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The influence of information and communication technology (ICT) on future foresight processes — Results from a Delphi survey

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ABSTRACT

Information and communication technology (ICT) tools are increasingly being used to implement foresight exercises. Until now, it has not been analyzed how this development affects the quality and structure of foresight processes. In this paper, a Delphi study is conducted to analyze the future path of ICT in foresight and to identify channels by which ICT drives progress in foresight and where there are limitations to this development. Using a real-time variant of the method, we posed 20 projections about ICT in 2020 to 177 foresight experts. In analyzing both quantitative and qualitative results of the study, we reveal that ICT will likely promote a shift in the focus of foresight exercises from scanning and data retrieval to more qualitative steps, such as interpretation, decision-making and implementation. In a growing foresight market, ICT should contribute to more efficient and accurate foresight processes with better accessibility to information, easy-to-use collaboration tools, data and knowledge linkages, quantitative modeling tools and process optimization. However, the qualitative nature of the discipline, value-driven challenges, as well as technological and competitive barriers should assure that foresight will remain a creative and human-centered activity with ICT tools only serving as supportive tools.

1. Introduction

In an age of increasing complexity and pace of innovation, futures thinking and foresight are becoming more important and attractive than ever before. Engaging in strategic foresight supports organizations in maintaining sufficient flexibility for future developments and unforeseen circumstances. While governments and public institutions may employ foresight to prepare for the long-term, companies can equip themselves with capabilities to react to weak signals and to quickly change the course of action according to market demand [1]. Consequently, the implementation of foresight practices, such as scenario planning, has increased [2]. The velocity and dynamism of the environment go along with a torrent of data, which society and technological progress are generating. Decision-makers and individuals in general are unable to process all of this information. Hence, there is a need for supportive tools, which rely on information and communication technology (ICT) [3]. Futurists and strategists consider ICT tools to have addition potential for increasing the quality of futures research, for example via internationalization, indexing and brain research (e.g. [4]).

Foresight processes are already supported by a large diversity of software applications. This includes trend databases, analytical software for trend extrapolation or scenario software packages. Since foresight – defined as a systematic, participatory, future-intelligence-gathering and medium- to long-term vision building process aimed at enabling present-day decisions and mobilizing joint action ([5], p. V) – is ultimately about adaptation to future developments that should reflect in decision-making [1,6], software serving any facet of forward-looking decision support can be called an ICT-based foresight tool. For the purpose of the research at hand, we define ICT-based foresight tools as ICT used to initiate, automate, implement or support foresight processes. For foresight processes, we employ a generalized version of Reger's [7] technology foresight process (see Fig. 1). Furthermore, we argue that the use of ICT tools will have profound consequences on the nature of foresight processes.

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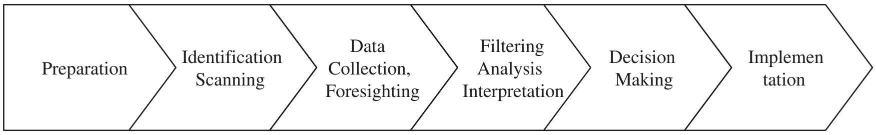

Fig. 1. Main phases of the foresight process.
Modified from Reger (2001).

Bañuls and Salmeron [8] considered ICT support in foresight to be an antecedent of foresight support systems (FSSs) which aim at supporting strategic decision making. This relates FSSs to decision support systems (DSSs), which share the same goal [9]. However, DSSs have been more adept in operational and managerial tasks thus far. Courtney [10] attributed this to the fact that DSSs commonly require numbers or similar 'hard' information as input, but stated that complex – or wicked [11] – problems of decision-making in modern society require more 'soft' or qualitative input. Foresight is usually an approach to tackle wicked problems (e.g. [12]) and, as a creative and group-based process, primarily relies on qualitative information. Thus, it is not surprising that foresight has lagged behind other – more operative – processes when it comes to incorporating ICT into professional processes. For example, Bishop and Collins [13] listed a number of scenario techniques, the vast minority of which involves ICT tools. In recent years, however, the transfer from academic thinking to actual employment of supportive software in companies' foresight processes has gained traction [8].

While overall ICT promises to be a driver for further development in foresight, it also seems probable that there are barriers and limitations to the adoption of ICT-support in foresight. The above argument already demonstrates that the more qualitative a process is the harder it becomes to support it with ICT. In addition, as is true for all DSSs, the sophistication of the FSSs cannot turn bad input into usable outcomes (cf. [14]). The complex nature of decision making environments poses various challenges for FSSs (cf. [10,15]) including non-linear interactions and influences as well as ethical questions such as accountability and responsibility issues. This shows that a structured conception of ICT's possible future contribution to foresight processes does not exist yet. The research at hand addresses this lack of conception, by aiming to aggregate expert opinions on the future role of ICT in foresight and projecting the resulting changes in foresight process execution.

As a structured group communication process the Delphi technique is appropriate to achieve this aim [16], especially since we were confronted with a situation of future uncertainty [17]. Fitting to the research at hand we employed an ICT-based real-time variant of the technique. It was conducted among 177 internationally renowned foresight experts from 38 countries. The participants were presented with 20 projections about the future role of ICT in foresight in 2020. The experts estimated the probability of occurrence for each projection. In addition, they rated the impact on the foresight profession if the projection was to occur, as well as the desirability of the projection taking place. By analyzing and discussing the results of this survey, we contribute to the systematization of research being conducted in the various fields of ICT-based foresight tools. We identify how ICT can drive progress in foresight, as well as reveal limitations to this development. Furthermore, we strive to encourage researchers to enrich their peers' work.

The remainder of this paper is structured as follows. The next section retraces the conceptualization of the projections posited to the Delphi panel. Thereafter, we outline the further methodological process employed for the Delphi study. We briefly state both the quantitative and the qualitative results of the Delphi survey. ICT-based drivers in foresight processes as well as limitations are identified before we draw conclusions.

