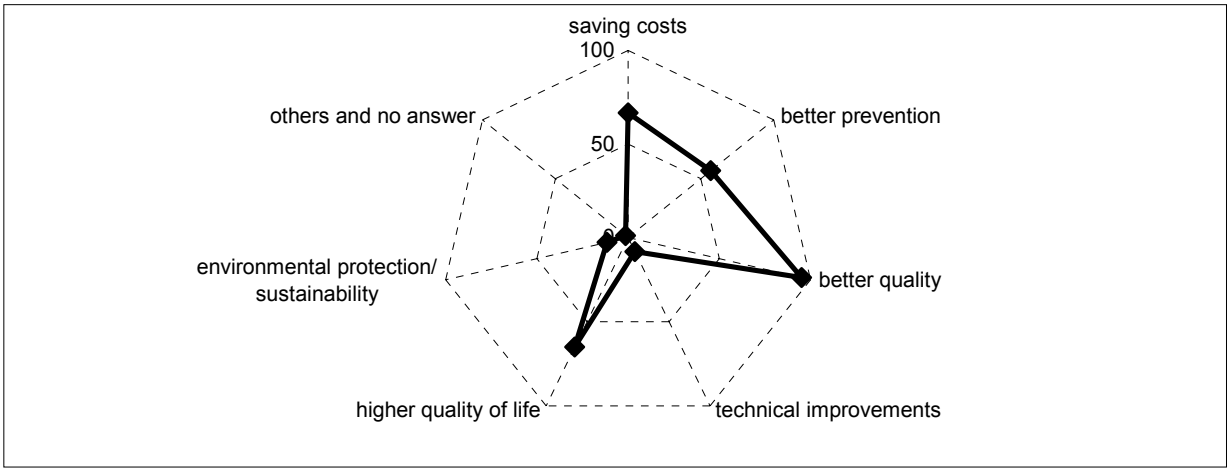



The realisation of this thesis is considered possible at a very early stage (the earliest stage in the survey at hand), with respect to it's testing. The median is ranged at the year 2010, the low quartile at the year 2008, the high quartile at 2012. The distribution of answers is thus relatively low, as shown in illustration 46.

**All in all, do you personally consider the realisation of this thesis desirable?**
98 percent of the answering participants – the majority – consider such a system desirable. Only 2 percent say "do not know".

**What is the realisation of the thesis important for?**

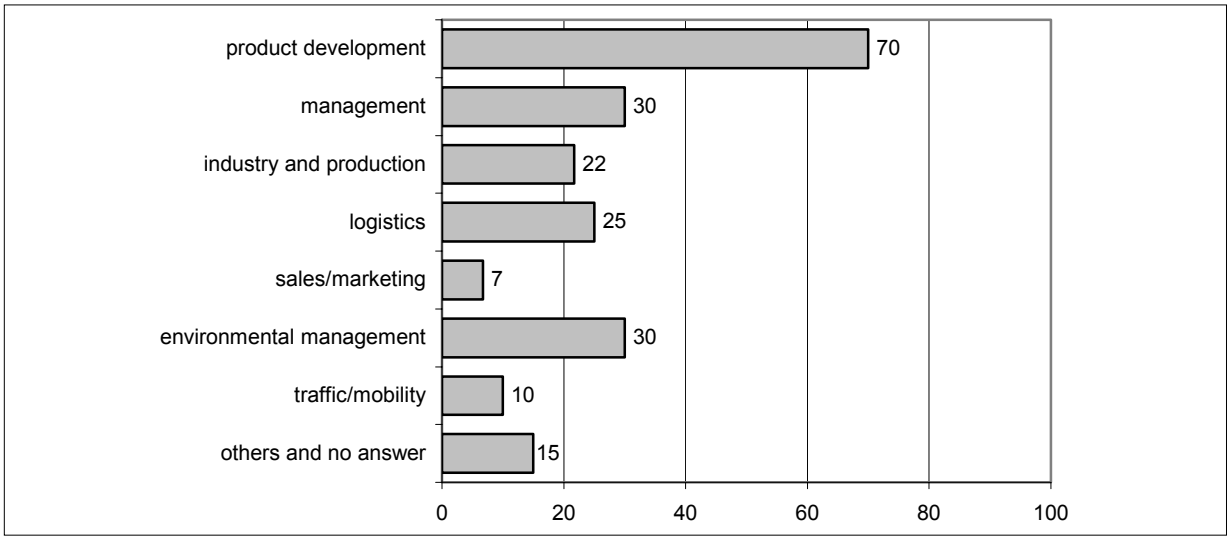
**Illustration 47:** Importance of thesis 10 (in percent)




The development is especially important for a good quality of healthcare. Expert systems and databases are also considered as important for cost saving and reduction, a higher quality of life and better prevention (illustration 47).

**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

**Illustration 48:** Thesis 10 – Applicability in other areas (in percent)

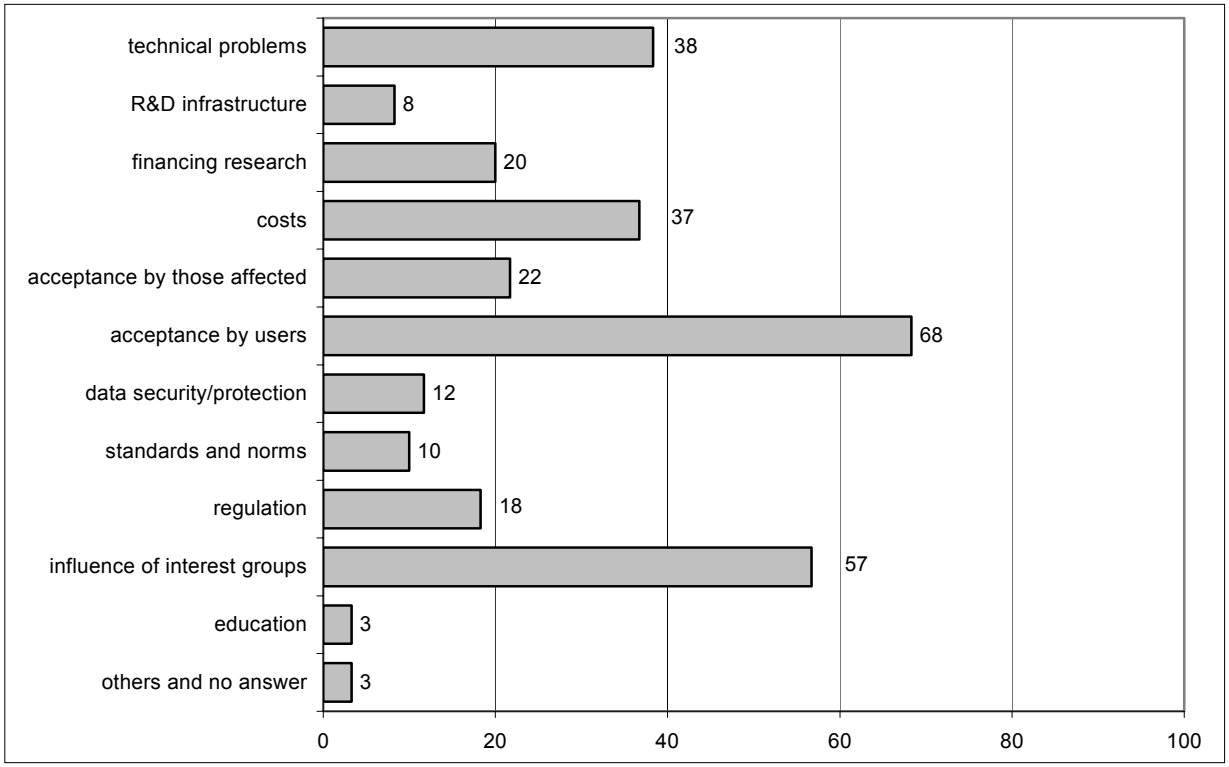



Similar to evaluation on other databases this technology – adjusted to an appropriate context – is applicable in many other areas (illustration 48). 70 percent of the 60 answering participants in the second Delphi round named product development here. But also management,

environmental management, logistics and industry and production are named. All the same, 15 percent of the participants marked “nothing and no answer”. One comment is more specific and names sports medicine and especially doping as a further area of application.

**Where do you see obstacles for the realisation of the thesis?**

**Illustration 49:** Obstacles for the realisation of thesis 10 (in percent)




GA very clear statement concerning the obstacles: Even if the topic is feasible at an early stage through trial applications, the potential realisation and broad application is forestalled by acceptance issues by users and the influence of interest groups. Apart from that, technical problems and cost issues are secondary. However, all other possible obstacles such as research funding, acceptance by those concerned, data security and data protection, regulations, standards and norms as well as the research and development infrastructure are named. Practical application will take a while with regard to all these obstacles.

**Prospect**

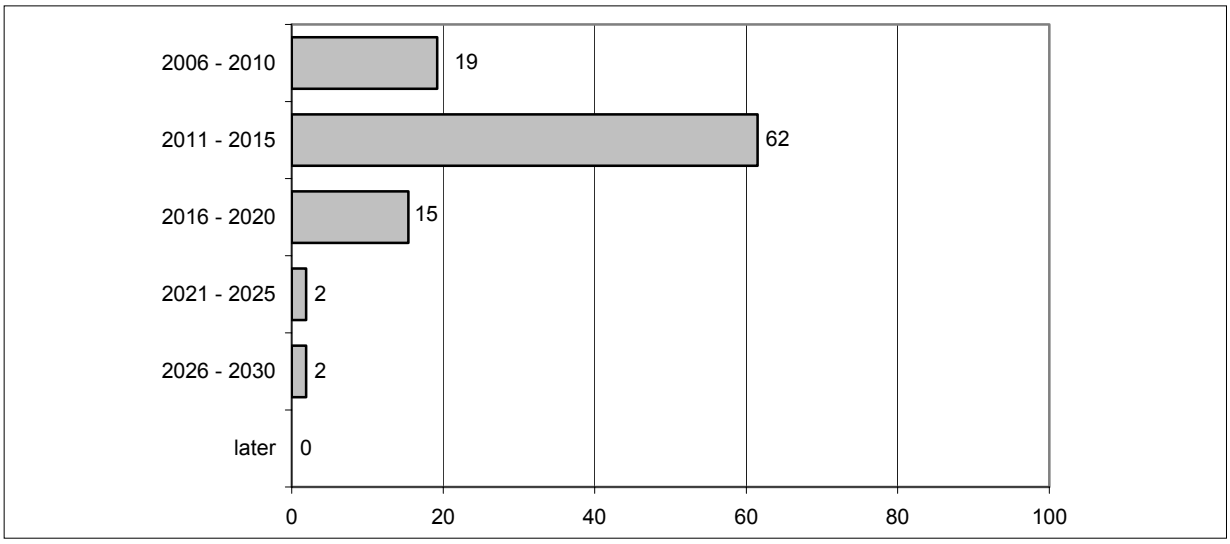
Expert systems and databases which monitor the customised required medication combination for individual patients with respect to undesired medication interaction and recommend a pharmaceutical therapy with reduced adverse reactions and side effects are possible in the form of pilot experiments in the near future and small databases do in fact already exist. However, broad application is confronted by many obstacles, especially the acceptance by users and the influence of interest groups. Similar to all theses involving expert systems this technology, too, is applicable to many other areas.

Thesis 11: Labs-on-Chips are broadly applied for "point of care" diagnoses of clinically relevant parameters such as proteins, antibodies, hormones, bilirubine, cholesterol, urea as well as enzymes in blood and urine.

Retrieving data regarding clinically relevant parameters directly at the location where they are needed – the "point-of-care" – is the content of this thesis. The whole system is to be realised via a minimal laboratory on a microchip. This way, blood and urine of a patient could always, no matter where he or she is, be analysed with regard to illnesses.
This thesis was evaluated by 5 Delphi experts. This shows clearly that the thesis is more particular than others and that not that many persons can or want to evaluate it. Accordingly only 13.7 percent of those answering estimated their expertise as high. 41.2 percent estimated it as medium and 45.1 percent as low.

**When do you expect the realisation of this thesis?**
Even if the thesis and its context seemed nearly utopian according to the commentaries, everybody considered the labs-on-chips as realisable (nobody said "never"), what is more, during the oncoming 10 to 15 years. Most probably the realisation will be subject to the substances which are to be accounted for (some at an earlier stage, others later), but the timeframe for realisation is relatively unanimously agreed upon: The median states the year 2013, the low quartile (Q1) estimates the year 2011, the high quartile (Q2) the year 2015. The variance is shown in illustration 50.

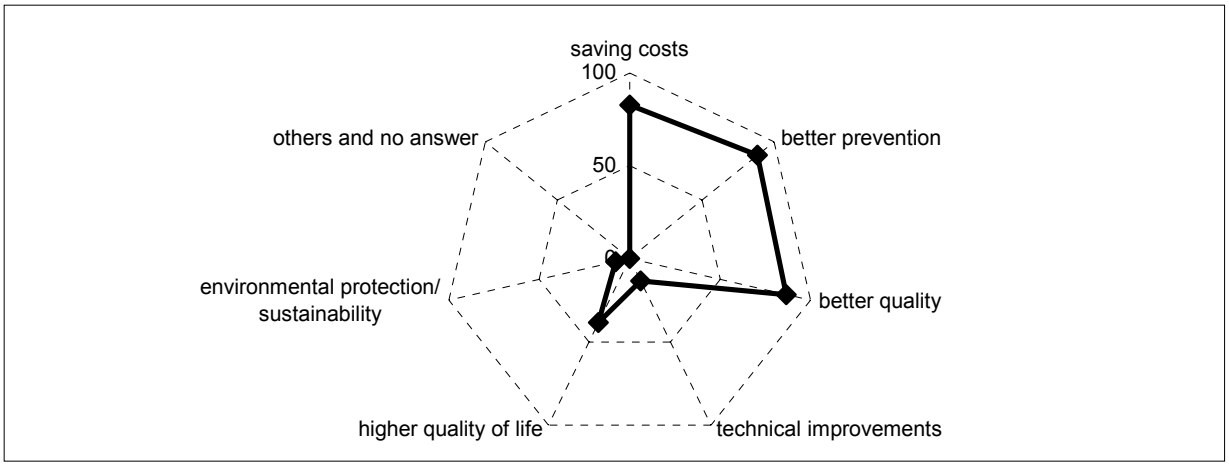
**Illustration 50:** Realisation time for thesis 11, distribution of answers in 5-year steps (in percent)




**All in all, do you personally consider the realisation of this thesis desirable?**
96 percent of the Delphi experts consider the "on-site-laboratory" desirable. Only 2 percent say "do not know" or "no".

## What is the realisation of the thesis important for?

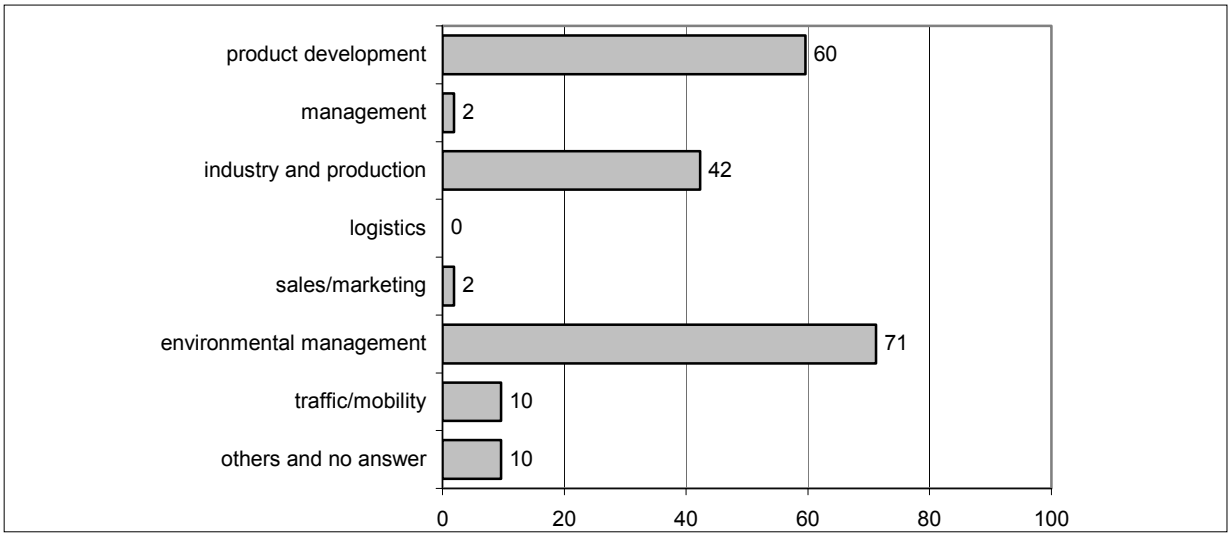
**Illustration 51:** Importance of thesis 11 (in percent)




According to more than 80 percent of the experts participating in the Delphi the labs-on-chips are especially important for a better quality of healthcare, better prevention as well as cost reductions and saving (illustration 51). Nearly half of the experts also consider the thesis important for higher quality of life since the term point-of-care diagnostics implies that trained patients are able to use the chips on their own or at least do not need to go to a hospital or visit a practice-based physician.

**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

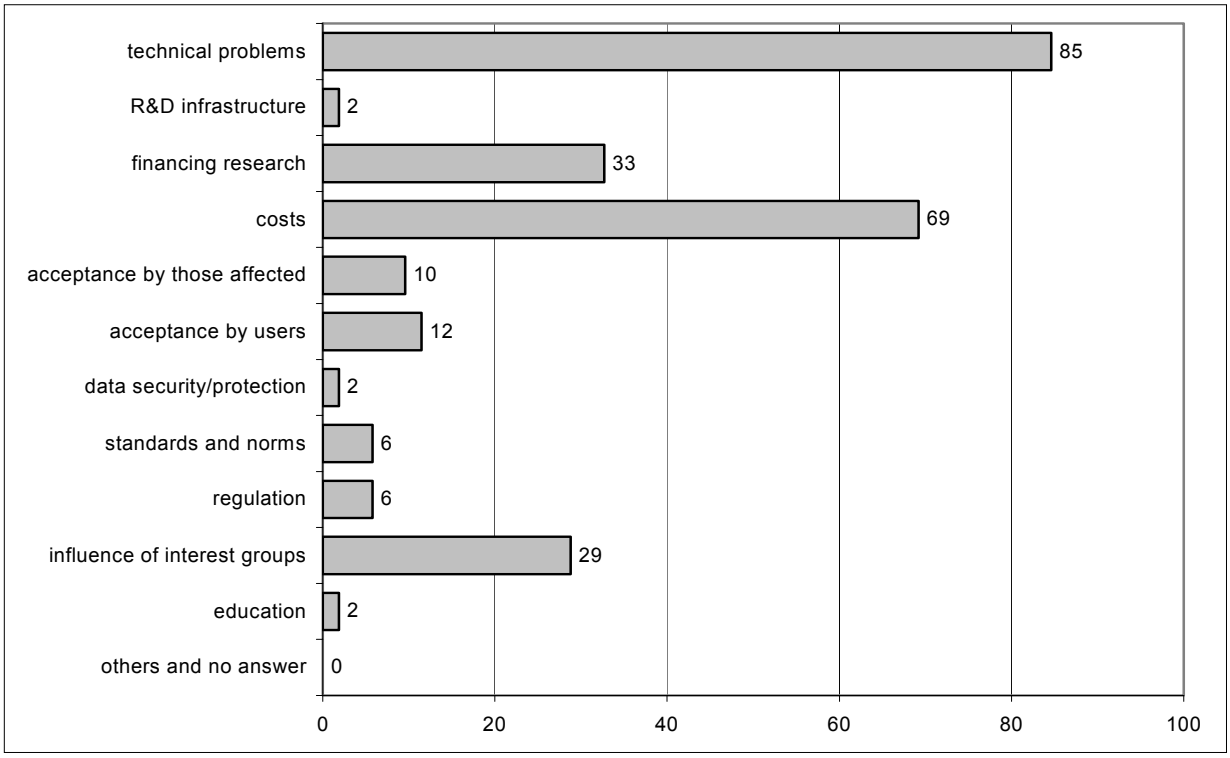
**Illustration 52:** Thesis 11 – Applicability in other areas (in percent)




Labs-on-chips as a method of accounting for and proving the existence of substances can be applied in environmental management, in product development as well as industry and production, say the Delphi experts (illustration 52). Once developed, the principle must only be applied to different substances and environments.

**Where do you see obstacles for the realisation of the thesis?**

**Illustration 53:** Obstacles for the realisation of thesis 11 (in percent)




Obstacles in the way of realisation are mostly characterised by technical problems (illustration 53). Bio-sensors to this day are yet very unstable and make proving the existence of substances a challenge. The second largest challenge is considered to be miniaturisation. The obstacle named second is the costs. Possibly the influence of interest groups and research funding are obstacles for a realisation in the near future.

**Prospect**

Labs-on-chips for "point-of-care" diagnostics of blood and urine are considered feasible in the next 10 to 15 years. If a quick method of analysis is sought other application areas are possible, as well, i.e. environmental management as well as production and product development. The thesis is thus considered desirable. However, technical obstacles and costs lie in the way of realisation. These obstacles are considered surmountable. Step by step a relatively large market will develop in other areas and sectors (e.g. environmental management or industrial production), as well.

## Thesis 12: Protein-chips for "Point of Care" diagnostics have been developed and tested.

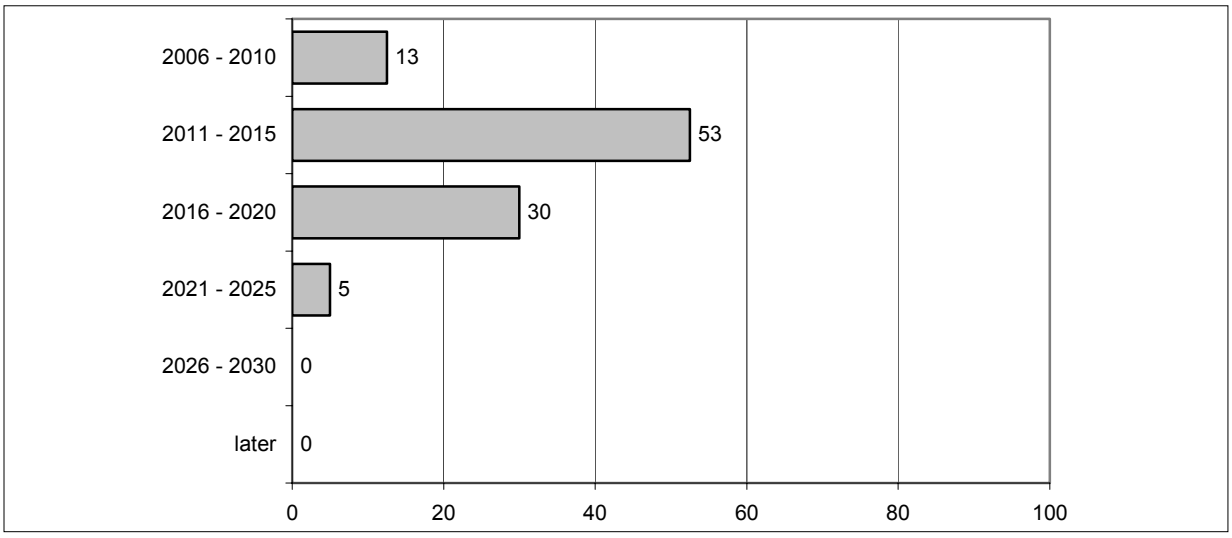
The protein-chip is a promising instrument of protein research (see also theses no. 34 and no. 35) in clinical diagnostics, molecular biological research as well as the food analysis and environmental analysis. A related method is the DNA-chip. Antibodies are the proteins used most for diagnostical processes. Proteins, viruses, toxins and pesticides in a sample (blood serum, milk, urine etc.) can be traced. The specific property of antibodies which absorb the substance (antigen) is used. Prior to this, antibodies or the antigen are marked with an enzyme. The enzyme-catalysed reaction serves as a proof for the existence of an antigen. Basically the protein-chip offers the possibility to trace and deliver proof of substances in clinical diagnosis, mostly in the blood. This measurement should be taken directly at the location where the patient is.

This thesis was only evaluated by 43 participants. All the same 11.6 percent of them estimated their expertise as high, 32.6 percent as medium and 55.8 percent as low. The results thus represent a low expertise and a far smaller sample of those evaluating than in many other cases.

**When do you expect the realisation of this thesis?**

Even though the topic is very specific the answers as to the time of realisation are not widely distributed: Protein-chips are expected to be realisable by the year 2014 (Q1: 2012, Q2: 2017). Nobody doubts the realisation. The answers are distributed as depicted in illustration 54.

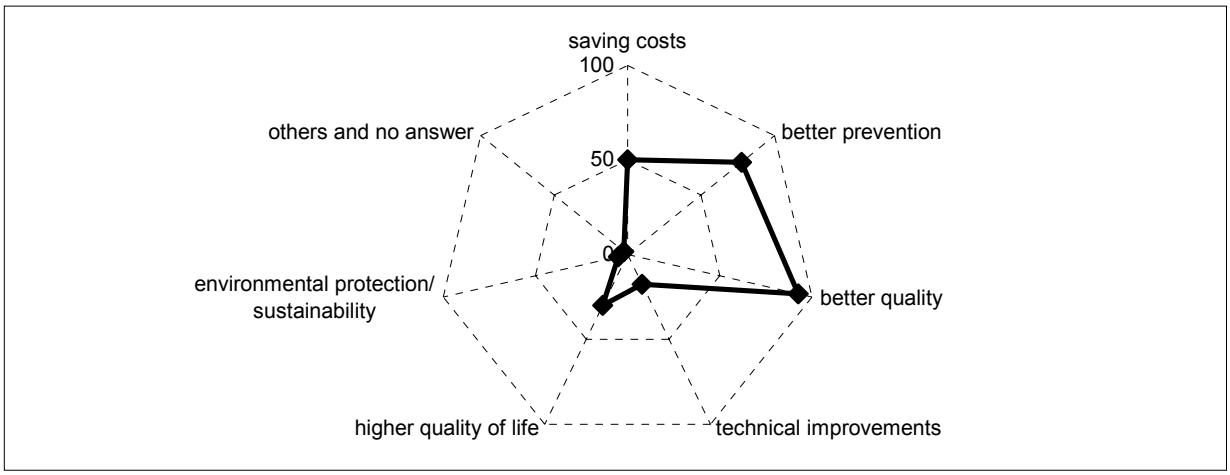
**Illustration 54:** Realisation time for thesis 12, distribution of answers in 5-year steps (in percent)



**All in all, do you personally consider the realisation of this thesis desirable?**
Protein-chips for "point-of-care" diagnostics are considered desirable by 94 percent of those answering. Respectively 3 percent say "no" or "do not know".

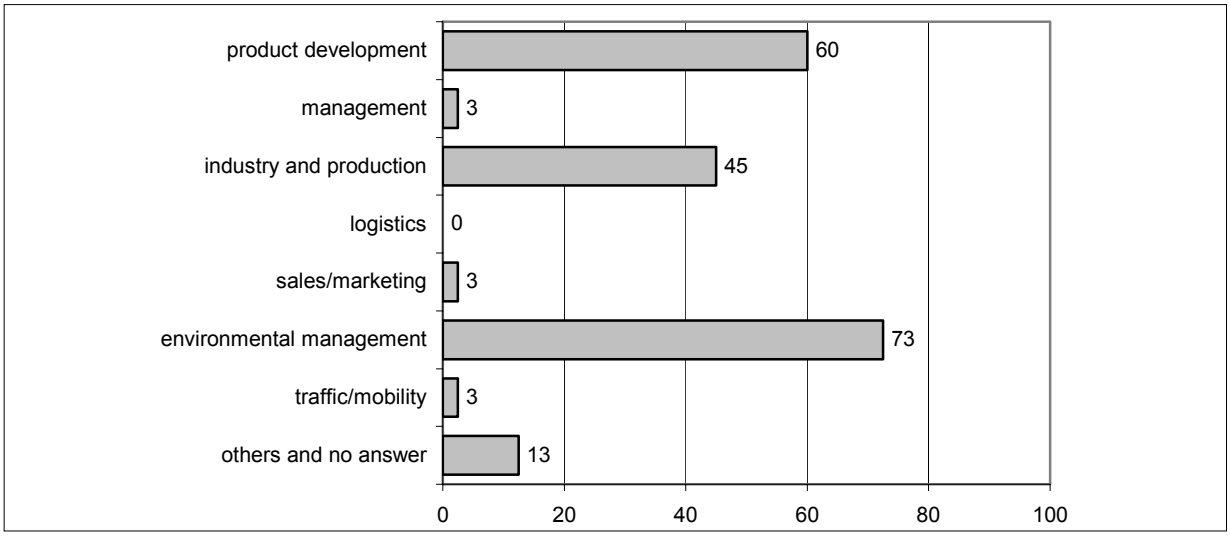
**What is the realisation of the thesis important for?**
The topic is considered very important for a better quality of healthcare (illustration 55). Some of the participants are of the opinion that it could also serve towards cost reduction and saving as well as a higher quality of life.

**Illustration 55:** Importance of thesis 12 (in percent)




**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**
Protein-chips will be applicable in other areas, too. Especially environmental management, product development as well as industry and production are named here.

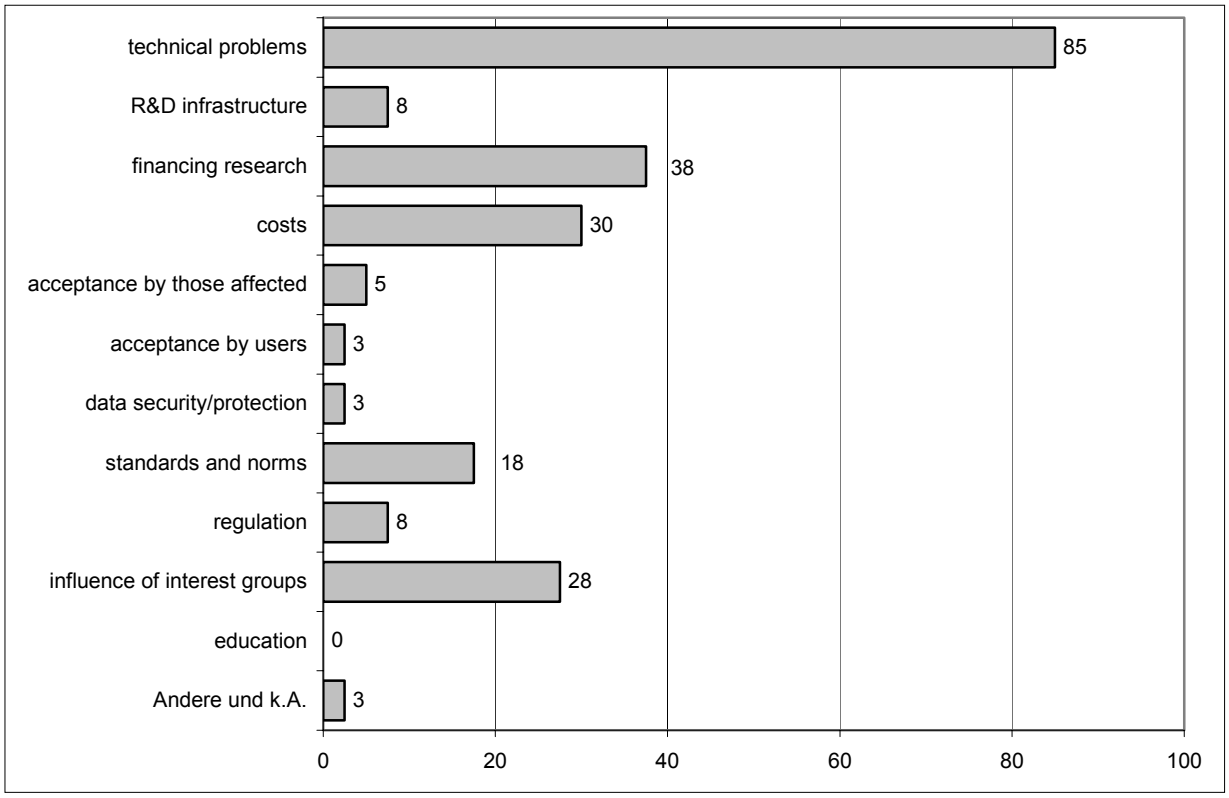
**Illustration 56:** Thesis 12 – Applicability in other areas (in percent)




**Where do you see obstacles for the realisation of the thesis?**

Before the topic can be realised there are several technical obstacles to be overcome (illustration 57). They pose as the real challenge. Research funding, costs and a possible influence of interest groups are named respectively by one third of the Delphi participants.

**Illustration 57:** Obstacles for the realisation of thesis 12 (in percent)




**Prospect**

The realisation of protein-chips for "point-of-care" diagnostics is confronted with mainly technical obstacles. These, however, seem overcomeable to the Delphi participants who consider the topic desirable and feasible. Realisation is expected around the year 2015. Then protein-chips could serve purpose to other sectors such as environmental management and contribute towards an improvement of health prevention and the quality of healthcare.

## Thesis 13: Histological diagnosis of tissue in vivo is possible with the help of spectroscopic, microscopic laser scanning methods.

In many cases histological examinations today require a tissue sample. The method is time-consuming and stressful, so that the idea developed of applying spectroscopic, microscopic laser scanning methods which "scan" the tissue in vivo without taking a specimen.

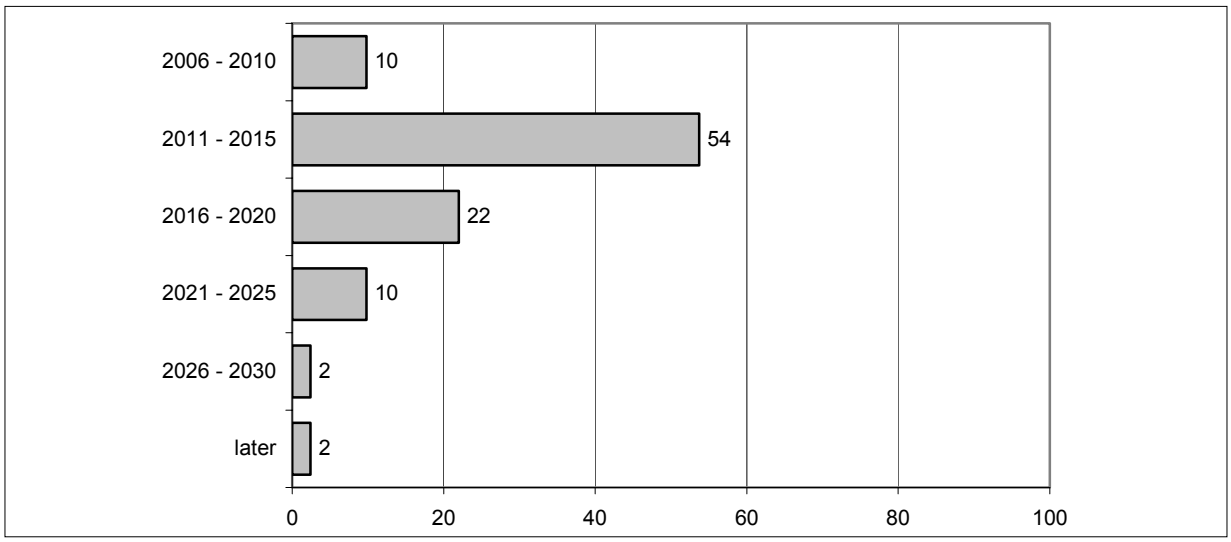
For a histological analysis e.g. a melanoma scanning needs to be three-dimensional. "Confocal laser scanning", an already existing method of three-dimensional scanning, is applied in microscopy (laser scanning microscopes) and ophthalmology (laser scanning ophthalmoscopes). The principle of confocal scanning is based on a focused laser beam scanning a specimen (in microscopy sometimes the object itself is moved instead) and the reverberating light is detected behind a small orifice. Through alignment of the orifice only the light from the focal plane is detected and one receives a cross section of exactly the area focused on. How thick the section is depends on the depth of focus of the microscope used. A 3D-data record can be obtained by taking pictures of adjoining sections – one only needs to adjust the focus differently between each photograph.

This topic, too, is very specific and only 46 percent of the participants answered here. Of those, 19.6 percent estimated their expertise as high, 21.7 percent as medium and 58.7 percent as low. This background explains the differences between answers given which vary especially in terms of the estimated realisation time.

**When do you expect the realisation of this thesis?**

The approach is considered feasible by all those answering and nobody says "never". The time estimate for realisation is around the year 2012 (median), with a range of seven years (Q1: 2012, Q2: 2018). The answers, however, vary much more than for other theses (see illustration 58), 2 percent of those answering even consider a laser scanning system of this kind realisable only after the year 2030.

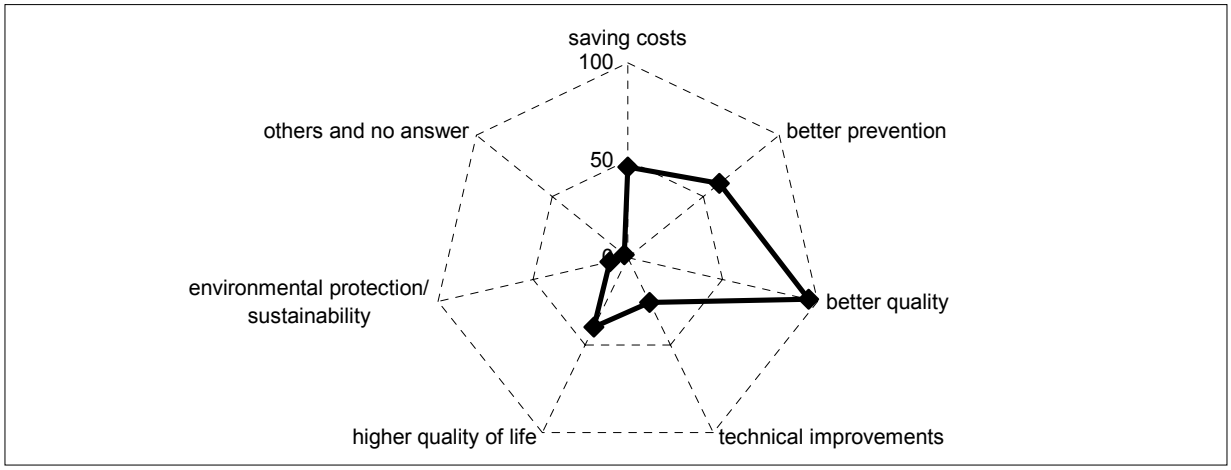
**Illustration 58:** Realisation time for thesis 13, distribution of answers in 5-year steps (in percent)




**All in all, do you personally consider the realisation of this thesis desirable?**
93 percent of the Delphi participants consider the topic desirable, 7 percent say "do not know".

**What is the realisation of the thesis important for?**
The topic is very important for a better quality of healthcare. Its relevance for better prevention, cost reductions, a higher quality of life and technical progress is also named. Those with real expertise considered the topic interesting for the latter reason more frequently than other participants. What remains is the necessity to verify whether persons with high expertise are confident that laser scanning methods have that large an impact as presumed and can define precisely what they will be important for.

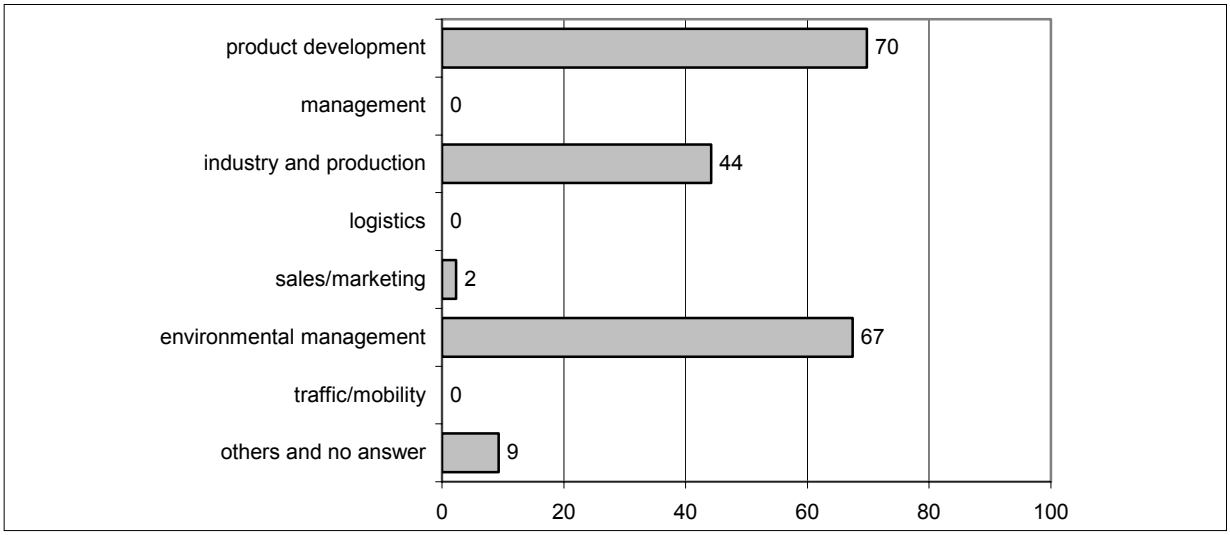
**Illustration 59:** Importance of thesis 13 (in percent)



**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

Laser scanning systems can also be applied in product development and environmental management, probably even in industry and production.

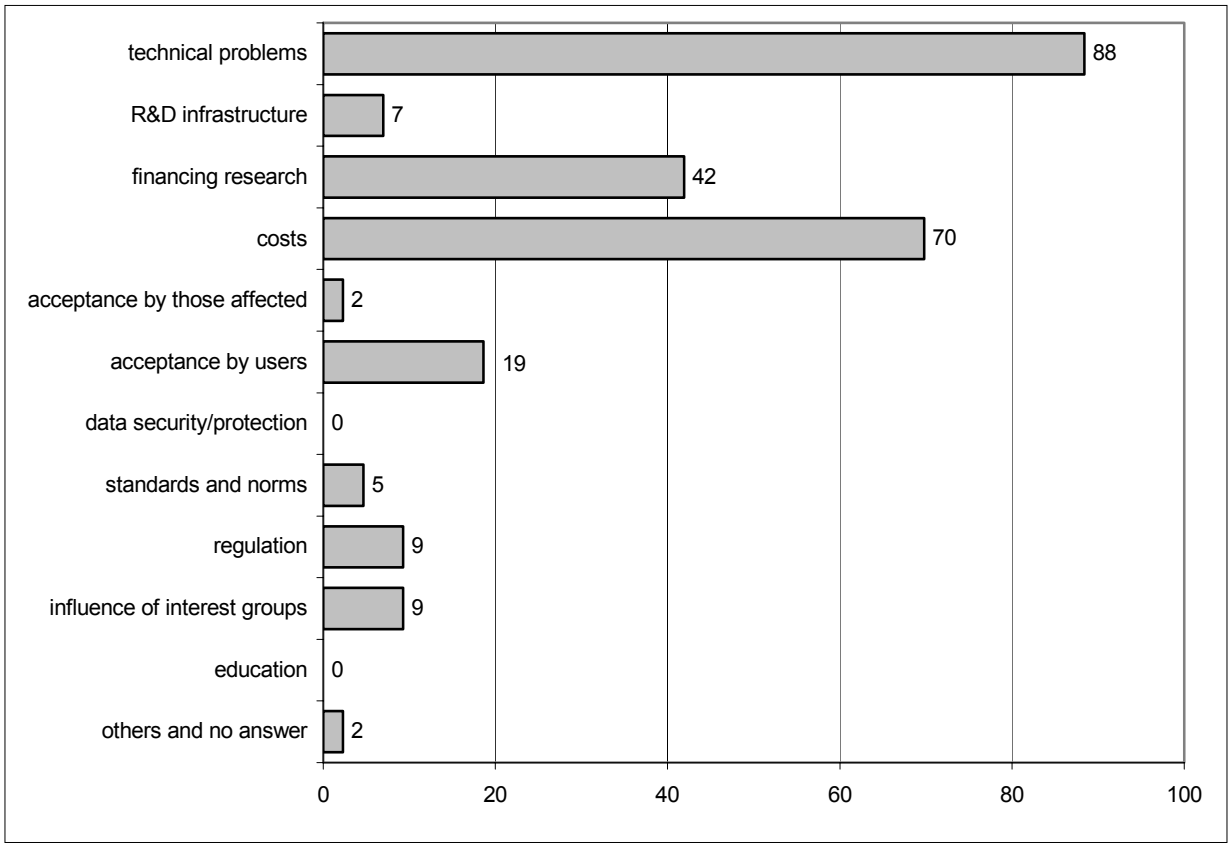
**Illustration 60:** Thesis 13 – Applicability in other areas (in percent)




**Where do you see obstacles for the realisation of the thesis?**

The obstacles on the way towards realisation are clearly of a technical nature (see illustration 61). The second largest obstacle is seen in costs. But also research funding is an area which needs to be observed. All other obstacles are not named very often, however, some persons regard the acceptance by users (surgeons reduce workload, for others laser scanning involves a lot of training) as an obstacle.

