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ABSTRACT

Business Intelligence aims at providing decision support based on available information and tailored to the recipient's context due to the level of aggregation and form of delivery. The future internet will dramatically broaden both the spectrum of available information and the user's possible contexts. Further, we do not only expect a quantitative dart but a qualitative switch which will require the application of new methods and paradigms. This paper's aim is to systematically analyse implications of the future internet on Business Intelligence in order to identify possible perspectives, chances and risks for BI and vice versa by summarizing and categorizing current research.

Keywords

Business intelligence, future internet, ubiquitous computing, web 2.0, social software.

INTRODUCTION

Our research group has been working in the context of the traditional business service called Business Intelligence for more than two decades. BI is an established and accepted research field and important part of many companies' IT infrastructure. As it sees itself, BI is the central institution for the acquisition, processing and dissemination of management related and relevant enterprise information (Negash and Gray, 2008). Today, we see the steadily rising importance of Internet technology including Web 2.0 applications. It has already reached business applications and it can be assumed that the 'Future Internet' will have significant impact on IT infrastructures. As all business needs performance measurement, management and control (Otley, 1999), the important question here is: where is BI in this picture? How does that fit to data warehouses and management dashboards? Will BI adopt these trends and see evolutionary change? Or will these new trends appear in such a disruptive manner that BI misses the connection?

In the remainder of our contribution, we are going to explore these questions in detail. Our aim is to shape the idea of how BI will look like in the time of the 'Future Internet'. In doing this, we start by discussing existing trends in BI. Afterwards, we develop an overview on trends driven by the Future Internet, which could change IT substantially. After building the discussion's foundation by clarifying both BI and Future Internet, we apply a deductive approach in order to identify possible implications on BI which go further as current trends. We underpin our findings with examples – where existing – and complete the paper with a comprehensive and critical conclusion.

CURRENT TRENDS IN BUSINESS INTELLIGENCE

Technological innovations build the basis for the functional capabilities and the organizational significance of next generation BI solutions. This section elaborates on technically triggered trends in BI. We conducted a broad inspection of BI related publications within the current literature landscape focusing on papers published from 2006 to 2009. The identified trends were clustered according to their effects on the three perspectives of BI, technology, (business) functionality and organization, as described in the Business Intelligence Maturity Model (biMM) proposed by Chamoni and Gluchowski (2004). The biMM differentiates the maturity of BI solutions applying 94 criteria, evaluating key processes and practises.

From a *technological* perspective next generation BI is being shaped by the commoditization of IT-infrastructure (Carr, 2004). Specifically the general availability of broadband internet access (Savage and Waldman, 2005) and cloud-based computing resources (Benlian, Hess and Buxmann, 2009) as well as next-generation database technology (Zukowski, Heman, Nes and Boncz, 2006) and the spread of stream processing environments (Etzion, Chandy, Ammon and Schulte, 2006) will open up new horizons for architecting BI systems.

These technological innovations may trigger *functional* changes. Real-time monitoring can support situation awareness of front-line managers by displaying the current status of business processes in situ (Delic, Douillet and Dayal, 2001), forming the basis for what is generally referred to as operational intelligence (Arnett, 2009). Predictive analytics subsume statistical algorithms and mathematical techniques which are applied to the discovery of trends and predictions based on historical data. The maturation and proliferation of data mining tools reduces complexity and complicatedness of the tasks at hand for applying those methodologies. No wonder ambitious research already aims at incorporating them into operational business processes (Felden and Goeken, 2009; Muehlen, Indulska and Kittel, 2008).

A massive *organizational* shift may derive directly from the capabilities provided by these technology-based functionalities. While BI traditionally has focused on providing information in a long-term, strategic-level context, the vision of a "BI for the masses" (Microsoft, 2002) is getting into the realms of possibility. Once the limitations of IT for processing vast volumes of data vanish, the means of BI can be applied on and provided for operational decisions. New levels of automation might become tangible reality, introducing both: increased agility and adaptability (Azvine, Cui, Nauck and Majeed, 2006) as well as disruptive changes and challenges into the organizational fabric (Parasuraman, Sheridan and Wickens, 2000).

RELATED WORK

There are isolated and rather ad-hoc approaches that deal with the utilization of Web 2.0 technologies for business intelligence. Thus, the concept of "social business intelligence" aims to a) combine user forums, wikis and blogs that store unstructured content with structured data warehouse data to derive valuable and actionable statements (Löser, Hueske and Markl, 2008). Concerning this, significant technological challenges have to be overcome for successful and practical applications (Löser, Hackenbroich, Thu, Berthold, 2008).

Ferguson focuses on deployment scenarios for mash-ups in business intelligence applications (Ferguson, 2008). The discussion of the underlying technologies still shows the required solution complexity, which should largely remain invisible to the user.

Czernicki announces next-generation Business Intelligence under the short form BI 2.0, as he linked the integration of Web 2.0 and business intelligence technologies with agile development methodologies and service orientation (Czernicki, 2009). In this way we are to address a broad range of end-users through the use of intuitive interaction possibilities and to free them from tedious, routine data-related tasks. Howson takes up interactivity termed as Rich Reportlets and points out that Web 2.0 technologies can help to design BI interfaces in a more appealing way in order to better fit to user tasks (Howson, 2008).

The next section will examine Future Internet Business Services identifying transitional changes in four perspectives before we integrate the results in section 4.