2. Conceptualization and development of projections

The Delphi projections posed to the panel were arrived by through desk research, a series of three workshops among a team of foresight academics and a pretest by five further external experts from industry and academia in order to ensure clarity, completeness and understanding of the projections. This process verified the validity of the projections' content and ensured that major topics were not disregarded [18]. The projections were formulated based on the guidelines from Salancik et al. [19], which provide specific orientation regarding the optimal number of words and type of formulation required. The final set of projections is presented in Table 1 below. Furthermore, each projection subsequently deducted from literature.

During our review of literature, we observed that ICT-based tools have radically overhauled many business processes, such as supply chain management (e.g. [20]) or marketing (e.g. [21]), and have contributed to overall productivity growth (e.g. [22]). We also noted that progress in such technology continues according to Moore's law (the number of transistors on integrated circuits doubles roughly every two years). Even if the speed of progress should diminish [23], computer capacity will still increase significantly until 2020. Furthermore, since qualitative processes, such as foresight has not yet profited from large efficiency gains through ICT, progress hinges less on hardware but more on advancements in software development and social practices. Consequently, many authors believe this can significantly improve processes, outcomes and knowledge exchange (e.g. [24]). Simultaneously, prominent futurists have been calling for increased application of ICT in foresight and foresight has slowly started to be incorporated in DSSs. We, therefore, pose four projections (with short titles in parentheses) describing how ICT support has significantly penetrated the realms of foresight, as well as subsequent strategic decision making, and how product development in ICT-based foresight tools has continued to thrive:

P1 2020: Information and communication technology (ICT) has revolutionized the practice of futures research (Practice of Futures Research).

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Table 1
Summary of Delphi projections and short titles.

No.	Projection	Short title
1	2020: Information and communication technology (ICT) has revolutionized the practice of futures research.	Practice of Futures Research
2	2020: The demand for ICT solutions in futures studies has grown significantly over the past decade.	Demand Increase
3	2020: The product variety in ICT-based foresight tools has increased.	Product Variety
4	2020: Strategic decision making without support of ICT-based foresight tools has become an exception in the business context.	Strategic Decision Making
5	2020: The efficiency of future-oriented planning processes could be significantly enhanced by the application of ICT- based foresight tools.	Planning Efficiency
6	2020: The quality of foresight data for future-oriented planning could be significantly enhanced by the application of ICT-based foresight tools.	Foresight Data Quality
7	2020: The reliance on individual expert knowledge has diminished while the trust in group wisdom and collective intelligence is emerging.	Group Wisdom
8	2020: Futures studies have become very popular due to innovative ICT applications (e.g. web-based, real-time, social media).	Futures Studies Popularity
9	2020: Open foresight has become standard practice in business.	Open Foresight
10	2020: Internationally recognized quality standards have been established in futures research	International Standards
11	2020: An intelligent interconnection of ICT-based foresight tools (e.g. integrated software packages, harmonization of interfaces) allows for higher quality in future-oriented planning processes than individual ICT-based foresight applications.	Integration of ICT-Tools
12	2020: The reliance on ICT-based futures research has increased the amount of manipulated future-relevant data.	Data Manipulation
13	2020: Wise interpretation of futures-oriented knowledge, rather than its availability, has become the key challenge in the field of futures studies.	Data Interpretation
14	2020: ICT solutions have improved the ability to anticipate future developments of complex systems.	Anticipation of Complex Systems
15	2020: Automated decision-making by means of ICT-based foresight tools has become a standard procedure.	Automated Decision Making
16	2020: ICT-based foresight tools have eliminated problems of scenario transfer into strategy.	Scenario Transfer
17	2020: ICT-based foresight tools have largely displaced the market for futures consultancy services.	Consultancy Market
18	2020: The broader application of ICT in futures research has increased customers' need for futures consultancy services.	Need for Consultancy
19	2020: Non-ICT-based futures studies are applied for niche topics only.	Niche Topics
20	2020: The governmental surveillance of foresight communities has increased.	Governmental Surveillance

P2 2020: The demand for ICT solutions in futures studies has grown significantly over the past decade (Demand Increase).

P3 2020: The product variety in ICT-based foresight tools has increased (Product Variety).

P4 2020: Strategic decision making without support of ICT-based foresight tools has become an exception in the business context (Strategic Decision Making).

Shim et al. [9] reported that DSSs are usually designed to arrive at a decision more efficiently and to render this decision more effectively, raise the quality of the decision. This assumption can also be observed as the main goal of many authors researching ICT-based foresight tools. For example, Salo and Gustafsson [25] employed an Internet survey, as well as group support software, during a workshop to this purpose. In other examples, the substitution of paper-based Delphi surveys with real-time Delphi methods increases the efficiency of the process, while maintaining at least the same quality (e.g. [26,27]). This Delphi modification potentially improves the quality of the method because it is possible to seamlessly access experts from all over the world, as well as an overall larger number of participants. This benefit is noted by Dalal et al. [28], whose "Expertlens" system employed many elements of the Delphi method. Coates [29] also called for more cost-efficient, yet high-quality and reliable foresight processes and suggested involving larger numbers of people. Many authors praised the potential benefits of ICT tools for fast and efficient communication. It is also possible to flexibly adapt and substitute the experts involved in a process according to needs (e.g. [30]). However, ICT not only increases the number of experts that can be involved, but with data mining and web mining techniques, it also enables us to more efficiently analyze the large amounts of data available via databases and the Internet. For example, data mining has become essential in the prediction of bankruptcies (see [31] for a discussion of examples). Lee et al. [32] incorporated web mining into their statistical analysis of patent citation for technological forecasting. Chan and Franklin [33] employed data mining to retrieve textual data from financial news articles for financial sequence prediction that exceeds the commonly used financial data in quality. These findings prompt us to posit two additional projections.

P5 2020: The efficiency of future-oriented planning processes could be significantly enhanced by the application of ICT- based foresight tools (Planning Efficiency).

P6 2020: The quality of foresight data for future-oriented planning could be significantly enhanced by the application of ICT-based foresight tools (Foresight Data Quality).