**Illustration 61:** Obstacles for the realisation of thesis 13 (in percent)




**Prospect**

To histologically analyse tissue in vivo with spectroscopic, microscopic laser scanning methods seems to be in fact realisable and is considered realistic over the next ten years. This specific topic could only be evaluated by 46 persons which again makes the range of answers relatively large. Clearly technical problems and cost issues need to be solved prior to a realisation. However, then laser scanning can enable a higher quality of healthcare and the scanning systems can be applied in areas such as product development or environmental management.

## Thesis 14: Routine whole-body scanning with functional imaging is a standard procedure after accidents.

Nuclear spin tomographs or X-radiographs for molecular imaging or magnetic resonance imaging (MRI) for visualising soft tissue has been existing for quite some time now. Whole-body scanning is already possible with the help of nuclear spin tomographs (compare also Stern, 2004; Zechbauer, 2005; Handelsblatt, 2006 or Diagnoseklinik München, 2006). The acquisition and use of nuclear spin tomographs is immensely high (PriceWaterhouseCoopers, no year) so that they cannot be maintained and used everywhere. The costs do not stem only from the technical apparatus but also from staff expenditure. Today a whole body scan takes approximately 45 minutes to one hour[1] and is used for cancer diagnosis rather than after accidents. Data must be processed and information must be imaged very soon after an accident. So there are technical challenges as well as cost issues which need to be addressed before whole body scanning after accidents becomes a standard. Which apparatus will be used, whether there will be multimodal solutions or whether also in the future each case is treated specifically according to its requirements needs to be awaited and was not subject of the thesis.

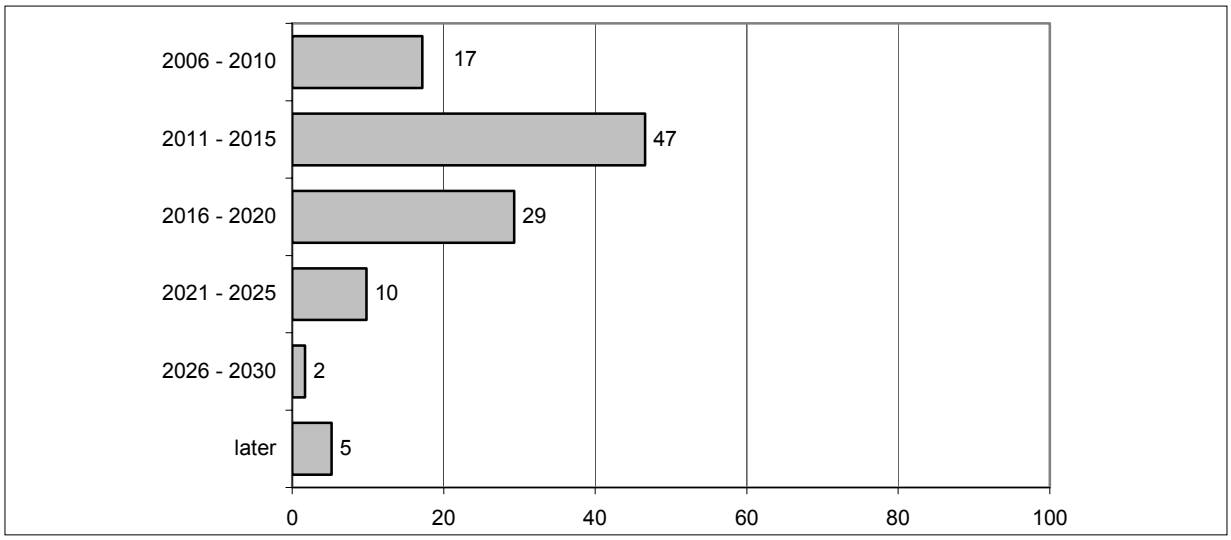
This thesis was evaluated by 63 participants, 25.4 percent of them estimated their expertise as high, 39.7 percent as medium and 34.9 percent as low. This makes results fairly supportable.

**When do you expect the realisation of this thesis?**

The realisation of such a standard application is expected around the year 2014, the range of evaluations varies along six years (Q1: 2011, Q2: 2017). 4.8 percent of those answering do not consider standard application feasible and about 5 percent postpone it to after 2030. The answers are distributed as shown in illustration 62.

[1] http://www.diagnoseklinik-muenchen.de/ganzkoerper_mrt_ab.php

**Illustration 62:** Realisation time thesis 14, distribution of answers in 5-year steps (in percent)



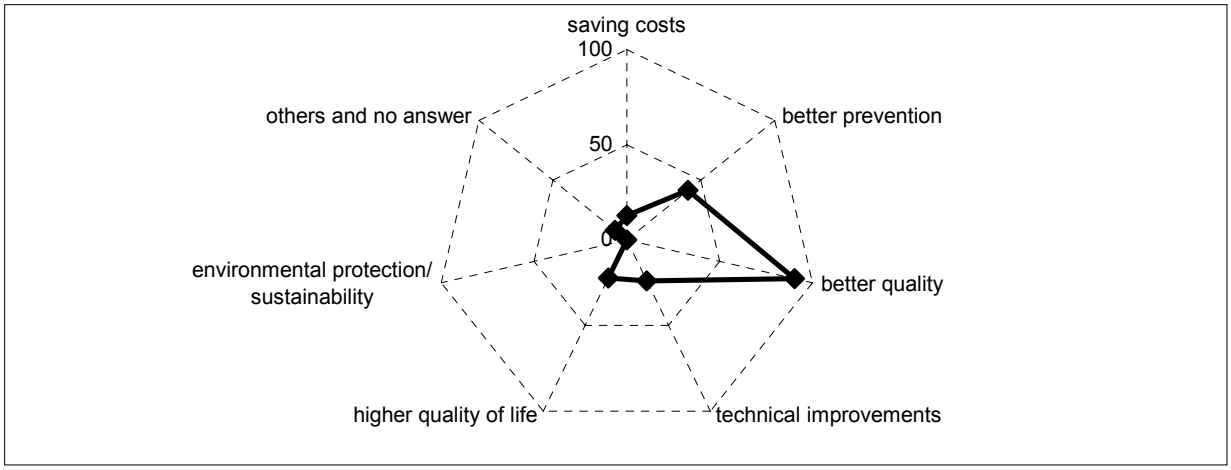

**All in all, do you personally consider the realisation of this thesis desirable?**

All participants, partly for cost reasons, do not consider a standardised use of whole body scanning after accidents desirable. 83 percent say it would be desirable, 11 percent say "not desirable" and 6 percent are not confident enough to make decisions on the topic. Accordingly are such commentaries which were made (during the workshop): "A whole body scan should not be made every time, first the necessity needs to be assessed."

**What is the realisation of the thesis important for?**

The topic will be especially important for the quality of healthcare. If the extent of injuries, especially of the inner organs, after an accident can be assessed very quickly it will be a significant improvement of quality. Also named is prevention, since whole body scans will surely be applied more in diagnostics (today especially cancer diagnostics).

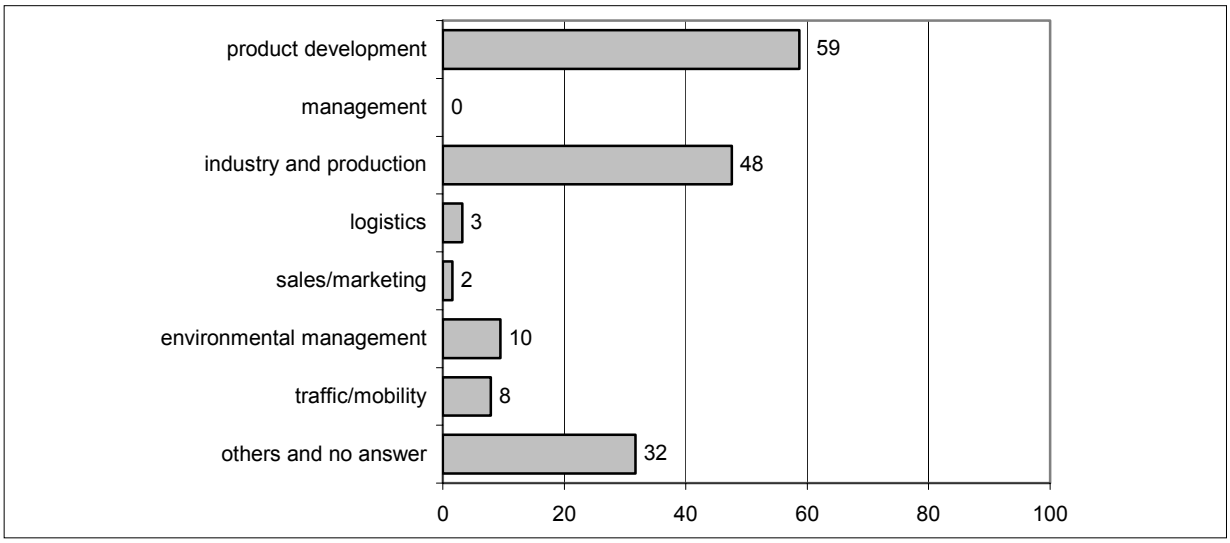
**Illustration 63:** Importance of thesis 14 (in percent)



**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

Whole body scanning or most probably scanning of other big objects is interesting for product development as well as industry and production, say respectively half of the participants. 32 percent name other areas of application, especially in the security and safety sector, e.g. flight security and criminal prevention.

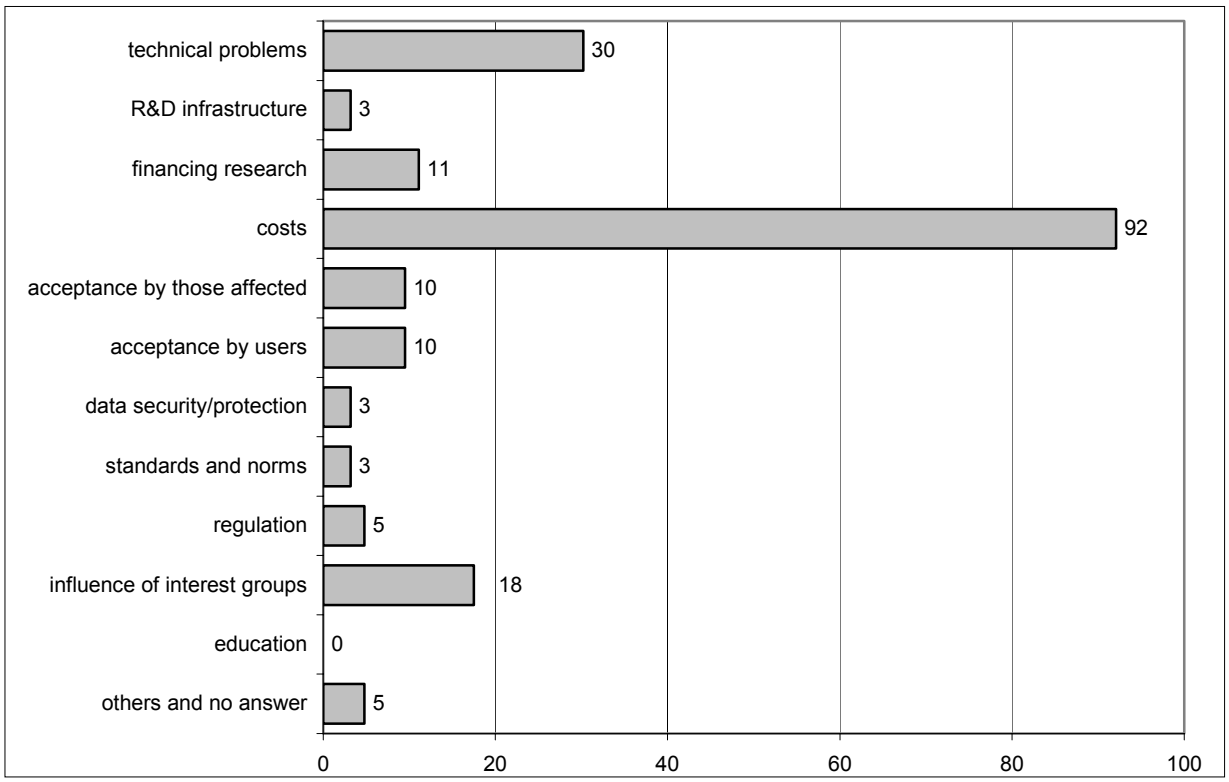
**Illustration 64:** Thesis 14 – Applicability in other areas (in percent)




**Where do you see obstacles for the realisation of the thesis?**

As implied before the costs pose the largest obstacle on the way to standard application, say nearly all participants. All other obstacles are secondary. 30 percent of the experts name technical problems which yet need to be solved. A smaller role is assigned to the influence of interest groups (the participants with higher expertise consider the obstacle more seriously than those with medium or low expertise), acceptance by those concerned as well as the users (here, too, persons with high expertise left more marks than the mean number of participants) and research funding. Several commentaries point out that whole body scanning involves a certain amount of radiation exposure, which ought not to be more intensive in standard application than “during a transatlantic flight”.

**Illustration 65:** Obstacles for the realisation of thesis 14 (in percent)




**Prospect**

Whole-body-scanning as a routine procedure after accidents is desirable, however, commentaries point out that such a scan is not necessary in all cases. The only obstacle named often is the issue of the costs which are extremely high. The problems of a technical nature seem to be solvable. Despite the costs the realisation of this thesis is hardly doubted.

Thesis 15: Valid diagnostic test procedures based on functional Magnetic Resonance Imaging (MRI) are clinically used for diagnoses with mental diseases (e.g. manic-depressive diseases) and diseases of the central nervous system (e.g. Alzheimer's disease).

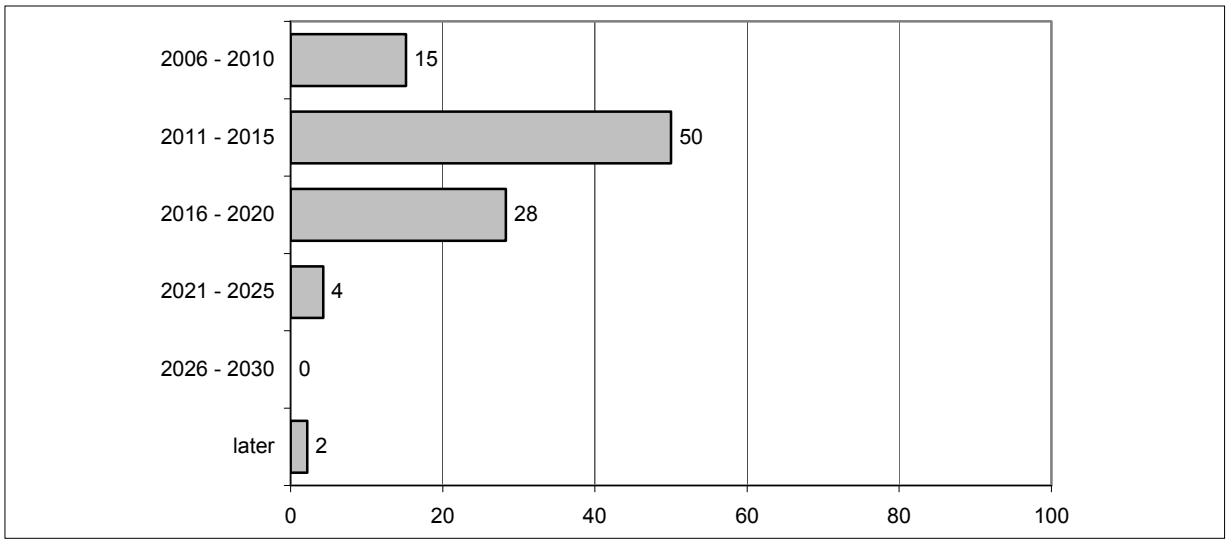
Magnetic resonance imaging is a process for imaging the structures of the inner body. With the help of MRI cross sections of the human (or animal) body can be produced which enable an exceptionally good evaluation of the inner organs and many organ mutations. Magnetic resonance imaging uses magnetic fields, not X-rays. It has been developed further during the past years as it supplies a strong tissue contrast and is thus effective in tumour diagnostics or the imaging of the brain and the spinal canal, cartilage, intervertebral discs and the bowel. For functional methods of MRI new approaches and applications are continuously being discovered (BMBF, 2005), especially neurological research makes more and more use of MRI. The strongest apparatus for MRI in Europe in use since 2005 can be found at the Leibniz Institute for Neurobiology (IfN) in Magdeburg and is supposed to even offer "detailed insight into the anatomy, the way of functioning and even metabolic processes of the brain which are critical for a better diagnosis of neurological diseases such as Alzheimer's disease, epilepsy, schizophrenia or multiple sclerosis or development of treating methods for these terrible diseases" (BMBF, 2006a). Still, there are those who warn against exaggerated expectations with regard to the conclusions which can be drawn from images (Hüsing, 2006). Also the commentaries of those answering point out that "the knowledge basis for correct interpretation of the imaged data" is as yet very small and represents the actual problem.

The thesis regarding functional MRI for the diagnosis of mental diseases and for diseases of the central nervous system was evaluated by 46 participants. Among those, 17.8 percent estimated their expertise as high, 42.2 percent as medium and 40 percent as low.

**When do you expect the realisation of this thesis?**

Analogical to many of the thesis in this Delphi study the application of MRI for this specific need is expected around the year 2014. The range is not very large, the low quartile being around the year 2012, the high quartile at around 2017. 2 percent of those answering estimate the thesis to be feasible only after the year 2030, nobody said "never". The answers are distributed over the 5-year steps as shown in illustration 66.

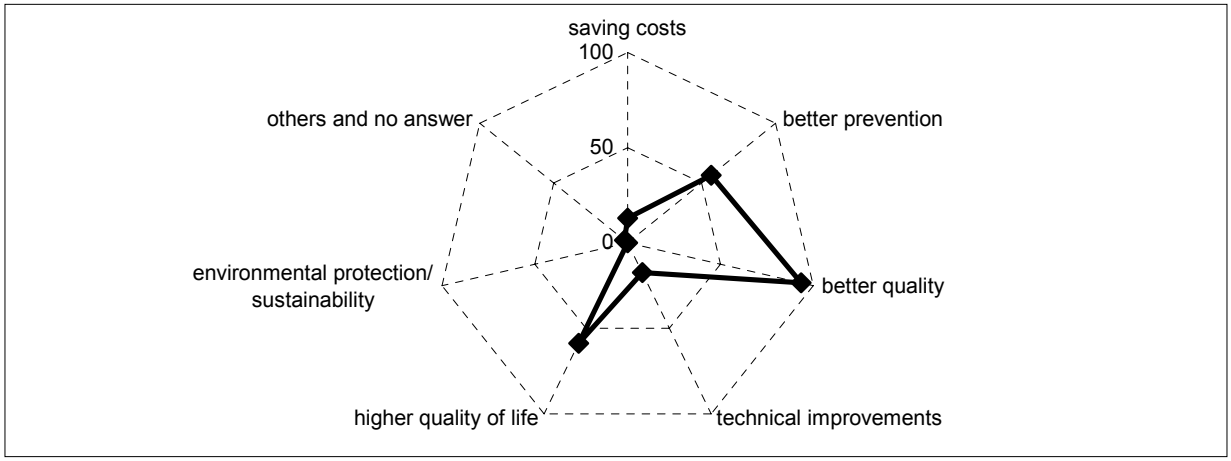
**Illustration 66:** Realisation time for thesis 15, distribution of answers in 5-year steps (in percent)




**All in all, do you personally consider the realisation of this thesis desirable?**
91 percent of the Delphi participants consider the topic desirable, 7 percent are not sure about a decision in this regard and 2 percent consider the topic not desirable.

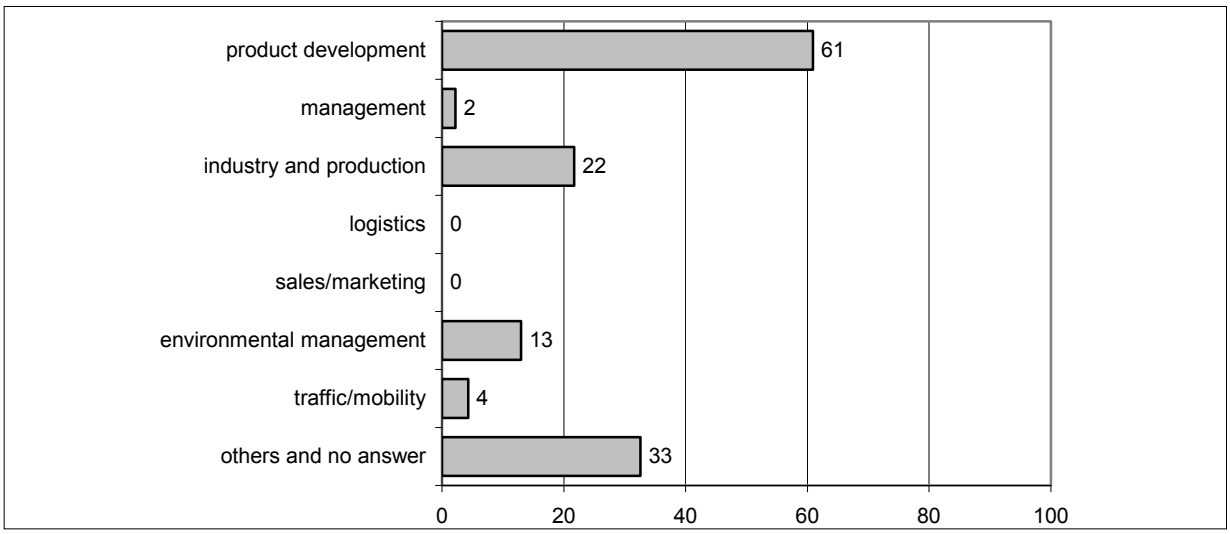
**What is the realisation of the thesis important for?**
The thesis is especially important for the quality of healthcare. Many of the Delphi experts also consider it important in terms of better prevention and a higher quality of life (see illustration 67).

**Illustration 67:** Importance of thesis 15 (in percent)




**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**
MRI is also applicable in product development. 22 percent of the participants also name industry and production, 13 percent environmental management and one third "others and no answer". One participant mentions the possible "military" use but does not elaborate further.

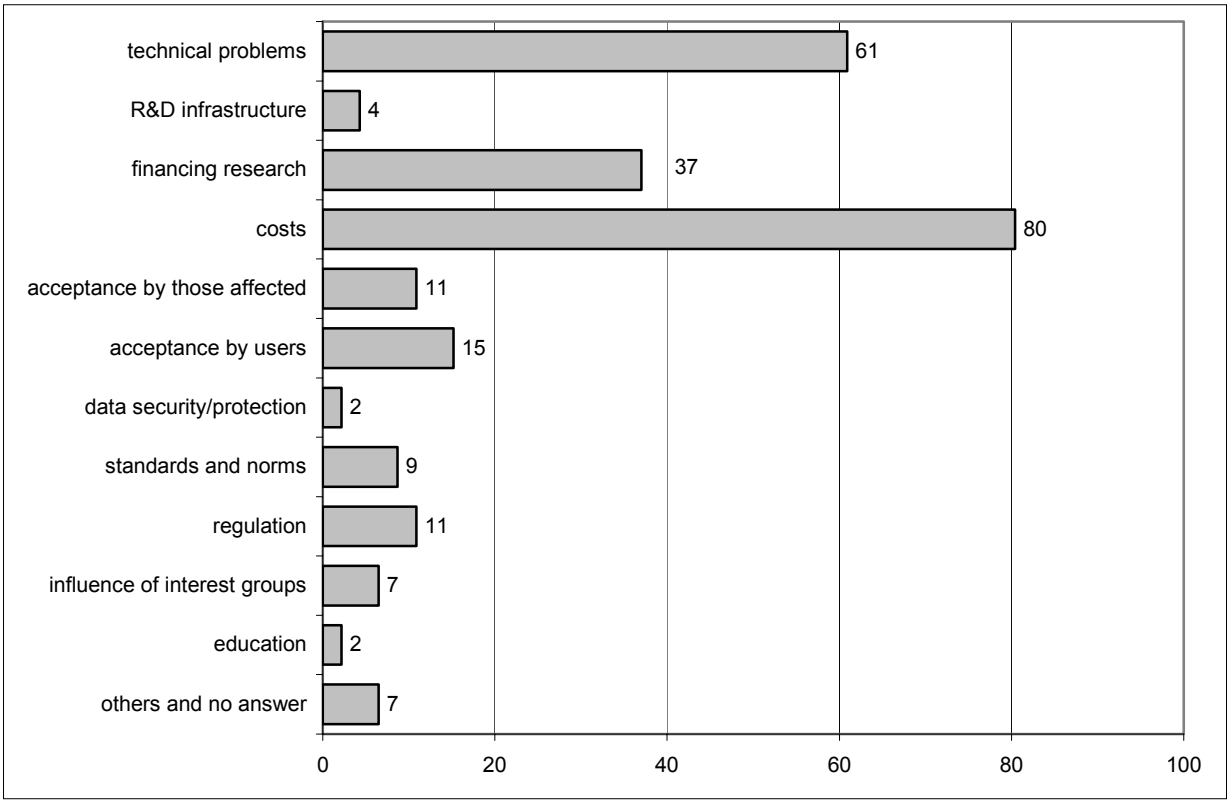
**Illustration 68:** Thesis 15 – Applicability in other areas (in percent)




**Where do you see obstacles for the realisation of the thesis?**

Obstacles for realisation are especially the costs and issues concerning the technical area. More than one third of the participants also name research funding. All other obstacles are mentioned, especially acceptance by users and regulations, though not as often as costs or technical problems (see illustration 69).

**Illustration 69:** Obstacles for the realisation of thesis 15 (in percent)



**Prospect**

To clinically use valid diagnostic test procedures based on functional Magnetic Resonance Imaging (MRI) for diagnoses with mental diseases (e.g. manic-depressive disease) and diseases of the central nervous system (e.g. Alzheimer's disease) is no trivial task. One obstacle is the interpretation of the generated data and pictures. Still, the topic is considered realisable over the oncoming 10 to 15 years. Most experts consider such a MRI-application desirable, however, there are issues such as high costs and technical problems to be solved on the way towards realisation. Once passed these issues, the quality of healthcare, prevention as well as the quality of life for those concerned will be drastically improved.

Thesis 16: Many hospitals employ robots for difficult and standard procedures in nursing (e.g. putting someone into another bed, changing of bedclothes etc.) in order to relieve the nursing staff and enable them to have more time for personal attentiveness towards the patients.

To employ robots in industrial production has become a standard. However, in the private sector, e.g. households, nursing of patients and aged persons they are seen from controversial angles. This could already be shown in earlier Delphi surveys, during which the discussion evolved whether "robots" was the applicable term or rather "apparatus" or "machines" (BMFT, 1993; Cuhls/Kuwahara, 1994; Cuhls/Breiner/Grupp, 1996 or Cuhls/Blind/Grupp, 1998). And yet, first developments of service robots are on their way in Germany, as well. One example for a robot in healthcare and nursing is the Care-O-Bot (Fraunhofer IPA, 2006). Especially in Japan robots are more and more considered for nursing patients and aged persons, also in the sense of humanoid and "understanding" robots (Ishii, 2006).

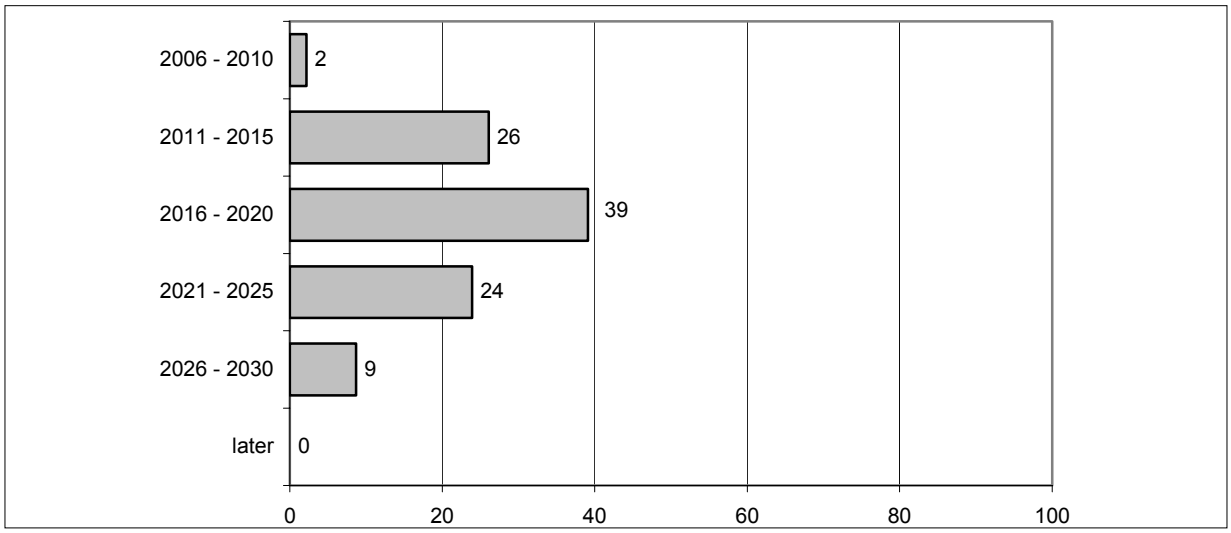
Still the thesis "Many hospitals employ robots for difficult and standard procedures in nursing (e.g. putting someone into another bed, changing of bedclothes etc.) in order to relieve the nursing staff and enable them to have more time for personal attentiveness towards the patients" remains one of the most controversial ones among those of the Delphi study at hand. Accordingly the commentaries range from "inhumane, anti-social", "dangerous: de-personnel-iasation in nursing", "must be averted" to "gain of time for real help to the persons" and "relief of the staff". One commentary even went so far as to say that maintenance of a functioning clinic with the given demographic development is no longer feasible without robots.

Robots in nursing were evaluated by 63 Delphi experts. 18 percent of those answering estimated their expertise as high, 50.8 percent as medium and 31.1 percent as low.

**When do you expect the realisation of this thesis?**

A large share of 23.8 percent does not consider the thesis feasible. This is by far the largest value for non-feasibility in the whole survey. The other answers estimate realisation timeframes as shown in illustration 70, an interesting fact: nobody says "later". This means that the use of robots will be implemented by 2030 or not at all. The median is set relatively late around the year 2018 (Q1: 2015, Q2: 2022).

**Illustration 70:** Realisation time for thesis 16, distribution of answers in 5-year steps (in percent)



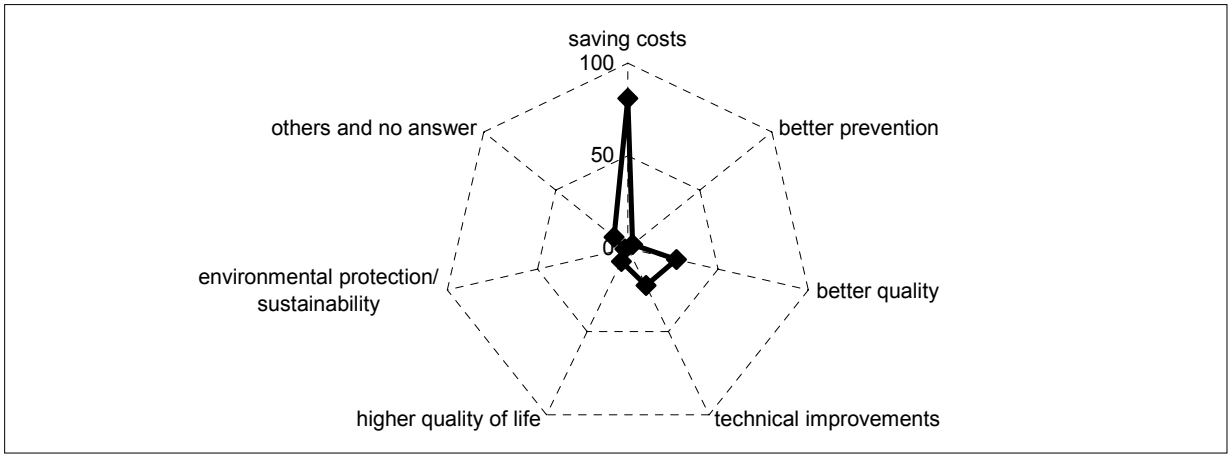

**All in all, do you personally consider the realisation of this thesis desirable?**

This controversial topic is only considered desirable by a scarce majority (54 percent). 31 percent do not consider it desirable and 15 percent did not answer this question.

**What is the realisation of the thesis important for?**

At least 81 percent of the participants state that the topic is very important for cost saving. However, those with high expertise relativise this: only 55 percent of them consider the topic important. Very few experts consider the nursing robots important for the quality of healthcare and technical progress. None of the participating female experts made a cross for the importance of technical progress, but 19 percent of the male participants.

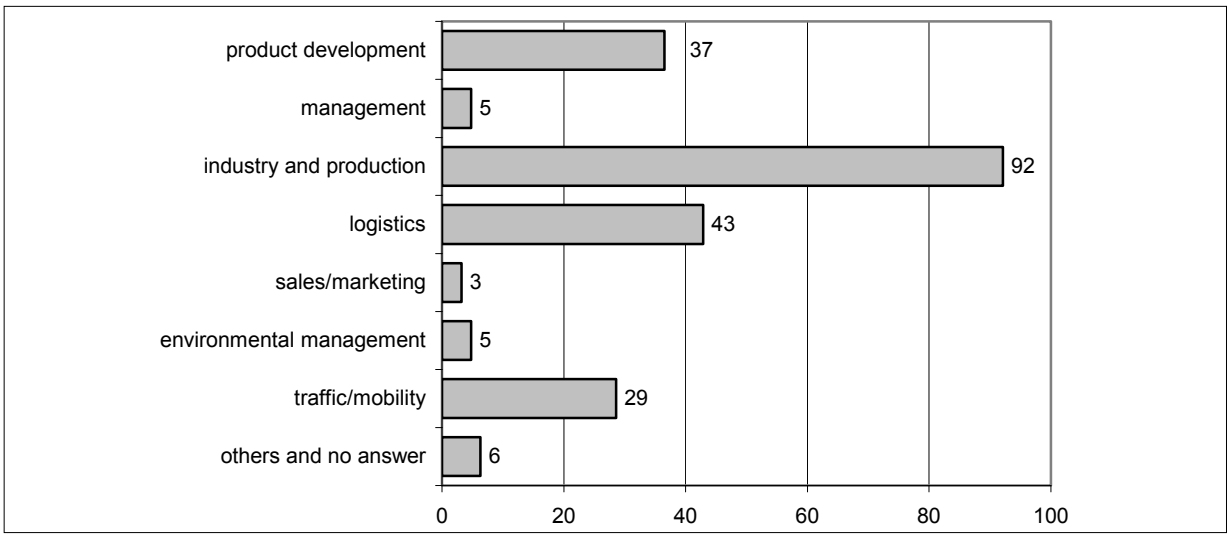
**Illustration 71:** Importance of thesis 16 (in percent)



**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

Robots can generally be used in many areas, so all categories are named, especially industry and production. Additionally, they can be used in logistics, product development or traffic/mobility.

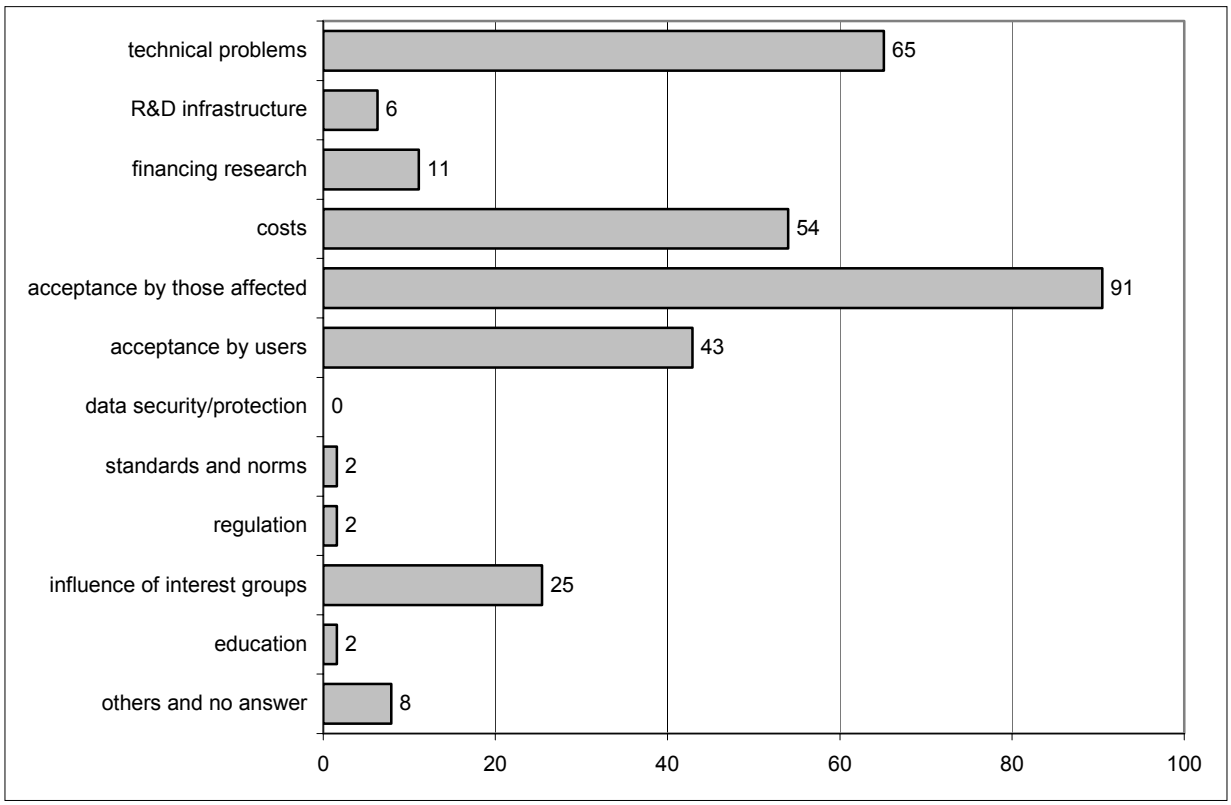
**Illustration 72:** Thesis 16 – Applicability in other areas (in percent)




**Where do you see obstacles for the realisation of the thesis?**

The realisation is clearly subject to the acceptance by those concerned – if they have a choice to make in this issue. Also acceptance by users is critical. Further obstacles are to be considered in the technical area – and they are more strongly regarded by those with high expertise than by others (82 percent with high expertise, 65 average of all answers given), as well as the costs for robots in nursing. One quarter of the participants (even 45 percent of those with high expertise) also see influence of interest groups as an obstacle. The topic could fall through not due to issues regarding the technical feasibility, but rather due to issues regarding the acceptance – according to nearly one quarter of the Delphi participants.

**Illustration 73:** Obstacles for the realisation of thesis 16 (in percent)




**Prospect**

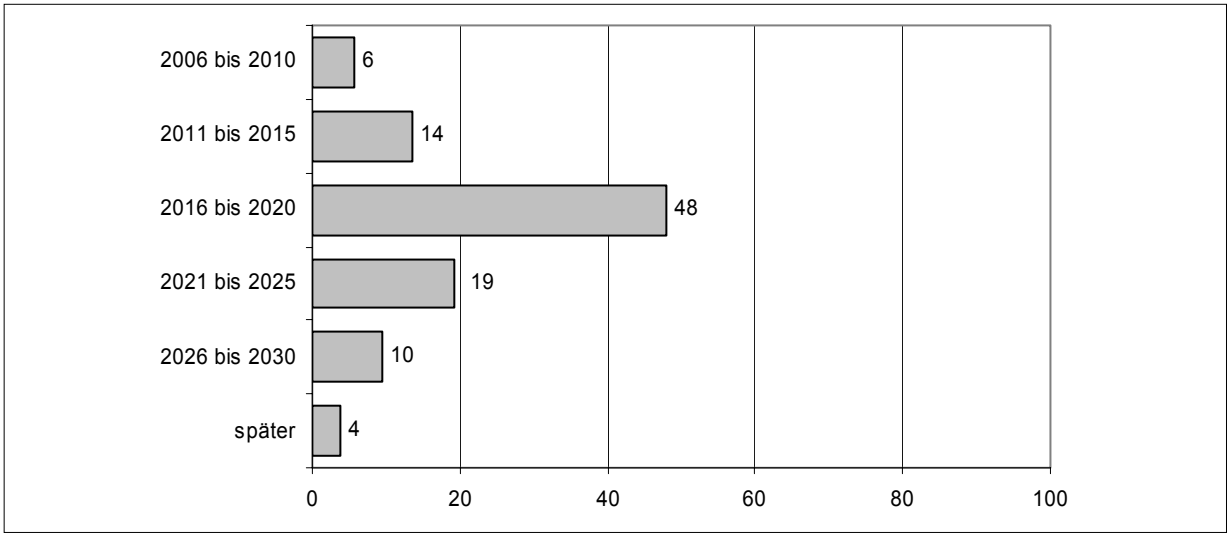
Robots in nursing are and will be a controversial subject, even if the thesis confines their use to difficult and standard procedures and even though there is the benefit of the staff being relieved and having more time for the patients. Only slightly more than half of the participants – very few in this item – consider nursing robots desirable and one third strictly dismiss their use. If they are to be realised – and this is questioned by nearly one quarter of the Delphi experts – it will happen before the year 203, most probably between 2016 and 2020 as robots always play a leading part for cost reductions. The realisation will be subject to technical feasibility as well as issues of acceptance by those concerned and by user acceptance.

## Thesis 17: Surgeries within the body, which are conducted by a remote-controlled micromachine, equipped with sensors and actuators, are possible.

Minimally invasive and endoscopic surgery is as standard in many areas even today. The advantage of all minimally invasive techniques is the fact that lesions are kept very small and involved shorter healing processes. This thesis takes one more step ahead: A micromachine featuring sensors and actuators is supposed to permeate the body and operate via a remote control. The technical challenges here are the miniaturisation in control, the development of adequate sensors, the actuators performing the surgery and the alignment of the whole system. With the help of this theory even the tiniest and hardly accessible parts of the body could be operated.
55 Delphi experts evaluated this thesis. 18 percent of them estimate their expertise as high, 50 percent as medium and 32 percent of them estimate it as low.

**When do you expect the realisation of this thesis?**
This thesis represents a rather long-term project and is considered realisable by the year 2019, with a range of seven years. The low quartile ranges at the year 2016, the high quartile at 2023. Illustration 74 shows that some of the participants consider the thesis feasible only after 2030. Only 1.8 percent of the participants say “never”.

