Future Information Technology for the Health Sector
- A Delphi Study of the Research Project FAZIT -

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Abstract. 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 a Delphi study in the context of the research project FAZIT. In order to find answers to this question, information technological developments were identified, which could become relevant during the next 20 years.

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 (ICT) contribute to improving or economising the Health System? What is, though technically possible, not desirable?

By means of this Delphi Study 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 an 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 (research project for current and future information and media technology and its use in Baden-Wuerttemberg), which is facilitated by the state of Baden Wuerttemberg. Since the beginning of 2005, in the context of FAZIT the demand and applicability for innovative information and media technology has been analysed and longterm drivers, which lead to new market opportunities for ICT in Baden-Wuerttemberg, are

M. Ulieru, P. Palensky, and R. Doursat (Eds.): IT Revolutions 2008, LNICST 11, pp.122–139, 2009.

identified. The project is supported by the MFG Foundation Baden-Wuerttemberg (MFG Stiftung), the Centre for European Economic Research (ZEW) 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 this text gives an overview of the results of all theses. The report is concluded with a short glimpse into the future. Detailed evaluations for each thesis and the results are described in the extensive research report which can be download free of charge on the website www.fazit-research.org.

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 shortterm 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).

2 Overview of Results

2.1 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 50th respectively 51st 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

Table 1. (*continued*)

Documentation tasks in hospitals are routinely performed via voice entry.	2013
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

Table 1. (*continued*)

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
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

Table 1. (*continued*)

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, 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.

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. 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")

2.2 Nearly All Selected Theses Are Desirable

In this Delphi study the desirability of the theses was directly determined. The question 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 four 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")

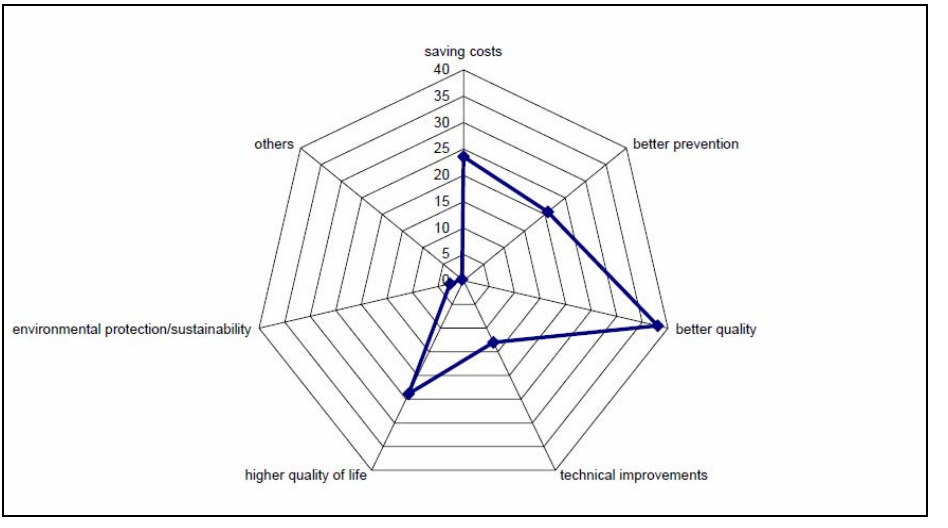
Two of these theses, which are not necessarily desirable, show the highest ratios for "never realisable". Perhaps they will not be realised or only realised at a later stage, since, in their contemporary form, they do not belong to the desirable theses. Especially controversial, for many years now, are 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.

2.3 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 2 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.

Illustration 1. 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 genomecomprising 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?

As a selection 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.).

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.