The previously mentioned approach of involving a greater number of people with more diverse backgrounds, for example in Delphi applications, demonstrates that the wisdom of the crowds theory (cf. [34]) is a popular approach to improve data quality. This theory is based on the idea that group judgment is generally more accurate than individual judgment (e.g. [35]). In addition to web-based Delphi platforms, the practice of prediction markets is the main ICT-based foresight tool that relies on crowd input. Prediction markets make use of the Hayek hypothesis of efficient markets [36] in order to aggregate asymmetric knowledge provided by trading participants. Thus, the crowd opinion about a defined future outcome can be expressed in one market price. Numerous academic papers which examine prediction markets have been published (e.g.

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[37,38]) and the application has been successfully transferred to the business world (e.g. [39]). Furthermore, theoretical foundations have been continuously enhanced: for example Hanson [40] developed a mechanism to make prediction markets manageable for smaller numbers of participants. However, crowd wisdom does not always need to be direct input from participants in exercises or users of a certain platform or software. For example, Kostoff [41] only used the ideas behind crowd wisdom for his data mining approach. The author demonstrated that expanding text mining techniques to literature of different academic disciplines, thus incorporating unfamiliar and unknown reasoning in one's research, helps to anticipate and achieve radical innovation. Text- and data mining thus not only have the potential to raise the efficiency of foresight processes but also the diversity of input. The significant academic interest in applying crowd wisdom to foresight tools leads us to posit our next projection.

P7 2020: The reliance on individual expert knowledge has diminished while the trust in group wisdom and collective intelligence is emerging (Group Wisdom).

One of the principal barriers to harnessing crowd wisdom is a lack of participation (e.g. [42]). Only if people provide their knowledge to the question at hand, will crowd wisdom be generated. Consequently, incentivization – or the lack thereof – will be a major factor in deciding whether crowd wisdom can be successfully applied on a consistent basis. Servan-Schreiber et al. [43] demonstrated that this incentive does not need to be monetary in nature. If anything, intrinsic motivation proves to produce better results. Consequently, we assume that increasing popular interest in futures research would facilitate the data retrieval process for crowd-sourcing applications. Our corresponding projection therefore aims to determine whether this generic form of motivation will occur:

P8 2020: Futures studies have become very popular due to innovative ICT applications (e.g. web-based, real-time, social media) (Futures Studies Popularity).

For strategic foresight, the crowd-sourcing approach often necessitates that the foresight-practicing organization retrieves input from outside the organization. Several authors have suggested that the correct approach to achieve this should be to involve the direct stakeholders (for instance suppliers and customers) in the foresight process (e.g. [44]). This is comparable to the ideas of Daheim and Uerz [45], who - analogous to the term Open Innovation – label this approach “Open Foresight”. The link between developments in innovation and foresight has been made before (e.g. [46–48]). Therefore, we posit the next projection as:

P9 2020: Open foresight has become standard practice in business (Open Foresight).

Rinne [49] proposed an application that could qualify as Open Foresight as much as Open Innovation: He envisioned an electronic market for “Virtual Innovations” where innovations can be traded and integrated in technology roadmaps. The author argued that such a roadmap would facilitate innovation and support in understanding future directions of the developmental path. The electronic market could be used to disperse virtually conceived of but never realized innovations and future-relevant knowledge. Moreover, customers could provide feedback about future expectations and possible acceptance of technology. Rinne further laid out that such a market would require standardization in order to work. Increasing overall reliability and quality of data is a concern of several authors. Scapolo and Miles [50] discuss the difference of outcomes when using different methods. The fact that they also provide one of only very few examples (others include e.g. [51]) of direct comparison of different foresight methods shows the need for quality assurance. Similarly, Georghiou and Harper [52] reflect on the current status of future-oriented technology analysis and come to the conclusion that future research should aim for progress within the discipline e.g. by bringing in further insights from other disciplines as well as overcoming the epistemological divide between qualitative and quantitative approaches. While Pang [53] reviews a network approach to standardization, the most striking example is envisioned by Tetlock [54] who suggest a permanent panel to supervise and evaluate forecasters. We similarly see potential for improvement in quality assurance and accordingly posit projection 10:

P10 2020: Internationally recognized quality standards have been established in futures research (International Standards).

A great deal of research has been dedicated to improve foresight quality by combining multiple methods. The group of Michel Godet has long proposed a modular approach to foresight that combines the use of different tools (e.g. [55]). Bañuls and Turoff [56] aimed at ameliorating scenario quality by proposing to combine the Delphi method, Cross Impact Analysis and interpretive structural modeling to build coherent scenarios. Bañuls and Salmeron [57] additionally combined the multi-criteria and scenario methods. In a later publication, they designed a more complicated FSS that incorporates databases, communication, scenario software and a prediction market [8]. Similarly, von der Gracht et al. [58] created a foresight platform that combines quantitative and qualitative data in a trend database, a digital future workshop, and a prediction market application. Tseng et al. [59] argued that the combination of different methods provides a more holistic picture of future developments and thus combined scenario analysis with the Delphi method and the technological substitution model in order to assess future market penetration of OLEDs in the display market. This ongoing stream of literature leads to projection 11.

P11 2020: An intelligent interconnection of ICT-based foresight tools (e.g. integrated software packages, harmonization of interfaces) allows for higher quality in future-oriented planning processes than individual ICT-based foresight applications (Integration of ICT-Tools).

While analyzing the prospective quality of foresight data, we also strive to account for adverse developments. The example of the 2009 hacking of the Climatic Research Unit at the University of East Anglia (Climategate) demonstrates that the increasing prominence of a futures-related topic not only increases the scrutiny of data quality but also attracts malicious attacks. Such controversy negatively affects the reputation of a discipline [60]. The increasing reliance of organizations on

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cloud-computing additionally exposes them to security risks of their sensitive data [61]. Furthermore, especially if data-mining gains in importance, much futures-relevant data will be retrieved from databases, such as e.g. patent databases [62]. However, databases are challenged with data security issues [63]. We therefore formulate:

P12 2020: The reliance on ICT-based futures research has increased the amount of manipulated future-relevant data (Data Manipulation).