**Illustration 74:** Realisation time for thesis 17, distribution of answers in 5-year steps (in percent)

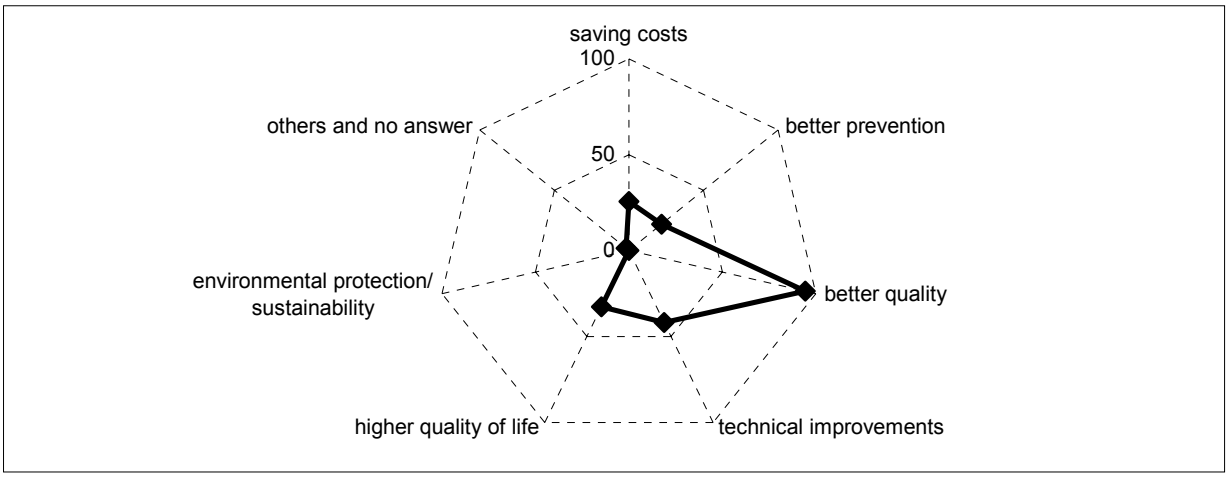



**All in all, do you personally consider the realisation of this thesis desirable?**
93 percent of the participants consider the thesis desirable. Only 2 percent do not consider it desirable, the other 5 percent do not answer in terms of desirability.

**What is the realisation of the thesis important for?**

A micromachine performing remote-controlled surgery is generally assumed to be important for the quality of healthcare (illustration 75, marked by averagely 95 percent of the answering persons, however, "only" marked by 75 percent of those with high expertise). The topic is also important for technical progress and a higher quality of life for patients. Some of the Delphi experts also name better provision and prevention and cost saving and reduction.

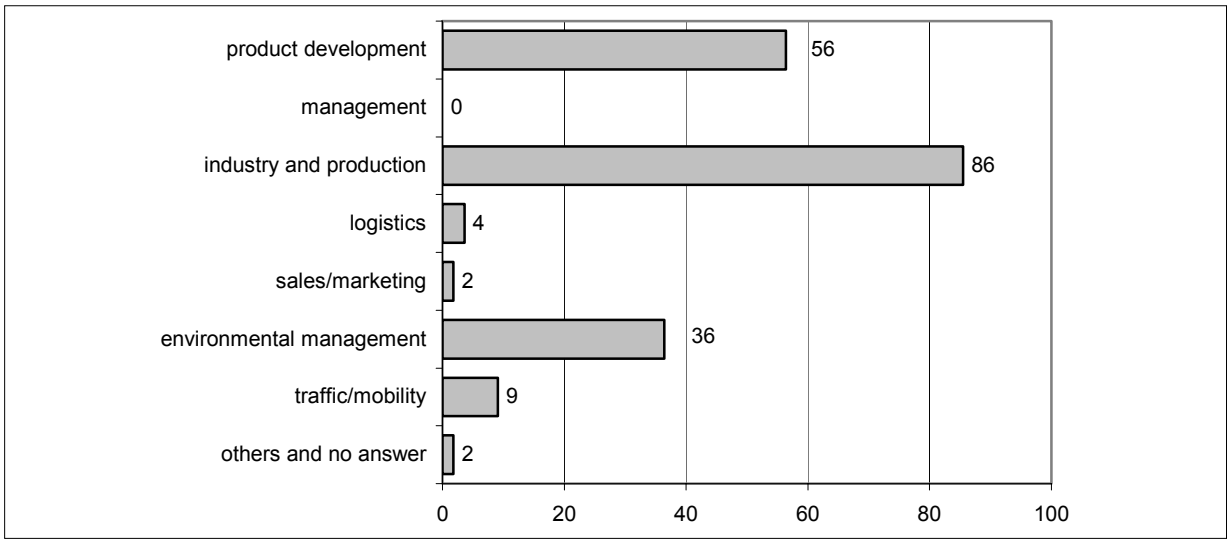
**Illustration 75:** Importance of thesis 17 (in percent)




**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

Micromachines featuring sensors and actuators will also be applicable in industry and production, product development and environmental management (illustration 76). Very few persons assume there are application possibilities in mobility and traffic.

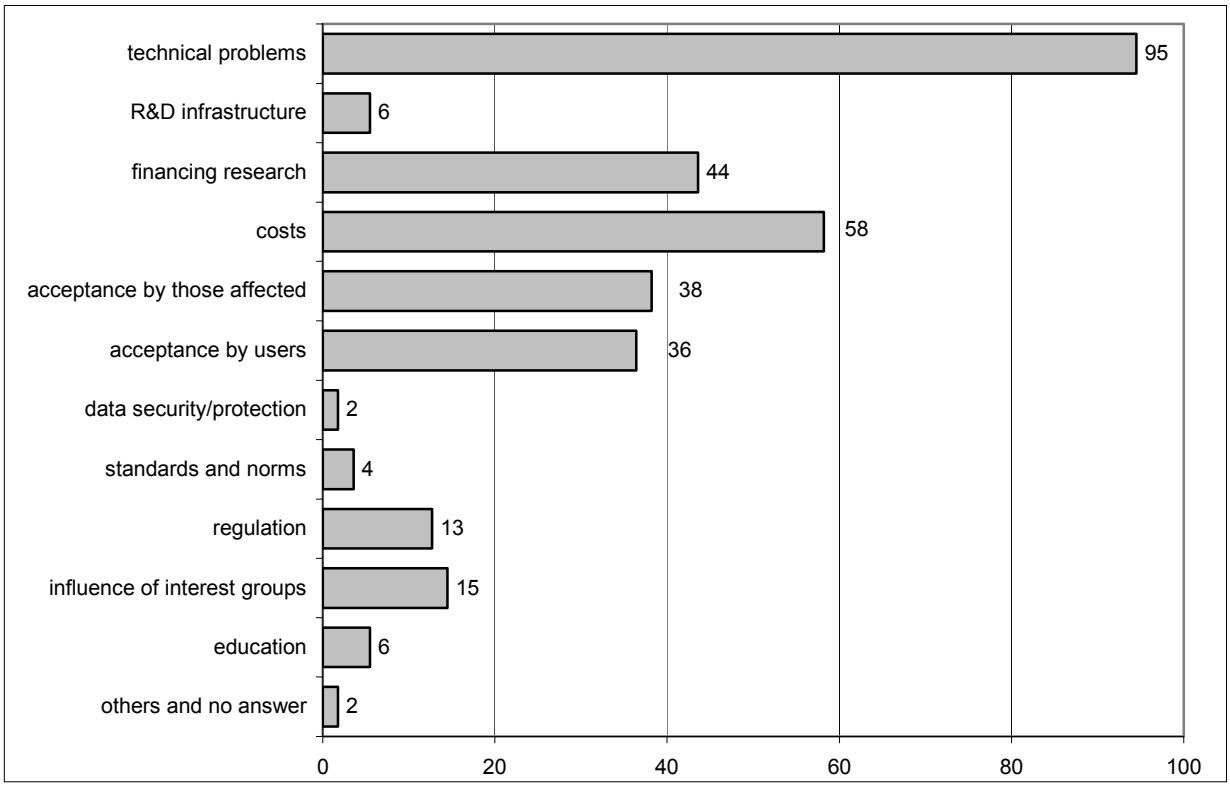
**Illustration 76:** Thesis 17 – Applicability in other areas (in percent)



**Where do you see obstacles for the realisation of the thesis?**

However, there are numerous obstacles standing in the way towards realisation (illustration 77). Named first are the technical problems, followed by costs and research funding (marked more frequently by those with high expertise, of course). But technical issues are not the only obstacles. Often the acceptance by those concerned and users is named as an obstacle. Persons acquainted with the subject among the Delphi experts name acceptance of users far more often as a problem. It is also noted in commentaries that regulation issues can pose a problem: Questions of liability and safety requirements are not yet settled. 15 percent of the participants and even 38 percent of those with high expertise also name the influence of interest groups as an obstacle.

**Illustration 77:** Obstacles for the realisation of thesis 17 (in percent)



**Prospect**

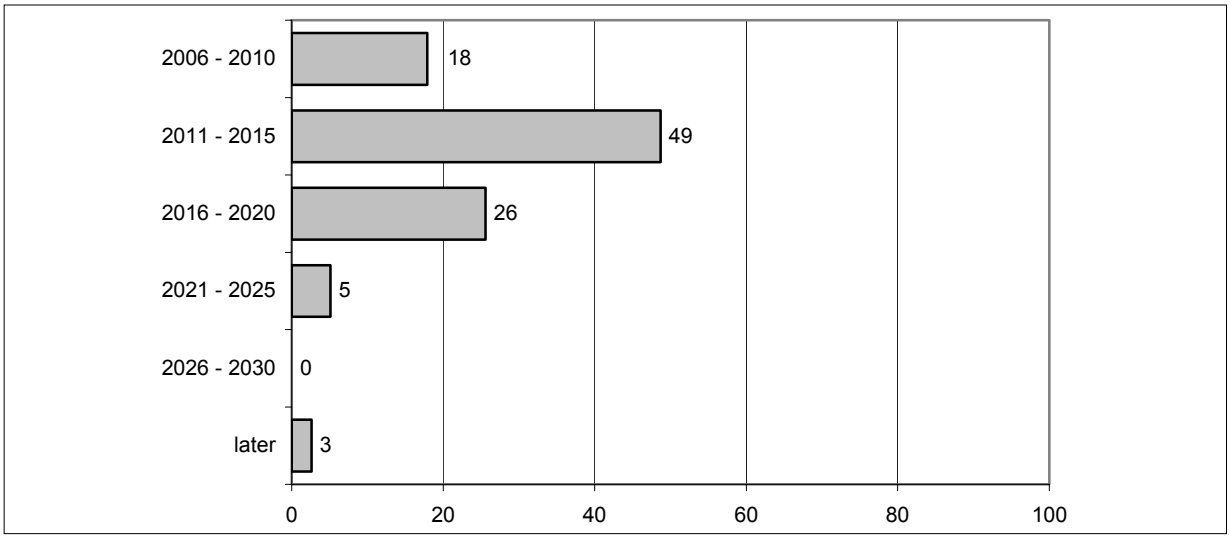
Micromachines that permeate a body and perform surgeries there with the help of actuators and sensors will most probably not be realised during the oncoming 10 years but they will become reality, since they provide a far better quality of healthcare, here: surgeries. It will take longer than 10 years, probably up to 20 years to solve the serious technical problems with regard to feasibility. The thesis, however, is strongly desired. Its application will have to overcome obstacles concerning acceptance by users as well as by those concerned. Surgeons as users are not keen on handing their scalpels away and learning to control a machine instead – in the same way as patients are not keen on having a machine actually in their body (according to the discussion during the workshop) – who knows, who is really in control? Micromachine systems are relevant for other areas of technical progress, e.g. industry and production, as well. For this reason the named obstacle research funding should be able to be cleared.

## Thesis 18: Fully functional robot systems have been developed and tested for transdermal intervention (e.g. biopsy robots).

This thesis involves permeation of a body with the help of robot systems. Contrary to thesis no. 16 nothing is said about the system being remote-controlled and it does not need to be so small as to permeate a body. The robot systems referred to here are located outside the body, intervention takes place with various means (e.g. needles, stents etc.). A possible application of these robot systems are biopsies, the removal of tissue for instance for diagnostical purposes or therapy planning.
44 persons evaluated robot systems for transdermal intervention. Of those, 26.8 percent, a large proportion, estimated their expertise as high, 36.6 percent respectively as medium and low.

**When do you expect the realisation of this thesis?**
The thesis on robot systems for transdermal intervention is expected to be realised earlier than the previous thesis concerning surgeries with micromachines. The median is estimated for the year 2014 (Q1: 2011, Q2: 2017). Nobody doubts the probable realisation of the thesis in general, however, around 3 percent of the experts answering estimated the feasibility for after the year 2030 (illustration 78).

**Illustration 78:** Realisation time for thesis 18, distribution of answers in 5-year steps (in percent)

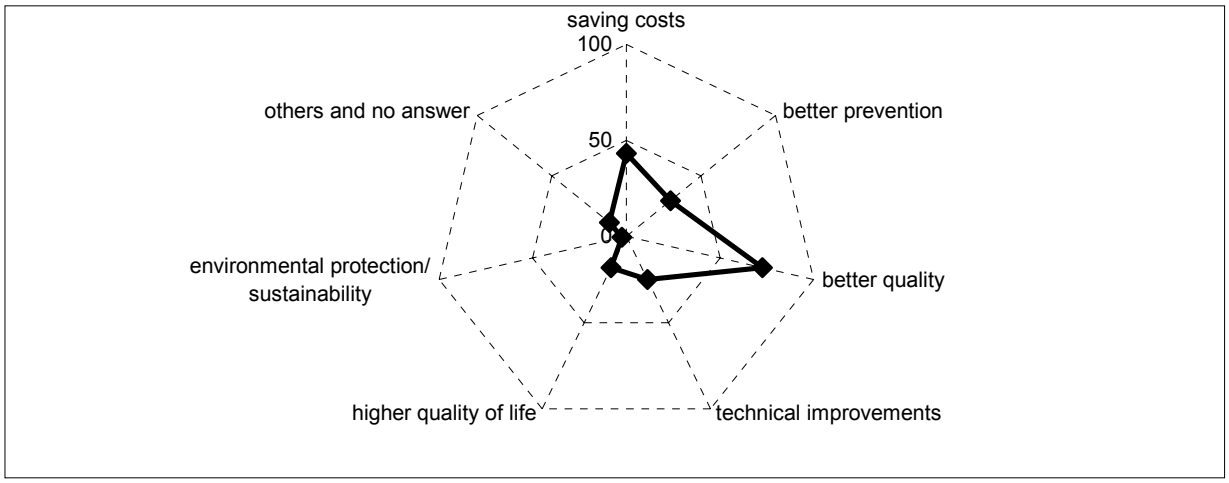



**All in all, do you personally consider the realisation of this thesis desirable?**
Robots for transdermal intervention belong to the controversial topics: The content of the thesis is considered desirable by "only" 70 percent of the participants. This, however, is more than half of those who answered and thus already surprising. The scepticism regarding a robot intervening transdermally into a person, probably oneself, was considered far larger by consulting experts during the thesis preparatory time (workshop 2006). Only 9 percent do not consider the topic desirable, further 21 percent (a comparatively large share) do not participate in the evaluation on desirability.

**What is the realisation of the thesis important for?**

Robots which can operate under the skin are very important for the quality of healthcare (illustration 79) as they can work very precisely and offer a high grade of diagnostical safety, so stated in commentaries. Costs too can be saved since professional staff is "better instituted" (commentary). Some Delphi experts consider the topic important for better provision and prevention and for technical progress.

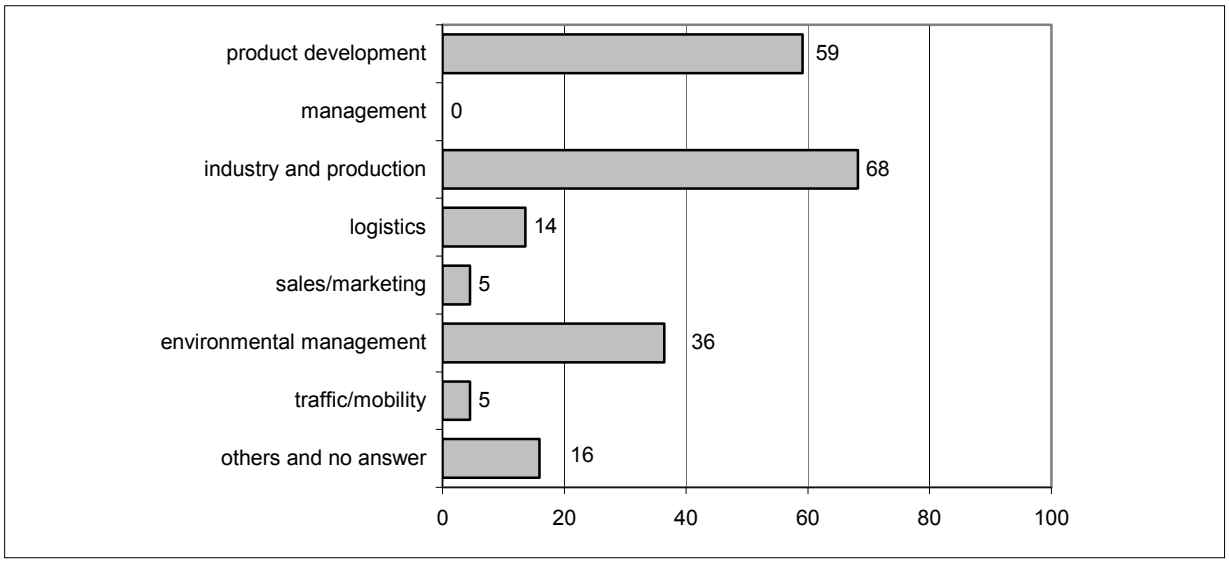
**Illustration 79:** Importance of thesis 18 (in percent)




**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

Robots can be generally used in product development as well as industry and production (illustration 80), robot systems similar to the biopsy robots evaluated as such. However, they can also be interesting for environmental management, possibly also logistics. Other areas of application are mentioned, as well, commentaries refer to military use (weapon disarming/defusing).

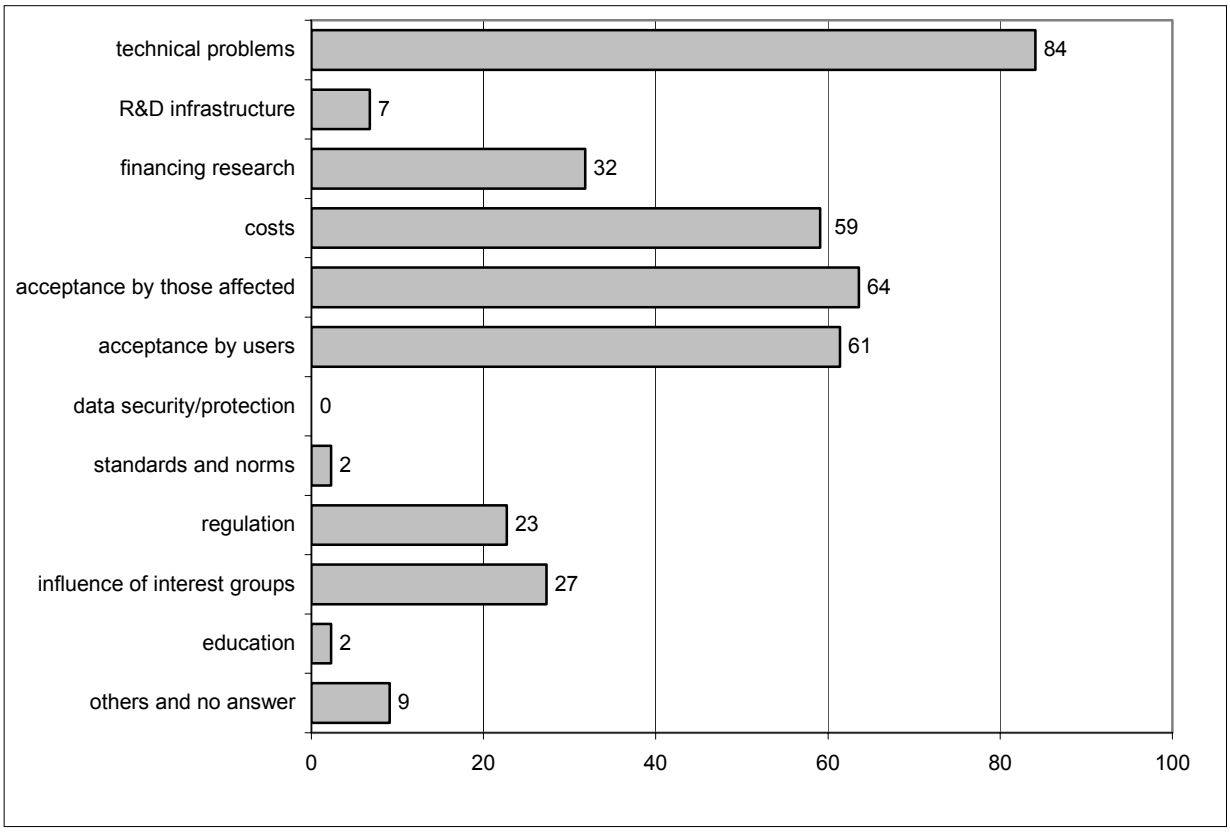
**Illustration 80:** Thesis 18 – Applicability in other areas (in percent)



**Where do you see obstacles for the realisation of the thesis?**

The largest obstacles stem from the technology which has not as yet been developed sufficiently (illustration 81). However, acceptance by those concerned and users as well as the high costs are obstacles to be considered. Further issues are seen in research funding, the influence of interest groups and regulations. 9 percent of the participants claim there are other obstacles, but only liability questions are named.

**Illustration 81:** Obstacles for the realisation of thesis 18 (in percent)




**Prospect**

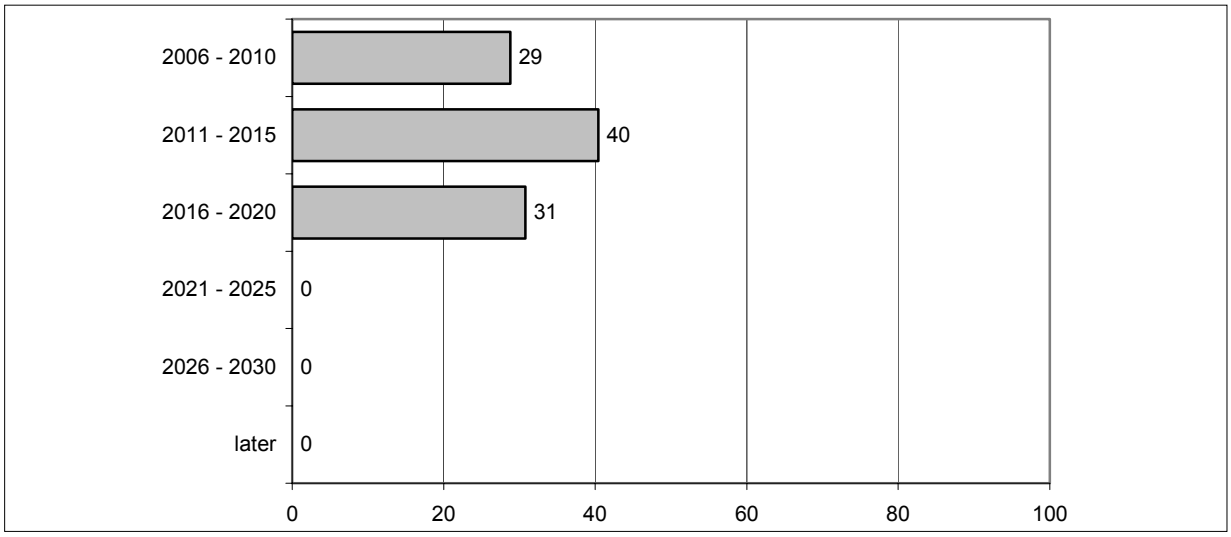
Robot systems for transdermal intervention (e.g. biopsy robots) will definitely become reality in application and are considered possible and, by the majority, also desirable around the year 2015 even though 9 percent of the participants do not share this point of view. Like the biopsy robots other robot systems will be applied in similar systems of product development and production and industry. However, before their use on human beings there are several obstacles which need to be overcome, technical problems as well as costs and questions of acceptance by those concerned and users.

Thesis 19: Voice recognition and correct relation of a voice to the person speaking is so accurate, that surgeons are able to navigate instruments through voice commands and are thus effectively relieved.

Voice recognition is improving continuously however, it reaches boundaries where features such as intonation, dialect, imprecise articulation or tone pitch. If surrounding sounds are added the relation of a voice to the person speaking as well as the precision of recognition suffers. In order to navigate instruments during surgery safely voice recognition must be 100 percent correct.
This thesis was evaluated by 58 Delphi participants, 38.2 percent of them – a large percentage – estimated their expertise as high.40 percent of them estimate it as medium and 21.8 percent as low.

**When do you expect the realisation of this thesis?**
The answers as to the timeframe of realisation are distributed with relatively low variance as shown in illustration 82. The median of estimates is the year 2013 (Q1: 2010, Q2: 2016). On the other hand 10.3 percent of the participants say "never" realisable. One tenth of the Delphi experts respectively do not believe that a precision as high as it is necessary can be achieved. The topic will be realised before 2020 – or not at all.

**Illustration 82:** Realisation time for thesis 19, distribution of answers in 5-year steps (in percent)

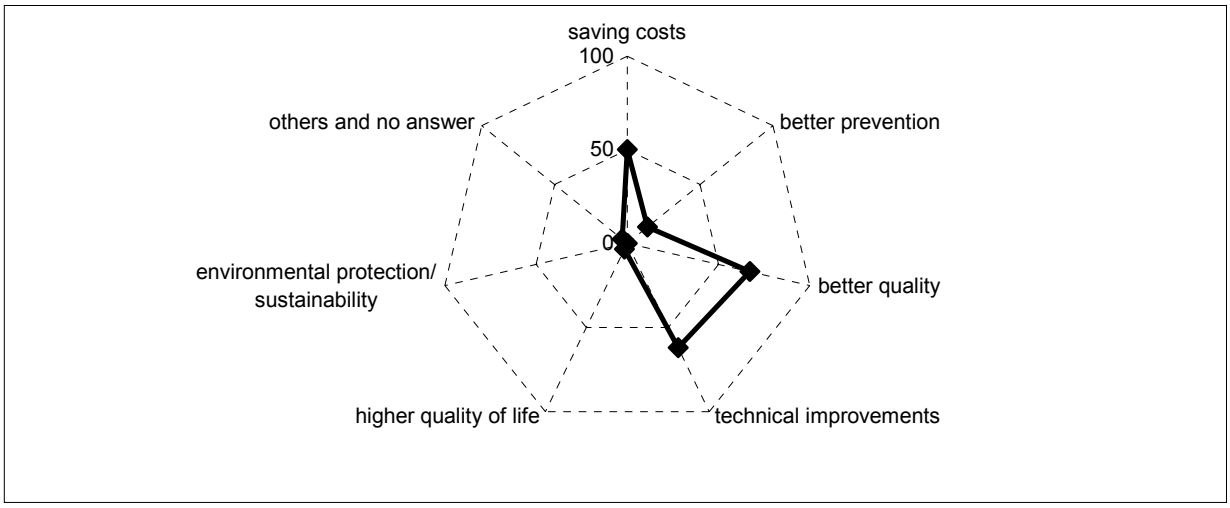



**All in all, do you personally consider the realisation of this thesis desirable?**
Voice recognition in the operating theatre is considered desirable by 83 percent of the Delphi experts. 10 percent do not consider the thesis desirable (most probably it is those participants who also say "never realisable") and 7 percent say "do not know".

**What is the realisation of the thesis important for?**

Voice recognition in an operating theatre is important for a better quality of healthcare, technical progress and cost saving and reduction (illustration 83).

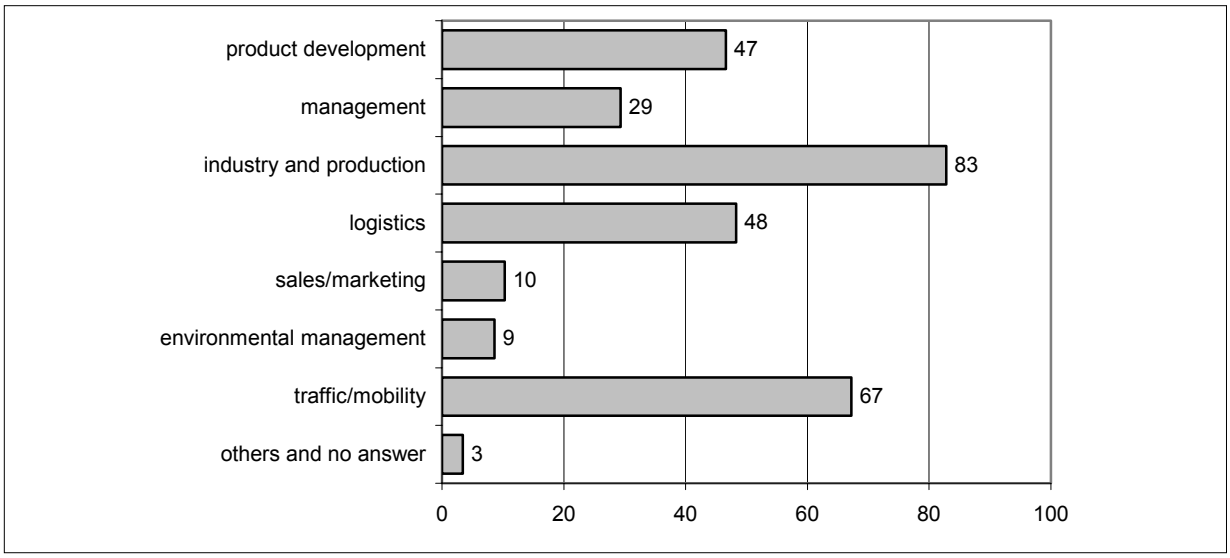
**Illustration 83:** Importance of thesis 19 (in percent)




**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

Voice recognition is a topic which can be important in very different sorts of areas. All of the offered areas were marked, especially frequently the areas industry and production, product development, logistics and mobility/traffic. Even management is named by nearly one third of those answering (illustration 84).

**Illustration 84:** Thesis 19 – Applicability in other areas (in percent)

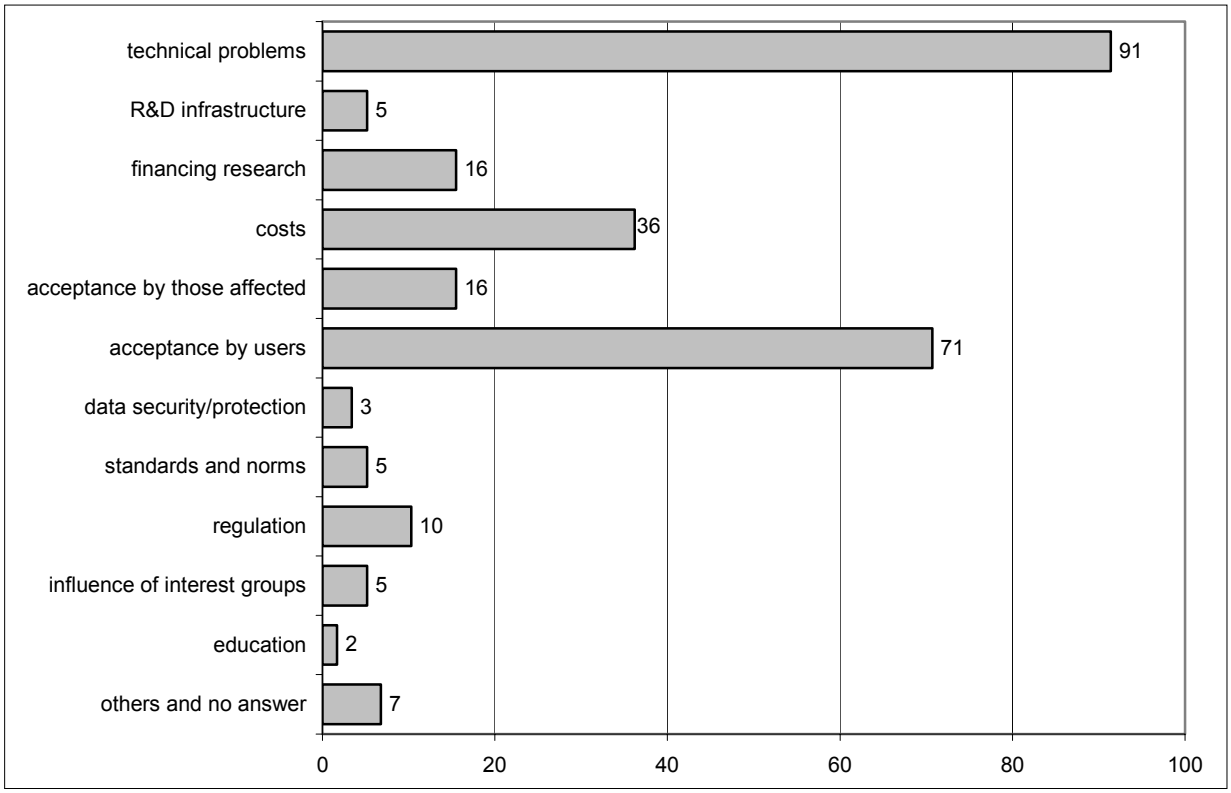



**Where do you see obstacles for the realisation of the thesis?**

The obstacles are clearly located in the technical area. However, also user acceptance is also named as an obstacle, less so acceptance by those concerned. High costs are mentioned

(illustration 85) and commentaries also refer to aspects of safety, stating that "the balance of risk is very high". These issues were already discussed during the Delphi workshop.

**Illustration 85:** Obstacles for the realisation of thesis 19 (in percent)




**Prospect**

Voice recognition will assert itself more and more. However, to achieve the precision necessary for navigation instruments in the operating theatre is technically difficult. In spite of this 90 percent of those answering say it will be as precise as necessary by the year 2020 (median 2014). The other 10 percent say this precision will "never" be realisable. There will always be a residual risk. Whether voice recognition during surgeries will be accepted by users is another question. In other areas this will pose less of a problem: the application of corresponding systems is seen for areas such as industry and production, product development, traffic and mobility, logistics and even in management.

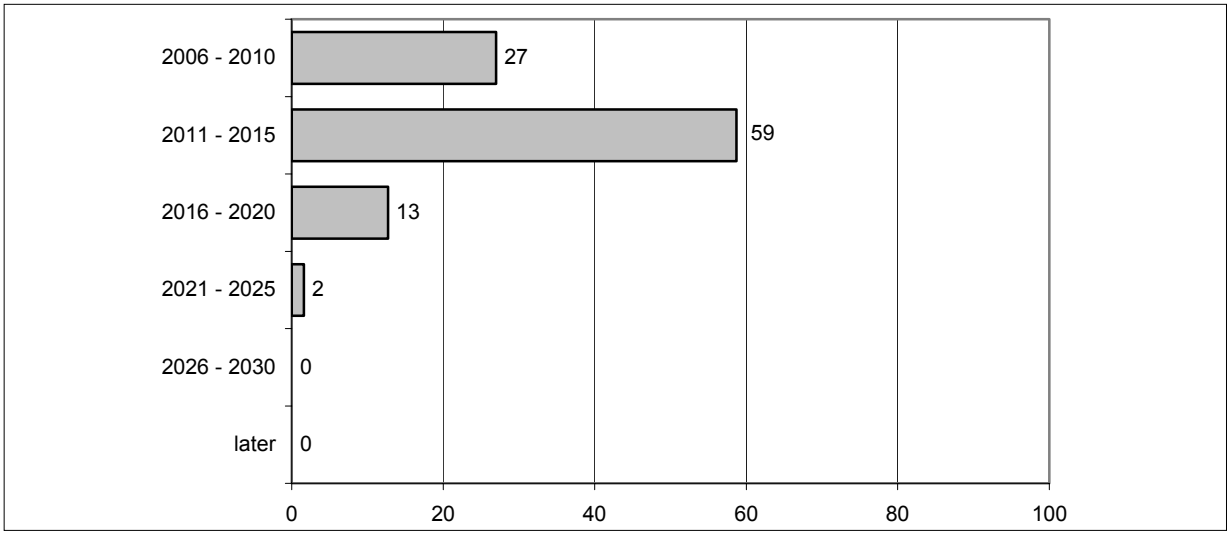
## Thesis 20: Documentation tasks in hospitals are routinely performed via voice entry.

Administrative tasks are a major part of workload in hospitals. If this task could be completed via voice entry this would mean significant relief to doctors and the nursing staff. But also here – in the same way as in the thesis before – precision and reliable recognition is critical. A wrong therapy on the grounds of deficient documentation would lead to fatal consequences. Routine voice entry is especially difficult as the recording takes place with background sounds (e.g. during the doctor's round). Filtering out the noise poses as one of the technical challenges. This thesis was evaluated by 63 participants, more than on third of them (36.7 percent) – a large share – estimate their expertise as high. Further 45 percent estimate their expertise as medium.

**When do you expect the realisation of this thesis?**

To routinely perform documentation tasks in the hospital via voice entry is considered nearly unanimously realisable during the oncoming 10 years. The median estimate is the year 2013, the low quartile ranging in the year 2010, and the high quartile at 2015. Nobody considers precise voice entry as unrealistic and nobody considers the realisation to take place after 2025.

**Illustration 86:** Realisation time for thesis 20, distribution of answers in 5-year steps (in percent)



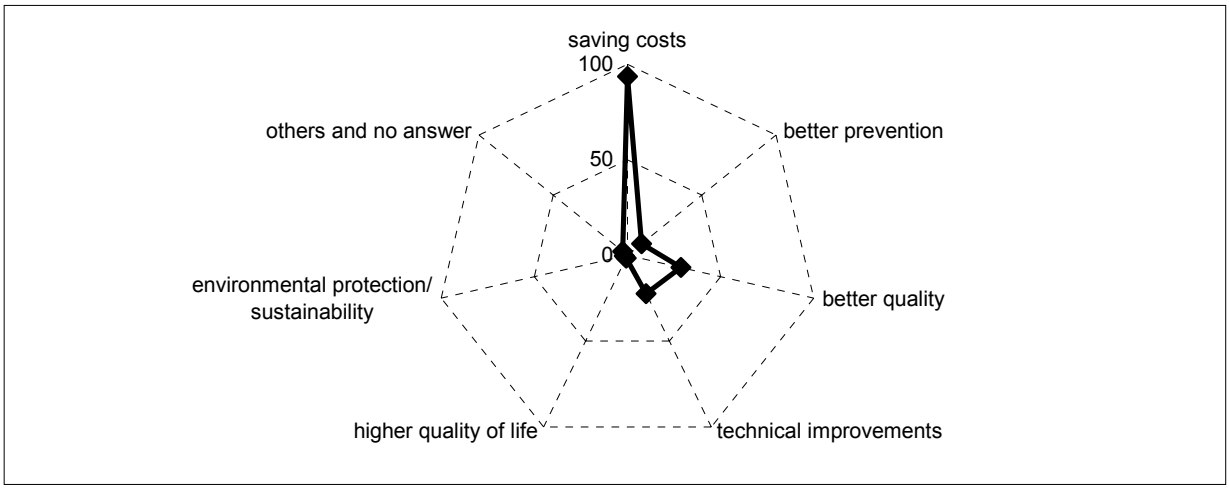

**All in all, do you personally consider the realisation of this thesis desirable?**

98 percent of those answering consider performing documentation tasks routinely via voice entry desirable. One person says "do not know".

**What is the realisation of the thesis important for?**

The main focus of voice entry procedures is clearly the reduction of costs (illustration 87), as many administrative tasks would be dropped (multiple data entry etc.). Very few Delphi participants consider the topic important for the quality of healthcare and technical progress.

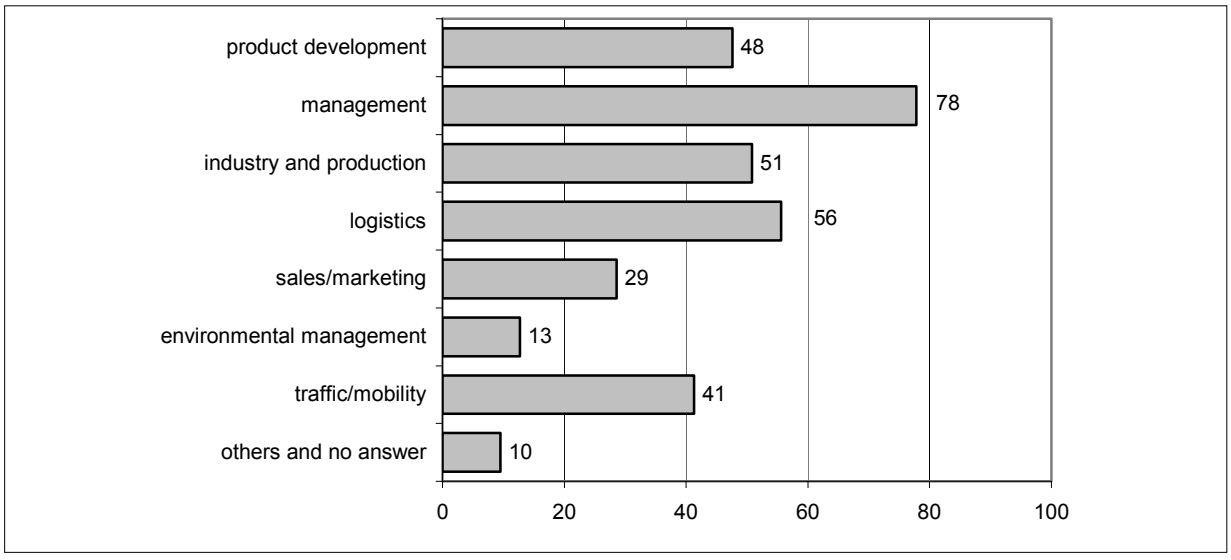
**Illustration 87:** Importance of thesis 20 (in percent)




**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

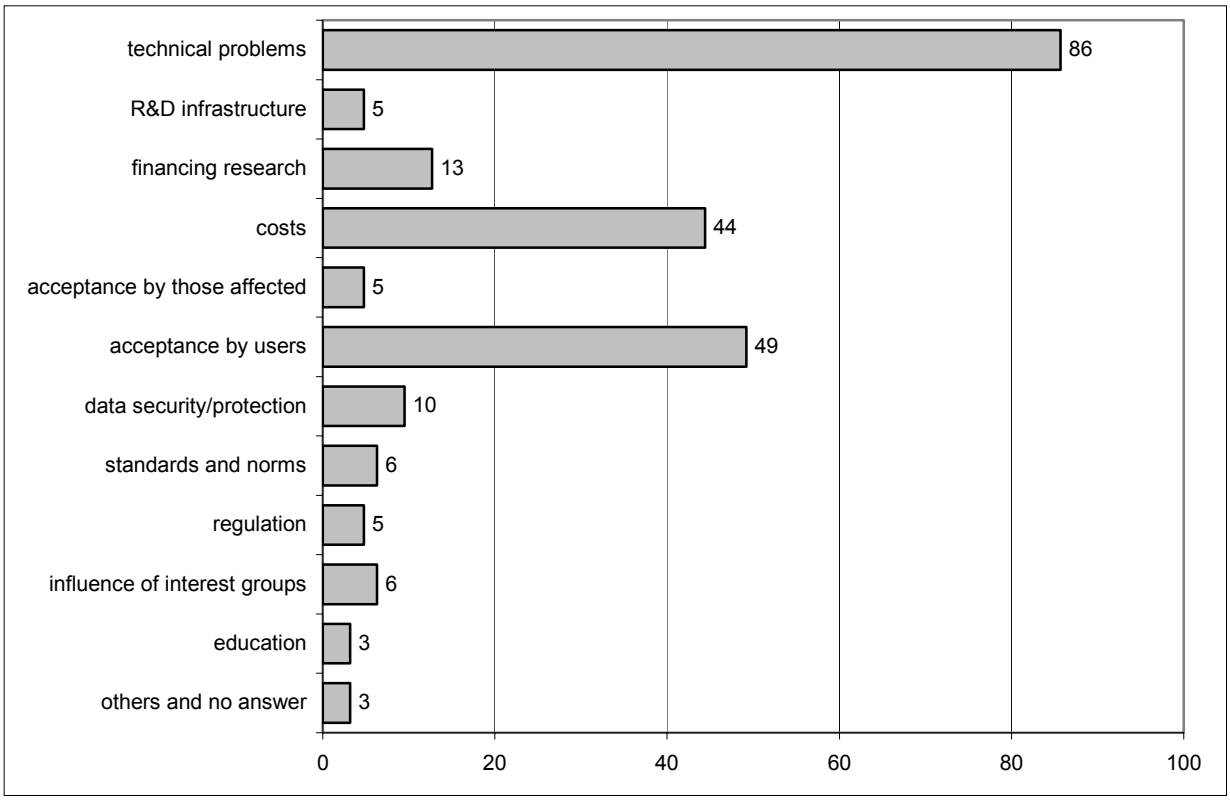
Voice entry will be miscellaneously by applicable and lead to cost saving wherever it is practised. All offered areas are thus named by the participants, even if with various markings (illustration 88). Most often named is the sector management.