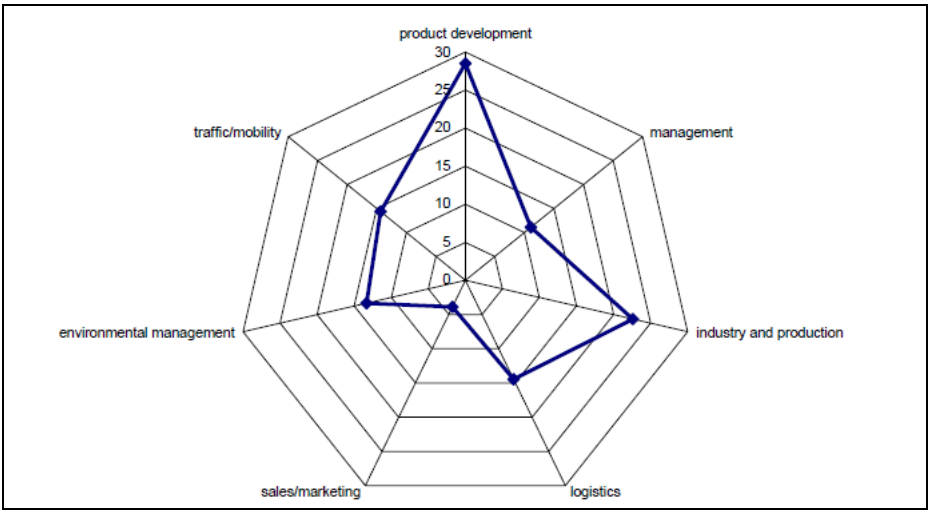
- Virtual reality is a standard in training of medical staff (e.g. virtual surgery, practising of minimally invasive interventions, endoscopy, rescue practices, patient interviews etc.).
- Labs-on-Chips are broadly applied for "point of care" diagnoses of clinically relevant parameters such as proteins, 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.

2.4 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 illustration 2). 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 2.

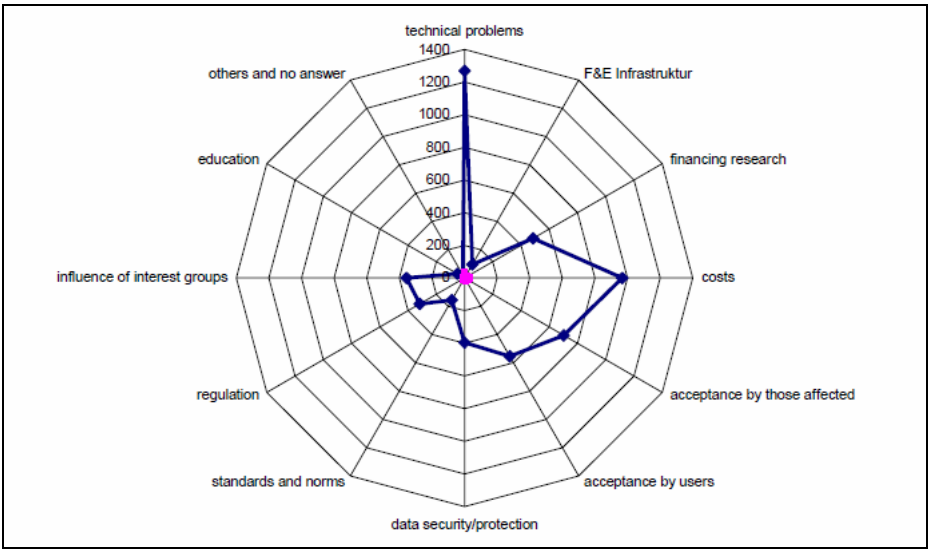
Illustration 2. Application of the technology of the theses in other areas



2.5 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 3, 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 3. 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" on average. 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. In singular cases, this contradiction is rare to be found 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 theses 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.

3 A Short Glance at the Future: 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.

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, 2006 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. Both 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 autodestructing 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.

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 as well as transdermal intervention.

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. Worth mentioning here, again, retina implants, artificial organs, micro machines and implantable minimal systems, but also radiotherapy planning, voice recognition, analysis of the genome in healthcare routine and a "noninvasive long-term blood pressure sensor".

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-Wuerttemberg 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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