The previous projections aim at determining whether foresight data will be retrieved efficiently, at better quality, by whom and how it will be provided. However, as Coates [29] noted, foresight cannot use data to predict the future. Rather, it stimulates our creativity. As already discussed, Courtney [10] called for more qualitative input in DSSs, and an increasing amount of research on more qualitative and interpretive applications has materialized. For example, Robinson et al. [64] identified large potential in participatory backcasting software. With decision maps, Comes et al. [65] introduced a graphical component to futures-oriented decision-making software. Heinonen and Hiltunen [66] even used ICT to stimulate foresight thinking among colleagues during everyday situations and promoted creativity-inducing digital and virtual elements for “Creative Foresight Spaces”. We observe that the focus of ICT on foresight might have shifted and data availability could become a non-issue. In order to test this assumption, we project:

P13 2020: Wise interpretation of futures-oriented knowledge, rather than its availability, has become the key challenge in the field of futures studies (Data Interpretation).

A great deal of research is also dedicated to applying the strengths, namely computational capacity, to future-oriented, interpretative reasoning. Scientists trying to estimate the degree and results of global climate change have long used modeling of complex systems as their most important method (e.g. [67]). Macal and North [68] noted rapid progress in agent-based modeling and simulation (ABMS). They listed a number of exemplary applications and attest to its potential capability to support decision-making. Wondering why ABMS is not used by executive administrations, Farmer and Foley [69] argued that a full-fledged model-economy would help to anticipate future effects of present policies. Similarly, Ahmed et al. [70] criticized that modeling is not applied to scenario software. We accordingly posit:

P14 2020: ICT solutions have improved the ability to anticipate future developments of complex systems (Anticipation of Complex Systems).

With ICT delivering decision support, the question arises whether ICT will not only support the process but also make actual decisions in the future. For short-term decision-making, this is already a reality. For example, in modern Smart Grids, electricity prices are set automatically (e.g. [71]) and algorithmic trading on financial markets has long been common (e.g. [72]). Davenport and Harris [73] listed additional operative examples, yet also indicated that automatic decision making is likely to move further up the organizational hierarchy. However, for long-term decisions, automatic decision making seems more obscure and possibly hinges on the progress in Artificial Intelligence (AI). While they remain in the minority, at least some experts expect AI to reach the human level in the 2020s [74]. Rinne [49] already envisioned self-organizing technology. Embedded in standardized roadmaps, innovative technologies can automatically align themselves to fitting tasks, thus at least suggesting mid- to long-term decisions on a more informed basis than humans. Along this line of thought, we project:

P15 2020: Automated decision-making by means of ICT-based foresight tools has become a standard procedure (Automated Decision Making).

In a certain way, by automatically deriving consequences after analyzing the technology landscape, this approach by Rinne [49] also begins to automate the transfer from foresight to action. More generically, Gausemeier et al. [75] coined this process scenario transfer, describing it as the derivation of opportunities and threats from scenario analysis and the subsequent formulation of strategies and actions. Among others, additional approaches to employ ICT for scenario transfer rely on multi-criteria decision making (MCDM) tools: Campanella and Ribeiro [76] devised a MCDM framework flexible to dynamic circumstances, or, as previously discussed, complex modeling with the goal of identifying levers. At present, none of the described approaches are directly linked to scenario planning. However integrated tools, such as those described for projection 11, could quickly change this situation. Projection 16 consequently predicts:

P16 2020: ICT-based foresight tools have eliminated problems of scenario transfer into strategy (Scenario Transfer).

Due to the potential changes projections 14–16 could cause, the consequences for the practice of foresight should be considered. Currently, strategic foresight is often project-based and implemented by consultancies. While Rohrbeck and Gemunden [77] considered a combination of continuous processes and issue-driven projects to be best-practice, it might become common to apply easy-to-use and permanently available ICT-based foresight tools for continuous processes conducted in-house. This would have serious consequences for the existing market structure. Alternatively, it seems possible that the proliferation of ICT-based foresight tools might spawn a completely new demand for consultancy services, such as for maintenance, implementation and support. Our next two projections 17 and 18 consequently state:

P17 2020: ICT-based foresight tools have largely displaced the market for futures consultancy services (Consultancy Market).

P18 2020: The broader application of ICT in futures research has increased customers' need for futures consultancy services (Need for Consultancy).

The relegation of Non-ICT-based methods for foresight, such as participative workshops, future conferences and interviews, was a further apprehension derived from our workshop sessions. In many areas ICT-based activities already have or are threatening to displace non-ICT-based processes. Looking at areas such as travel agencies and book retailing for example, Goldmanis et al. [78] find a clear correlation in both fields from increases in ICT-based retailing and store closures and decreasing “face-to-face” retailing. Analogously we hypothesize that the rise of ICT-based foresight might lead to a demise of said Non-ICT-based methods and confine them to application in very specialized or non-mainstream areas. We therefore posit:

P19 2020: Non-ICT-based future studies are applied for niche topics only (Niche Topics).

Lastly, the workshop sessions revealed concerns about possible government surveillance of foresight tools and networks in case of fast development of ICT-applications and respective success. Impetus to this rationale came from a perceived rising tendency to curb critical web-based international debates as exemplified by the restrictive approach towards the WikiLeaks platform [79]. Overall, surveillance as a form of governance is in many eyes becoming more common (e.g. [80]). We therefore formulate our last projection as:

P20 2020: The governmental surveillance of foresight communities has increased (Governmental Surveillance).

3. Research methodology

The projections deducted in Section 2 were assessed by a panel of foresight experts via the Delphi method. As a foresight method, the Delphi method can be used as an interactive, structured process to consolidate the opinions of expert groups [16] and is based on three basic assumptions of judgment [81]: (1) group results are more accurate than individual results; (2) expert groups perform better than layperson groups; and (3) controlled and anonymous feedback of the group opinion leads to converging individual responses.