**Illustration 88:** Thesis 20 – Applicability in other areas (in percent)



**Where do you see obstacles for the realisation of the thesis?**

**Illustration 89:** Obstacles for the realisation of thesis 20 (in percent)




Despite all unanimousity for the realisation there are obstacles which need to be observed. They are clearly located in the technical area. Apart from this users need to be convinced and also the costs are a factor not to be brushed aside.

**Prospect**

To routinely perform documentation tasks in hospitals via voice entry will be realised in the near future. This will be a great contribution towards cost saving in the health sector. Even today, voice entry works, but the necessary precision will still take some time. Accordingly documentation tasks can be performed in such a way in many areas, especially in management. The technical problems which are as yet large can be overcome. However, initial costs are considerable and users need to be convinced in order to establish voice entry as a standard.

## Thesis 21: A non-invasive long-term blood pressure sensor has been developed.

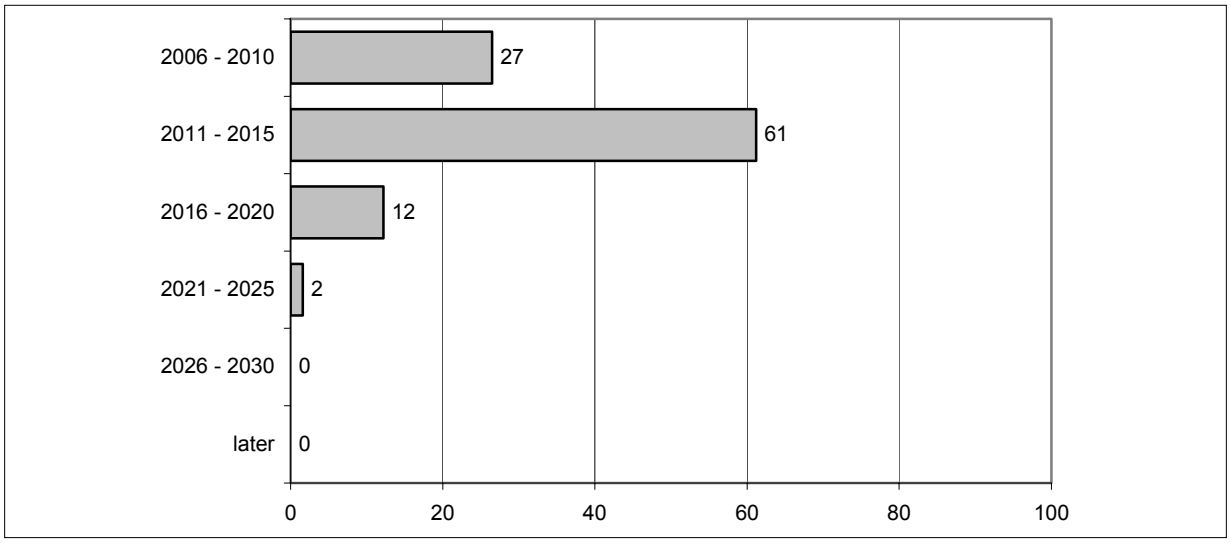
Measuring blood pressure in a physician's practice is always a snapshot. For this reason many patients have their own blood pressure gauge at home in order to rule out excitement in the practice ("white scrubs effect"). For many patients at risk or after accidents this selective control is, however, not sufficient and a continuous long-term measurement is necessary. So far long-term measuring is only possible over a period of several days and a tedious procedure as it is associated with an instrument that is carried along. For this reason a small precise blood pressure sensor on the surface of the skin (meaning non-invasive) would be ideal for long-term measuring. An invasive blood pressure sensor with remote data recording and reading is already in testing (Info Netzwerk Medizin, 2000). Non-invasive blood pressure sensors for selective measuring (only for a short period of time and as yet without data conveyance) also exist and developers are currently working on non-invasive blood pressure sensors for long-term measuring. The estimates made by our Delphi experts might be outdated due to ongoing developments in this area (BNN, 2002).

52 Delphi experts evaluated this thesis. One quarter of them estimate their expertise as very high and 36.5 percent estimate it as medium.

**When do you expect the realisation of this thesis?**

The experts are fairly unanimous about the realisation time being between the year 2010 and 2015 (median 2012). Only few persons marked later periods of time and nobody said "never".

**Illustration 90:** Realisation time for thesis 21, distribution of answers in 5-year steps (in percent)

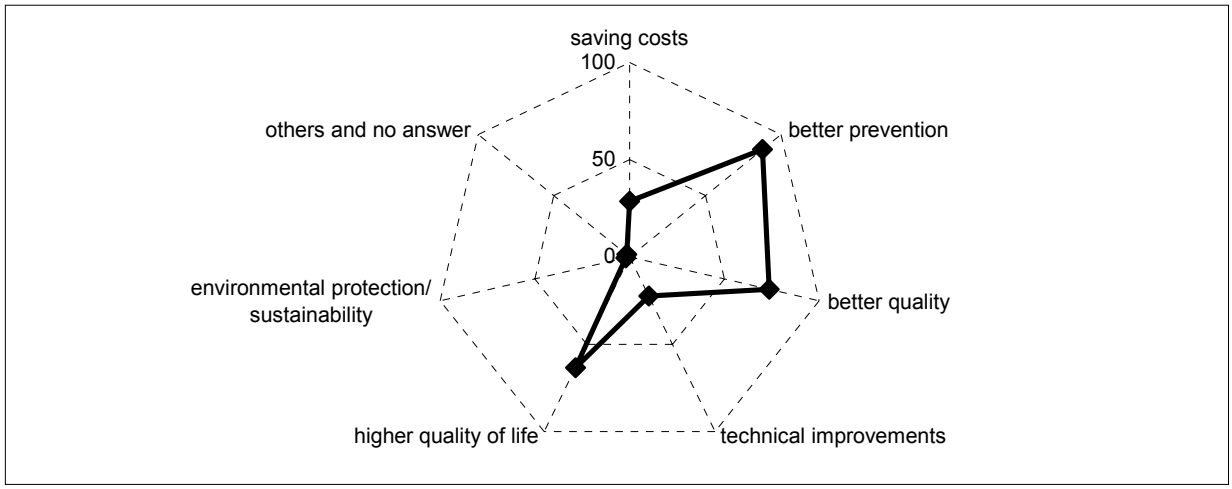



**All in all do you personally consider the realisation of this thesis desirable?**

98 percent of the Delphi experts consider a non-invasive blood pressure sensor desirable, only two percent do not.

**What is the realisation of the thesis important for?**

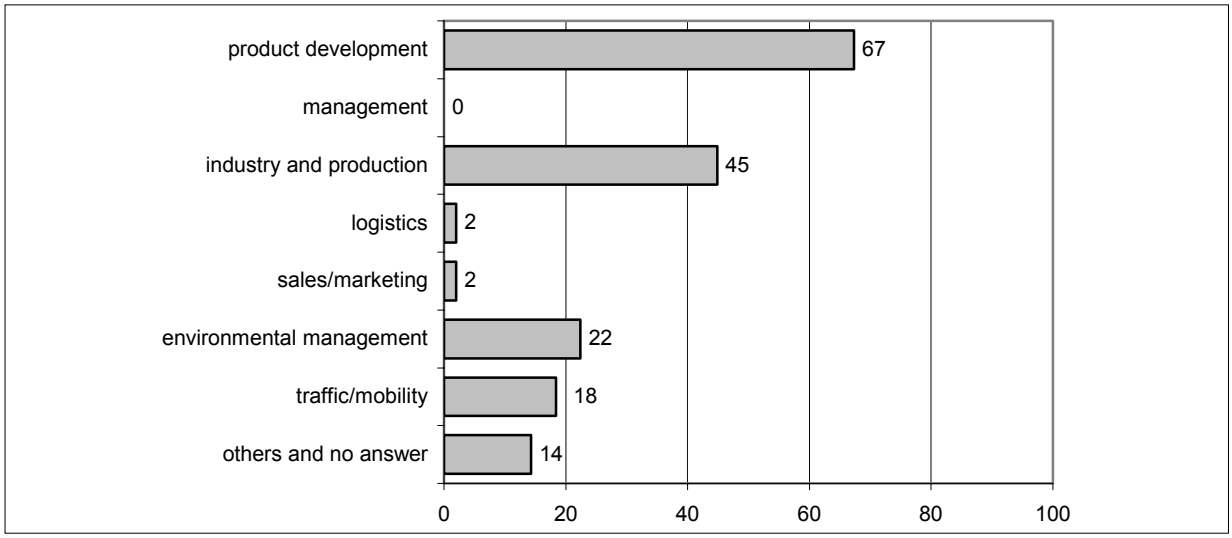
**Illustration 91:** Importance of thesis 21 (in percent)




The non-invasive blood pressure sensor for long-term measuring is considered as important for better prevention, a higher quality of life as well as higher quality of healthcare (illustration 91). Few also consider it important for cost saving and technical progress.

**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

**Illustration 92:** Thesis 21 – Applicability in other areas (in percent)

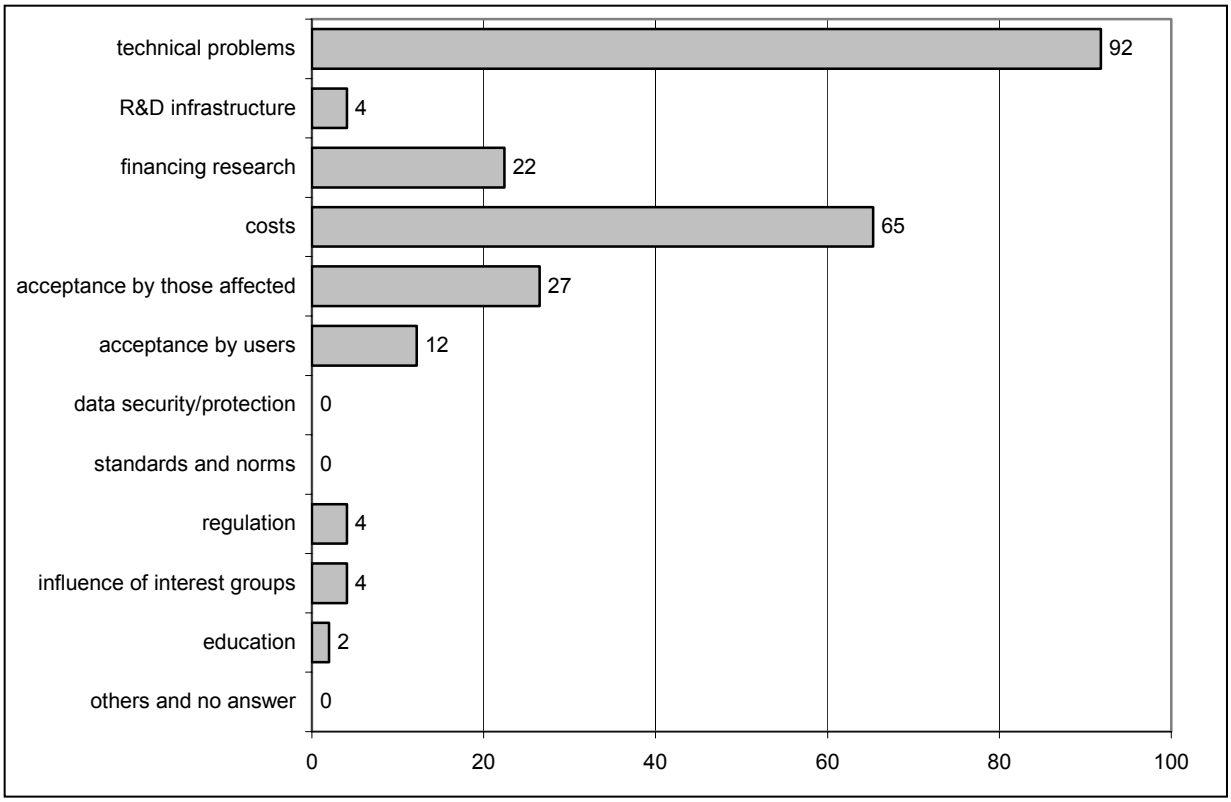



Similar sensors can be applied in product development, industry and production, possibly also in environmental management as well as traffic and mobility. Many of the experts also mark “others” here, but do not specify any further (illustration 92).

**Where do you see obstacles for the realisation of the thesis?**

Obstacles on the way to realisation are found especially in the technical sector (illustration 93). The costs, too, are a significant obstacle, persons with high expertise, however, relativise these technical problems ("only" 77 percent namings instead of instead f 92 percent) while they name costs more frequently (77 percent instead of 65 percent). Furthermore named is research funding and acceptance by those concerned who may not want long-term observation, as stated by those with high expertise (38 percent versus 27 percent average). Few name acceptance by users. One commentary refers to possible problems of handling. What is remarkable is the fact that nobody names data security and data protection issues as an obstacle. This means all participants assume safety, presumably because the technology is not necessarily connected with data conveyance.

**Illustration 93:** Obstacles for the realisation of thesis 21 (in percent)



**Prospect**

To develop a non-invasive long-term blood pressure sensor may not sound very complicated, however, the technology is elaborate. So far it is the technical problems and the issue of costs which have prevented a realisation to this day. But the thesis will be realised at the latest within the next 10 to 15 years. The topic is very important for better prevention, the quality of healthcare and a higher quality of life of those concerned (small sensor instead of large device). Still, the issue of acceptance by those concerned needs to be improved.

Thesis 22: Clinically applicable systems consisting of implantable glucose sensors, actuators and insulin reservoirs as well as corresponding control software have been developed, allowing an optimum fine-tuning of diabetes patients.

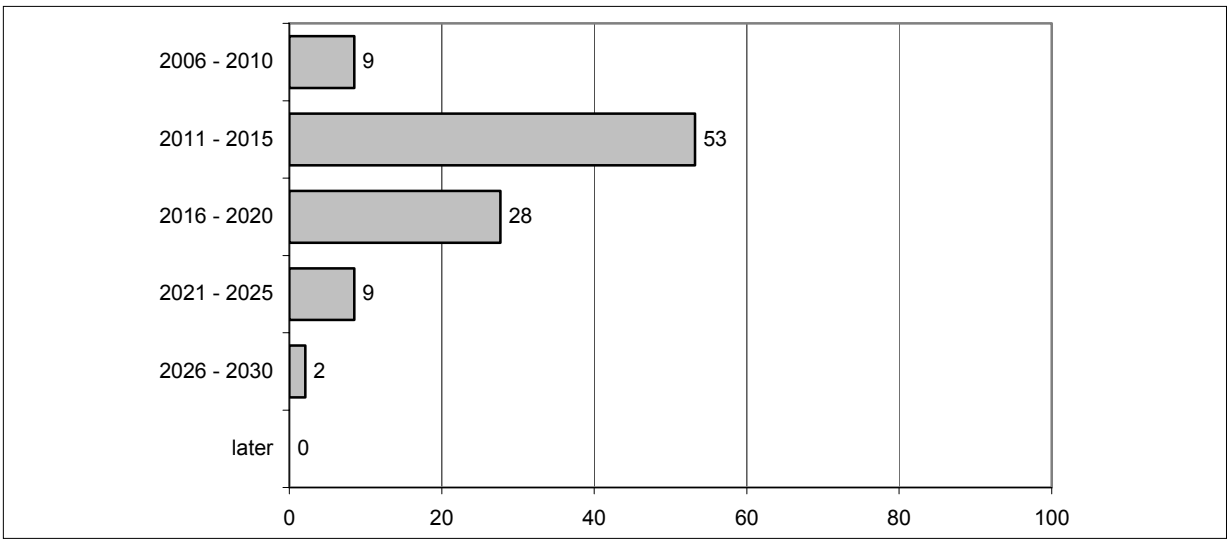
Diabetes has become one of the most predominant diseases in industrial countries during the past years and due to malnourishment an increase of incidences is expected. For the treatment of diabetes patients an optimum fine-tuning, i.e. a supply of insulin according to the blood sugar level, is important in order to prevent consequential damages, e.g. of the kidneys, the heart, eyes etc. So far solutions are characterised by determining the blood sugar level or having it determined and administering an adequate dose of insulin per tablet, injection or pen. To automate this in a system by implanting a glucose sensor which delivers exact measuring data and automatically releases an appropriate amount of insulin from a reservoir would make things far easier for patients and enable exact doses. Patients would not need to think about the correct dose before each meal, wrong handling could be prevented and the problem of "compliance" would not even arise (Bührlen, 2003).

48 Delphi participants evaluated this thesis. Of those, 24.4 percent estimate their expertise as high, 40 percent as medium. 35.6 percent estimate their expertise as low, which makes the topic quite specific. It is assumed that those answering make their estimations on solid grounds.

**When do you expect the realisation of this thesis?**

The diabetes system with a glucose sensor, actuators and insulin reservoirs including the controlling unit is considered realisable for the year 2014. The low quartile lies around the year 2012, the high quartile at 2018. The distribution of answers is thus not large, as shown in illustration 94. Nobody says later than 2030, and nobody says "never", which means the thesis is generally considered feasible.

**Illustration 94:** Realisation time for thesis 22, distribution of answers in 5-year steps (in percent)

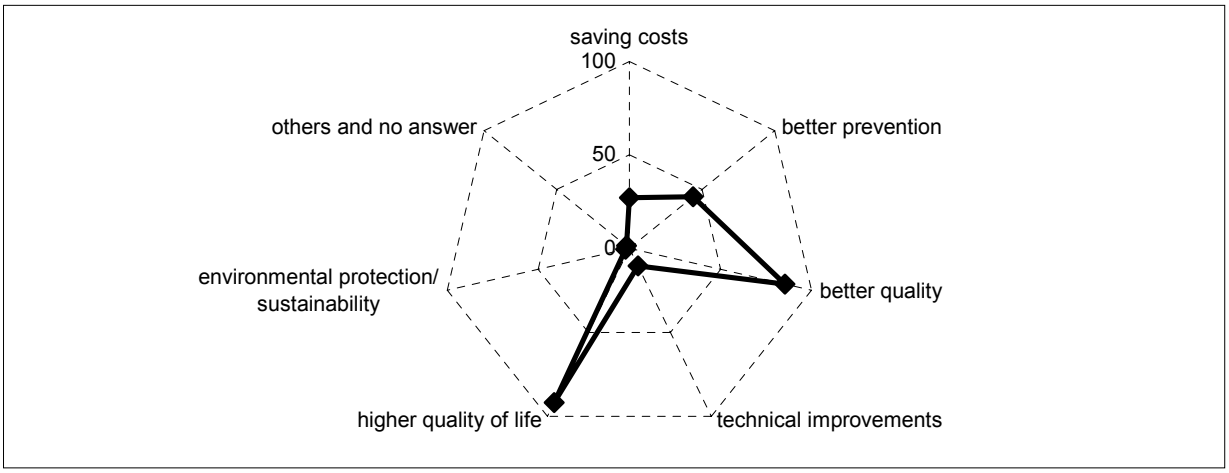



**All in all, do you personally consider the realisation of this thesis desirable?**

This thesis, too, is considered desirable by 98 percent of the participants. Only 2 percent consider it "not desirable". One argument for "not desirable" (made during interviews in the phrasing phase of the theses) stated that such a system would not make dietary change interesting for patients. If persons could be fine-tuned that easily and they did not need to learn to comply there would not be any incentive for changing their dietary habits. "So carry on with cola, french fries and other sweets", the system would take care of everything.

**What is the realisation of the thesis important for?**

**Illustration 95:** Importance of thesis 22 (in percent)

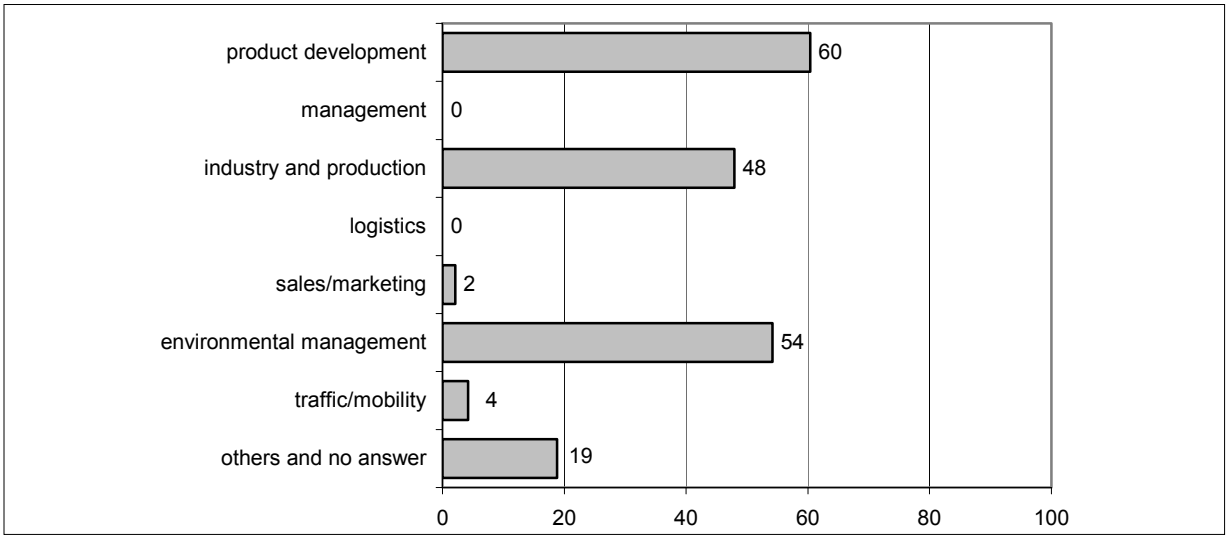



A system which guarantees an optimum insulin provision is important for a higher quality of life of patients, which today is very limited. The system can also be important for the quality of healthcare and better prevention, state the experts. Possibly it can also contribute to cost saving say participants with high expertise rather than the average of participants (36 percent compared to 27 percent). One commentary points out the benefit of higher life expectancy that the person concerned can maybe expect due to adjusted and more exact insulin intake.

**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

A system which records data via a sensor and releases substances from a reservoir can also be applied in product development, production and industry as well as environmental management. “Other areas” is also named and especially process engineering is referred to.

**Illustration 96:** Thesis 22 – Applicability in other areas (in percent)



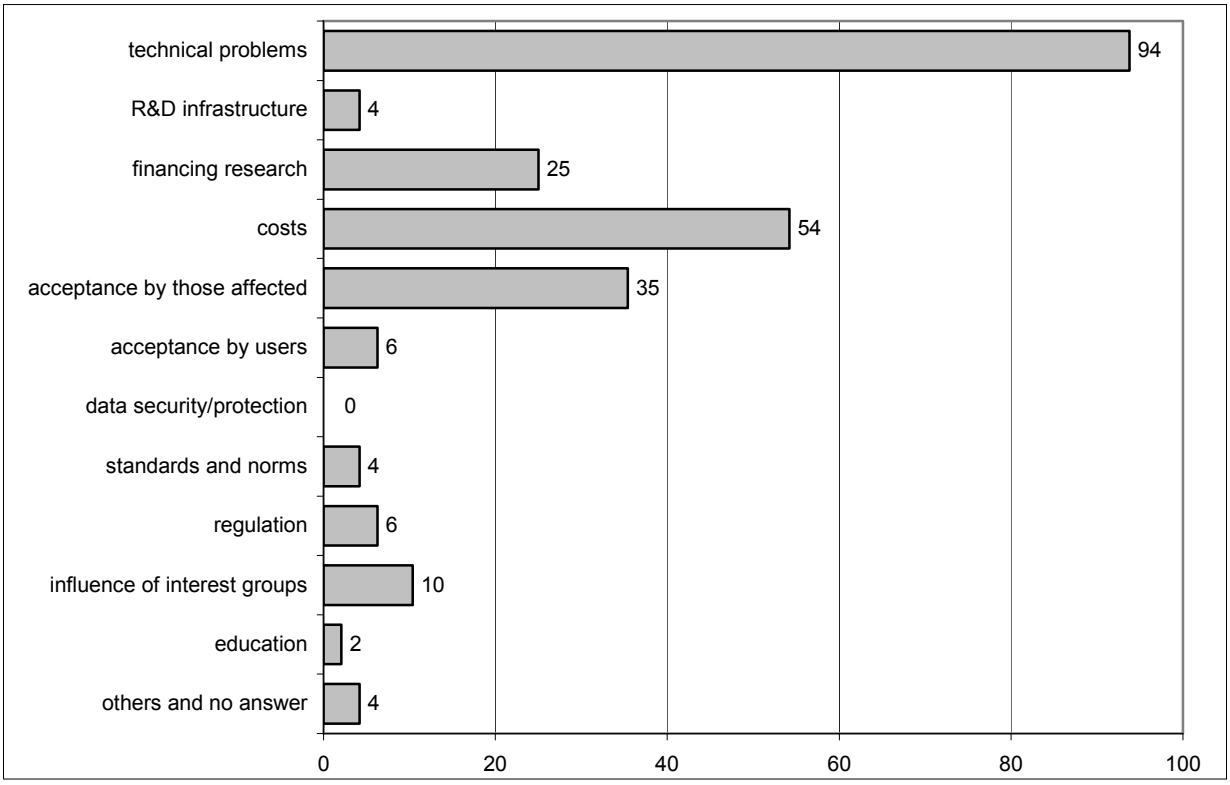

**Where do you see obstacles for the realisation of the thesis?**

Most apparent are the technical challenges which have until today prevented a realisation. One of the challenges concerns the implantable glucose sensor which needs to be stable over a long period of time and very exact. First successful facts have been released on this topic[2]. An external wrist glucose sensor has received market approval[3]. It is still not clear in how far the sensor is accurate in practical use. The next challenge are the actuators which need to be so small that they do not impair and at the same time must be stable over a long period of time, as well. Additionally, there is the control mechanism which, too, needs to be stable over a long period of time and very precise. Commentaries refer to the necessity of “reliability of algorithms” and that primarily the “knowledge on measurable recording of ALL relevant data for insulin release” is mandatory.

The second obstacle named by more than half of the participants is represented by the costs (54 percent), although participants with high expertise relativise the issue a little (only 45 percent of namings). As with all implants acceptance by those concerned is a concern which needs to be addressed and methods for convincing them need to be sought. Also mentioned is research funding and 36 percent of those with high expertise name the influence of interest groups as an obstacle, on average this point is only named by 10 percent of all participants (see illustration 97).

[2]http://www.diabsite.de/aktuelles/nachrichten/2000/000829b.html;
http://www.sensile.com/senmedical/data/investors_media/sensile_glucose_sensor_nzz.pdf
[3] http://www.diabetes-kids.de/article.php?sid=402

**Illustration 97:** Obstacles for the realisation of thesis 22 (in percent)




**Prospect**

Systems consisting of an implantable glucose sensor, actuator(s) and an insulin reservoir as well as control software which enable the long-term fine-tuning of diabetes patients is considered to be clinically applicable and realisable by the year 2015 and also considered desirable by nearly all Delphi participants. The system is important for a higher quality of life of diabetes patients and the quality of healthcare. Until it can clinically be applied, however, many technical obstacles need to be overcome, the main one being the development of an implantable glucose sensor which is integrated in the total system and controls insulin release according to safe algorithms. Costs and acceptance issues by those concerned can postpone further broad application. Similar systems, however, are applicable in other areas such as product development, industry and production or environmental management.

## Thesis 23: Entire artificial kidneys have been developed.

More and more people are confronted with chronic kidney failure, the permanent and progressing decline of their kidney function, e.g. due to diabetes. Generally this leads to ultimate kidney failure, a diagnosis for approximately 15.000 persons per year – and kidney substituting programmes such as dialysis or kidney transplantation take over the important function of the own organ. Altogether 65.000 persons undergo dialysis in Germany, around 20.000 have received a transplant organ[4]. An artificial kidney could save the pains of dialysis for many patients. External large dialysis apparatus do exist and are often called "artificial kidneys", however, her, artificial organ implants are meant.

The first successful kidney transplant ever took place in Boston in 1954. In Germany M. Brosig conducted the first kidney transplant in Berlin-Westend on 27 November 1963 (TransplantForum, 2007). In Germany, around 2.000 kidneys received from dead donors are transplanted annually. More than 90 percent of the patients are discharged from hospital with a functioning organ. Even though living transplantations are possible more kidneys are required than the number of those released for transplantation. This is why the idea of implanting an artificial kidney seems obvious. The development of such an organ, however, is not as easy as one may assume.

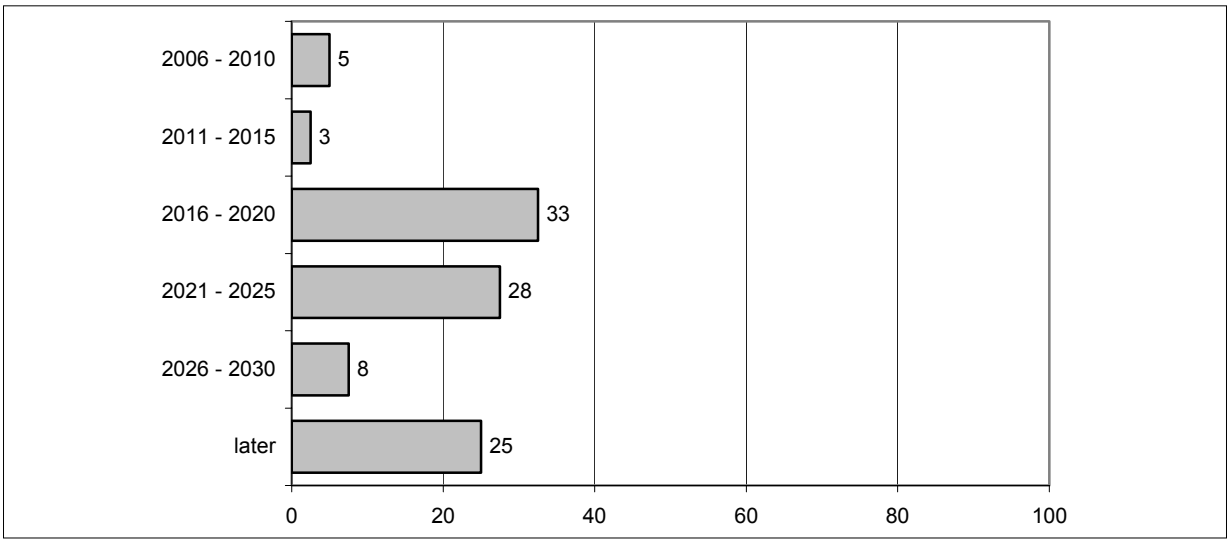
Only 45 persons evaluated this thesis. Only few of them, 11.1 percent, estimated their expertise as high. 35.6 percent of them estimate it as medium and 53.3 percent as low. Perhaps the general low expertise applied for the evaluation is the reason for relatively high variance among the answers.

**When do you expect the realisation of this thesis?**

The development of artificial kidneys is actually *not* expected for the oncoming en years. And even after that experts are not agreed upon their evaluation, as depicted in illustration 98. The median is the year 2022, the low quartile already ranges at a late stage, 2018 and the high quartile after 2030. One quarter of those asked presume realisation to take place "late", only after 2030. This is one of the realisations discussed in the Delphi study at hand estimated very late in the timeframe. In spite of this estimate, only 2.3 percent of the participants say "never" will the thesis be realised. This, however, refers to development and not the actual clinical application. The evaluation is altogether quite unstable as the expertise estimated by the participants themselves is fairly low on the subject.

[4]http://www.kfh-dialyse.de/cnv/index.html

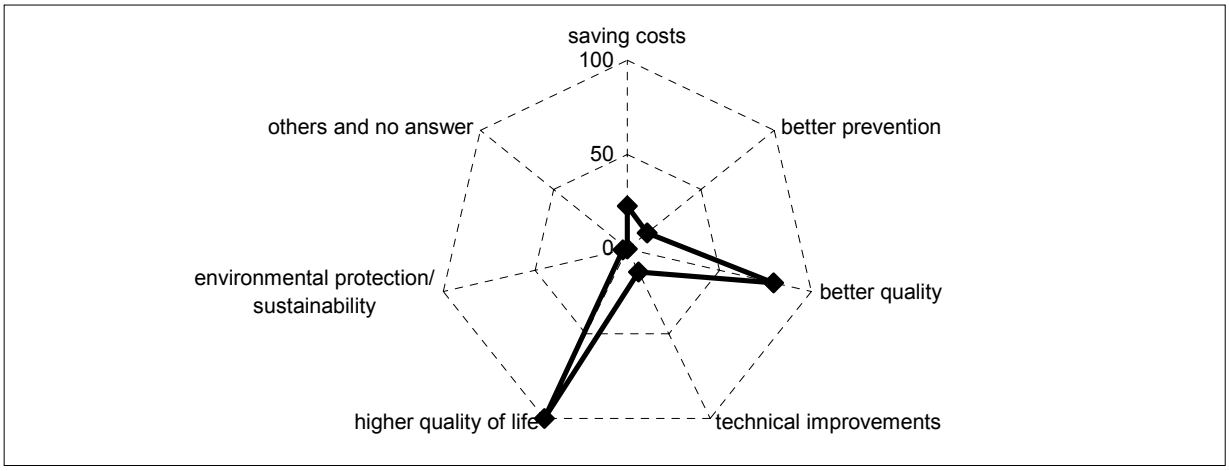
**Illustration 98:** Realisation time for thesis 23, distribution of answers in 5-year steps (in percent)




**All in all, do you personally consider the realisation of this thesis desirable?**
All of those answering (100 percent) consider artificial kidneys desirable.

**What is the realisation of the thesis important for?**

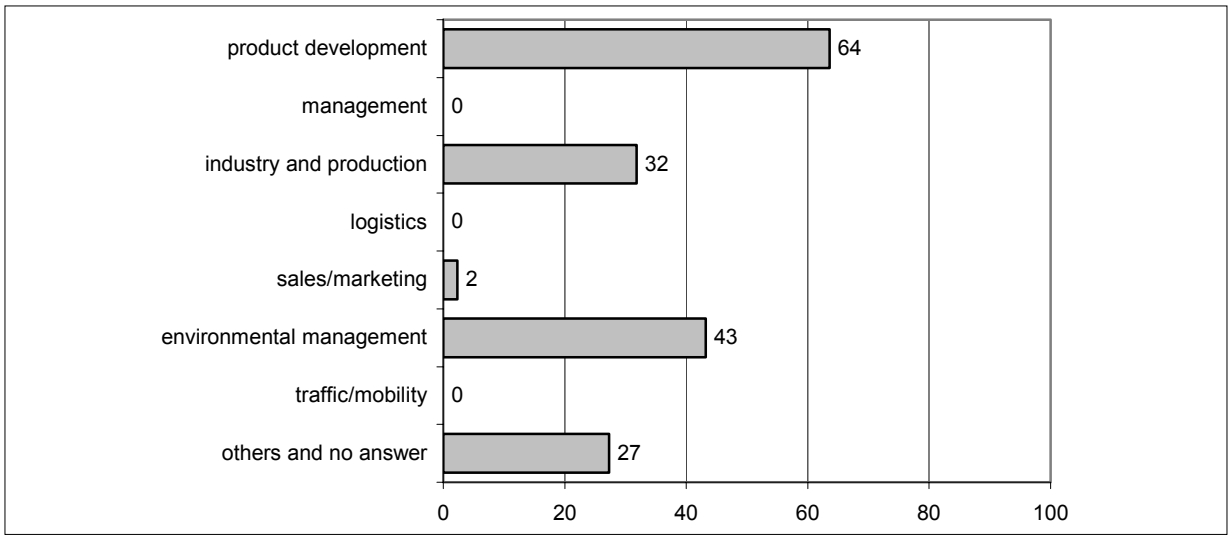
**Illustration 99:** Importance of thesis 23 (in percent)




Analogue to desirability all participants consider the topic important for higher quality of life as well as the quality of healthcare.

**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

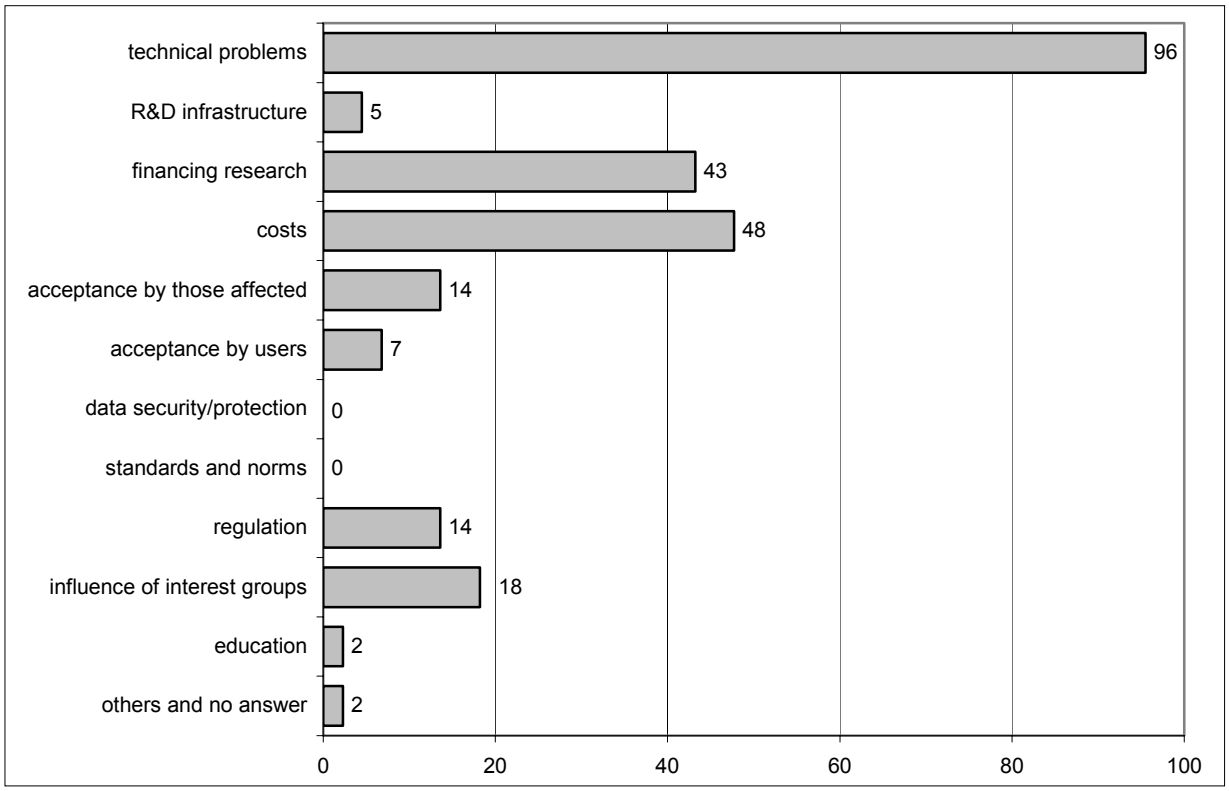
**Illustration 100:** Thesis 23 – Applicability in other areas (in percent)




Similar technology can be applied in product development, environmental management, industry and production as well as other areas, named here is process engineering. Namings are not as high as for many other theses.

**Where do you see obstacles for the realisation of the thesis?**

**Illustration 101:** Obstacles for the realisation of thesis 23 (in percent)



Nearly all participants see technical problems as an obstacle towards realisation (illustration 101). An artificial kidney is a highly complex system with a high passage rate and the separation of very diverse substances, a task not easily completed. When compared to dialysis apparatus and their size today the challenge of integrating so many functions in one relatively "small" device and supplying it with energy becomes apparent. The costs, too, are considered to be an obstacle, as well as research funding. Some experts also name the influence of interest groups, regulations and even acceptance by those concerned. The minority of experts with high expertise even consider the obstacles t be larger than the average of participants.

**Prospect**

To develop entire artificial kidneys is considered desirable by all experts in order to enhance the quality of life for dialysis patients. The topic would also be important for the quality of healthcare, as the artificial organ could take over long before the natural kidney's complete failure or before structures have been affected through insufficient blood filtering. But: The artificial kidney is only considered to be realised at a very late stage in spite of a general agreement on realisation as such. Technical problems (ranging from membranes to miniaturisation) are in the way of early realisation. And also the costs and research funding are considered a problem. The supporting technology could, however, also be applied in other areas.

## Thesis 24: An artificial heart and lung implant receives market approval.

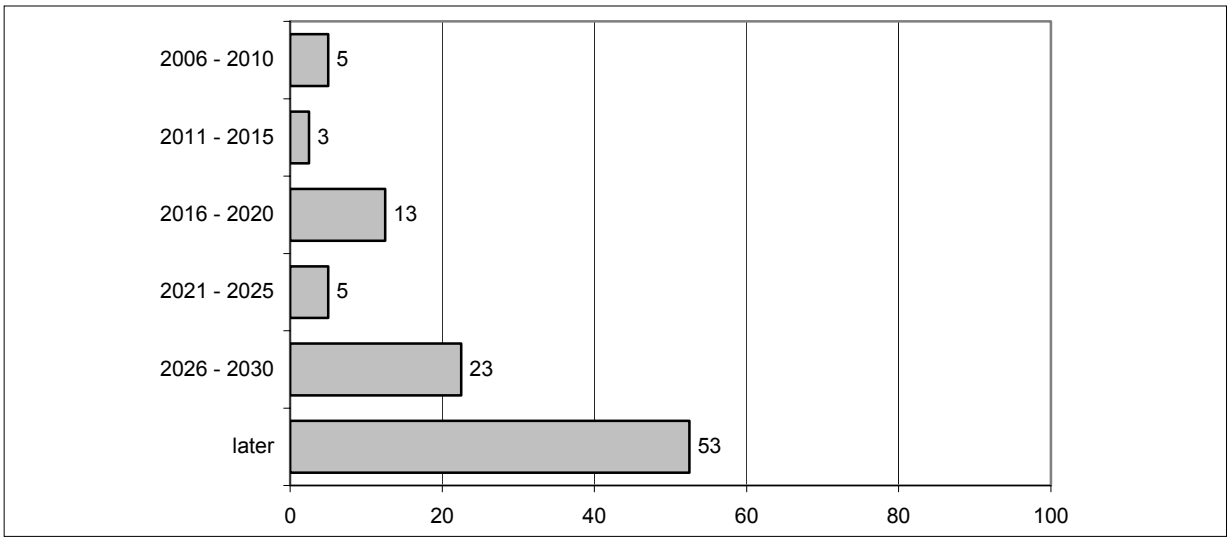
A heart implant is only considered for persons with incurable heart diseases and also then only when the own heart fails. This is considered especially when an adequate donor organ is not available. Even though the heart is a relatively simple organ, a cavernous muscle functioning as a pump, the heart implant has the meaning of the Holy Grail of modern medicine. Heart implants are different from external heart-lung machines which in certain cases, e.g. during surgery, substitutes the functions of both organs and is only connected to the blood circulation of the patient at one location. A bilaterally supporting heart must be connected to the heart circulation as well as the lung cycle. Heart implants are supposed to be applied for a period of time far longer. The record is currently (2006) set at 17 months. Certain models are supposed to completely substitute the invalid heart of the patient which is then removed. Others work as facilitators and the own organ remains in place. Like the artificial kidney (thesis 23) an artificial heart and lung implant would make the donation of a natural organ obsolete and one could be able to save the life of those for whom there is no matching donor organ. In practice, such a development with market approval is yet far away.

Only 44 participants evaluated this thesis at all, and among those only 11.4 percent estimate their expertise as high. 31.8 percent had medium expertise and most of the participants (56.8 percent) estimated their own expertise as low. This thesis was evaluated with lower expertise than most of the other theses.

**When do you expect the realisation of this thesis?**

This thesis represents the by far latest realisation of the Delphi study (see illustration 102) with a large variance as to the answers. The median already is located after the year 2030. Despite this the heart and lung implant is considered realisable by most participants, only 2.3 percent of those answering say “never”.

**Illustration 102:** Realisation time for thesis 24, distribution of answers in 5-year steps (in percent)

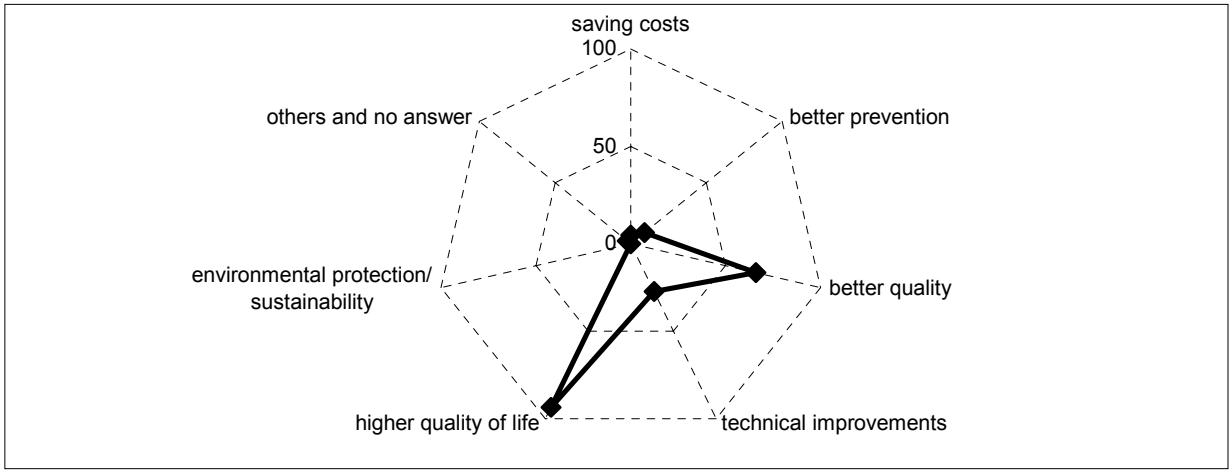



**All in all, do you personally consider the realisation of this thesis desirable?**

88 percent of the participants consider the heart and lung implant desirable. Only 5 percent say "not desirable", 7 percent say "do not know".

**What is the realisation of the thesis important for?**

**Illustration 103:** Importance of thesis 24 (in percent)

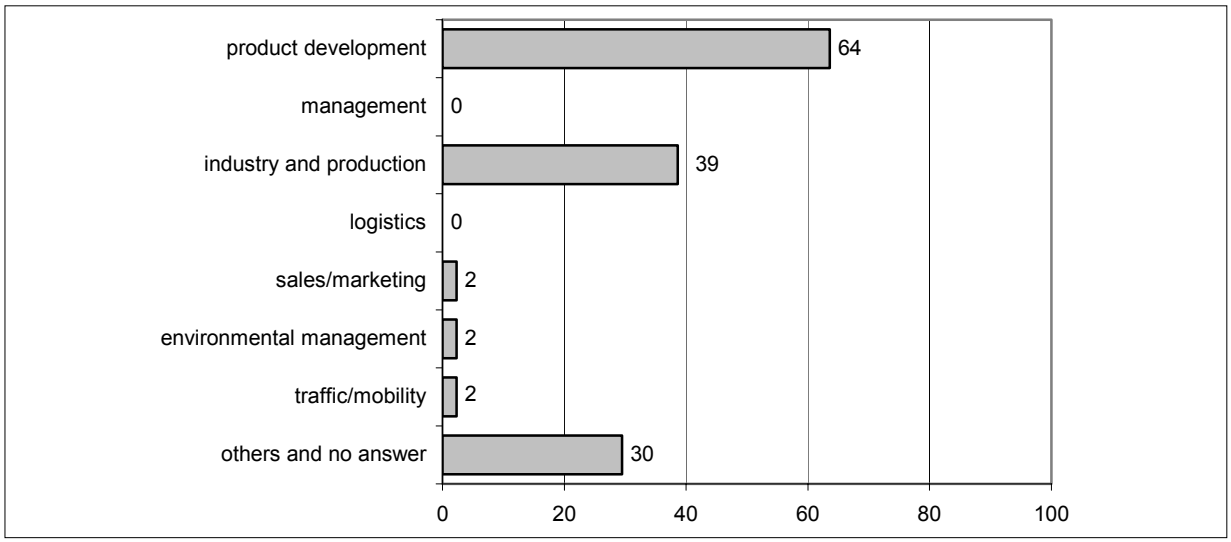



The artificial heart and lung implants would be especially important for a higher quality of life of the patients (illustration 103) and also for the quality of healthcare. However, it would also benefit technical progress. Commentaries point out "longer life expectancy" and "longer life in spite of organ deficiencies", as, without such a "machine" some patients would not survive. Commentaries also referred to ethical issues.

**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

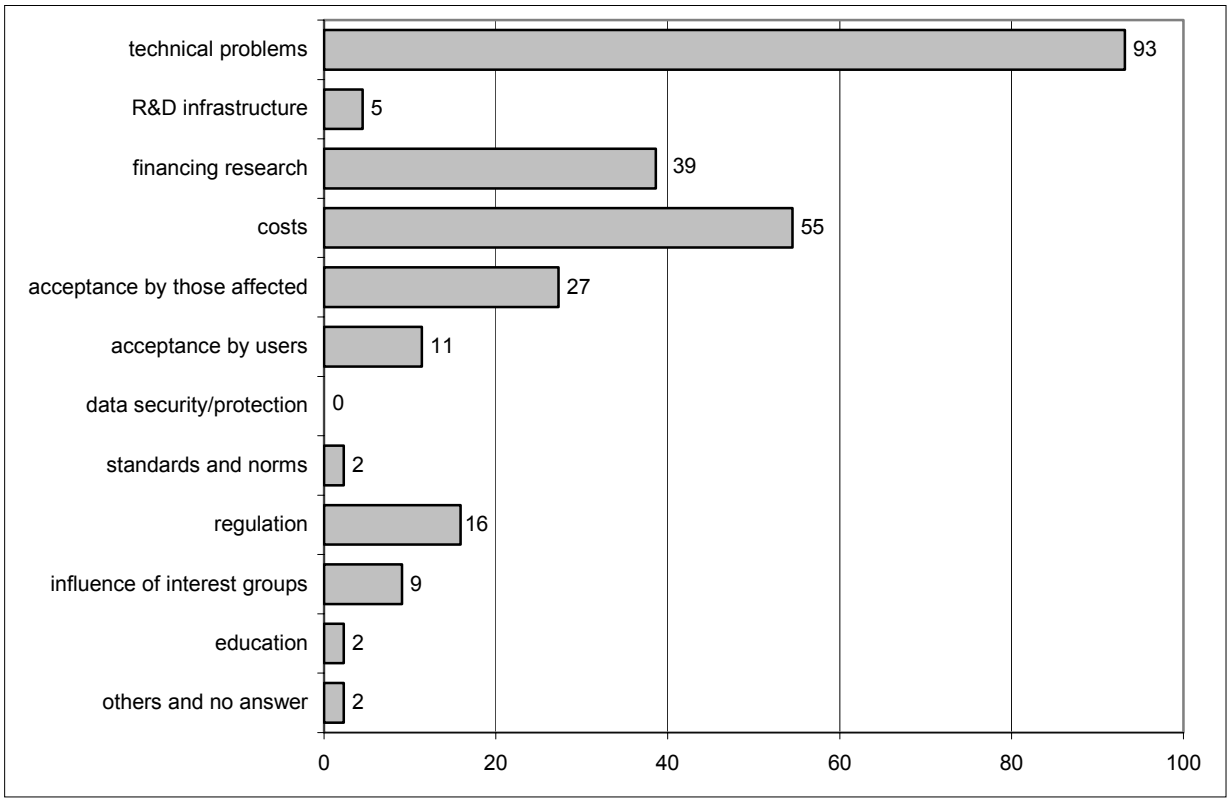
A similar apparatus would also be applicable for product development (illustration 104) as well as industry and production. These answers are not specified any further, they could refer to the development of micropumps with high passage rates. "Others and no answer" is also frequently marked (30 percent is a high rate here), this is not specified further either and seems to mean "no answer".

**Illustration 104:** Thesis 24 – Applicability in other areas (in percent)




**Where do you see obstacles for the realisation of the thesis?**

**Illustration 105:** Obstacles for the realisation of thesis 24 (in percent)



The main obstacle is characterised by technical problems (illustration 105). To develop the device is difficult as it is (large passage rate with small size, control, longevity, material issues, energy supply etc.) but market approval is even more difficult, since there will be hardly anybody offering to be a test person. Heart-lung machines today are so large that a large amount of technical work is necessary if the device is going to be so small and supplied with energy. The second obstacle named is the costs, followed by research funding. Also acceptance issues for those concerned and users, too, play a role. Regulation is named as an obstacle in 16 percent (7 namings) of the answers.

**Prospect**

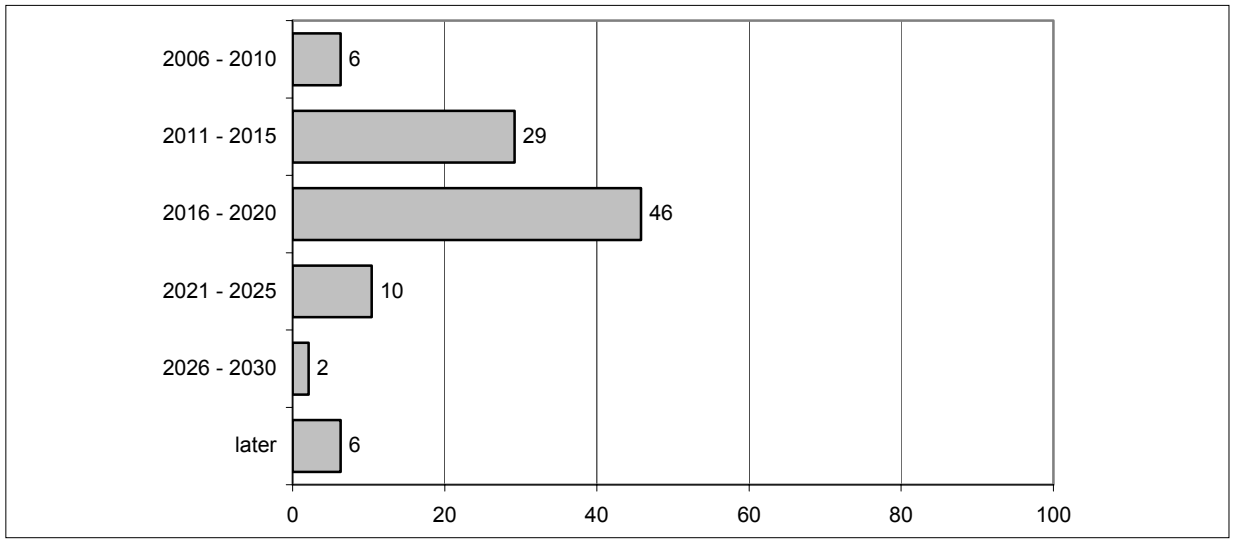
It will take very long until an artificial heart and lung implant receives market approval; but nothing is considered impossible. Many of the participants consider it desirable and important for the quality of life (or even the survival) for the patients concerned. Technical obstacles, however, make realisation yet be a long time away. Issues of costs and acceptance are only minor compared to technical problems.

## Thesis 25: Vital parameters (blood pressure, blood levels, antibodies, hormones) can be deciphered via implanted chips.

This thesis resembles theses no.11 and no. However, here the issue does not regard the measurement of vital parameters via external chips (e.g. lab-on-chip) moreover the chips in this thesis are implanted – a further development. Implanted chips measure blood pressure, analyse blood parameters, antibodies, hormones etc. and the data can be retrieved without any further intervention. This means a great amount of help to long-term observations and diagnoses and could be important for athletes, as well. 52 of the Delphi participants evaluated this thesis, one quarter of them estimate their expertise as high, 38.5 percent as medium and 36.5 percent as low. This means generally the thesis is evaluated with high expertise.

**When do you expect the realisation of this thesis?**
The realisation of implantable chips is expected around the year 2017 (Q1: 2014, Q2: 2020). The answers are distributes as shown in illustration 106 with a focus on the medium offered time steps and a large variance for later timeframes. 6 percent of the participants only expect realisation to be feasible after 2030 and 4 percent do not believe it to be realised.

**Illustration 106:** Realisation time for thesis 25, distribution of answers in 5-year steps (in percent)



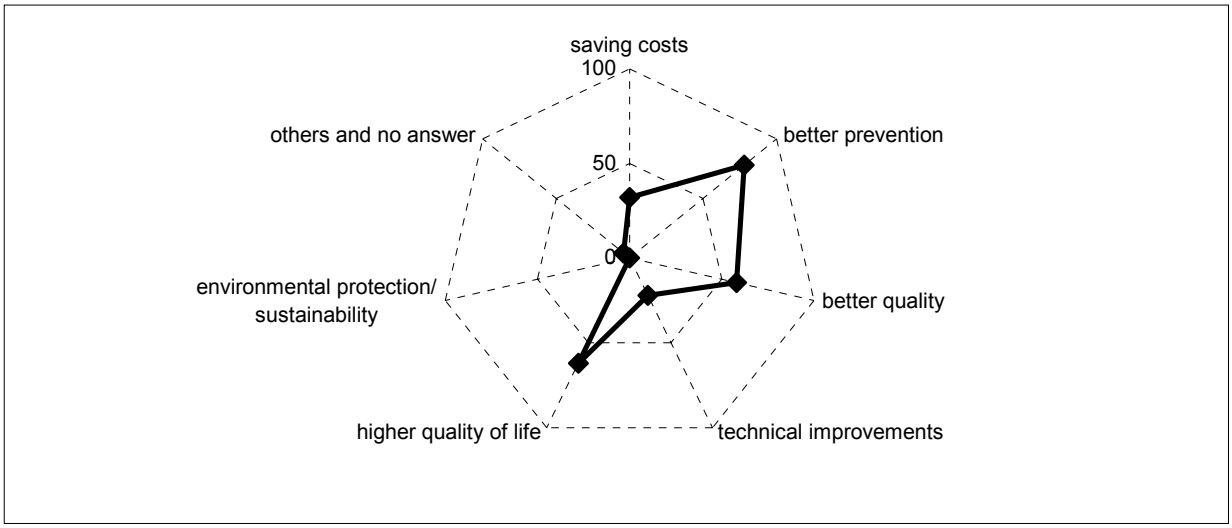

**All in all, do you personally consider the realisation of this thesis desirable?**
To gather information on vital parameters via implantable chips is one of the rather controversial theses. In spite of this, 74 percent of the Delphi participants consider this thesis desirable, a value far lower than for other theses. Even more cautious are those with high expertise: only 62 percent of them consider the thesis desirable. Remarkable is the fact that older Delphi participants consider the topic more desirable than younger ones (87 respectively 88 percent of the 46 to 65 year olds say desirable compared to 60 respectively 58 percent of the 26 to 45 year olds).

16 percent of the participants do not consider the reading of vital parameter data desirable at all. Commentaries refer to surveillance possibilities which are enabled and which they do not like at all (“Big brother is watching you.”). 10 percent say “do not know”.

**What is the realisation of the thesis important for?**

Deciphering vital parameters via implanted chips is considered important as to a higher quality of life for patients, better prevention and important, too, for the quality of healthcare. One quarter of the participants also name its relevance for cost saving as well as the technical progress.

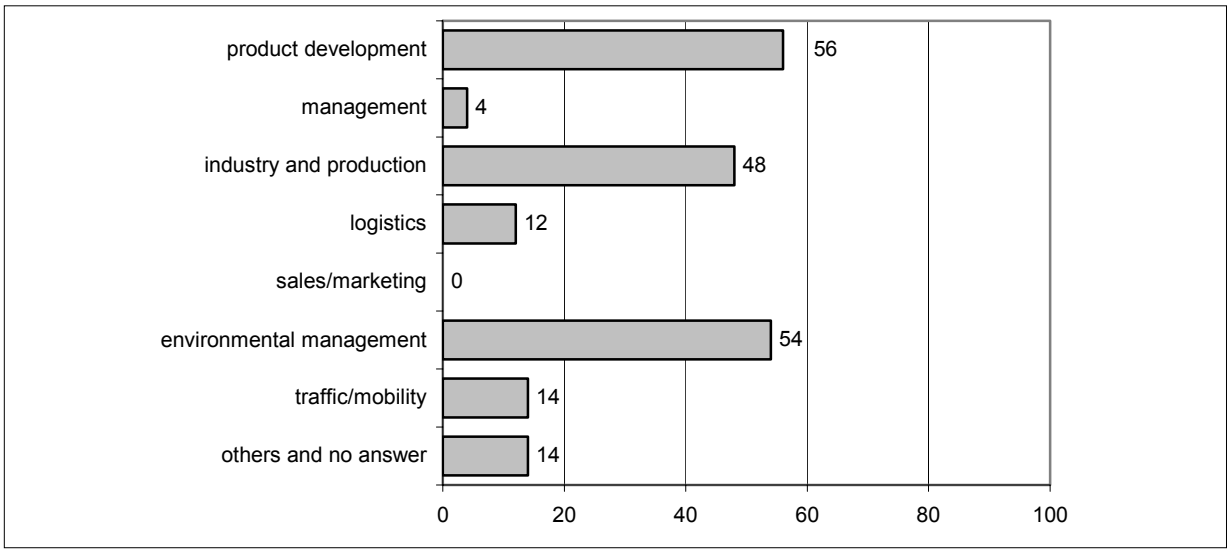
**Illustration 107:** Importance of thesis 25 (in percent)




**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

Decipherable implanted chips can be applied in product development, industry and production as well as environmental management (illustration 108). Apart from "others" also logistics and traffic/mobility are named.

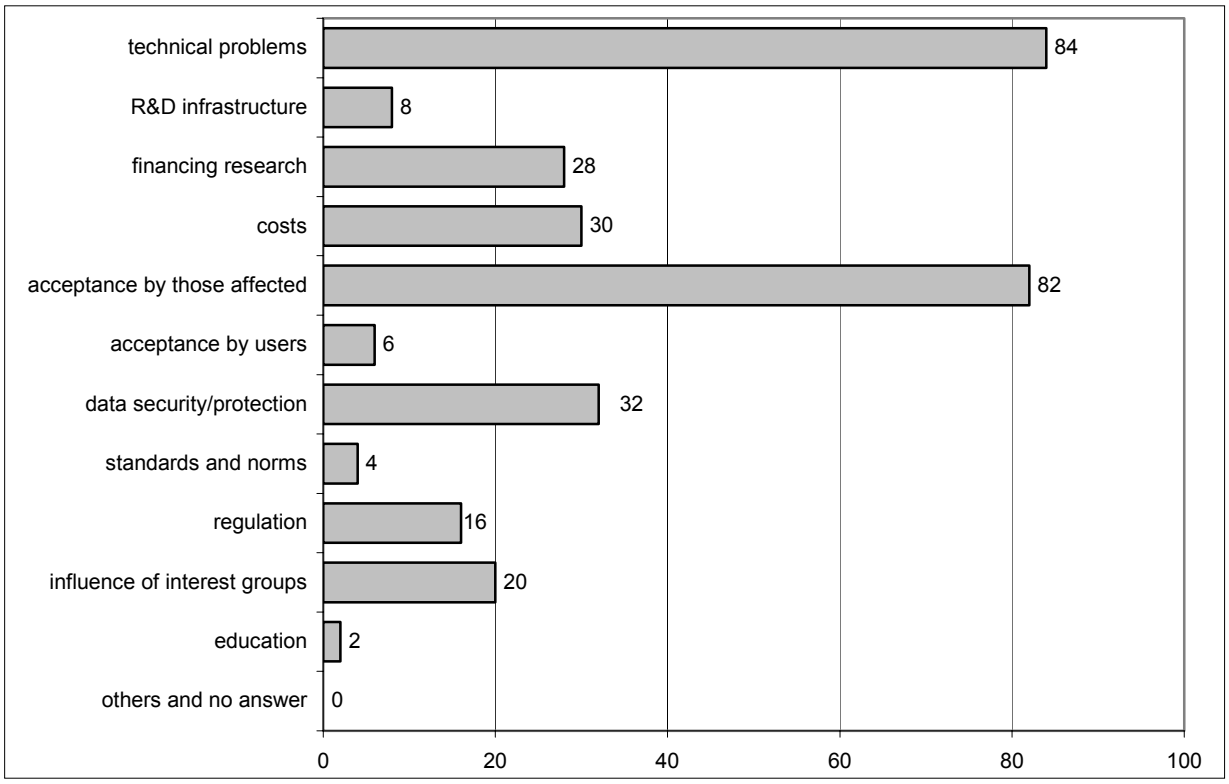
**Illustration 108:** Thesis 25 – Applicability in other areas (in percent)



**Where do you see obstacles for the realisation of the thesis?**

Evident obstacles against realisation are to be seen in the technical area and in acceptance by those concerned (illustration 109). In the same way as for other intervention-applied technologies, "devices" or "things" (biopsy robots, micromachines etc.) there are reservations against an object inserted in the body. It seems emotionally obscure to have something within the body about which one cannot say exactly what it is doing or which is not controllable by oneself. This is why acceptance problems are presumed for all these topics. Also, there are data security and data protection issues, which is said by nearly one third of the participants. The same applies to research funding and costs. 20 percent of those answering also refer to the influence of interest groups (38 percent of those with high expertise, in fact) and 16 percent (but only 8 percent of those with high expertise) see regulation as a problem. Commentaries also refer to ethical questions as an obstacle.

**Illustration 109:** Obstacles for the realisation of thesis 25 (in percent)



**Prospect**

As with all theses which include a device to be implanted in the body this thesis regarding the possibility to decipher vital parameters via a chip is viewed with scepticism and not considered as desirable as many others. The commentary “big brother is watching you” is a classical way of expressing the fear of being monitors and not relying upon data protection and the security of very personal information. In spite of this the topic is considered important for prevention, the quality of healthcare and the quality of life for those concerned. And there are other areas of application, too. Even if many of the participants – perhaps not with as much expertise as otherwise – show slight uncertainty about the timeframe of realisation they are sure about the chips being realised. When – this is a question the Delphi participants are discordant about.

## Thesis 26: Blind persons can orient themselves within a room with a retina implant.

Retina implants are visual prostheses for visually strongly impaired or blind persons, whose retina has lost its function due to an illness, whose optic nerve, however, still supplies an intact connection to the brain. There are various approaches to substitute the function of degenerated nerves in the retina artificially. The principle of the approaches is basically the same. The picture which is perceived by the eye of a healthy person should be photographs, converted to electrical impulses and conveyed to the nerves. Over the past years two very promising implants have been developed – the subretinal implant and the epiretinal implant. The subretinal implant is inserted in the eye below the retina while the epiretinal implant is implanted on the surface of the retina.

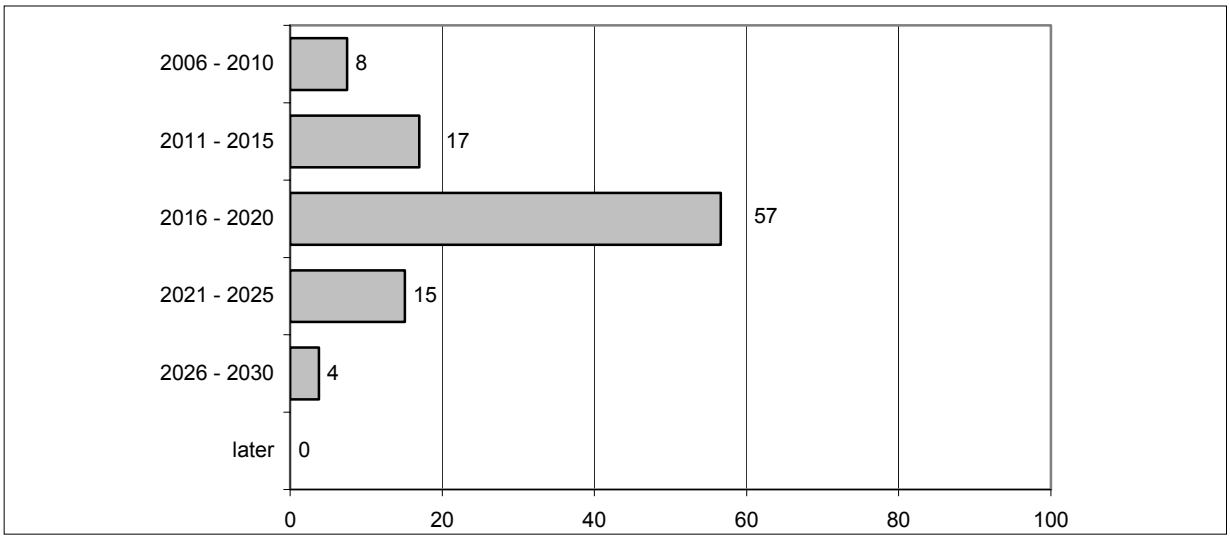
54 participants evaluated this thesis, but only 15.1 percent of them estimate their expertise as high. 34 percent estimate it as medium and half of the participants (50.9 percent) as low. This makes clear that the thesis at hand is not being evaluated by many experts.

**When do you expect the realisation of this thesis?**

Te realisation of a retina implant which enables blind persons to orient themselves within a room is considered realisable only quite late, around the year 2018 (Q1: 2016, Q2: 2020), even though there have been claims about success in the area[5]. The distribution in illustration 110 shows that more than half of the Delphi experts marked the timeframe between the years 2016 and 2020. Nobody assumes realisation to take place after 2030, far later, and nobody marked "never" as an option. Perhaps the discrepancy of evaluations regarding realisation and first companies which manufacture the implants is caused by lack of knowledge. Most probably the current implants will only succeed if the patient is visually impaired to a certain degree, not if the patient is completely blind.

[5] http://www.retina-implant.de/;
http://www.optobionics.com/;
http://www.intmedimplants.ch/;
http://www.2-sight.com/ ;
http://www.sciencegarden.de/berichte/200609/zeitleiste/zeitleiste.php;

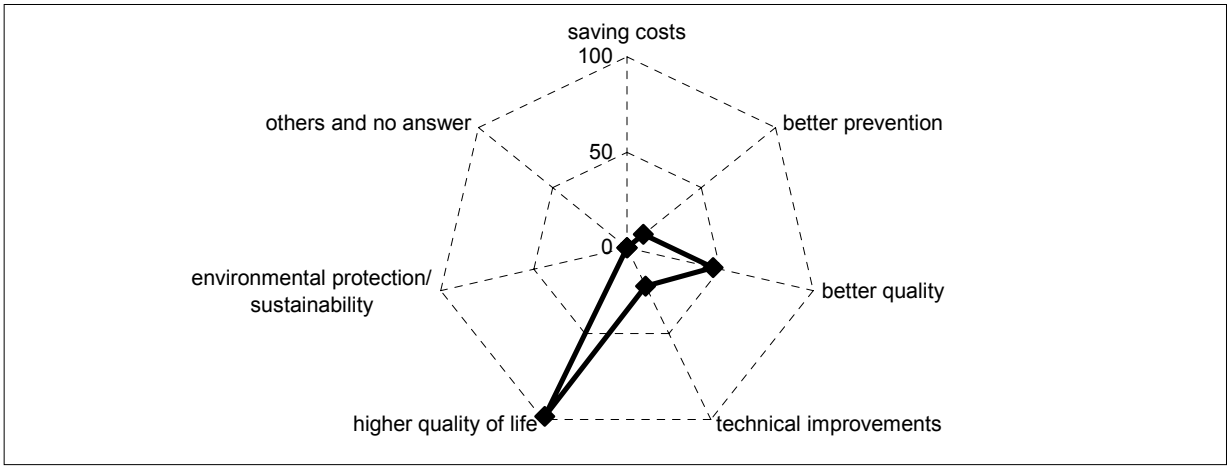
**Illustration 110:** Realisation time for thesis 26, distribution of answers in 5-year steps (in percent)




**All in all, do you personally consider the realisation of this thesis desirable?**
All participants (100 percent) consider the retina implant for blind persons to orient themselves within a room desirable.

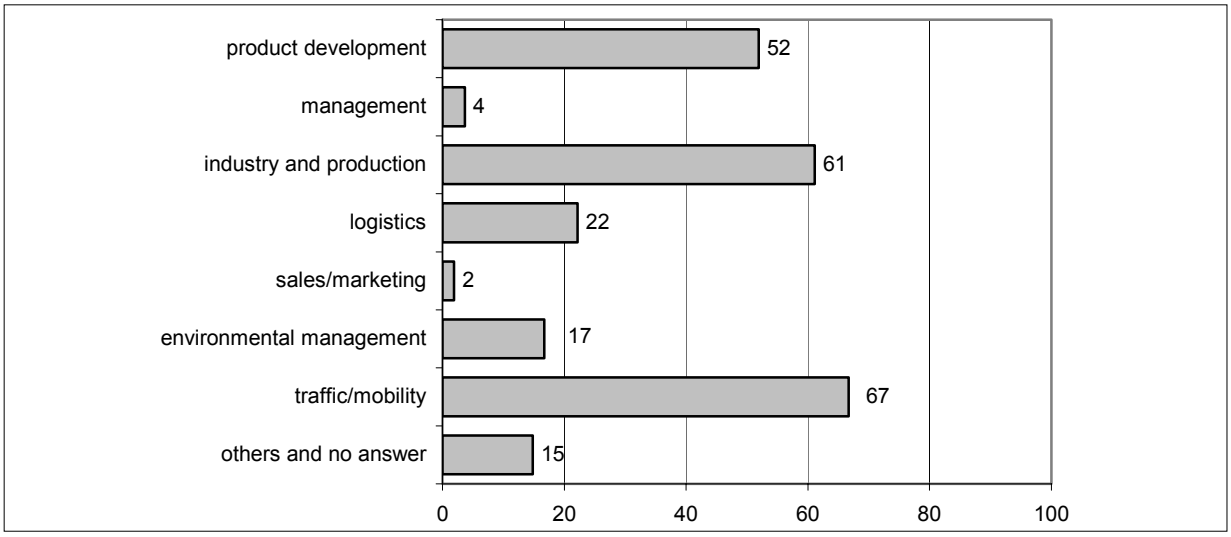
**What is the realisation of the thesis important for?**
All participants consider the thesis important for a better quality of life. Half of them also name the quality of healthcare, nearly one quarter (even 38 percent of those with high expertise) technical progress.

**Illustration 111:** Importance of thesis 26 (in percent)



**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

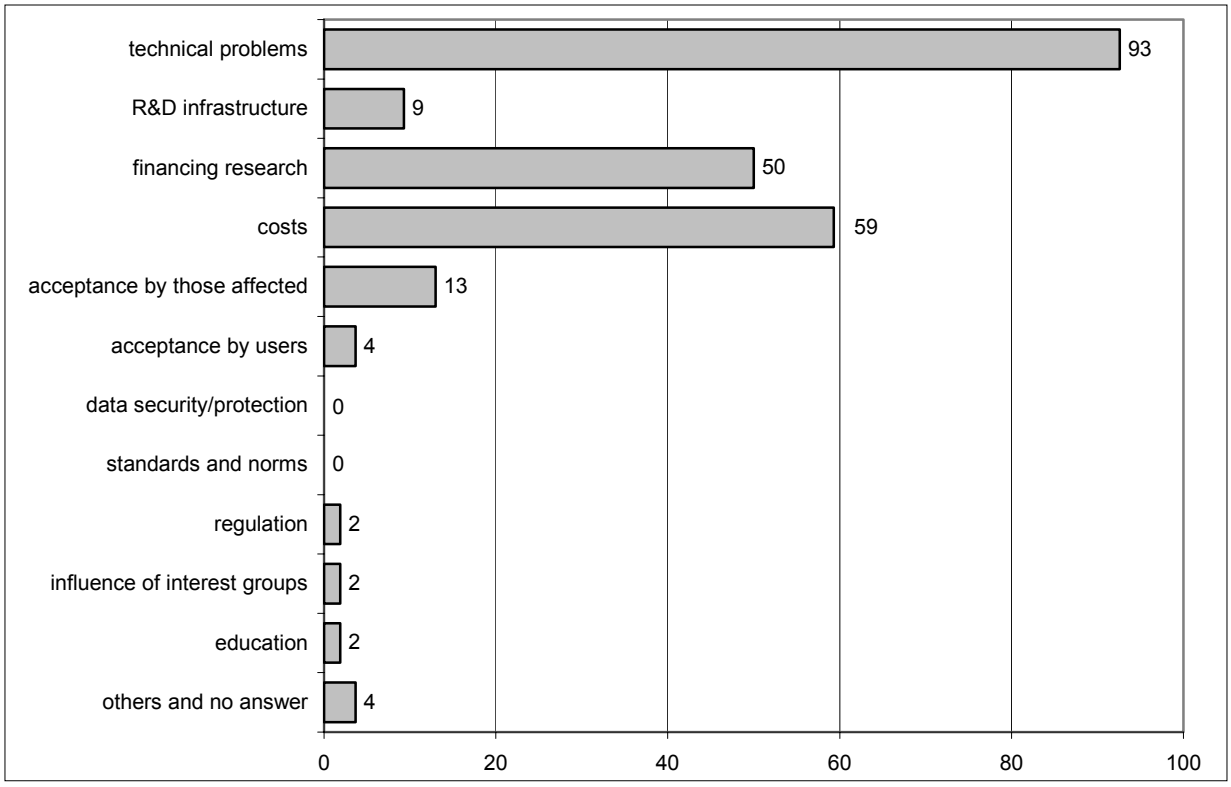
**Illustration 112:** Thesis 26 – Applicability in other areas (in percent)




Implants for a limited orientation possibility are also considered applicable in product development, in industry and production as well as traffic and mobility (illustration 112). Some participants name environmental management as well as "others".

**Where do you see obstacles for the realisation of the thesis?**

**Illustration 113:** Obstacles for the realisation of thesis 26 (in percent)



The main obstacle is clearly seen in technical problems (illustration 113). However, costs and research funding are also named as obstacles by those with high expertise even more frequently than by others. Some of the participants name the acceptance by those concerned – 38 percent of those with high expertise name this, too, which applies for all implants, only slightly less so for this thesis.

**Prospect**

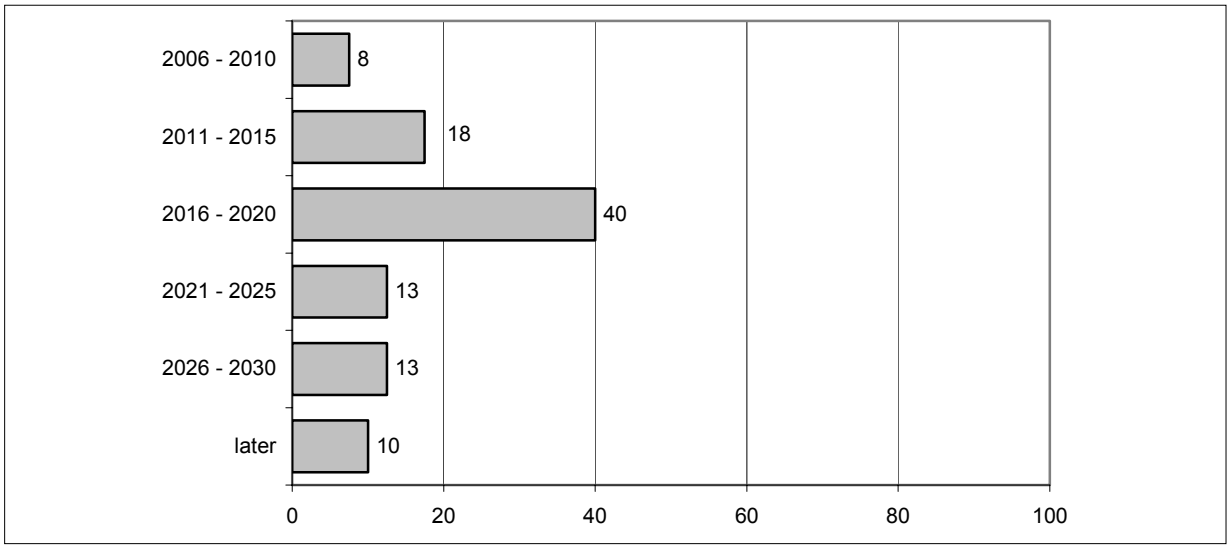
Retina implants which enable blind persons to orient themselves within a room are considered desirable by all Delphi participants unanimously, as they open new dimensions improve the quality of life for those concerned. The participants do not agree in terms of the expected time of realisation – perhaps on grounds of a lack of expertise – altogether realisation is expected at a later stage. This is odd, as there have been first mentions of success for retina implants and also manufacturing companies in the market. Nowadays, however, they are still competing with technical issues, high costs and research funding, another one of the foreseen obstacles.

Thesis 27: Retina implants improve dramatically and thus become ready for use through combination of functional and morphological data, the evaluation of the data by expert systems and the cross-inking of the various systems.

This thesis goes a bit further than the previous one and describes the combination of an implant with a total system in which different types of data are combined and evaluated so that more valuable "filtered" information is transferred to the nerves and enables patients to detect patterns in a better way.
This thesis is very particular. Only 43 participants answered here and 19.5 percent of them estimate their expertise as high. 34.1 percent of them estimate it as medium and 46.3 percent of the participants estimate their expertise as low.

**When do you expect the realisation of this thesis?**
The estimation of the realisation time shows a broad range of answers (illustration 114) and 10 percent of those answering even postpone the topic to "later" date, i.e. after the year 2030. The median lies in the year 2019 (Q1: 2016, Q2: 2025), which is very late. However, realisation is considered possible and none of the participants say "never".

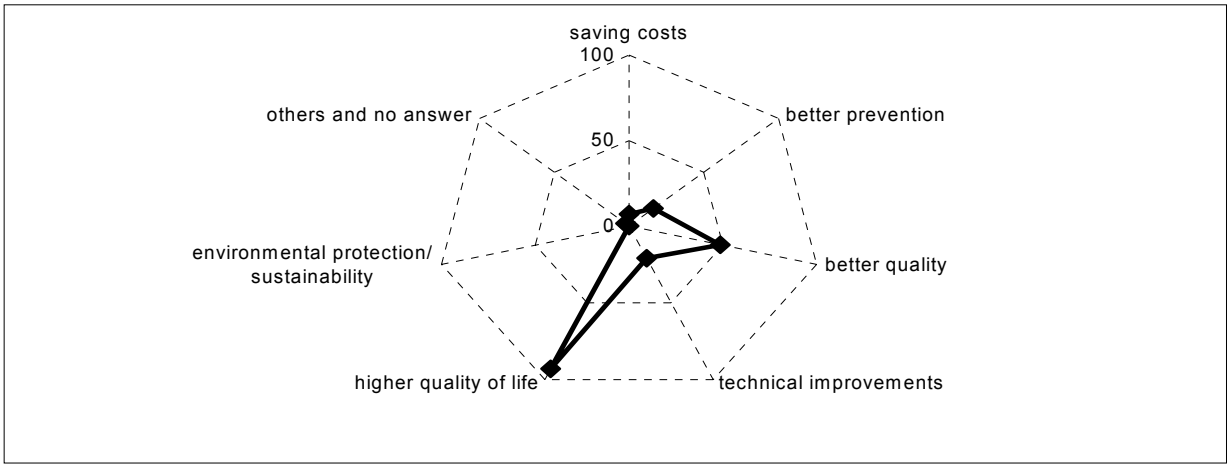
**Illustration 114:** Realisation time for thesis 27, distribution of answers in 5-year steps (in percent)




**All in all, do you personally consider the realisation of this thesis desirable?**
95 percent of the experts consider the thesis desirable and 5 percent do not provide any information as to desirability.

**What is the realisation of the thesis important for?**

**Illustration 115:** Importance of thesis 27 (in percent)

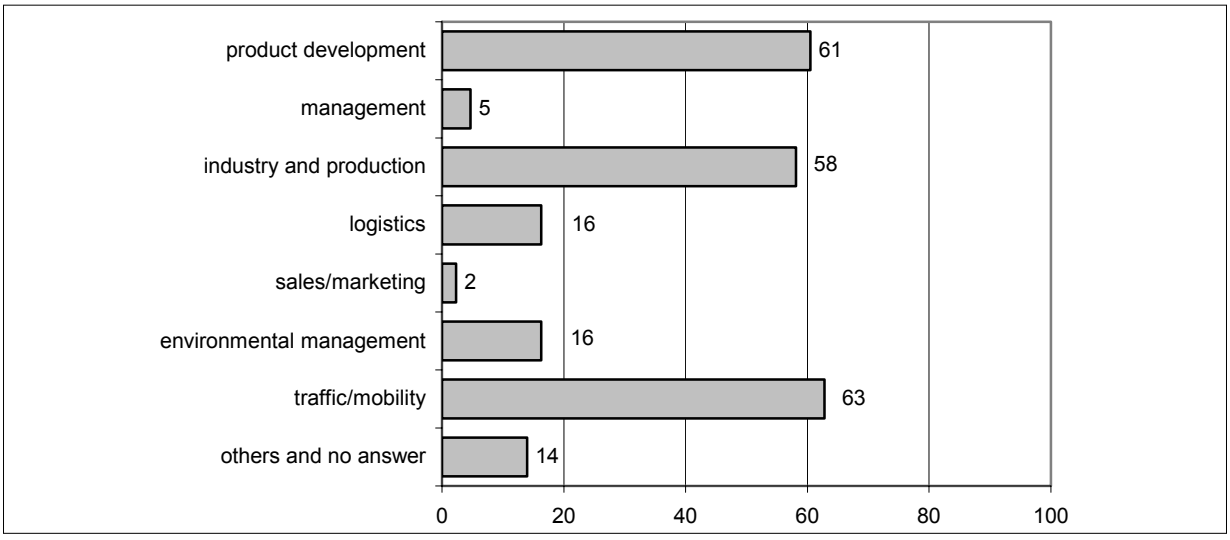



Similar to the previous thesis the Delphi participants consider the system with the retina implant relevant for improving the quality of life for visually impaired and blind persons (illustration 115). Half of the participants regard the system important for the quality of healthcare. All the same, one quarter of those answering regard the topic as important for technical progress. Persons with high expertise among those answering regard the thesis as far more important in terms of technical progress (38 percent) and for better quality of healthcare (also 38 percent).

**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

Similar visual systems can also be applied in product development, industry and production and especially in traffic and mobility. But also logistics and environmental management are application areas for such systems.

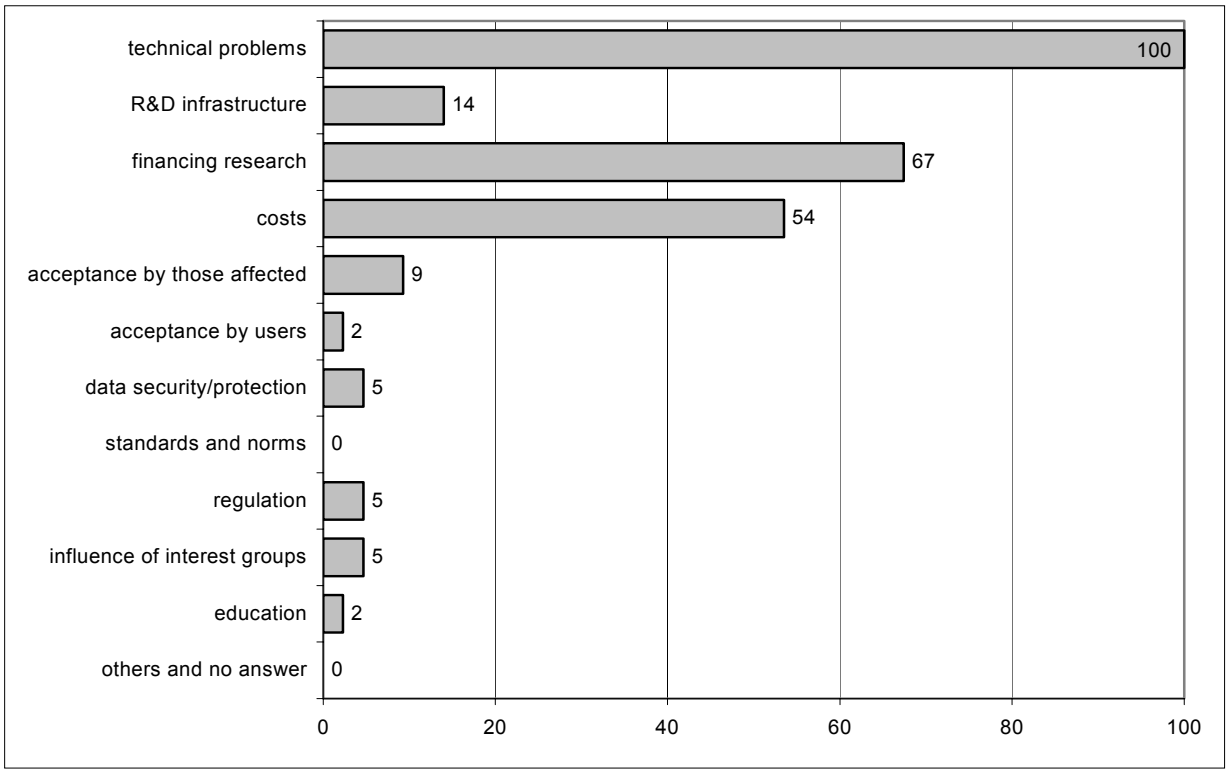
**Illustration 116:** Thesis 27 – Applicability in other areas (in percent)



**Where do you expect obstacles for the realisation of the thesis?**

This thesis has so far not been realised on account of technical reasons. All Delphi experts claim that technical issues are the main obstacle (illustration 117). Research funding and costs are only the second obstacle named, more often by persons with high expertise than by others. 14 percent of the participants and even 25 percent of the experts name the research infrastructure as an obstacle, 9 percent name acceptance by those concerned.