The Delphi method has been thoroughly studied and analyzed. Especially its validity and reliability have been criticized in the past (e.g. [82,83]). However, more recent research examined the results of numerous applications and showed that rigorous execution leads to valid and reliable results [84–86]. For the research at hand it was particularly important that the method is applicable to issues of high uncertainty [87]. Additionally, Delphi may overcome negative group effects, such as bandwagon or halo effects [17,88,89]. The survey used for this research was organized as an online real-time Delphi survey [26,27] in order to streamline the process, improve the convenience for participants, and facilitate a truly global survey. Participating experts assessed the projections according to three dimensions: expected probability (EP) on a scale of 1–100%; impact on the "foresight industry" (I) on a 5-point Likert-scale; and desirability (D) on a 5-point Likert-scale. Each dimension could be commented on, in favor of either a high or a low value. After providing their assessments, the experts received immediate feedback on the statistical group opinion, with a boxplot illustrating the mean and interquartile range (IQR). Moreover, participants had the opportunity to read other experts' comments. The portal was open for ten weeks and each expert could log in an unlimited number of times to review and contribute to the discussion and make revisions to previous decisions.

On the one hand, the reliability of a Delphi process can only be guaranteed if experts are properly selected [90,91]. On the other hand, diverse perspectives on the topic are needed in order to achieve the most accurate results in group judgments [92]. Therefore, we included foresight experts from universities, application-oriented research institutions, foresight consultancies, industry and administrative institutions. We pre-announced our survey at two of the key foresight conferences and subsequently invited all speakers and authors to participate:

- World Future 2011, Vancouver
- 4th International Seville Conference on Future-Oriented Technology Analysis 2011

Furthermore, we invited members of the following networks:

- Oxford Futures Forum 2011
- World Future Society
- Cambridge Futures Thinking Seminars
- Millennium Project
- Club of Rome
- Global Business Network

Additional invitations were sent out to speakers and participants of the following conferences:

- European Futurists Conference
- Stockholm Futures Conference
- 13th International Conference organized by Finland Futures Research Centre and Finland Futures Academy at University of Turku
- Symposium for Foresight and Technology Planning (Symposium für Vorausschau und Technologieplanung) in Berlin

Lastly, we invited the editorial boards of journals in the field of foresight and strategic planning:

- Strategic Management Journal
- Technological Forecasting and Social Change
- Long Range Planning
- Futures
- Foresight

Overall, 952 experts were invited to participate in the survey. Apart from the announcements at the above-mentioned conferences, all invitations were sent out via email; experts were reminded to participate twice. Overall, 177 experts from 38 countries[1] participated, equaling a response rate of 18.6%. The professional perspective of the participants was well mixed (see Fig. 2): 34% stemmed from universities, 30% from foresight consultancies, 15% from applied research institutions, 13% from industrial enterprises and 8% from administration. On average 2.9 logins and 11.8 written comments per participant (for a total of 2082 written comments with 1192 regarding expected probability, 420 regarding impact in case of occurrence and 470 regarding desirability of occurrence) indicate a high degree of involvement among all participants.

For the evaluation of the projections, we calculated the final means of EP, I and D, and the conversion rate from initial to final EP values. For EP, the IQR was used to determine the level of agreement among the panel, a measure in line with previous research [47,93]. We defined an IQR of ≤ 25 as consensus among the panel. Since we hypothesized that the professional

[1] Argentina, Australia, Austria, Azerbaijan, Belgium, Brazil, Canada, Chile, China, Denmark, Estonia, Finland, France, Germany, Greece, India, Iran, Israel, Italy, Japan, Korea, Kuwait, Mexico, Netherlands, Singapore, Slovenia, South Africa, Spain, Sweden, Switzerland, Taiwan, Tanzania, Thailand, Turkey, UAE, UK, USA, and Venezuela.

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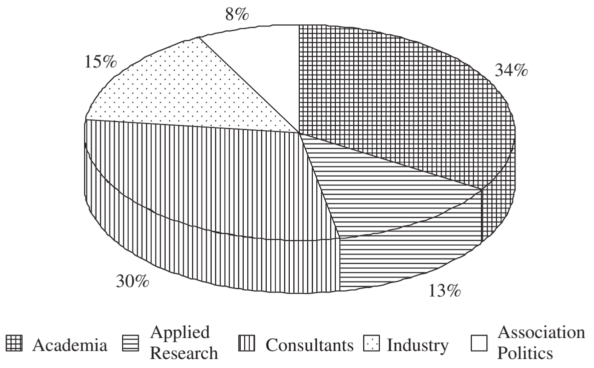

Fig. 2. Delphi participants by professional background.

background of the participants might bias the perception of ICT's role in foresight, we controlled for group bias. We employed a non-parametric Kruskal–Wallis one-way analysis of variance on all three dimensions of every projection.

In order to identify the underlying reasoning of the participants regarding the expected probability of occurrence, we additionally analyzed the comments given for high and low probability on all projections. Comments that just rephrased the stated projection were disregarded. The arguments were coded along the coding procedure from Corbin and Strauss [94] and subsequently aggregated into nodes. These nodes were then again aggregated into higher level tree nodes.

4. Results

The detailed results for all projections are summarized in Table 2. Almost all projections have an impact factor of 3 or higher (except for P19, which had an impact of 2.9), indicating that the chosen projections were considered as relevant for the foresight industry. All projections show convergence (indicated by the negative value), indicating that the Delphi process worked as intended. Consensus was achieved for nine of the 20 projections.

According to their expected probability of occurrence, we clustered the projections into five groups. We found three unambiguous expectations of occurrence (which we defined as EP > 70%), five projections with a high expectation of occurrence (EP > 60%) and five with low degree of expected occurrence (EP > 50%). On the other hand, three projections showed a low degree of expected non-occurrence (EP < 50%) and four projections a high degree of expected non-occurrence (30% < EP < 40%). The vast majority of results were not influenced by group bias. The Kruskal–Wallis one-way analysis of variance tested significant only for the EP (on a .05 level) and the desirability (on a .01 level) of P18 (Need for Consultancy).

The experts assigned a desirability of above three to most projections. Ecken et al. [95] demonstrated that this indicates that most posited developments are seen as opportunities. Only five projections – namely P12 (Data Manipulation), P15 (Automated Decision Making), P17 (Consultancy Market), P19 (Niche Topics) and P20 (Governmental Surveillance) – show a desirability below three and can thus be regarded as threats. One projection – P7 (Group Wisdom) – is rated with a desirability of exactly three and can thus neither be classified as an opportunity nor as a threat.