**Illustration 117:** Obstacles for the realisation of thesis 27 (in percent)




**Prospect**

Retina implants will only improve and be ready for application quite late – around the year 2020 – through the combination of functional and morphological data, their evaluation by expert systems and the interfacing of the different systems. This thesis is so particular that only few of the experts evaluated it but nearly all of them considered it to be desirable. It is especially important for the quality of life of patients. As complicated and particular the thesis may seem, everybody assumes technical problems to pose the main obstacle but insists that realisation is feasible. Then such visual systems can also be applied in other areas such as traffic and mobility, product development or industry and production.

## Thesis 28: Regional microwave hyperthermia can be ideally planned with a computer simulation of the biothermal conduction.

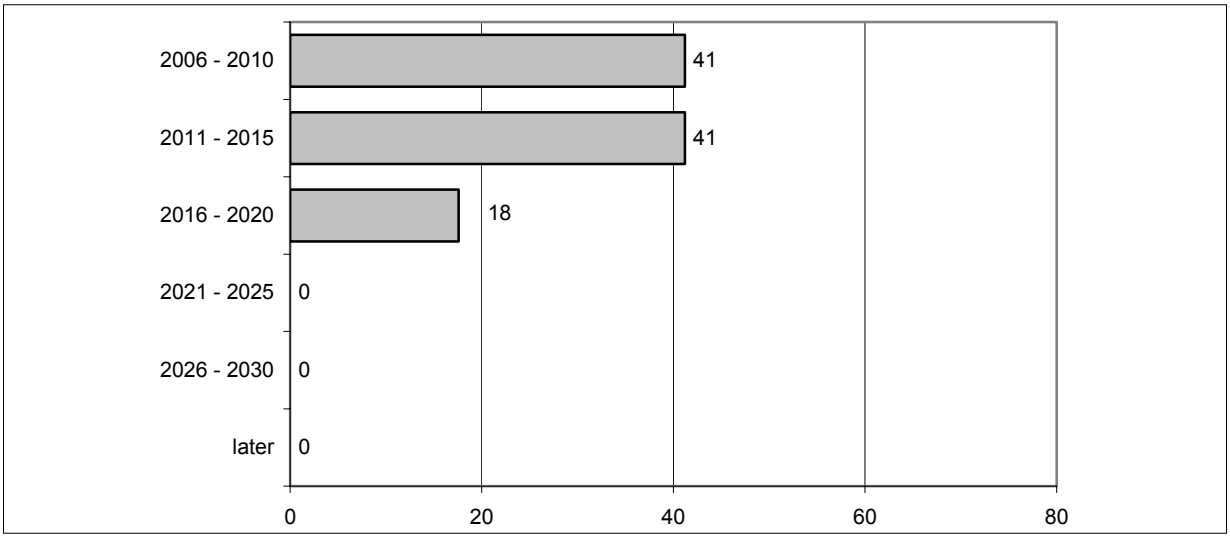
Microwave hypothermia is a process which is especially applied in oncology (cancer research and therapy). With this procedure local cells, i.e. only cells of a certain areas, are heated. This thesis deals with the subject of exactly planning which area needs to be treated at which temperature and intensity. A computer simulation is helpful which shows how the biothermal conduction, meaning the distribution of temperature in a body respectively in this body area spreads. The aim is not to damage or harm any healthy tissue parts.

Microwave hypothermia is a very specific topic and only few Delphi participants are familiar with it and only 35 of them evaluated the thesis. Of those, 11.4 percent estimated their expertise as high, 45.7 percent as medium and 42.9 percent as low. The thesis was evaluated accordingly with medium expertise.

**When do you expect the realisation of this thesis?**

The few participants agree upon realisation times (illustration 118). The topic is considered feasible quite soon, around the year 2012 (low quartile: 2009, high quartile: 2015).

**Illustration 118:** Realisation time for thesis 28, distribution of answers in 5-year steps (in percent)

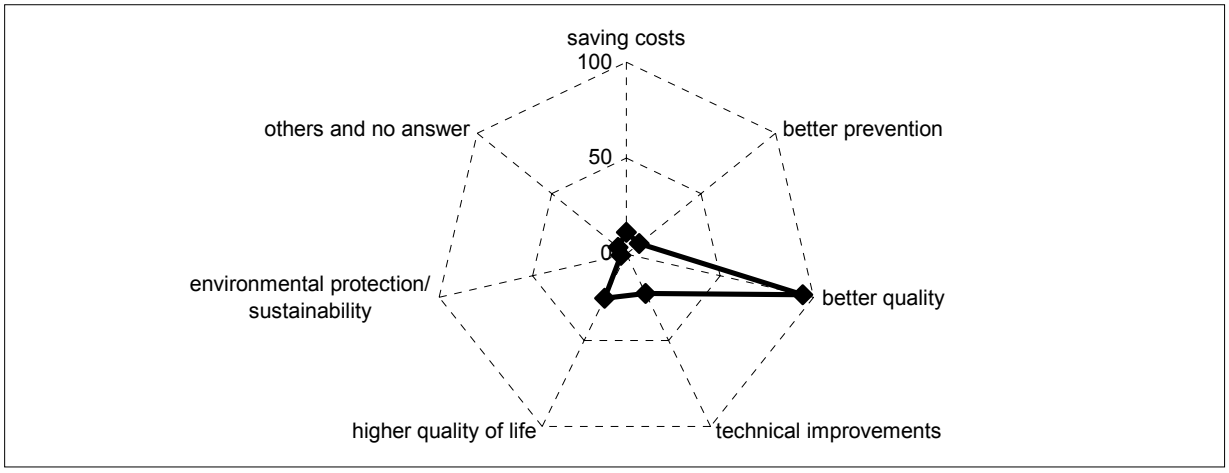



**All in all, do you personally consider the realisation of this thesis desirable?**

The topic is considered desirable by 94 percent of the participating experts. 6 percent of the Delphi experts say “do not know”.

**What is the realisation of the thesis important for?**

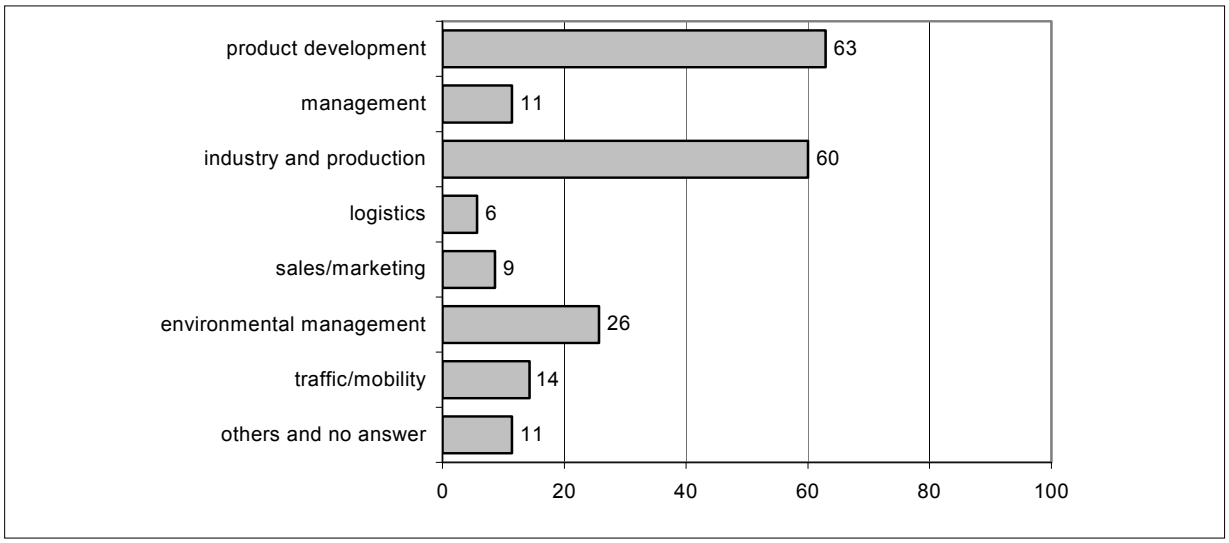
**Illustration 119:** Importance of thesis 28 (in percent)




Nearly all Delphi experts say that the issue is especially important for the quality of healthcare and one quarter of them considers the thesis also important for higher quality of life as well as the technical progress.

**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

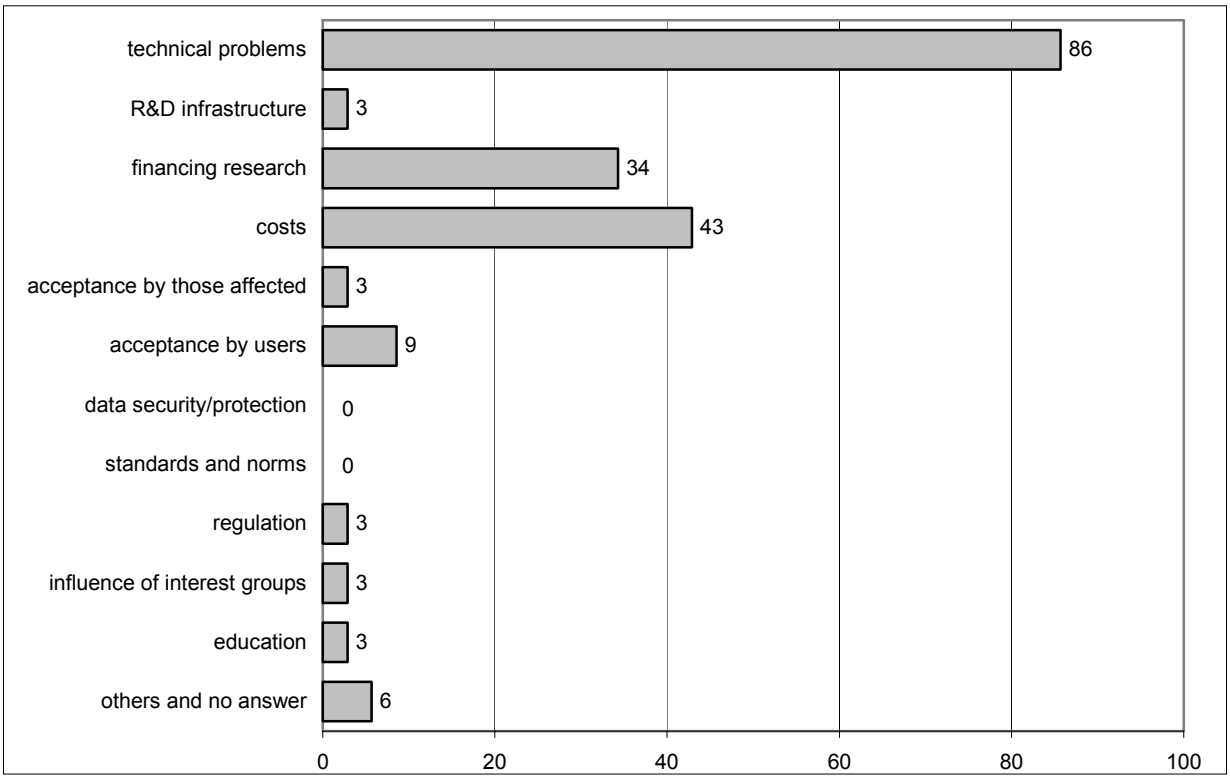
**Illustration 120:** Thesis 28 – Applicability in other areas (in percent)




Computer simulation for thermal conduction respectively for it's planning can be applied in many other areas. The phrasing of the thesis and the answers do not make absolutely clear what the answering participants refer to, whether it is the microwave therapy or the computer simulation. This is why all of the offered topic areas are marked, product development and industry and production are especially named (illustration 120).

**Where do you see obstacles for the realisation of the thesis?**

**Illustration 121:** Obstacles for the realisation of thesis 28 (in percent)




Technical problems prevent an early realisation of the thesis. The costs, too, and research funding are seen as obstacles (illustration 121).

**Prospect**

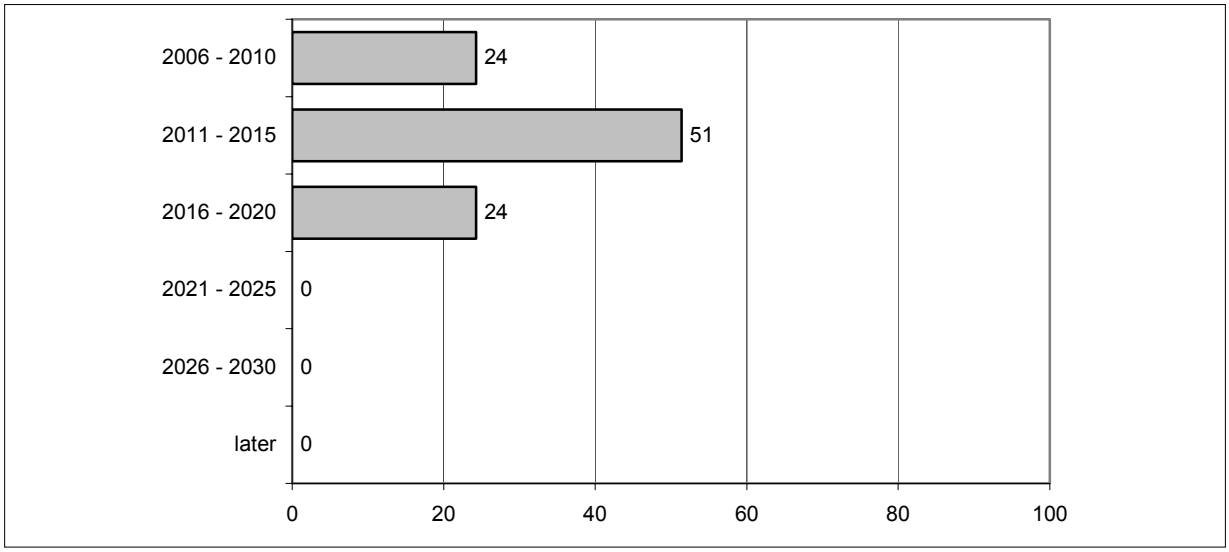
Optimum planning of regional microwave hypothermia with the help of a computerised simulation of the biothermal conduction is a technical challenge. Also the costs and research funding can prove to be obstacles for the realisation of the thesis, even if not considered too strongly. The thesis is especially relevant for the quality of healthcare and is applicable foremost in product development as well as industry and production, but other areas are mentioned as well. The realisation will be possible in the near future (median 2009), at the latest by the year 2020.

## Thesis 29: Computer-supported planning of biologically adaptive resonance therapy (ART), which allows an individual adaptation of the therapy to heterogeneous tissue, is possible.

Biologically adaptive resonance therapy is an oncological approach used to destroy tumour tissue via radiotherapy. In order to optimally adapt the radiation, computer-supported planning should be conducted. In this planning it is important to consider the different kinds of tissue for calculations in order to – as described in the previous thesis – obtain as few side effects as possible and not harm any healthy tissue. Various approaches are being developed (Thorwarth et al., no year; Birkner, 2002).
This very particular thesis was only evaluated by 38 participants. This is less than half of the Delphi participants and only 13.2 percent of those answering in this respect estimate their expertise as high. Exactly half of the participants estimate it as medium and the other 38.6 percent estimate their expertise as low.

**When do you expect the realisation of this thesis?**
Computer-supported planning of a biologically adaptive resonance therapy is considered possible during the oncoming 10 years (illustration 122). The median lies around the year 2013, the low quartile at 2011, the high quartile at the year 2015. In so far the experts are relatively united in their estimates.

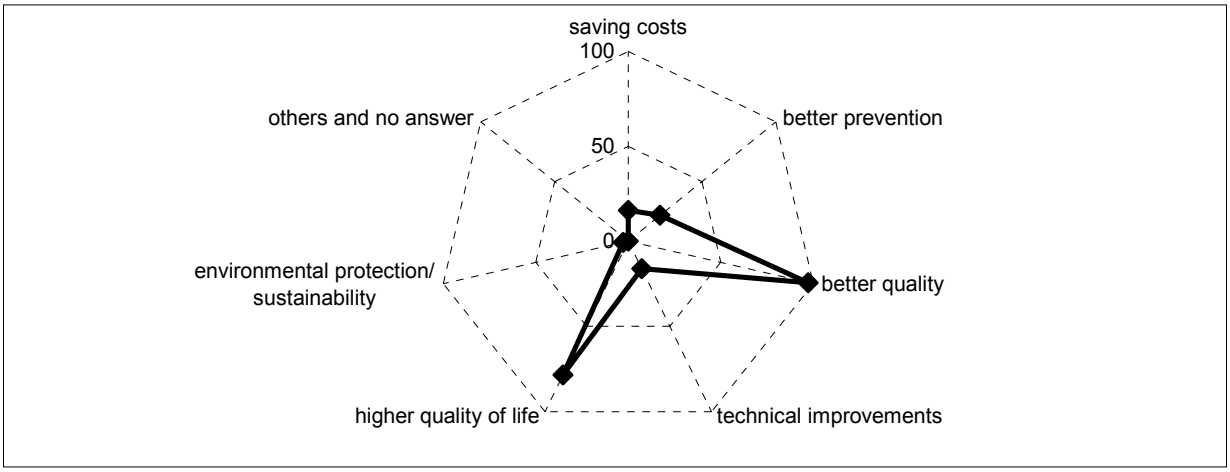
**Illustration 122:** Realisation time for thesis 29, distribution of answers in 5-year steps (in percent)




**All in all, do you personally consider the realisation of this thesis desirable?**
Computer-supported planning of a biologically adaptive resonance therapy (ART), which allows and individual adaptation to heterogeneous tissue is considered desirable by all participants (100 percent).

**What is the realisation of the thesis important for?**

**Illustration 123:** Importance of thesis 29 (in percent)

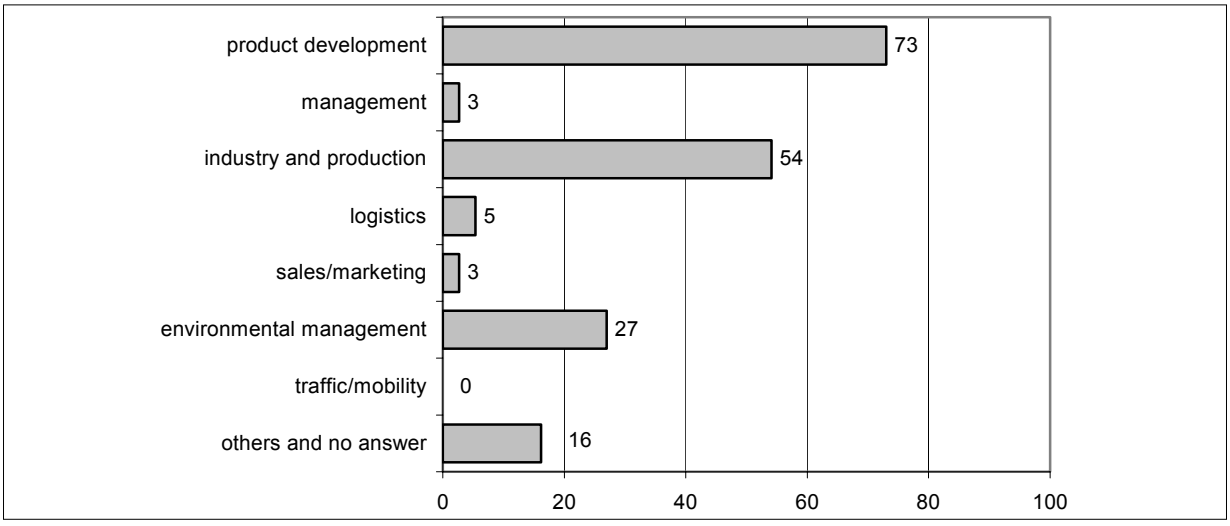



The topic is very important for a higher quality of the life of patients and even more so for the quality of healthcare (illustration 123).

**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

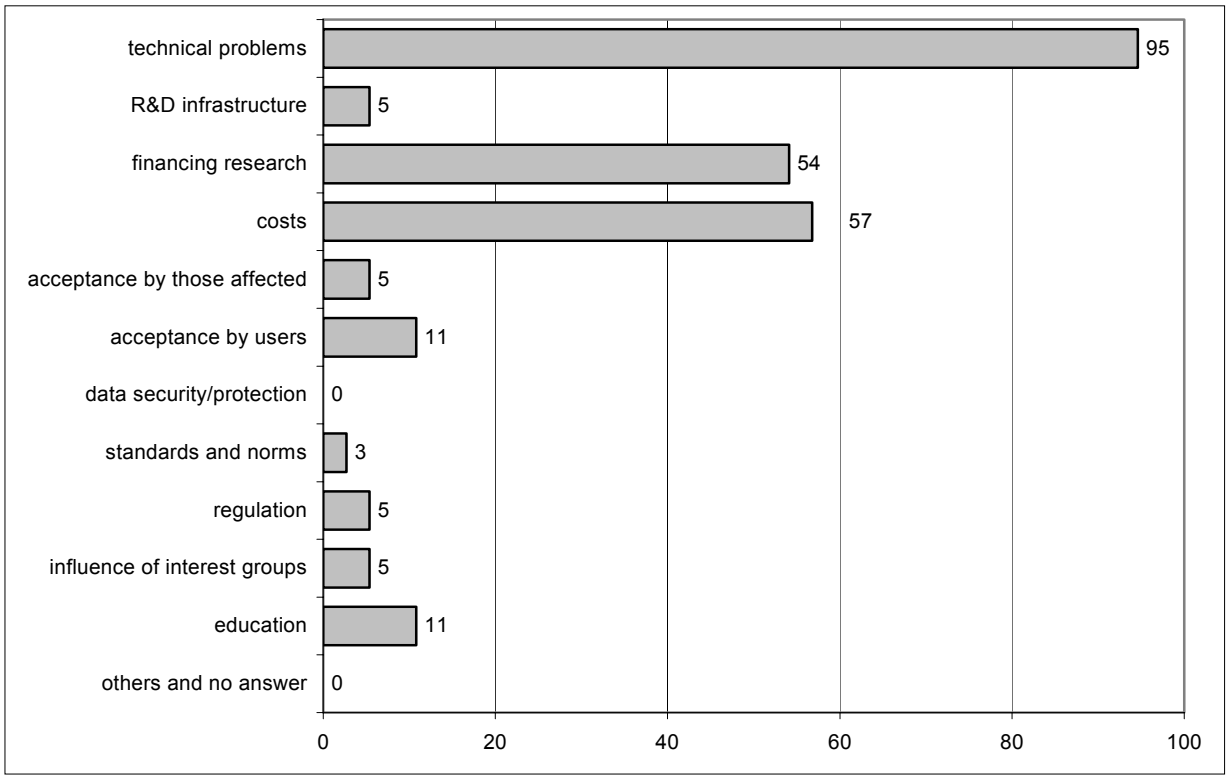
This technology, too, can find application possibilities in areas such as product development, industry and production as well as even environmental management (illustration 124).

**Illustration 124:** Thesis 29 – Applicability in other areas (in percent)



**Where do you see obstacles for the realisation of the thesis?**

**Illustration 125:** Obstacles in the realisation of thesis 29 (in percent)




Problems for realisation are clearly those in the technical area (illustration 125), otherwise the thesis might be reality already even now. Also costs and research funding are among the obstacles considered to be serious. 11 percent of those answering see an obstacle in acceptance by users and in education and training, an issue which is rarely mentioned otherwise.

**Prospect**

Computer-supported planning of a biologically adaptive resonance therapy (ART), which allows individual adaptation of the therapy to heterogeneous tissue is considered possible for the near future (median 2014). Technical problems, costs and obstacles in research funding seem overcomeable. There is no controversy as to the desirability of the topic and realisation is considered to be important for the quality of healthcare as well as a better quality of life for cancer patients.

## Thesis 30: Interactive electronic logopaedics trainers are a standard.

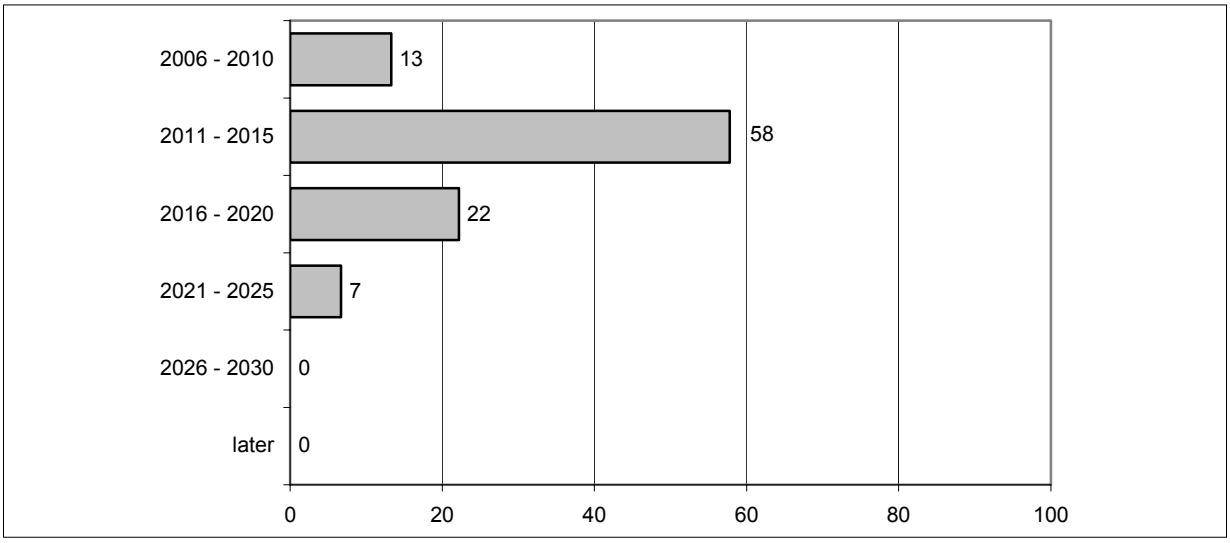
Interactive logopaedics trainers could enable speech training at home or anywhere else at any time for an affordable price. They are not only meant for speech acquisition of children, they could also offer constant training possibilities to accident victims, to patients after strokes or persons suffering from other illnesses.

This thesis was evaluated by 48 participants. 21.3 percent of them estimated their expertise as high, 36.2 as medium and 42.6 percent as low.

**When do you expect the realisation of this thesis?**

Electronic logopaedics trainers could be realised around the year 2014 (Q1: 2012, Q2: 2016). The distribution of answers is depicted in illustration 126. Nobody expects realisation after the year 2025 or not at all.

**Illustration 126:** Realisation time for thesis 30, distribution of answers in 5-year steps (in percent)

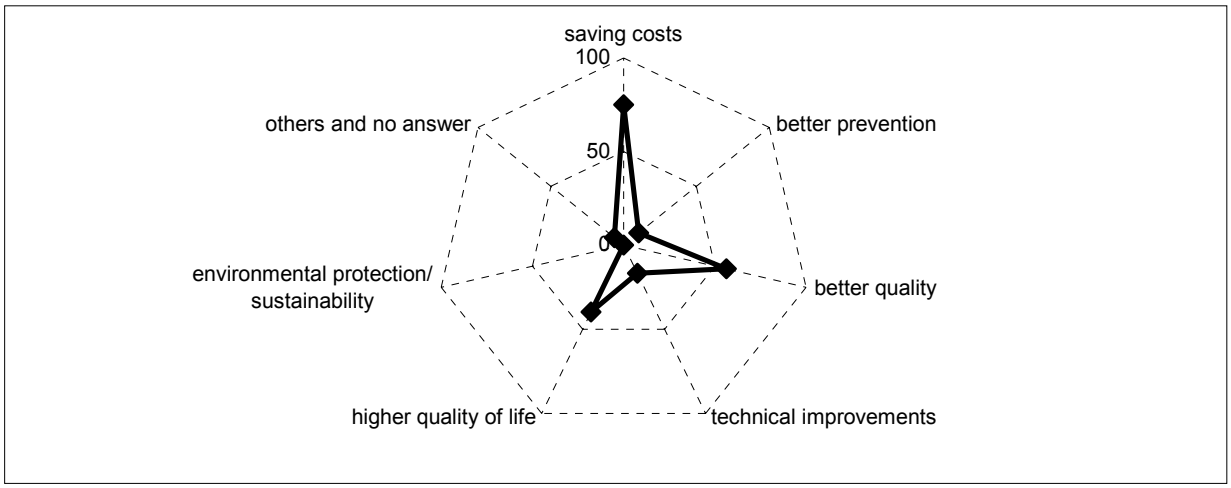



**All in all, do you personally consider the realisation of this thesis desirable?**

Interactive logopaedics trainers as a standard are desired by "only" 79 percent of the participating experts. This makes the topic one of those with the lowest degree of accordance, 8 percent do not consider it desirable and 13 percent say "do not know". Commentaries point out that human trainers with the corresponding personal contact are far more desirable.

**What is the realisation of the thesis important for?**

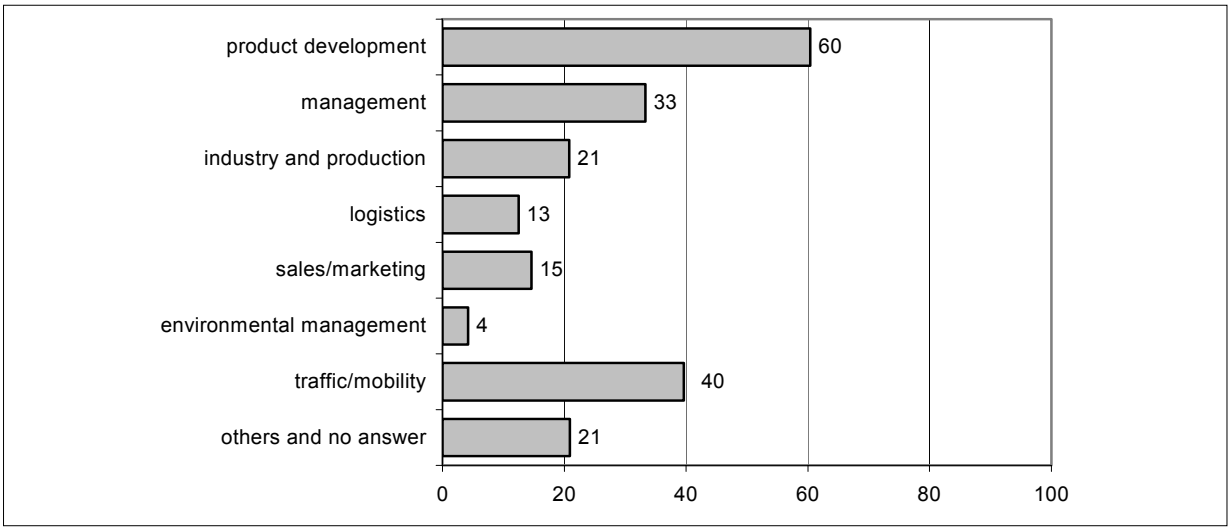
**Illustration 127:** Importance of thesis 30 (in percent)




Interactive logopaedics trainers are important for cost reduction and saving but also for the quality of healthcare (this was marked by participants aged 56 years and above far more frequently than by the younger ones) as well as a higher quality of life for those concerned (illustration 127).

**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

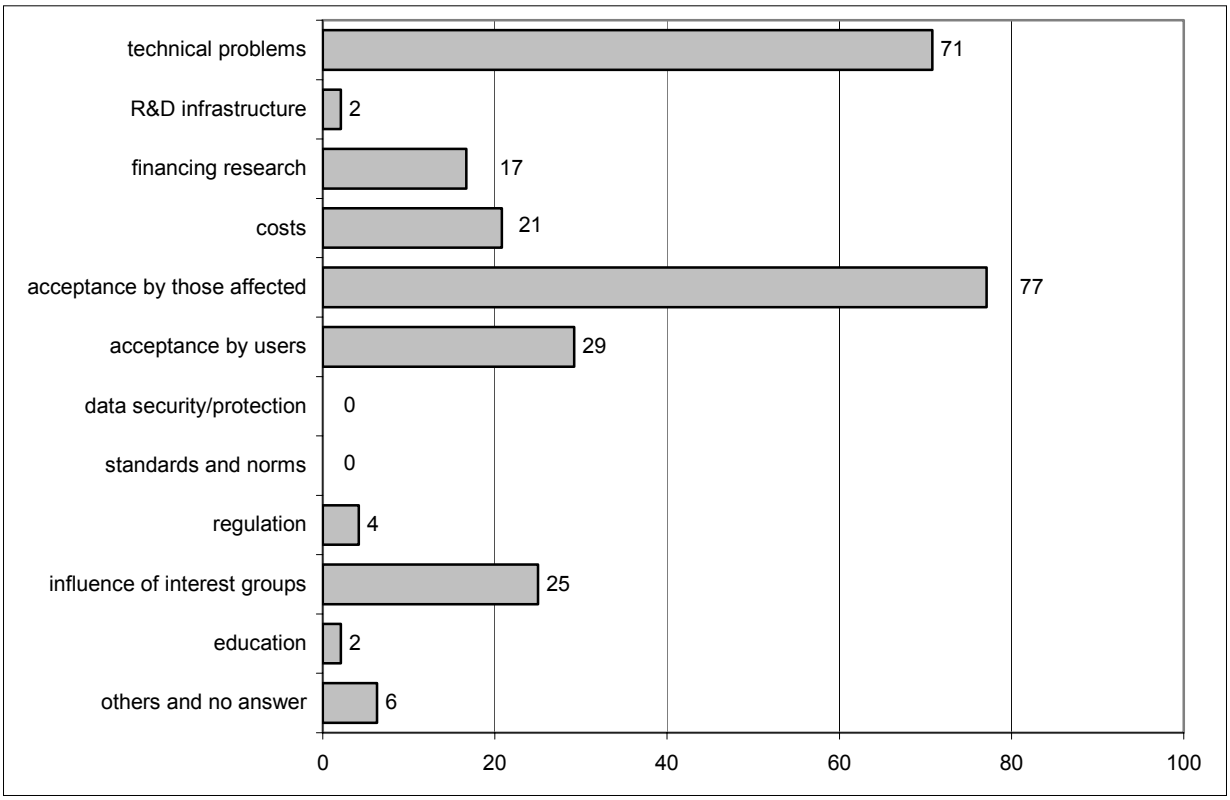
**Illustration 128:** Thesis 30 – Applicability in other areas (in percent)




Similar interactive trainer systems can be applied in nearly all other areas (illustration 128). Commentaries especially refer to the learning of foreign languages and the application in language schools.

**Where do you see obstacles for the realisation of the thesis?**

**Illustration 129:** Obstacles for the realisation of thesis 30 (in percent)




The system needs to be accepted by those concerned – this seems to be the highest obstacle. The same counts for acceptance by users. However, technical problems are apparent, as well. Apart from this costs are named, research funding and one quarter of the participating experts also name the influence of interest groups which could prevent realisation (illustration 129). One commentary doubts that electronic logopaedics trainers can approach the issue of the persons in need of training holistically.

**Prospect**

Interactive logopaedics trainers could become a standard by the year 2015 or shortly after. Obstacles for this prognosis are acceptance by those concerned, by users and technical issues. The topic is important for cost savings, but also for the quality of healthcare (training everywhere and at any time) as well as the quality of life for those concerned. The technology can be applied in many other areas, ranging from product development to mobility. Language schools, too or the teaching itself could benefit from a simile technology. In spite of all this, not all participants consider the topic desirable and would prefer to continue with personal contact in the form of a human trainer.

Thesis 31: A wireless label system (RFID) is introduced to common households, allowing patients who easily and often forget things (due to dementia, Alzheimer's disease etc.) to find anything and be attentive to things of importance.

Wireless label systems (RFID, Radio Frequency Identification) are considered to be one of the new basic technologies with broad application possibilities once the existing technical and other problems are solved. Transponders attached to or implemented in objects record data which can be deciphered remotely and without visual contact, depending on the version (passive/active), the frequency band, the transmission power and environmental influences from distances ranging between few centimetres to more than one kilometre. The data transmission between the transponder and the reading device takes place by means of electromagnetic waves. Low frequencies inductively use a near field, high frequencies are transmitted via an electromagnetic far field (Fraunhofer, 2005).

Wireless label systems are already applied in many areas but offer more options. RFID enables automatic identification and the localisation of objects. An RFID system comprises of a transponder (also smart tag, smart label, RFID-chip, RFID-tag or wireless-label, by critics also called "snooping chip"), reading devices with an antenna (also called "reader") and the integration with servers, services or other systems, e.g. point of sale systems in supermarkets, fee settlement in traffic or even for the identification of cows at mechanical milkers.

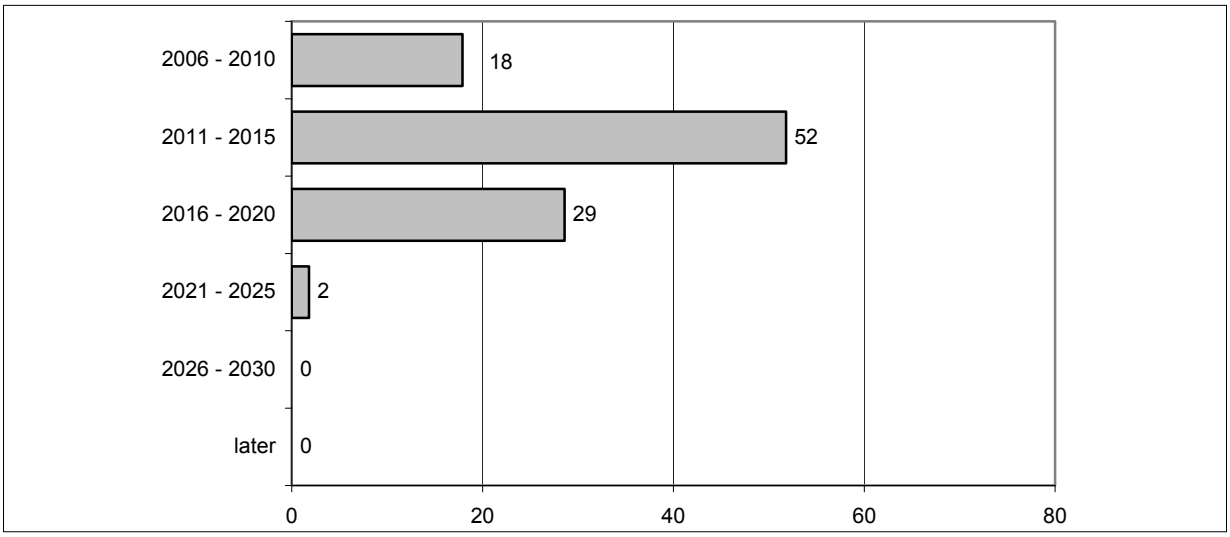
Whether wireless label system or RFID systems will be applied in common households seems to be merely a question of time. Here they could be used to find objects or to draw a person's attention to certain things.

This topic was evaluated by more participants than the preceding theses – there were 58 evaluators. 45.6 percent of them (the highest value in the whole study) estimate their expertise a high and 38.6 percent as medium. This makes this topic the one evaluated with the largest expertise in the whole Delphi study at hand.

**When do you expect the realisation of this thesis?**

In fact the many experts expect realisation quite soon around the year 2014 (Q1: 2011, Q2: 2016). The evaluations are distributed as shown in illustration 130. Nobody estimates realisation only after the year 2025. However, there are a few doubtful participants, 3.4 percent of those answering say "never" realisable.

**Illustration 130:** Realisation time for thesis 31, distribution of answers in 5-year steps (in percent)

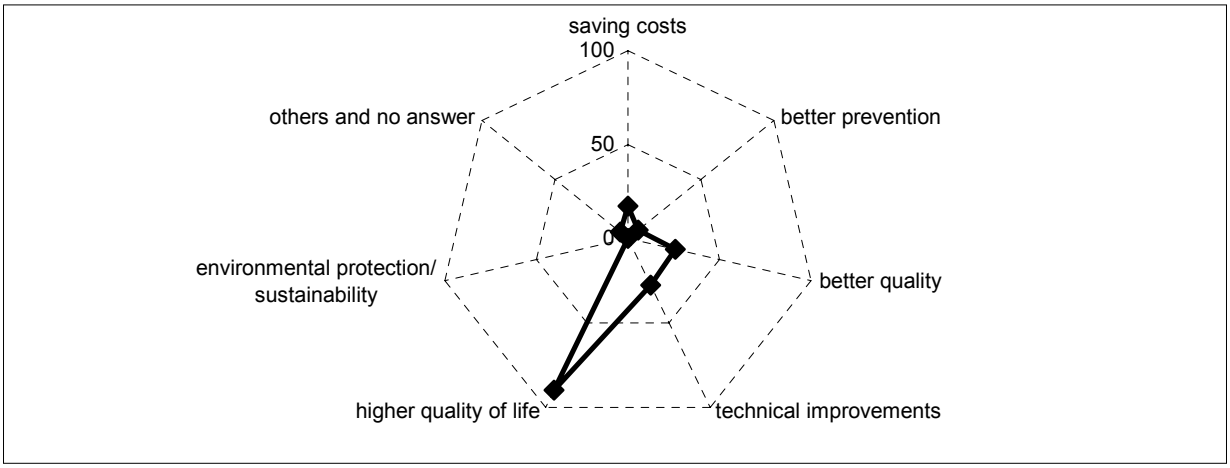



**All in all, do you personally consider the realisation of this thesis desirable?**

84 percent of the participants consider this RFID application desirable. 12 percent say "no", 4 percent say "do not know". This makes the topic to one of the controversial ones, which may be due to the fact that wireless labels also enable all-time surveillance of persons and their belongings in the household, which does not suit everybody.

**What is the realisation of the thesis important for?**

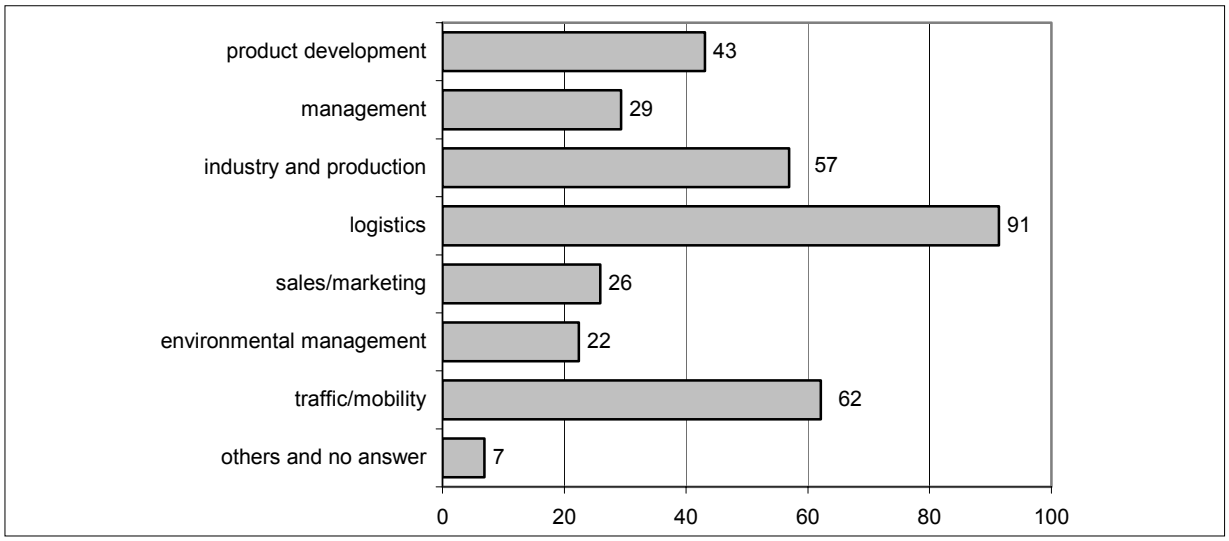
**Illustration 131:** Importance of thesis 31 (in percent)




The topic is important for a higher quality of life (illustration 131) as persons in need of care can invulnerably remain in their familiar environments for a longer amount of time.

**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

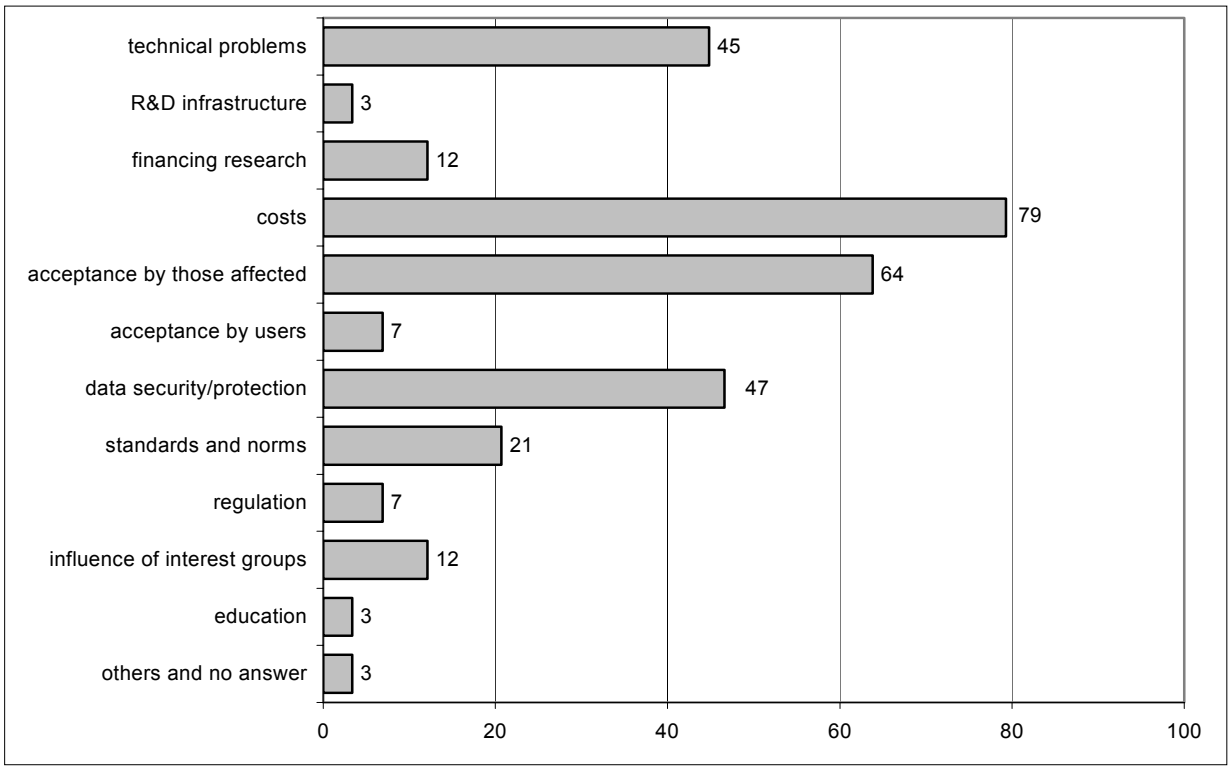
**Illustration 132:** Thesis 31 – Applicability in other areas (in percent)




RFID is considered applicable in many other areas (illustration 132), especially, of course, logistics and first systems have been developed for this sector. Traffic and mobility are named second, followed by industry and production, product development, management, sales and environmental management. Furthermore, access control is named.

**Where do you see obstacles for the realisation of the thesis?**

**Illustration 133:** Obstacles for the realisation of thesis 31 (in percent)



For the application of RFID in common households the obstacles seen are less the technical issues than the costs (illustration 133). The older the experts are, the less they consider the costs as a problem, but the more important they regard the issue of data security and data protection. Also the acceptance by those concerned as yet needs to be created. Another aspect is data protection and security with corresponding regulations, standards and norms.

**Prospect**
Wireless labels in households for locating objects will be realised. Even though many persons have concerns about monitoring possibilities and rather object to strong surveillance they still expect the realisation of this thesis during the next 10 years. Obstacles are seen in acceptance problems and costs, not so much in technical terms, as for other theses. This is fact due to the development of the topic by today. RFID systems will open a large market with many application possibilities.

Thesis 32: Ambient Intelligence in a house allows monitoring of patients at home (via camera, thinking carpet, furniture equipped with sensors, immobility sensors), reporting irregular features to an emergency call centre.

The idea behind "ambient intelligence" or the "intelligent environment" is the assumption that all devices which possess electronic parts can be connected to each other in a network. The new aspect is, that these things interlink in an autonomous manner and adapt to the user independently and according to the given situation in order to create additional value and use. The intelligent environment stays on the sideline and only acts whenever it is required. This is possible due to the reduced size of electronic devices and due to wireless communication technology, meaning microchips, sensors, wireless transmission systems etc. This development changes the meaning of objects and infrastructures to no longer passive but active environments. The applied electronics does not merely interlink electronic devices; in addition, environments in households and offices, e.g. clothing, furniture, windows, shutters, carpets etc. receive an additional function (Fraunhofer, 2005).

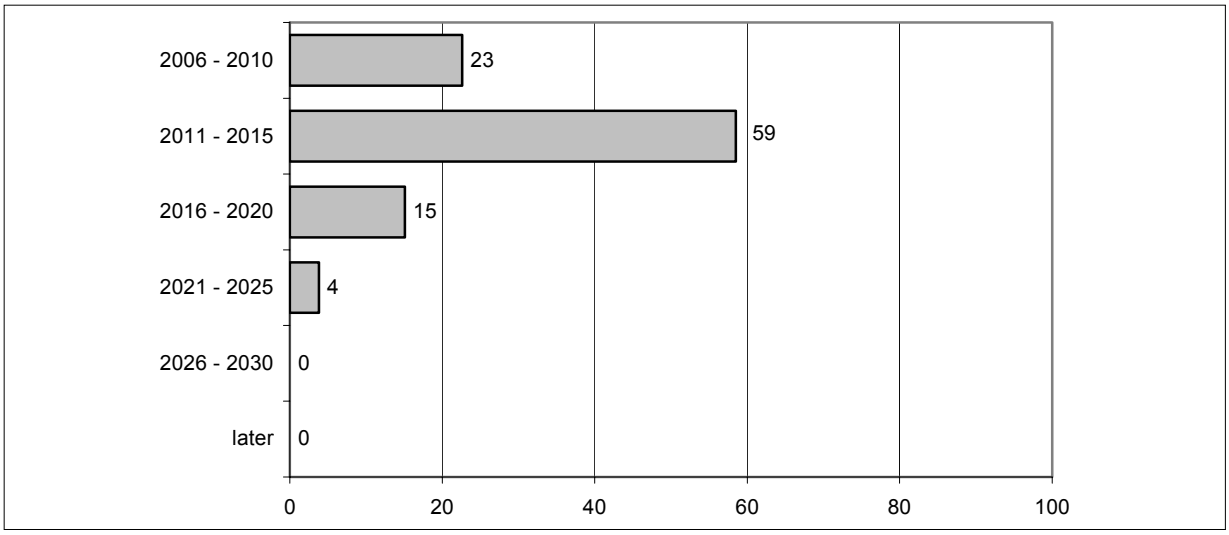
In this thesis ambient intelligence is supposed to serve the purpose of monitoring patients so that they are enabled to remain in their familiar environment for a longer period of time or discharged from hospital earlier.

54 participants evaluated this thesis, 34.6 percent of them estimate their expertise as high. 46.2 percent estimate their expertise as medium, so this thesis is evaluated by persons with an expert background.

**When do you expect the realisation of this thesis?**

The Delphi participants are fairly unanimous about the realisation timeframe, too (illustration 134). Their estimate lies at around the year 2013 (median) with little variance (Q1: 2011, Q2: 2015). However, 1.9 percent of those answering say "never".

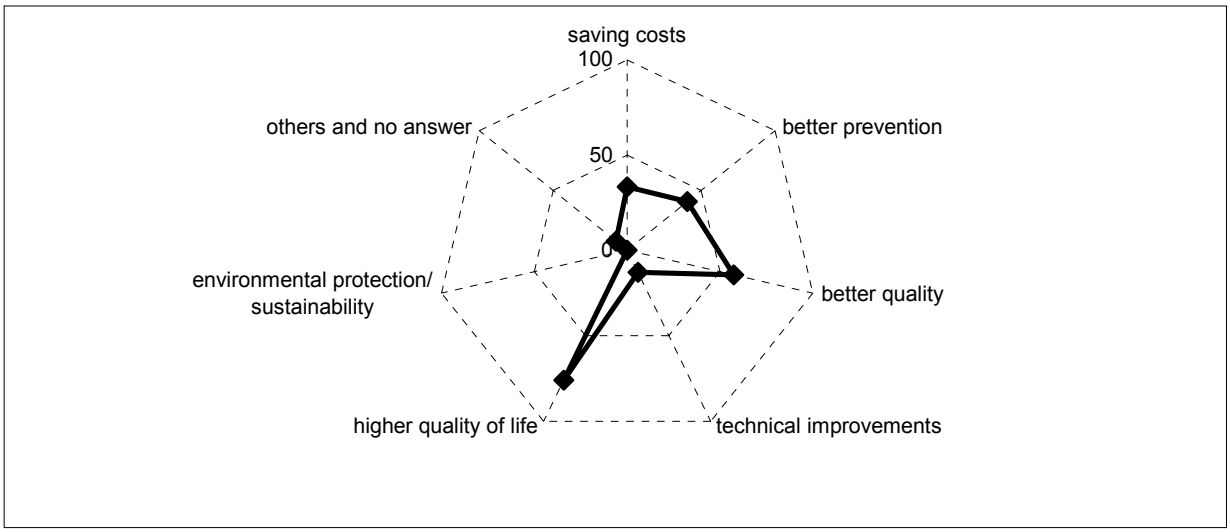
**Illustration 134:** Realisation time for thesis 32, distribution of answers in 5-year steps (in percent)



**All in all, do you personally consider the realisation of this thesis desirable?**
Probably due to the fact that this topic has two sides it does not belong to one of those theses desired unconditionally. 80 percent of the Delphi participants consider the topic desirable, however there is a share of 13 percent who does not consider the topic desirable and 7 percent mark "do not know". Commentaries point out to a facilitation of total surveillance of persons with the help of the system, this being the reason for not desiring realisation. They find fault with the "lack of privacy" and say a system as described is only "desirable for those patients incapable of managing on their own". Moral aspects are also pointed out.

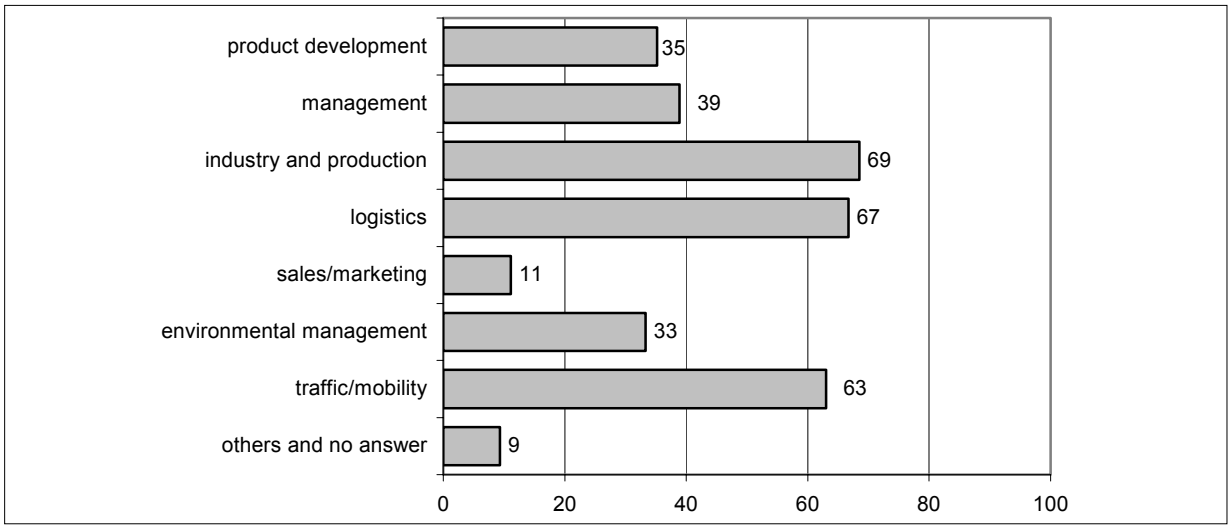
**What is the realisation of the thesis important for?**
This thesis is considered as very important for a higher quality of life. The quality of healthcare, too and prevention would improve, and some participants also consider the thesis important for cost saving.

**Illustration 135:** Importance of thesis 32 (in percent)



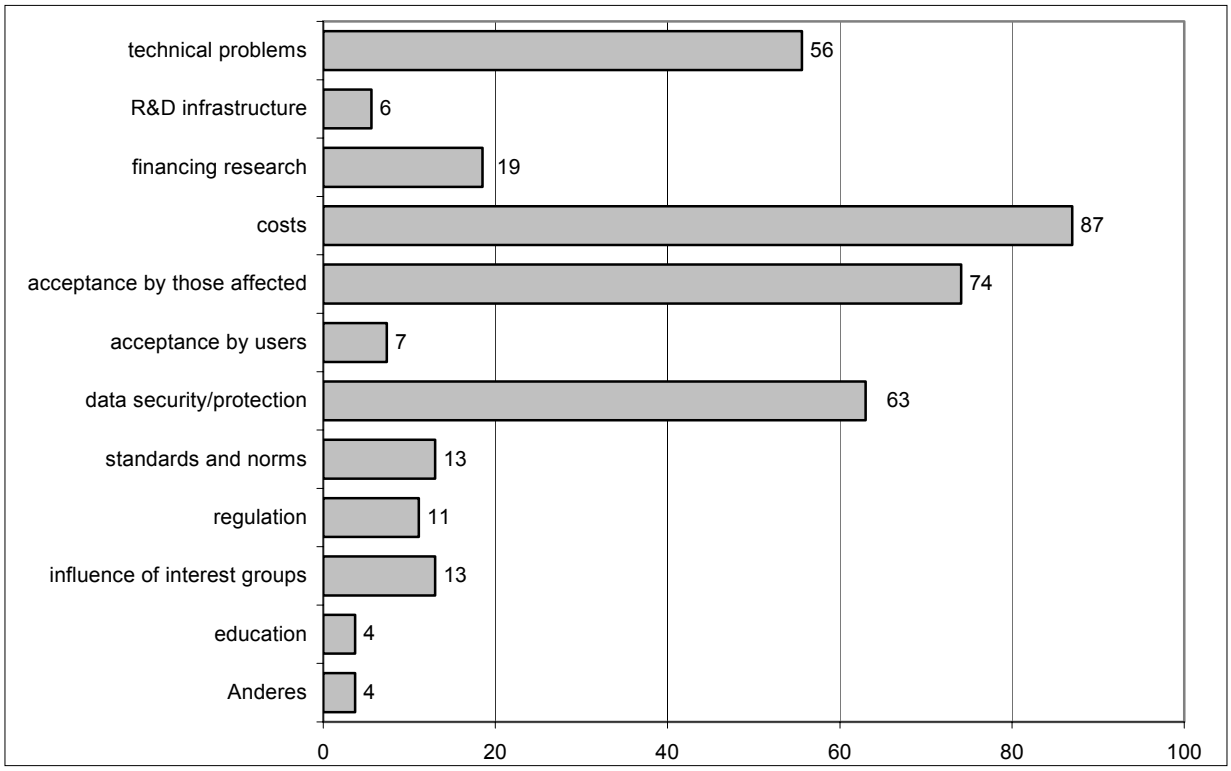

**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**
Ambient intelligence possesses the character of a cross section. The technology will be applicable in many other sectors. All offered areas are mentioned, especially industry and production, logistics, traffic and mobility as well as others which are not specified any further.

**Illustration 136:** Thesis 32 – Applicability in other areas (in percent)




## Where do you see obstacles for the realisation of the thesis?

**Illustration 137:** Obstacles for the realisation of thesis 32 (in percent)




It is not the technical issues which are considered as obstacles, moreover costs. Corresponding to the question as to desirability the second largest obstacle is the acceptance by those concerned. For this issue, data security and data protection problems as yet need to be solved. Technical problems are only named by slightly more than half of those answering.

**Prospect**

Ambient Intelligence, the "intelligent environment" at home could be applied for monitoring patients at home (via camera, "thinking carpet", furniture with sensors, immobility sensors), notyfing an emergency call centre for irregularities. The costs which would be involved to build a corresponding infrastructure pose one obstacle, as well as acceptance by those concerned. The related data protection and data security issues will have to be addressed before realisation. Ambient intelligence, however has the character of a cross section: If interlinks and networks can actually be built with objects in the sense of the thesis, then the technology will be of use to many other areas as well – from the industry to traffic – and then there will be big markets opening up.

Thesis 33: Wireless rechargeable implanted defibrillators are used, which convey their measured data to a control unit, which then conveys its data to a service centre for a checkup and for an emergency report, if necessary.

A defibrillator is a medical device, which can cause cardiac arrhythmias such as ventricular fibrillation and ventricular flutter (defibrillation) or ventricular tachycardia, atrial fibrillation and atrial flutter (cardioversion) to cease by means of directed power surges. Defibrillators are kept at disposal in intensive care units, emergency rooms as well as ambulance vehicles, physicians practices and since 1990 more so also in public places and buildings (for the use in cases of emergency by medical amateurs) for so-called "reanimation". The devices referred to are automated external defibrillators, which guide the user with voice commands and generally give instructions for the necessary cardio-pulmonary reanimation.[6]

This thesis involves the development of defibrillators for patients at risk which are implanted and thus automatically available. They are designed to be rechargeable remotely, to record data and deliver the data to a control unit. The control unit transfers the data to a service centre for a check and in cases of irregularities the treating physician is alerted. Even today implantable pacemakers and defibrillators exist[7], however there is no total system as described in the thesis.

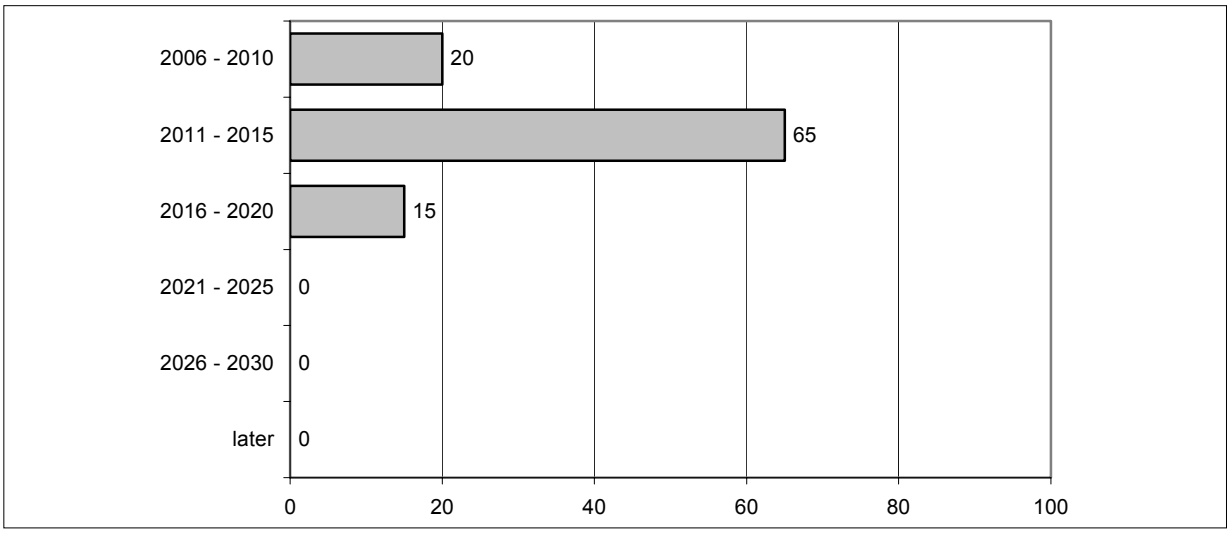
This thesis was evaluated by 43 Delphi participants. 23.3 percent of them regard their expertise as high and a further share of 37.2 percent regard it as medium. 39.5 percent of the answering participants estimate their expertise as low.

**When do you expect the realisation of this thesis?**

The thesis is considered realisable for the year 2013. The low quartile ranges at the year 2011, the high quartile at 2015. As shown in illustration 138 the distribution of estimates is not very large. In spite of this 4.7 percent of those answering do not consider the issue realisable.

[6] siehe auch http://www.herzschrittmacher.info/hintergrund.htm
[7] http://www.wlw.de/rubriken/defibrillatoren.html

**Illustration 138:** Realisation time for thesis 33, distribution of answers in 5-year steps (in percent)

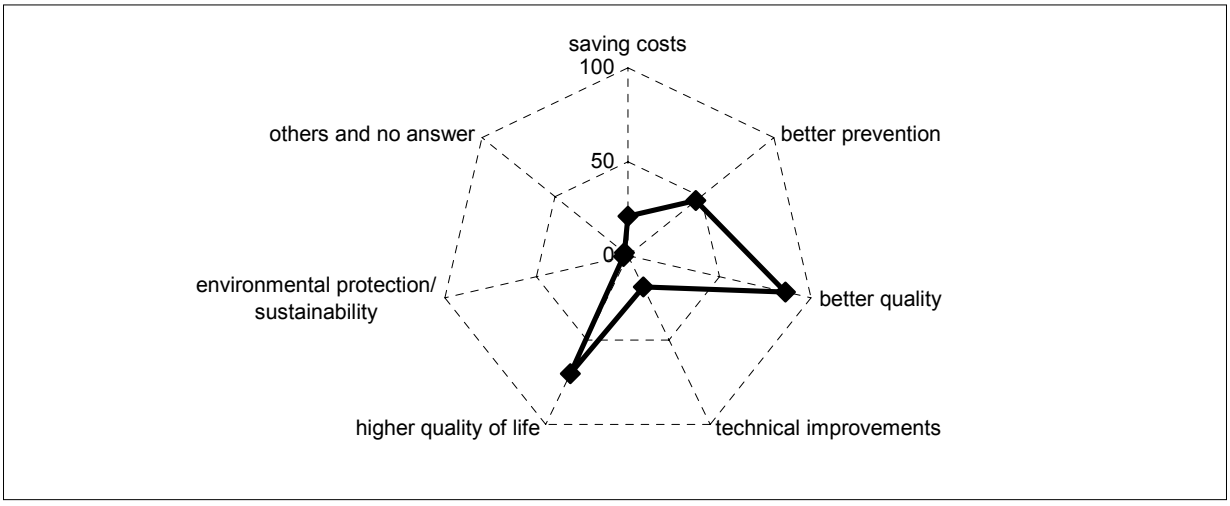



**All in all, do you personally consider the realisation of this thesis desirable?**

86 percent of those participating consider the thesis desirable. Respectively 7 percent say "no" or "do not know". Various participants warn against "false alarms", "production of data waste" and the "radio-technological chaos" which surely also includes safety issues.

**What is the realisation of the thesis important for?**

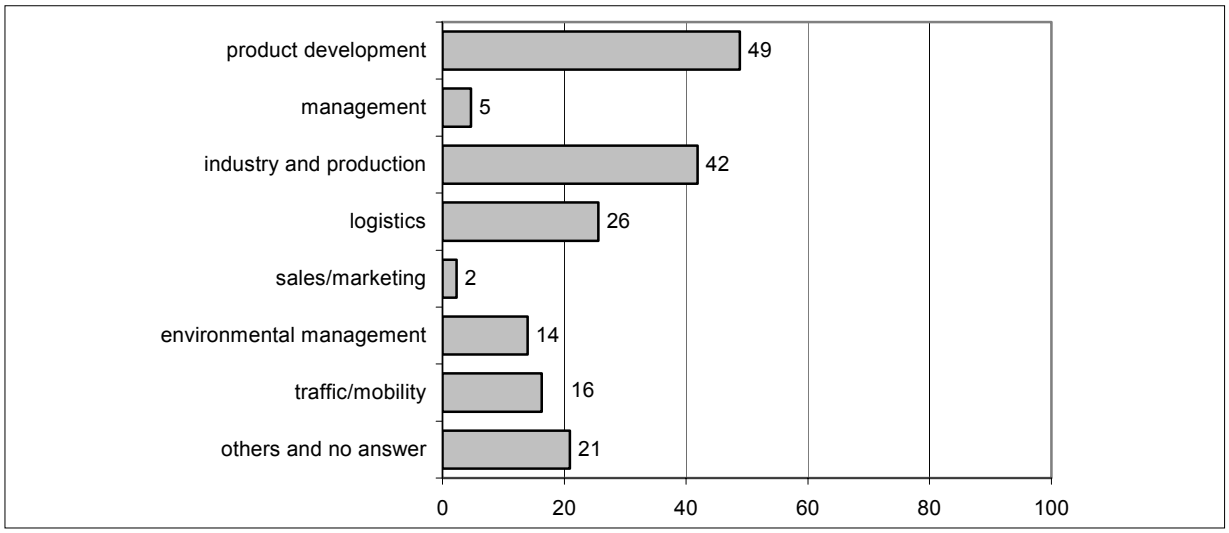
**Illustration 139:** Importance of thesis 33 (in percent)




The topic is considered important for the quality of healthcare and a higher quality of life for patients concerned. Nearly half of the participants consider the thesis important for better prevention.

**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

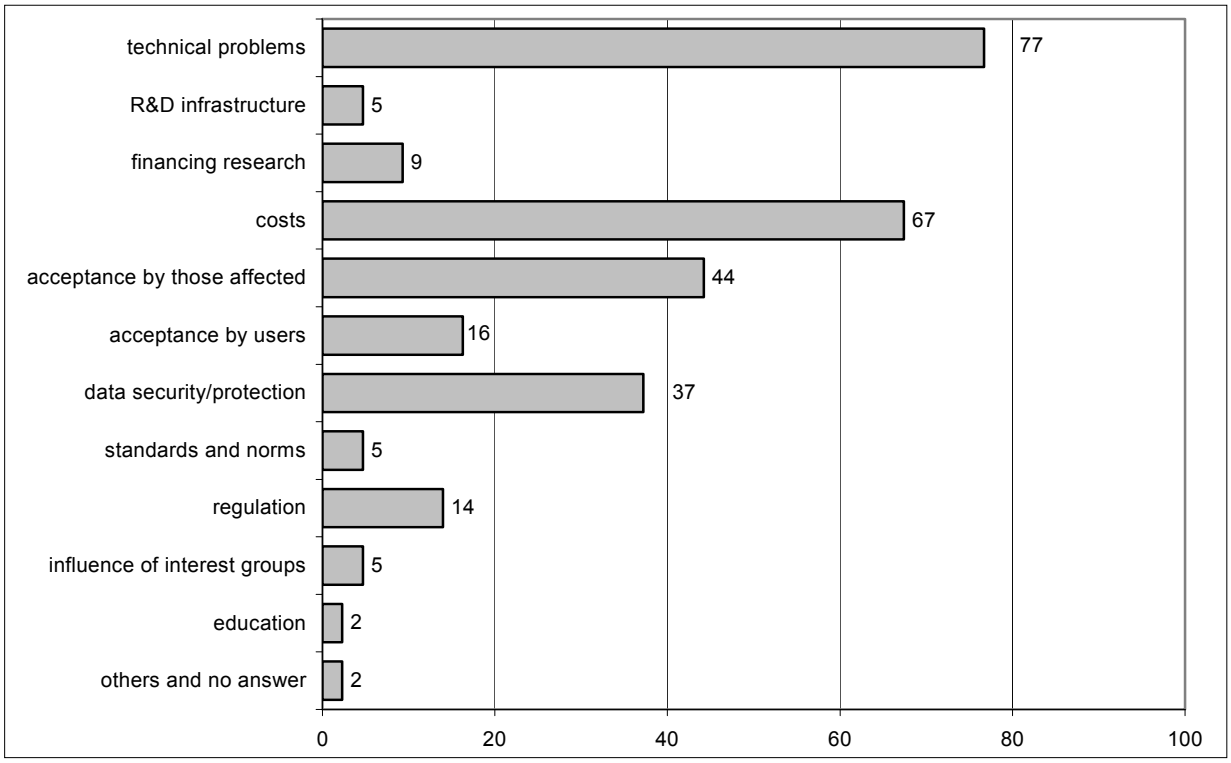
**Illustration 140:** Thesis 33 – Applicability in other areas (in percent)




The technology of transmitting data from an implanted device is also applicable in product development and industry and production. Environmental management and traffic/mobility are sectors which are also named apart from "other areas".

**Where do you see obstacles for the realisation of the thesis?**

**Illustration 141:** Obstacles for the realisation of thesis 33 (in percent)



Until today technical problems are obstacles which prevent realisation. However, costs are a large obstacle, too, say the Delphi participants. Further obstacles are data safety and data protection, but also acceptance by those concerned and possibly even user acceptance. 6 participants name regulations as an obstacle.

**Prospect**

Wireless rechargeable implanted defibrillators will be applied in the next 10 years. They are supposed to be able to transfer their measured and recorded data to a control unit which then transfers the data to a service centre for evaluation and to alert others if necessary. There are few doubtful participants who do not consider the topic desirable (7 percent) or realisable (4.7 percent) at all. Actual problems are of technical nature and costs, data safety and protection as well as acceptance problems pose as obstacles, as well. Implanted respectively integrated microdevices which are wirelessly rechargeable and transmit data to an external location will be applicable in many areas and prove to supply a large market.

## Thesis 34: Technologies are applied in research, which allow forecasts on biological activity of proteins and their functional domains via information as to their spatial configuration.

This thesis refers to proteomics, a science that comprises of the research of all existing proteins within a cell or a living creature, under defined conditions and at a defined point of time. Proteomics try to catalogue al proteins in an organism; the construction plan is supplied in the genetic endowment. For this, proteomics deals with the results from sequenced genomes. While the DNA merely records information the protein molecules consisting of amino acids fulfil various duties. They represent the basic substance of living and combat illness as antibodies, enable digestion as enzymes and guarantee mobility as muscle tissue.

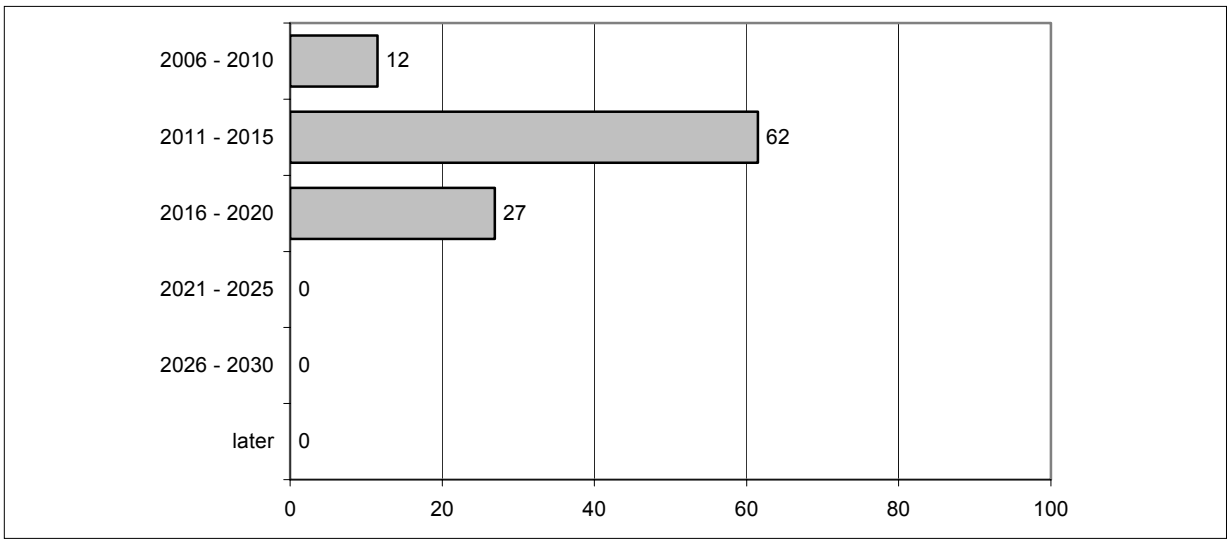
Contrary to the (static) genome the proteome is highly dynamic and can adapt with respect to altered conditions (environmental factors, temperature, genetic expression, substance administration etc.). One example for the dynamic character of the proteome is supplied here: A caterpillar and the butterfly, which will develop from it, possess the identical genome, however, they are different as a result of proteomes. Changes of the proteome can take place very quickly at times, e.g. by means of phosphorilisation or dephosphorilisation of proteins which have a major part in signal transduction. The thesis concerns “the biological activity of proteins and their functional domains by understanding their spatial configuration” and making these things predictable. For this, information techniques are required. Medicine lays hopes on proteomics for new agents against cancer, infection and other nervous diseases. Illnesses such as sickle cell anaemia, Alzheimer or the Creutzfeldt-Jakob disease stem from defectively configured proteins. So if it is known, which protein is responsible for the defect it is possible to develop a specific molecule, which will connect to the protein and shut it off. Medication against viruses such as influenza or AIDS is based on substances which were developed in this way. Also strong detergent enzymes and pesticides for the industry are conceivable in this respect. Biologists hope to find out how life actually works with proteomics. Bio-physicists are already speaking about the “molecular anatomy”. In so far, proteomics are an important future research area. Thesis 35, too, refers to proteomics.

Thesis 34 was evaluated by 33 participants. This is the lowest participation rate in the entire study. On the one hand this may be explained by exhaustion of those answering towards the end of the study on the other hand proteomics may be one subject that not many persons know much about. Still, 24.2 percent of the participating persons estimate their expertise as high, 15.2 as medium (a low number) and many participants (60.6 percent) estimate their expertise as low.

**When do you expect the realisation of this thesis?**

The thesis is considered feasible around the year 2014. The low quartile ranges at the year 2012 and the high one at 2016, this means the experts answering do not vary strongly in their estimate (illustration 142). No participant marked the timeframe after the year 2020 and only 3.4 percent say the thesis will “never” be realisable.

**Illustration 142:** Realisation time for thesis 34, distribution of answers in 5-year steps (in percent)

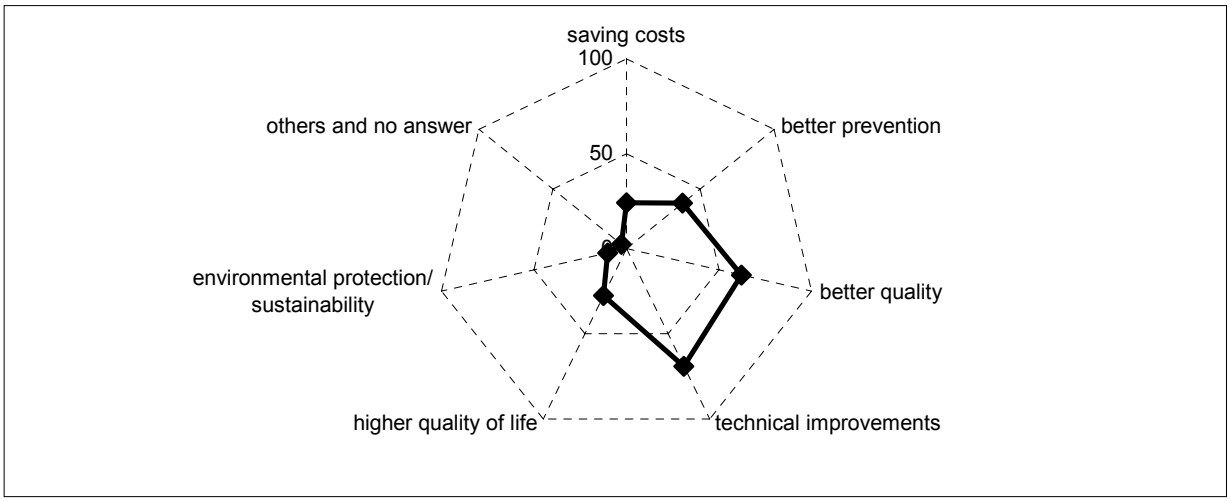



**All in all, do you personally consider the realisation of this thesis desirable?**

96 percent of the Delphi participants consider the thesis desirable and 4 percent mark "do not know".

**What is the realisation of the thesis important for?**

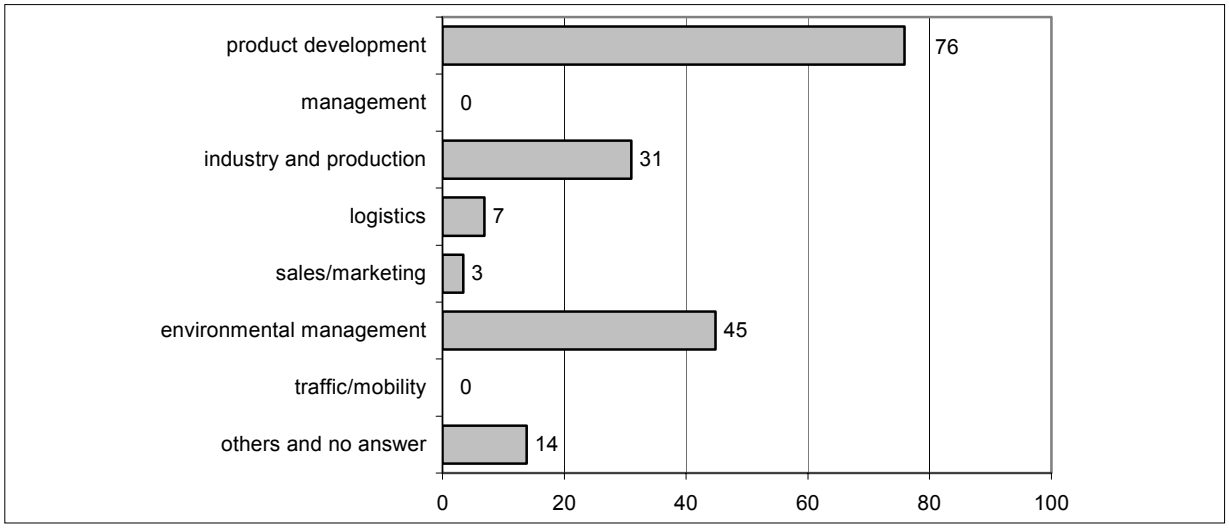
**Illustration 143:** Importance of thesis 34 (in percent)




The thesis is considered highly important for technical progress. Also the quality of healthcare, possible even better prevention or cost reductions is marked.

**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

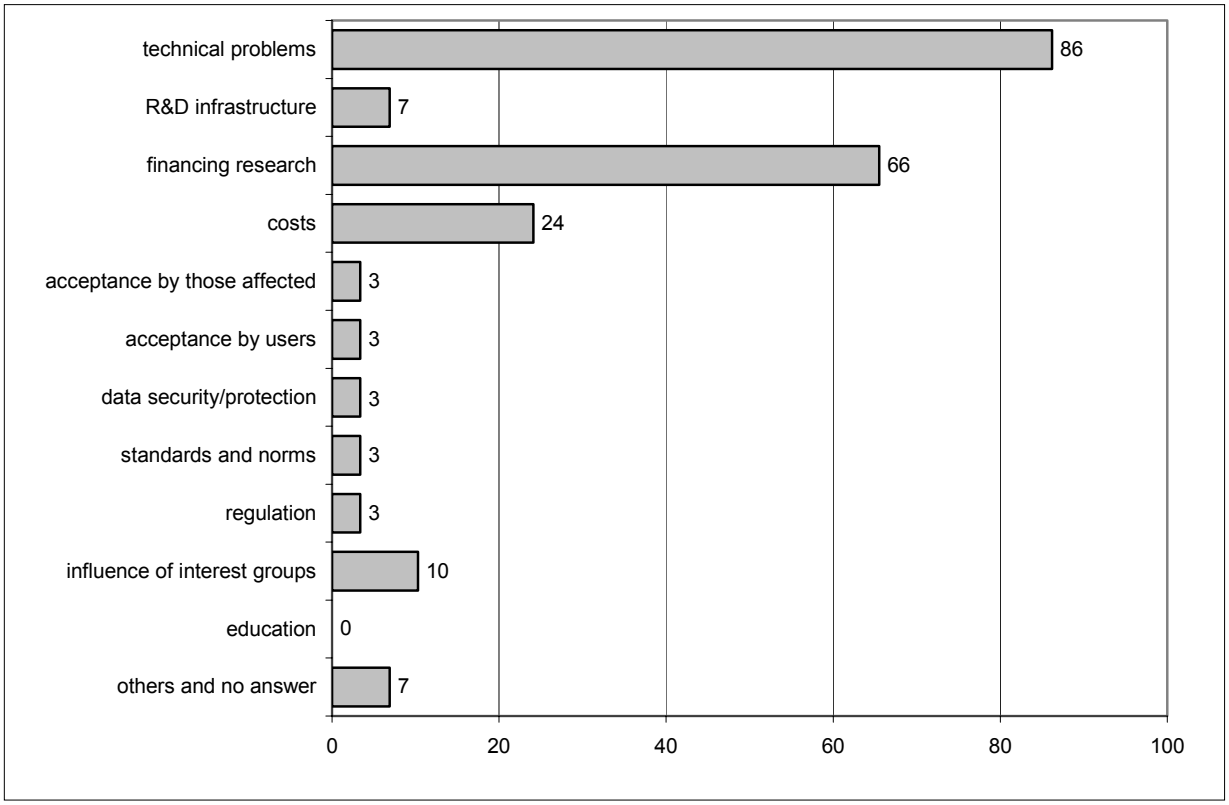
**Illustration 144:** Thesis 34 – Applicability in other areas (in percent)




The thesis' technology can be applied in product development (here, especially the pharmaceutical sector is aimed at, commentaries point out that there would be the factor of "saving time while developing new medication". Environmental management and industry and production are also considered as application areas. Compared to other theses "other areas" is often named, commentaries here refer to military use.

**Where do you see obstacles for the realisation of the thesis?**

**Illustration 145:** Obstacles for the realisation of thesis 34 (in percent)



Technical problems are the largest obstacle for the realisation, followed by (insufficient) research funding. Also named as an obstacle are the costs of application.

**Prospect**

To apply technologies which enable a prognosis on the biological activity of proteins and their functional domains by means of information on their spatial configuration in research is considered technically difficult but feasible by the year 2014. The topic is important for technical progress in particular, Delphi experts, however, assume there is further need with regard to research funding. Such technologies are applicable in product development (especially the pharmaceutical sector), but also in environmental management and industry and production.

Thesis 35: Standardisation and processing of the large mass of data delivered through proteomics has developed a predictive and integrative biology, consisting of techniques for visualising results, automatic matching with other genome-comprising data records as well as the integration of additional "-omics" (genomics etc.) approaches.

This thesis deals with the integration of proteomics with other approaches to systems biology. For the explanation of proteomics, please refer to the previous thesis 34. Systems biology is a relatively new branch of biosciences, which tries to understand biological organisms in their entity. The aim is to get the integrated picture of all regulatory processes of all levels, from the genome to the proteome, to the cell organelles to behaviour and biomechanics of the entire organism. Substantial approaches for this stem from the systems theory and its subterritories. Mathematically and analytically computer simulations and heuristics are used for research approaches in systems biology (see also Reiß, 2002).