Through coding we identified 12 second level nodes with 67 first level nodes. Overall 1173 cases were coded.[2] Out of this amount, 648 cases were categorized as supporting ICT as a driver in foresight, while 525 cases put limitations to ICT as a driver in foresight. The detailed results of the coding process are presented in Table 3.

Table 2
Delphi projections and results.

No.	Projection (Short title)	EP	I	D	IQR	CV
1	Practice of Futures Research	63%	3.7	3.7	30	−7.9%
2	Demand Increase	*72%*	3.7	3.6	20	−6.8%
3	Product Variety	*76%*	3.6	3.7	20	−14.2%
4	Strategic Decision Making	51%	3.4	3.2	35	−2.7%
5	Planning efficiency	65%	3.6	3.7	30	−7.6%
6	Foresight Data Quality	63%	3.6	4.0	30	−2.4%
7	Group Wisdom	*53%*	3.4	3.0	25	−4.9%
8	Futures Studies Popularity	56%	3.6	3.7	30	−6.0%
9	Open Foresight	*49%*	3.6	3.7	20	−6.9%
10	International Standards	45%	3.2	3.6	30	−4.4%
11	Integration of ICT-Tools	62%	3.6	3.8	30	−1.9%
12	Data Manipulation	61%	3.5	2.1	30	−4.9%
13	Data interpretation	*79%*	3.8	4.1	20	−10.7
14	Anticipation of complex systems	55%	3.7	4.0	30	−5.7%
15	Automated decision making	*32%*	3.2	2.3	20	−10.9%
16	Scenario Transfer	*32%*	3.3	3.2	25	−8.1%
17	Consultancy Market	*30%*	3.2	2.2	20	−17.3%
18	Need for Consultancy	*58%*	3.5	3.3	20	−2.2%
19	Niche Topics	36%	2.9	2.4	30	−7.7%
20	Governmental Surveillance	47%	3.0	2.4	30	−6.8%

EP = Expected probability (0–100%); IQR = Interquartile range; CV = Convergence rate, i.e. percentage change in standard deviation between the first and final Delphi estimates.
I: Impact (5 pt. Likert scale; 5 = very high); D: Desirability (5 pt. Likert scale; 5 = very high).
Note: Italic EP numbers indicate that consensus among experts was achieved.

5. Discussion

The unambiguous expectations clearly demonstrate two things: Firstly, according to our global expert panel it is quite likely that foresight will be increasingly implemented and supported by ICT-based tools. This development will be accompanied by many new software packages and a more diverse set of methodologies for interactive use by the year 2020. Secondly, the focus of foresight in general and of ICT-based tools in particular will likely shift from gathering information about possible future developments to the actual interpretation of information and the subsequent derivation of strategies and actions. Today, merely imagining and scanning long-term future developments is already considered to be an asset. However, in 2020 cutting-edge users of foresight technology may have moved on and put an emphasis on more tangible results, such as recommended actions or roadmaps. This is in line with Pang [53], who discussed foresight tools and collaboration mechanisms among futurists that could quickly lead to more accuracy and subsequently to more usable recommendations for implementable action. In the following discussion, we consider the rationales for our findings. We

[2] This differs from the total number of comments. While some comments contained multiple codes, comments merely restating the projection were disregarded.

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Table 3
Second- and first-level nodes of qualitative coding.

Drivers			Limitations		
Second level nodes	First level nodes	#	Second level nodes	First level nodes	#
Accessibility		109	*Competition barriers*		25
	Access to experts	7		Enforced conformity	14
	Financial access	12		Intellectual property rights	11
	Foresight access	31	*Norm and value barriers*		112
	Information access	59		accountability	16
Collaboration		125		Cultural barriers to foresight	14
	Communication	13		Cultural barriers to ICT	21
	Enabling collaboration	25		Decision makers' bias	11
	Facilitation of group processes	19		Face-to-face bias	8
	Knowledge sharing	17		Generational barriers	11
	Social networking, online interaction	30		Organizational, personal inertia	12
	Wisdom of the crowds	21		Organizational barriers	19
Efficiency		58	*Qualitative discipline*		138
	Automation of processes	8		Human cognition	19
	Cost efficiency	5		Human execution	16
	Process optimization	30		Human interpretation	32
	Real-time effects	15		Human intuition	15
Linkages		120		Individual creativity	28
	Cross reference of data	13		Philosophical, qualitative challenges	28
	Dealing with complexity	13	*Support tools*		86
	Global perspectives	3		Human-made and -used ICT	23
	Knowledge combination	33		Fundamentals remain the same	30
	Method, tool combination	32		Missing fundamentals	8
	Multi-sector, -stakeholder perspectives	18		Support thinking	25
	Tool mergers	8	*Technological barriers*		164
Market		97		Data input	27
	Affinity to technology	5		False security	8
	Competitive differentiation	25		ICT maintenance	17
	Market demand for foresight	16		Individualization	21
	Market demand for ICT	21		Information overload	15
	Supply increase	5		Insufficient technological progress	12
	Visibility	25		Non-linearity	31
Progress		55		Trivialization of complex issues	33
	Computer power	17			
	New IC technologies	22			
	Overall ICT growth	5			
	Progress in foresight methodology	3			
	Progress to foresight towards science	8			
Quantitative data-handling		84			
	Modeling and simulation	30			
	Objectivity	28			
	Pattern recognition, data mining	4			
	Semantic analysis	4			
	Transparent processes	10			
	Weak signal detection	8			

identify the ICT-based drivers which will shift the focus of foresight processes as well as the limitations, as depicted in Fig. 3.

The high probability of occurrence for P1 (Practice of Futures Research) underlines the first finding in the unambiguous expectations. Furthermore, P1 (Practice of Futures Research), P2 (Demand Increase) and P3 (Product Variety) clearly interact and amplify each other. On the one side, only if the practice of futures research benefits from ICT demand, development of respective tools increase. However, the desirability score of P1 ($D = 3.7$) demonstrates that the experts regard ICT's role in foresight as an opportunity and thus as a positive development benefitting the discipline. On the other side, it is equally obvious that a more widespread application of ICT in foresight (as in more demand) and increased efforts in tool development are necessary for ICT to revolutionize the practice of foresight.