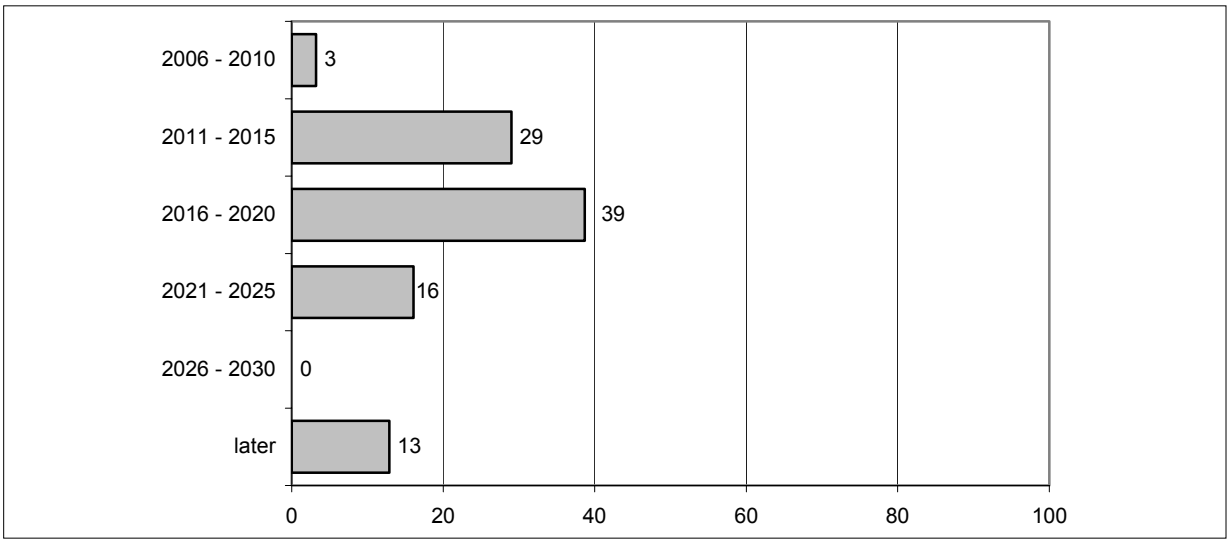
Classic proteome analysis looks for a certain protein which can be detected. Quantitative methods allow making statements about the amount of the respective proteins. In this way, one can know whether a specific kind of protein is found more often in cancerous cells than healthy ones. If combined, quantitative proteome analysis and other biological methods enable making statements about the function of proteins (e.g. protein-protein-interaction). Modern proteomics is an area with a range was broader than protein catalogues. Enormous amounts of data are recorded, processed, analysed and depicted. Database matching and the assistance of new information technology are indispensable.

This very particular thesis was evaluated by 34 participants, 14.7 percent of them estimate their expertise as high. 38.2 percent estimate it as medium and another 47.1 percent estimate it as low.

**When do you expect the realisation of this thesis?**

The realisation of this thesis is considered possible for the year 2018 (Q1: 2014, Q2: 2022), however, 13 percent of those answering say "later than 2030". The distribution of answers is shown in illustration 146. All those participating consider the development possible, nobody says "never".

**Illustration 146:** Realisation time for thesis 35, distribution of answers in 5-year steps (in percent)



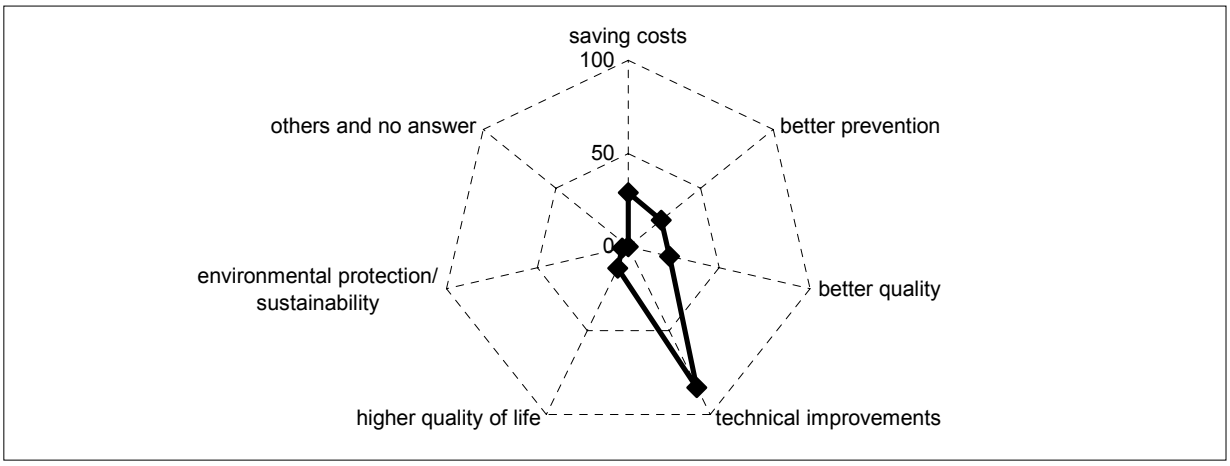

**All in all, do you personally consider the realisation of this thesis desirable?**

13 percent of the Delphi participants do not make a statement about desirability of the thesis. 87 percent, however, consider it desirable.

**What is the realisation of the thesis important for?**

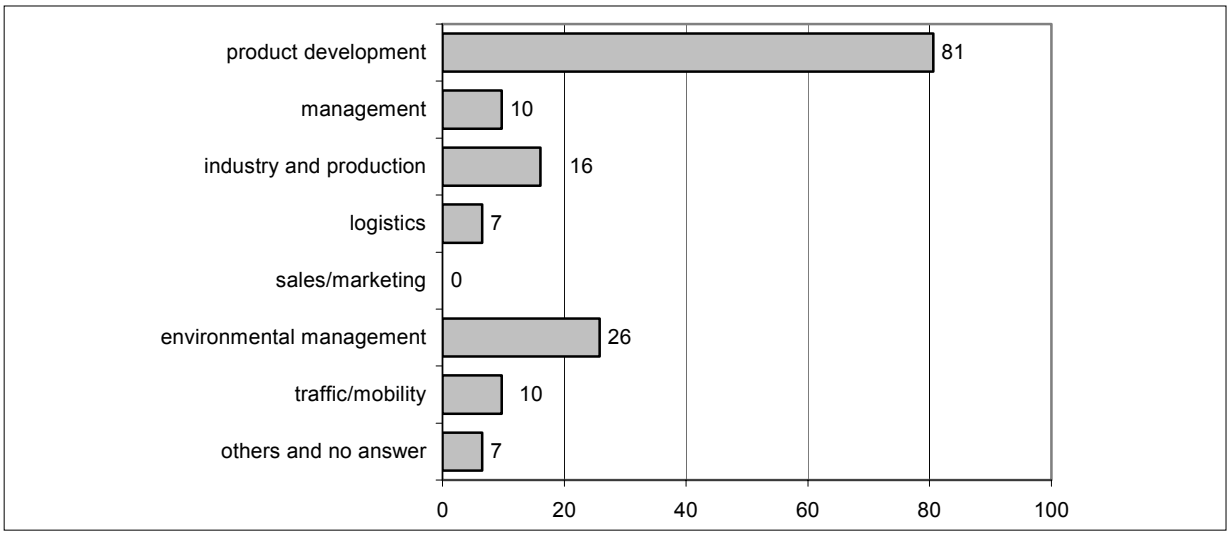
Nearly all experts consider the thesis most important for technical progress.

**Illustration 147:** Importance of thesis 35 (in percent)



**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

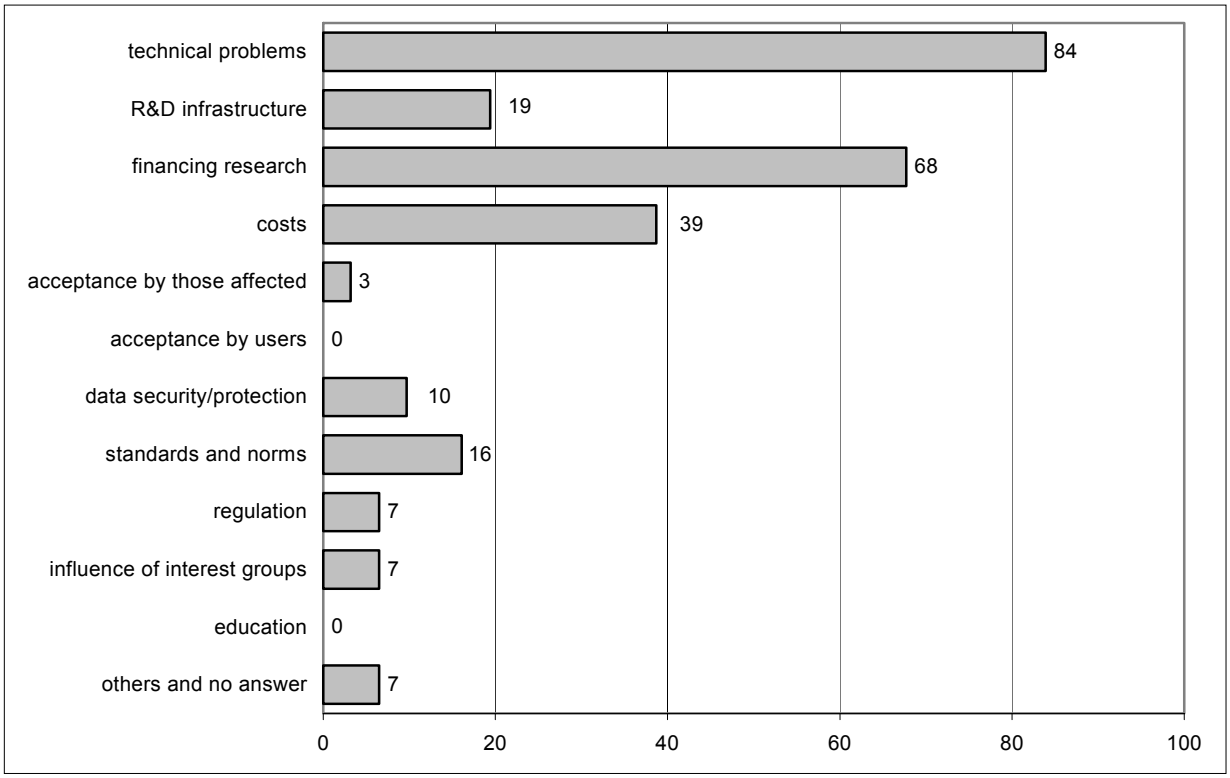
**Illustration 148:** Thesis 35 – Applicability in other areas (in percent)




This development, too, is applicable in other areas. Mainly named here is product development. One commentary points out to the acceleration of "development of new medication". Environmental management, too, is considered as a possible area of application.

**Where do you see obstacles for the realisation of the thesis?**

**Illustration 149:** Obstacles for the realisation of thesis 35 (in percent)



Standardisation and processing such enormous loads of data is a big technical challenge. This is why technical problems are the obstacle name foremost, followed by research funding. Costs, too, are named. Possibly the research and development structure of the state is not as yet prepared, as it is mentioned more often here than at any other point of time during the survey at hand. The issue of preparation status would have to be more closely analysed.

**Prospect**

Proteomics already involve large amounts of data and there will be more if genomics and other approaches are to be integrated in a systems biology. The data processing and characterisation is an enormous technical challenge and thus pose as the largest obstacle, followed by research funding and costs. Accordingly, the technology is considered important for technical progress and applicable in other areas, especially product development (e.g. probably pharmaceutical sector), too. The thesis is realistic; nobody considers realisation impossible. Realisation is considered around the year 2018.

## Thesis 36: Methods for quick analysis of the genome, e.g. DNA Chips, high-speed sequencing or genetic mapping are applied in healthcare routine.

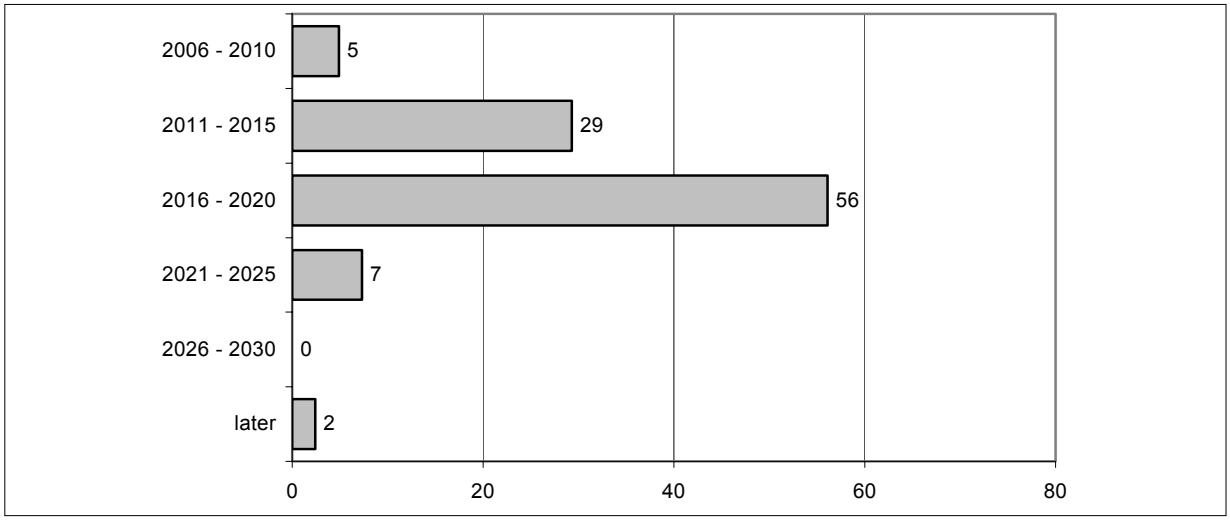
Quick genetic analyses can only be conductible with information technology. Approaches include DNA chips, high-speed sequencing (extremely fast determination of a DNA sequence, i.e. the succession of nucleotides in a DNA molecule) or genetic maps, which until today have not even been used completely in research. This thesis regard making these very elaborate approaches available for routine medical care. This would enable quick and more thorough diagnoses[8] and better targeted therapy possibilities.

44 persons evaluated this thesis. Only 11.4 percent of them estimate their expertise as high, 38.6 percent as medium and exactly half of the participants estimate their expertise as low. Since this topic is very particular again, only few participants with high expertise could be identified for this questioning.

**When do you expect the realisation of this thesis?**

Quick analyses of the genome in routine healthcare are considered possible for the year 2017. The low quartile estimates 2014 and the high quartile the year 2019. Two percent even say "after 2030" and 2.3 percent "never". The distribution of answers is shown in illustration 150.

**Illustration 150:** Realisation time for thesis 36, distribution of answers in 5-year steps (in percent)



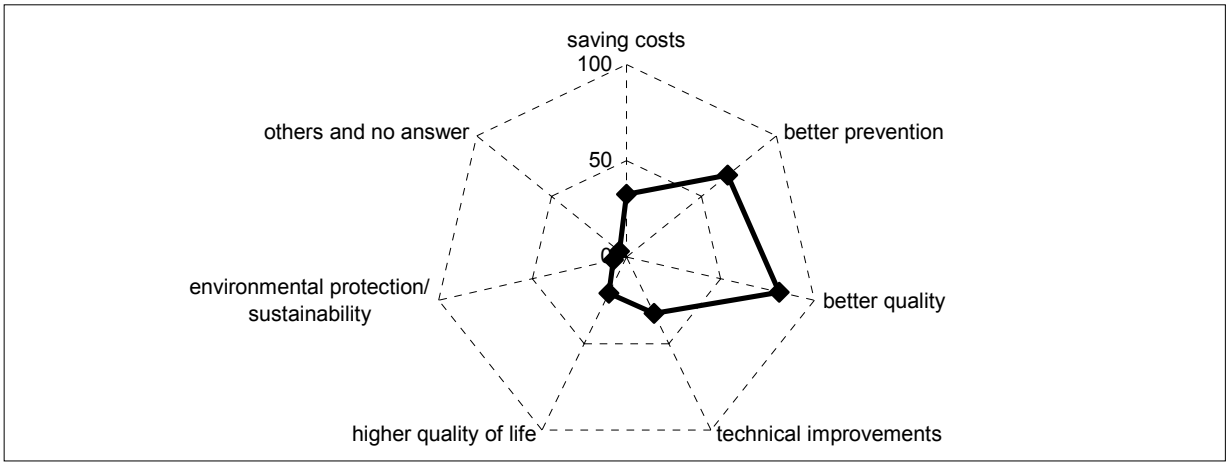

**All in all, do you personally consider the realisation of this thesis desirable?**

Methods for a quick analysis of the genome in routine healthcare are not desired as openly as many other these. "Only" 72 percent of those answering consider their application desirable, respectively 14 percent do not consider it desirable or do not know. On the one hand quick test results are hoped for, on the other hand there are doubts as to the benefit and use of the routine. It is pointed out that only in individual cases does it make sense to analyse the genome.

[8] vergleiche z. B. http://www.innovations-report.de/html/berichte/medizin_gesundheit/bericht-38909.html

**What is the realisation of the thesis important for?**

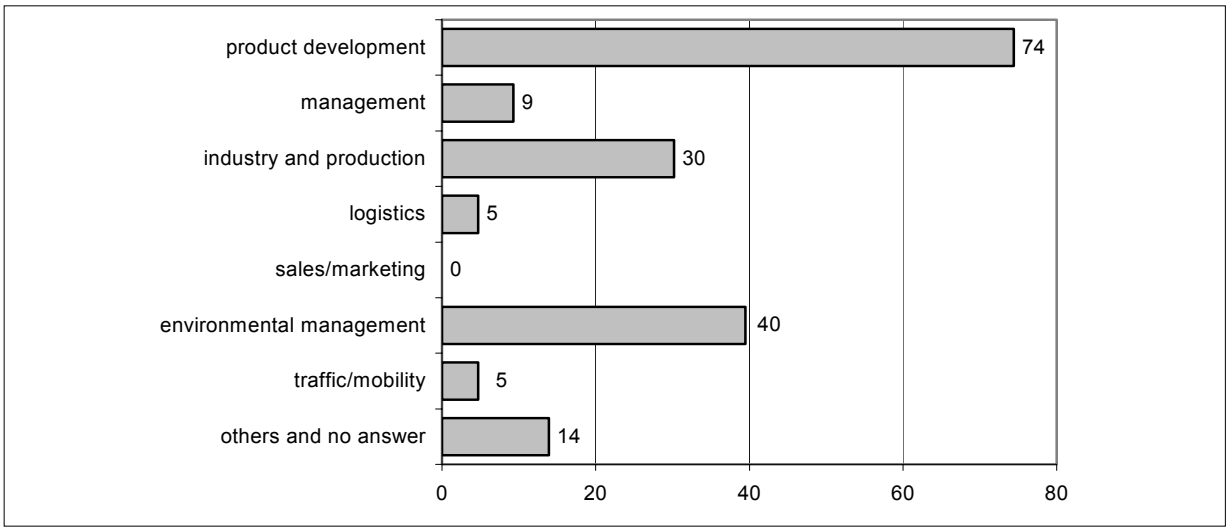
**Illustration 151:** Importance of thesis 36 (in percent)




The thesis is considered important for a better quality of healthcare and better prevention. However, the Delphi participants also consider the topic important as to technical progress as well as cost saving.

**Other than the health sector, in which areas will the technological development mentioned in the thesis be applicable, too?**

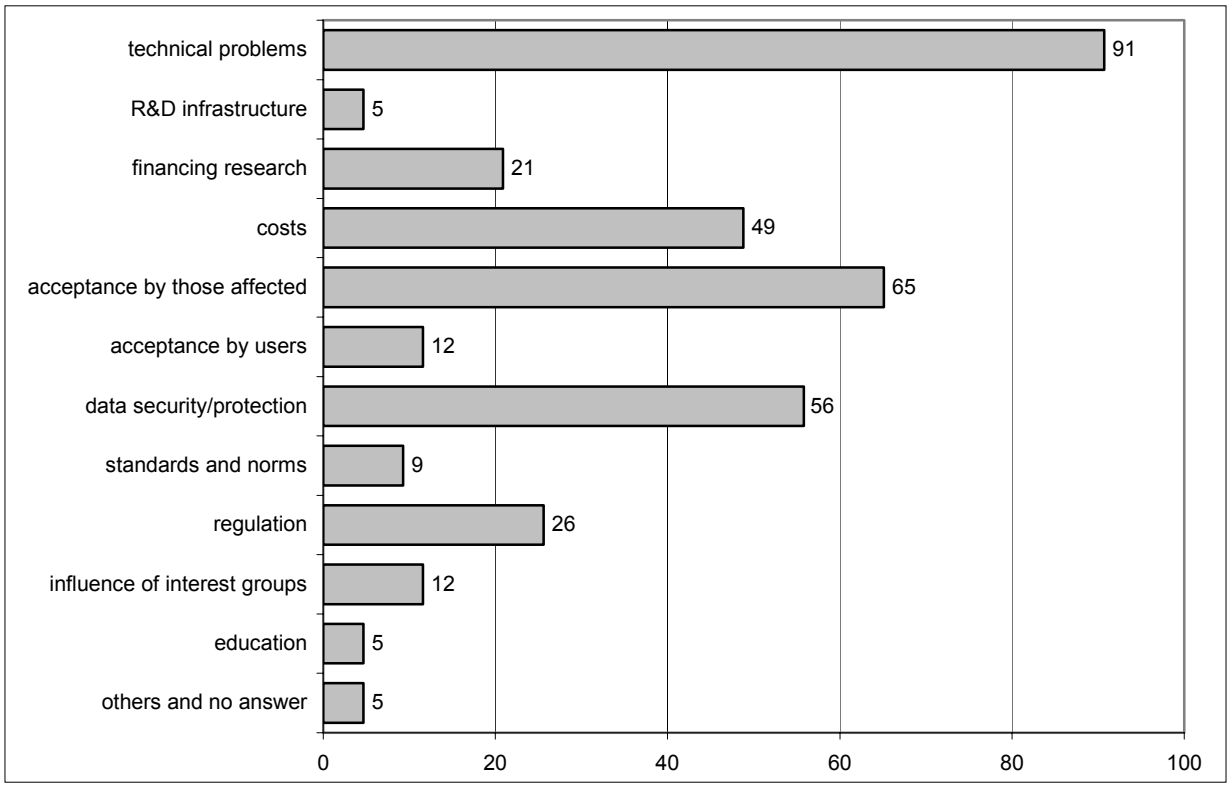
**Illustration 152:** Thesis 36 – Applicability in other areas (in percent)




Quick analysis of the genome is also applicable in other areas – and here, too, relation to pharmaceutical research and medication development is pointed out. Furthermore, the participants mention industry and production and "others", too. Commentaries refer to "criminal prevention and insurance frauds prevention".

**Where do you see obstacles for the realisation on the thesis?**

**Illustration 153:** Obstacles for the realisation of thesis 36 (in percent)




Because of its complexity the thesis has various obstacle to overcome before realisation. Firstly named are again technical problems, e.g. processing data in such a short period of time. Second is acceptance by those concerned. To complete a genetic examination for everyday illnesses may not be possible, but leaving DNA on file in cases of critical illness is a topic persons need to be convinced about. Data security and data protection need to be predefined at a high level, which also expresses the third obstacle or concern of the participants. Additionally, there are the costs to be regarded, which, however, will become less gradually as routine application spreads. Most Delphi participants complain that research funding is not adequate. Regulations, as well, may need to be adjusted prior to an application of routine genetic testing.

**Prospect**

To apply methods of quick analysis of the genome in routine healthcare is a technical challenge which can be mastered. Data security and protection are issues that need to guaranteed if the analyses are to be conducted in a widely spread manner. Acceptance for this by those concerned has yet to be encouraged. If the costs are acceptable, there is nothing else in the way towards the routine administration and this could begin around the year 2017. Analyses of the genome are applicable in other areas as well, in product development, in the industry, in environmental management, but especially in criminal prevention, altogether opening perspectives for a big market.

# 5. A short glance at the future

## 5.1. Methodical prospect

Now is the time for a couple of methodical annotations as well as a glance at the methodical future: Similar to the first FAZIT Delphi (von Oertzen/Kuhls/Kimpeler, 2006), one of the biggest challenges in conducting the study at hand was characterised by the identification of experts who would be able to address the wide spectrum of theses with sufficient professional knowledge. This undertaking was successful for most theses. Also involving patent applications of various classification groups has stood the test, as patent applicators are in fact able to answer with high expertise. The drawback was the fact, that home addresses gathered were partly no longer correct, which in turn made further time-consuming research necessary. In spite of this, the feedback with answers by 203 participants during the first round was highly satisfying. However, several Delphi studies have shown that the second round obtained rather low numbers of feedback (only 86 participants). Especially in comparison to older non-electronic surveys this is a very low response rate. There is no explanation for this phenomenon. Possibly the commitment when working with a medium as transient as the internet is no longer high or the incentive of receiving the final results of a survey are no longer as great as they used to be, in today's age of information overload.

The procedure of a multi-step topic selection working downwards from big topics to smaller ones has proven reliable. Especially the intermediate evaluation during a workshop, which showed very soon that technology and technical development are only partly an answer to the future issues of the health system, was helpful. In addition, in terms of cost reduction and saving two aspects were often stressed: One the one hand technology can contribute towards cost reduction, on the other hand costs (investment expenditure or running costs) represent one of the obstacles. Surveys can generate such contradictions and they are especially significant for the following theses:

- Ambient Intelligence in a house allows monitoring of patients at home (via camera, thinking carpet, furniture equipped with sensors, immobility sensors), reporting irregular features to an emergency call centre.
- A non-invasive long-term blood pressure sensor has been developed.
- Methods for quick analysis of the genome, e.g. DNA Chips, high-speed sequencing or genetic mapping are applied in healthcare routine.
- Many hospitals employ robots for difficult and standard procedures in nursing (e.g. putting someone into another bed, changing of bedclothes) in order to relieve the nursing staff and enable them to have more time for personal attentiveness towards the patients.

For thesis topics, there were many namings for "importance of cost reduction" as well as the obstacle "costs". To assess any of these topics focusing on the cost aspects alone would not make sense. So one needs to methodically balance the quality of the statistical product – which in the thesis is controversially registered.

Apart from the theses, their identification and the phrasing of their future development, the questions posed and the evaluation criteria are important for the quality of the results. In this screening the focus was brought to the questions as to realisation of the thesis, the obstacles and applicability in other areas. For the first time in a Delphi study of this scope the participants were asked whether a thesis was "desirable" or not. Although nearly all theses were considered desirable, there are differences which correlate to other aspects, such as importance or obstacles and thus offer further clues for additional development.

The future for surveys and also for Delphi methods certainly is designed by electronic versions. However, we give occasion to point out that experience in Germany has recorded a lower feedback rate than with conventional postal enquiry methods. On the one hand, this may be appropriated to fatigue symptoms generated by the number of questionings, on the other hand this may be related to the medium internet, as the answer rates during the first question round are still relatively high. The rate only declines as of the second round of questions (compare chapter 2.3, also the first FAZIT Delphi, by von Oertzen/Kuhls/Kimpeler, 2006). Electronic surveys need to be subject to standards equal to those of postal nature, for instance regarding the importance of each participant answering only once during one round, the sample of participants being clear and controllable, the generated data being valid for evaluation and the questionnaire being designed in a way which makes answering easy and comprehensible etc.

## 5.2. Where do new markets develop?

Human beings tend to orient themselves by conspicuities and ignore the rather normal "boringly evolving topics". For this reason, the reference may be permitted to state that the most attention attracting topics and in certain cases controversial theses of the Delphi study at hand may be of the highest media and public interest. However, this does not always apply to interest regarding market developments, as the mentioned technologies often involve risks for developers and manufacturers. For this reason, as a user of the data published in the scope of the study at hand, you need to specify between the different criteria respectively questions and use them as a framework for an analysis of your own, instead of simply adopting those topics which easily catch the eye on account of certain results.

For instance, it is assumed that "robots in nursing" and "biopsy robots" – each of the topics being considered desirable only to a certain degree and frequently discussed in commentaries – will become reality and thus appear on the market later than the mean subjects of other theses. Theses, which are of interest to the industry, e.g. technologies that can be applied and transferred to other areas, should be closely watched. They represent the most interesting and important topics of the study, in spite of receiving rather moderate estimates in terms of realisation dates – most often they are "only" located in the upper respectively early midfield of scheduled market appearance. The controversial topics have been characterised as such ever

since the Delphi study which was conducted in the year 1993 (BMBF, 1993) and this, too, not only in Germany (compare e.g. NISTEP, 1992), it is merely the estimated timeframes which have shifted.

For instance in the 1993 Delphi the similar thesis "Nearly all difficult tasks regarding the care of physically and mentally handicapped persons in hospitals are completed by robots." was considered as "not necessary" by 45 percent of the participants, "realisable", however, by the year 2014 with high variance of the statements (Q1: 2010, Q2: after 2020, the time scope limit of that year's study). The very same thesis was considered realisable for the year 2007 in a similar Japanese Delphi survey (NISTEP, 1992), also with high variance (Q1: 2002, Q2: 2013) and only one participant finding the thesis "not necessary". The German 1998 Delphi (Cuhls/Blind/Grupp, 1998) and the sixth Japanese Delphi (NISTEP, 1997) brought findings such as "robots as an assistance in nursing patients with high-grade physical or mental handicaps" being broadly applied and realisable around the year 2011 (median), "robots in order to relieve staff in nursing patients and old aged persons" (only in Cuhls/Blind/Grupp, 1998) broadly applied, too, even two years earlier.

For new markets in Baden-Wurttemberg topics such as proteomics, telemonitoring, voice entry for documentation tasks or data access from everywhere, which do not sound spectacular but require a high level of knowledge and know-how, are especially interesting. Of course, to a certain and large degree, they coincide with those topics discussed on a national level and which have, partly, been adopted by the Federal Government's high-tech-strategy (BMBF, 2006b and 2007). Only these technology approaches will lead to broad market application in other sectors. What goes without saying is the fact that for this Delphi study, all theses were selected with regard to their importance and impact on future development, some of them most probably developing in a more dynamic way than others.

One of the topics with an especially dynamic development is the retina implant with two theses (no. 26 "Blind persons can orient themselves within a room with a retina implant." and no. 27 "Retina implants improve dramatically and thus become ready for use through combination of functional and morphological data, the evaluation of the data by expert systems and the crosslinking of the various systems."). Both theses are considered very desirable, as they are extremely important for the quality of life of visually impaired and blind persons. That is why efforts already have been made in this area, in spite of high obstacles and costs, which will prove the estimates by Delphi experts to be wrong. Their estimates are very pessimistic and broadly distributed in terms of realisation times (median 2018 and 2020, respectively). Sometimes it is better if prognoses regarding time scopes are not fulfilled. Labelled as auto-destructing prophecies (prognoses estimating "never" or wrong timeframes on account of decisions based on today's knowledge), the complete retina implant topic could become one of those topics not "being realised" and thus trigger a possibly even earlier apparition than estimated here and now. Before, however, many technical obstacles need to be overcome.

Many of the selected technical topics are not restricted to the health sector, but equally relevant for other areas of application. In particular product development was frequently named, but also industry and production as well as logistics. It was not expected that the Delphi participants marked so many areas of application. Sometimes, interpretation is difficult

(What is meant by "product development"?), if commentaries do not supply further references. Which "new" products are meant? In the most cases, this was not elaborated upon. The signal, however, indicates that even though all selected topics regard information technology as well as health as such, the supporting technology is not confined to this sector. All theses referring to voice entry, for instance, could be applied in a variety of other areas, as well. Perhaps even at an earlier stage, since the accuracy, which needs to be guaranteed in an operating theatre should be reliably close to 100 percent. For other applications, such as secretarial tasks, this is not mandatory. For further information concerning this topic and others, please visit www.fazit-forschung.de. Within the FAZIT foresight approach many of the application fields only touched in this study are substantiated by scenarios which are developed in the year 2007. Well, back to the content of the Delphi theses.

Noticeable but not surprising is the fact that topics which literally "get under the skin" are very controversial. In the Delphi study at hand this concerns all theses regarding

- implantation ("Blind persons can orient themselves within a room with a retina implant." and "Retina implants improve dramatically and thus become ready for use through combination of functional and morphological data, the evaluation of the data by expert systems and the crosslinking of the various systems. ", "Entire artificial kidneys have been developed ", "Electrodes in the brain detect a beginning epileptic seizure and prevent it through specific electrical stimulation patterns.", "Clinically applicable systems consisting of implantable glucoses sensors, actuators and insulin reservoirs as well as corresponding control software have been developed, allowing an optimum fine-tuning of diabetes patients.", "Surgeries within the body, which are conducted by a remote-controlled micromachine, equipped with sensors and actuators, are possible." or "An artificial heart and lung implant receives marketing approval.") as well as
- transdermal intervention ("Fully functional robot systems have been developed and tested for transdermal intervention (e.g. biopsy robots).").

Generally speaking all these theses are considered desirable, however, they do not attain evaluation ranks as positive as others. Apart from technical problems issues regarding data protection and data security or acceptance by those concerned are named. These topics also raise ethical concerns and commentaries refer to rejection based on more emotional, rather than rational grounds.

Nearly all of the theses are considered realisable, however, obstacles must not be underestimated. The following theses, for instance, could fall through on account of related costs, since the item "costs" as an obstacle is often marked:

- Routine whole-body scanning with functional imaging is a standard procedure after accidents.
- Ambient Intelligence in a house allows monitoring of patients at home (via camera, thinking carpet, furniture equipped with sensors, immobility sensors), reporting

irregular features to an emergency call centre.

- Telemonitoring, i.e. close-meshed monitoring of patients (at risk), evaluation of the generated information in and by medical facilities and, if necessary, alerting the treating physician, has become a standard.
- Patients in hospitals are directed by an EDP-supported planning system, so that waiting periods, e.g. at admission, diagnostic procedures (X-ray, CT, endoscopy, etc.), operation are minimised and at the same time the overall efficiency of hospital facilities is enhanced.
- Valid diagnostic test procedures based on functional Magnetic Resonance Imaging (MRI) are clinically used for diagnoses with mental diseases (e.g. manic-depressive diseases) and diseases of the central nervous system (e.g. Alzheimer's disease).

Some of the above listed theses are considered to be very important, e.g. the topic "ambient intelligence", which will become important for an improvement of quality of life and also the technology may be found applicable in other areas. None of the theses is considered to be unrealisable, and if appropriately planned (cost reduction, large number of applications respectively more use, simplification of technology etc.) the problems regarding costs can be solved.

Technical issues pose more critical problems named as obstacles for certain theses by all or nearly all participants (see chapter 4). Worth mentioning here, again, retina implants ("Retina implants improve dramatically and thus become ready for use through combination of functional and morphological data, the evaluation of the data by expert systems and the cross-inking of the various systems.", "Blind persons can orient themselves within a room with a retina implant."), artificial organs ("Entire artificial kidneys have been developed.", "An artificial heart and lung implant receives marketing approval."), micro machines and implantable minimal systems ("Surgeries within the body, which are conducted by a remote-controlled micromachine, equipped with sensors and actuators, are possible.", "Clinically applicable systems consisting of implantable glucoses sensors, actuators and insulin reservoirs as well as corresponding control software have been developed, allowing an optimum fine-tuning of diabetes patients."), but also radiotherapy planning ("Computer-supported planning of biologically adaptive resonance therapy (ART), which allows an individual adaptation of the therapy to heterogeneous tissue, is possible."), voice recognition ("Voice recognition and correct relation of a voice to the person speaking is so accurate, that surgeons are able to navigate instruments through voice commands and are thus effectively relieved."), analysis of the genome in healthcare routine ("Methods for quick analysis of the genome, e.g. DNA Chips, high-speed sequencing or genetic mapping are applied in healthcare routine.") and a "non-invasive long-term blood pressure sensor".

According to the experts, the theses do not play a vital part for technical and technological progress itself or environmental protection and sustainability. The only thesis important with regard to environmental protection and sustainability is "Due to IT approaches (simulations, virtual animal models), 80% of all animal testing in medical and pharmaceutical research becomes redundant.".

New markets are expected in the areas of voice recognition, virtual reality and simulations, database approaches, sensory development, radio frequency identification (RFID) or new management and planning systems, either because they are generally considered important or because they reduce costs or the technology behind is so comprehensive that is not only applicable in the health sector, but also in other areas or sectors. In particular this criterion is valid for the following theses:

- Expert systems and databases, which monitor customised medications for individual patients with respect to undesired medication interactions and recommendations for a pharmaceutical therapy with reduced adverse reactions and side effects, are tested in pilot experiments.
- Patients in hospitals are directed by an EDP-supported planning system, so that waiting periods, e.g. at admission, diagnostic procedures (X-ray, CT, endoscopy, etc.), operation are minimised and at the same time the overall efficiency of hospital facilities is enhanced.
- A computerised system exists, which allows practice-based physicians to access all information at hand about the patient (cryptographically secured) via a terminal of their choice during house calls.
- Regional microwave hyperthermia can be ideally planned with a computer simulation of the biothermal conduction.
- Virtual reality is a standard in training of medical staff (e.g. virtual surgery, practising of minimally invasive interventions, endoscopy, rescue practices, patient interviews etc.).
- A non-invasive long-term blood pressure sensor has been developed.
- Documentation tasks in hospitals are routinely performed via voice entry.
- Telemonitoring, i.e. close-meshed monitoring of patients (at risk), evaluation of the generated information in and by medical facilities and, if necessary, alerting the treating physician, has become a standard.
- Labs-on-Chips are broadly applied for “point of care” diagnoses of clinically relevant parameters such as proteins, antibodies, hormones, bilirubine, cholesterol, urea as well as enzymes in blood and urine.
- Computer-supported planning of biologically adaptive resonance therapy (ART), which allows an individual adaptation of the therapy to heterogeneous tissue, is possible.
- Expert systems are routinely appointed to recommend specific advice for diagnoses and therapies to the healthcare staff.
- A wireless label system (RFID) is introduced to common households, allowing patients who easily and often forget things (due to dementia, Alzheimer’s disease etc.) to find anything and be attentive to things of importance.
- Wireless rechargeable implanted defibrillators are used, which convey their measured data to a control unit, which then conveys its data to a service centre for a check up and for an emergency report, if necessary.
- Interactive electronic logopaedics are a standard.
- Protein-chips for “Point of Care” diagnostics have been developed and tested.

- Technologies are applied in research, which allow forecasts on biological activity of proteins and their functional domains via information as to their spatial configuration.
- Histological diagnosis of tissue in vivo is possible with the help of spectroscopic, microscopic laser scanning methods.
- Clinically applicable systems consisting of implantable glucoses sensors, actuators and insulin reservoirs as well as corresponding control software have been developed, allowing an optimum fine-tuning of diabetes patients.

Of all the above mentioned, the following two theses are considered most important for better prevention. They were named by more than 80 percent of the Delphi experts:

- Labs-on-Chips are broadly applied for "point of care" diagnoses of clinically relevant parameters such as proteins, antibodies, hormones, bilirubine, cholesterol, urea as well as enzymes in blood and urine.
- A non-invasive long-term blood pressure sensor has been developed.

These technologies – which are, sometimes, not even spectacular – and their application may open doors to new markets, in Baden-Wurttemberg as well as in other places. The chances of their realisation during the next 10 to 15 years are not bad. Although technical obstacles remain and must not be disregarded they seem surmountable. As described in chapter 4 and recorded in patent applications, some enterprises already seem to be waiting in their starting blocks.

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# 7. Annex: Excerpt from the questionnaire, second round

# 8. Author, project and partner information

## About the authors

**Dr. Kerstin Cuhls** read Japanese and Chinese Studies and business administration at the University of Hamburg, spent one year at Kansai Gaikokugo Daigaku, Osaka, Japan and graduated with a Master's Degree. She has been working at the Fraunhofer Institute for Systems and Innovation Research as a project leader since 1992. In 1993 she was delegated to the National Institute of Science and Technology Policy (NISTEP) in Tokyo, Japan for four months. As of 2005, she has been working as a department-crosslinking foresight co-ordinator. Her research areas comprise of foresight concepts, methods of futurology, identification of "emerging technologies" as well as new socially relevant topics, innovation systems and innovation policies in Japan and China.

**Dr. Jürgen von Oertzen** studied political science and physics in Hamburg and Kingston Upon Hull (GB) and took his doctoral degree in political science at the Universities of Dresden and Halle. He obtained qualifications to act as mediator in the industry and working environments. Since 2005 he has been working at the Fraunhofer ISI for the department Innovation Systems and Politics, his main areas comprising of identification of future technologies and their opportunities and risks (foresight), evaluation of research policies and innovation policies, institutional research and safety research.

**Dr. Simone Kimpeler** studied communication science, sociology and economic policy in Münster and took her doctoral degree elaborating on constructivist discourse analysis. She has been working at the Fraunhofer ISI since February 2000 as a project leader and was appointed deputy head of department in 2001. Her field of functions comprises of analysis and associated research of innovation processes in the information and communication technology sector, especially with regard to economical and social effects. Further fields are the analysis of market development processes as well as market dynamics, foresight-processes, and the evaluation and benchmarking of innovation-stimulating programmes.

## About the FAZIT project

**FAZIT explores new markets for ICT**

Innovation and new markets – these are the vital factors for regional competition as well as for preserving and generating new jobs. The main focus of FAZIT is the identification of new markets for innovative information and media technologies. Biannually conducted representative enterprise surveys provide up-to-date location data on short- and medium-term developments in the IT and media sector as well as specific application areas in Baden-Wurttemberg. Determinants, goals and potentials, obstacles and benefit factors for the use of information and media technologies are registered and analysed. Workshops and case studies serve in providing more insight on selected market topics and discuss practical realisation potentials. Social and technical megatrends are screened in three Delphi studies and evaluated by experts regarding specific criteria such as feasibility. Following this, the theses are reviewed in a scenario procedure regarding the role of Baden-Wurttemberg in the future. The project's results and future outlook are finally consolidated in a concluding roadmap for Baden-Wurttemberg - new market opportunities are demonstrated and stimulation is created for both – the science sector and the industry.

**Non-profit research project, facilitated in the context of the "Zukunftsoffensive III" ("future offensive III")**

FAZIT is a non-profit *research project for current and future information and media technology and its use in Baden-Wurttemberg*, which has been facilitated by the state of Baden-Wurttemberg in the context of the "Zukunftsoffensive III". This project is supported by the MFG Foundation Baden-Wurttemberg, Stuttgart. The Centre for European Economic Research (Zentrum für Europäische Wirtschaftsforschung – ZEW), Mannheim and the Fraunhofer Institute for Systems and Innovation Research (Fraunhofer ISI), Karlsruhe, partner this project.

**For more information, please visit www.fazit-forschung.de**

## About our partners

**MFG Foundation Baden-Wurttemberg**
The MFG Foundation realises non-profit projects in the IT and media sector and the film industry. Main focus areas are research and development, the arts, creativity, culture and training and continued education. The MFG Foundation takes special measures to establish networks between the educational and research sector, e.g. by organising events (conferences, workshops) as well as advanced training activities and encourages innovative projects and research activities through studies, scholarships and competitions.
Internet: www.mfg.de/stiftung

**Fraunhofer Institute for Systems and Innovation Research**
The Fraunhofer Institute for Systems and Innovation Research (ISI) analyses the development conditions and markets and their corresponding effects on economy, the state and society. The research groups focus on new technologies, industrial and service innovations, energy policy and sustainable economic management as well as the dynamics of local markets and innovation policy.
Internet: www.isi.fraunhofer.de

**Centre for European Economic Research**
The Centre for European Economic Research (Zentrum für Europäische Wirtschaftsforschung – ZEW) operates in the area of application-based empirical economic research. The methodical activity is mainly microecomnomically and macroeconomically oriented. The research group Information and Communication Technology (ICT) at the ZEW attends to the developments and the effects of growing expansion of ICT, with the focus areas industrial and employment market economy. This, for instance, includes the effects of ICT-use on productivity, innovation, company organisation and company growth as well as the demands regarding qualification of employees.
Internet: www.zew.de