The results of the coding process further underline these findings. The direction of the practice and implementation of ICT foresight has long been characterized by an increasing focus on collaboration and participation. For example, the above employed definition of foresight by the European Foresight Platform includes both the words "*participatory*" and "*joint action*" [5]. Similarly, the node *Collaboration* clearly shows that the Delphi participants perceive ICT as a major enabler for working together. Technologies such as social media, chat programs and shared desktops drive have already developed today, yet the importance of this point is likely to lead to many more practical collaboration tools. *Collaboration* is amplified by the often mentioned view that convenient and financially affordable ICT tools will increase the *Accessibility* of future-relevant information and participation in foresight processes and thus lead to a growing number of contributors. *Market*

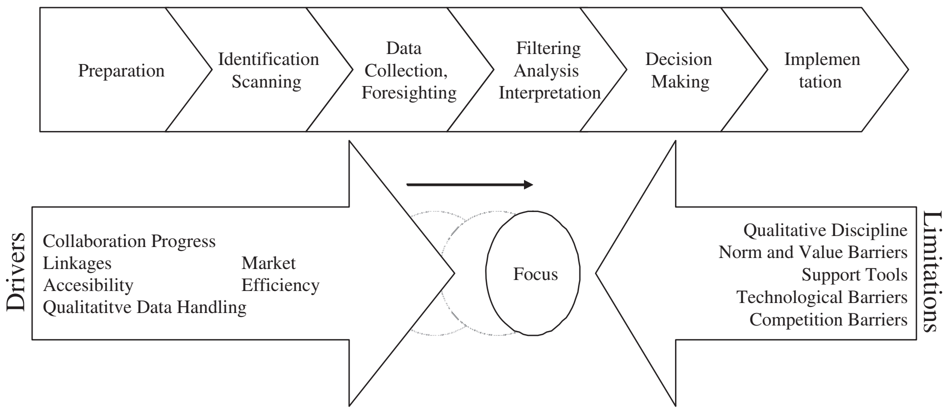

Fig. 3. ICT-based drivers and limitations to a shift of focus in the foresight process.

effects are also considered to be an overarching driver. Not only do a growing foresight market and a rising ICT affinity point towards higher demand, but also increasing competition and the resulting need for product differentiation should lead to higher supply and a higher product variety (*Market*). In addition, the *Progress* in ICT-based foresight tools is associated with further method and tool development.

The developing focus on data interpretation can predominantly be explained by considerations stemming from the highly expected occurrences. Increases in planning efficiency (P5), as well as in data quality (P6), lead to a shift of attention from challenges of data retrieval to the utilization of data in later stages of the foresight process. Gains in *Efficiency*, and thus an increased focus on more cognitive tasks, are mentioned throughout the comments of the Delphi survey. The node *Efficiency* includes expected process optimization as well as time savings, achieved through automation of processes or real-time calculations and communications. Meanwhile, the results of P11 (Integration of ICT Tools) suggest that much of these gains in *Efficiency* and quality will be achieved by integrating various foresight methods with one another. It can be argued that the integration and combination of tools lead to effective triangulation of questions, aggregating the findings of multiple methods. This aspect is underlined by the node *Linkages*. Many experts expect that ICT will be a major driver in achieving an effective combination of different kinds and sources of knowledge in foresight. This includes combining data from different sources, analyzing data with different methods and linking knowledge from different sectors, disciplines and experts, whose interconnection among each other via ICT was also identified as a driver in foresight data quality (*Collaboration*). Similarly, the code *Quantitative Data Handling* exemplifies that a higher usage of data mining, quantitative modeling and simulations in foresight could increase accuracy and credibility of foresight exercises. This situation would presumably be true even with today's capabilities, but the EP of 55% for P14 (Anticipation of Complex Systems) additionally signals that modest progress in this area can be achieved until 2020. However, regarding the code *Technological Barriers* two constraints to this driver can be identified: the outcome quality of quantitative calculations depends on the quality of data input; and non-linear developments cannot be modeled.

Looking further, it is more contested if crowd wisdom will contribute to an increase of quality in foresight data. The results put the EP of P7 (Group Wisdom) only slightly above 50%. Combined with the neutral desirability score (for a discussion of the interaction of EP and desirability in Delphi studies see [95]), this result indicated that despite the considerable hype about crowd wisdom, skepticism remains high and thus considerable obstacles remain for the implementation of respective tools. While the coding identifies ICT's ability to reach groups and enable *Collaboration* as drivers, the continued reliance of foresight as a *Qualitative discipline* on individual creativity is similarly identified as a contradiction. Generally, crowd sourcing is considered to be a complementary addition to expert knowledge. Especially for important decisions, only a gradual increase in the application of crowd sourcing should be expected. Similarly, P9 (Open Foresight) shows that open foresight and the broad and interactive involvement of stakeholders in the foresight process will likely remain the exception rather than the rule, even though ICT is considered to drive *Linkages* and *Collaboration*. *Norm and value barriers*, such as a generational bias of decision makers against ICT and against an "open-source" culture, are poised to slow down this development. Especially the latter bias corresponds to competition concerns by established management: knowledge sharing and reliance on crowd wisdom could damage intellectual property of the firm and lead to conformity of all companies in a given market (*Competition Barriers*). Overall, the EP for P8 (Futures Research Popularity, 56%) similarly suggests that the involvement of many non-experts in foresight processes will only increase gradually.

Both the continuing reliance on expert knowledge as well as the expected fragmentation of the market explain the experts' belief that foresight consultancies will thrive. The result for P17 (Consultancy Market) demonstrates a clear expectation that ICT-based foresight tools will not threaten the consultancies' market position. They will not only profit from increased demand for foresight and growth of the discipline (*Market*). The point is also underlined by the *qualitative nature of the discipline*, which demands that results and data from tools be further interpreted by humans. Human creativity is needed to derive action from these interpretations. For small and medium-sized enterprises without specific foresight capabilities, foresight will likely be performed by consultants,

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especially as the implementation of tools often requires deeper knowledge of the topic and may be work-intensive (*Technological Barriers*). The latter point is underscored by the results of P18 (Need for Consultancy), which suggest a mild expectation of ICT-based foresight tools increasing the demand for consultancy services by 2020. However, it is important to note that this last projection was subject to significant group bias, indicating that the EP might be somewhat overestimated, especially by participating consultants.

The results also reveal three major barriers to the expected increase in foresight process sophistication. First, EP for P10 (International Standardization; 45%), suggests that the proliferation of foresight tools will most likely have to be achieved without the installation of internationally recognized standards. The coding additionally shows that experts place too much emphasis on creativity (*Qualitative Discipline*) in order to succumb to the rigidity of standard-setting. The lack of this development threatens to lead to a more fragmented and inefficient market in ICT-based foresight tools than could be potentially achieved. Second, the expert panel determines a high probability of widespread data manipulation (P12, EP 61%). On the one hand, this might be explained by routine manipulation necessary for data processing. On the other hand, the higher visibility of foresight (*Market*) driven by ICT tools as well as the objectivity (*Quantitative Data Handling*) usually assigned to data-based results increase public-relation incentives for companies and other stakeholders to withhold important future-relevant information from the public (or to fabricate flattering information). Third, while the EP for P20 (Governmental Surveillance) remains below 50%, a distinct possibility exists that governmental surveillance of the profession may curb the creativity and the innovativeness of practitioners and enforce conformity in thinking and execution (*Qualitative Discipline, Competition Barriers*). In times of rising uncertainty, the results and methods of the private sector gain attractiveness for the public sector as well. Some experts also argue that governmental commitment to foresight might do more good than harm. However, the desirability score of only 2.4 proves that the majority of experts regard it as a threat rather than an opportunity.

Overall, this discussion demonstrates that ICT will be a future driver for certain parts of the foresight process. As a result, foresight will become more result and interpretation oriented. What is less clear, however, is the prevalence of important decisions that are taken with the support of ICT-based foresight tools. Klein [96] reported that in 2002, 90% of all critical decisions were made by intuition or “gut” feeling. For 2020, the EP of P4 (Strategic Decision Making; 51%) suggests that the employment of DSSs may have risen considerably, but might not yet be routine. Accordingly, the qualitative data of the Delphi shows that many experts believe that human intuition (*Qualitative Discipline*) will still be the deciding factor in decision making in 2020. Furthermore, it is likely that accountability issues, inertia, organizational barriers such as power politics and decision makers' pride and joy of independent decision making may hinder objectively helpful decision support (*Norm and Value Barriers*). Accordingly, the more extreme projections of the survey – namely P15 (Automated Decision Making) and P16 (Scenario Transfer) receive very low EPs. Their occurrence would go much further in curbing decision-makers' influence. This argumentation is complemented by skepticism towards the technical feasibility of the projections. In addition to the result of P19 (Niche Topics), which demonstrates that experts are quite certain that non-ICT-methods will continue to be used besides ICT tools in every topic and discipline, these results clearly show that foresight will likely remain a people's business by 2020.

The three codes *Qualitative discipline*, *Support tools* and *Technological barriers* underscored the previous argument. Especially foresight tasks that require human cognition, interpretation, creativity and execution face technological barriers that will probably not be overcome in the foreseeable future. This situation includes the unpredictability of non-linear processes handled in many foresight exercises and the tendency of quantitative approaches to trivialize the problem at hand. At the very least, automation of certain task will have to wait until significant *Progress* in Artificial Intelligence occurs, a degree of technological progress unlikely to be achieved by 2020. The coding identified the support function of ICT as an important limitation of ICT as a driver in foresight. Foresight methods remain the fundamental basis for foresight processes — ICT can only increase the *Efficiency* and the quality of these processes. This argumentation underlines the strongest finding of this study, namely that ICT has the potential to facilitate foresight data retrieval, but cannot solve the challenge of interpreting and further using this data (P13).

6. Conclusion

In the research at hand, we developed a set of projections about the future role of ICT for futures research, which was evaluated by a global panel of distinguished foresight experts. We revealed that ICT will be a driving force in the future development of foresight, both for process efficiency and effectiveness. In particular, ICT will drive developments in foresight via the seven drivers (1) *Accessibility*, (2) *Efficiency*, (3) *Collaboration,* (4) *Linkages*, (5) *Quantitative Data Handling*, (6) (ICT-) *Progress* and (7) *Market*. However, this development only functions in the boundaries, which we have identified as the *qualitative* nature of the *discipline,* the *support* function of ICT-tool as well as *competitive barriers*, *technological barriers* and *norm and value barriers.* While the drivers ease the tasks of obtaining and working with data, the boundaries mostly apply to the more qualitative tasks of foresight that transfer to action and responsibility. The focus of foresight practitioners should thus shift from the scanning stages of the foresight process to the latter stages of interpretation and decision making. Consequently, qualitative foresight approaches and methods should receive increasing attention in both practices as well as research and method developments. These findings demonstrate that foresight is likely to remain a very people-oriented process. Especially (strategic) decision making will, at most, be supported by ICT tools. However, overall this development should transfer ICT-based foresight tools further in the direction of DSSs. By integrating them into DSSs and with each other further focus is placed on the emerging research stream on FSSs.

As with any research, this study is limited in several dimensions. First, biases in the expert panel cannot be fully accounted for. Analysis showed minimal bias according to the professional background. Geographical bias in evaluation was not accounted for. Preliminary testing shows that there are

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some differences in assessment among participants from different continents (and thus presumably different foresight schools). Analyzing these differences would be promising for further research. Second, our findings are limited to the extent of the 20 projections. Future research might expand the scope of the study beyond the contents of our projections. The research at hand was designed mainly to identify drivers for foresight processes resulting from ICT implementation. Moreover, insights concerning specific tools and developments would also enrich future research.

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