FUTURE INTERNET BUSINESS SERVICES

Future Internet is a broad term which is used in manifold contexts. For the aim of this paper we do not refer to highly-speculative visions or basic technical improvements in terms of communication and protocols. In fact we focus on rather conceptual developments of the Internet which will occur in the next years, and the dawn of which is already observable. In order to discuss the Future Internet we refer to a conceptualisation of (Stocker, Griesser and Tochtermann, 2009), who suggest the four areas of People, Content, Things, and Services as the major categorical domains being affected by the anticipated developments.

Internet of People

A main attribute of current trends in the internet is the involvement of people. This phenomenon is well-known as web 2.0 (O'Reilly, 2005). A key concept of web 2.0 is the '*prosumer*', which means a system's user who a) is able and b) is motivated to contribute content to this system. Popular examples are Wikipedia or YouTube, which mark a significant shift from publisher-driven information supply towards user-driven information pools. This trend can be summarised with 'people as creators and actors', which often is the basis for whole business models (e.g. *Crowdsourcing*; Huberman, Romero and Wu, 2009)).

Beyond that, based on the prosumer *Wisdom of the crowds* (Surowiecki, 2005) names the possibilities which arise from the wide availability of user-driven information. For example, a single Tweet at the microblogging service Twitter might not have great impact. However, if many users post similar emotions or opinions, this can lead to a broad picture. Surowiecki introduces Wisdom of the crowds as a natural phenomenon which is independent from internet technology. However, especially the concepts of web 2.0 support these effects as it allows location-independent crowds to get visibility.

An important foundation for these trends and in the same time the result of the discussed developments is the *digital native* (Prensky, 2001). Today's young people have grown up in the digital world with video games, YouTube and Facebook. It is natural to them to use browser-based technologies and many of them have other attitudes towards personal data security and skills to deal with information overflow. It seems reasonable that people with this background will have other expectations towards information systems especially in the company they work compared to *digital immigrants*. Therefore, organisational and technical developments which consider these trends can be summed up with the claim *Enterprise 2.0*.

Internet of Content and Knowledge

The whole internet is about content. HTML is a language for representing content and Hyperlinks were created to enable content linking. Since the beginning of the internet it has been used for sharing of information and knowledge. With its mass of today's prosumers knowledge sharing on platforms like Wikipedia, Yahoo Answers or Twitter reaches new dimensions (Adamic, Zhang, Bakshy and Ackerman, 2008). While a *culture of knowledge sharing* is one of the main challenges in professional knowledge management (Huber, 2001), such culture seems to have been established in the internet automatically. It can be assumed that this trend will broaden in the Future Internet, abolishing copyrights and access restrictions (e.g. Open Access for academic publications, Creative Commons licence for content created by prosumers).
Early there have been initiatives to provide a better representation of Web content. Especially *Semantic Web* and *Linked Data* are approaches to enrich the Internet experience. While it still cannot be spoken from a broad application of these ideas in the public Web, these well-developed technologies are used in manifold use cases. A different approach to structure content bottom-up is *tagging*. Using tagging, users can assign free bywords to content in order to enrich it with meta-data. While tagging comes with problems in terms of synonyms, typos and missing semantics, user adoption of the approach is high. A recent example is the adoption of so-called hashtags on Twitter (Böhringer and Gluchowski, 2009). While Twitter did not support tagging, users created their own tagging mechanism in marking tags in their posting using a '#' symbol in front (e.g. '#AMCIS10'). Finally, Twitter added UI support for these hashtags.

In a Future Internet with broad adoption of tagging or semantic technologies, we can expect to see more intelligent possibilities for knowledge retrieval. An impressive demonstration of such use cases is the search engine Wolfram Alpha, which does not only search for full texts but tries to understand the query and provide additional information based on its semantic meaning (figure 1).

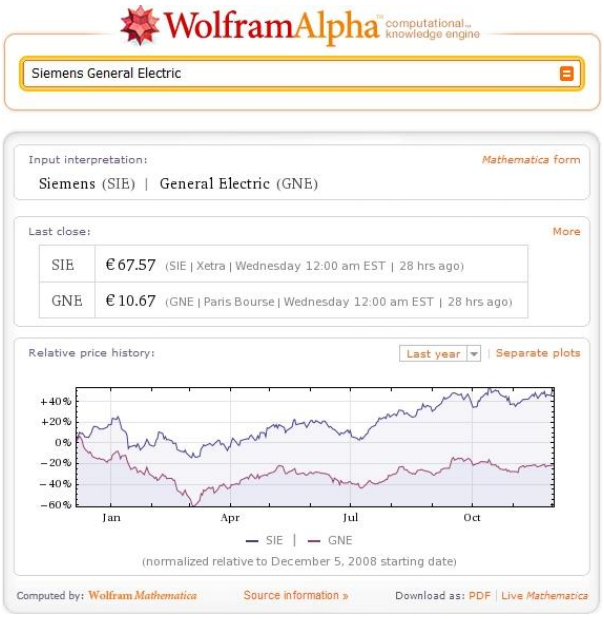

Fig. 1. An example of a Future Internet search engine.

Internet of Things

The vision of the *Internet of Things* comes along with other research claims like Ubiquitous Computing, Pervasive Computing and Ambient Computing. In general, they stand for a world where artificial computing devices are everywhere in the real world (Abowd and Mynatt, 2002). It is a world of ubiquitous sensors and intelligent agents. Weiser (1991) stated that "the most profound technologies are those that disappear", which means that the goal is to hide the underlying complexity from the user. While Ubiquitous/Pervasive Computing focuses on the broad availability of computing devices, Ambient Computing can be described as broader term including Artificial Intelligence and Human Computing Interfaces (Augusto, 2007). Along with the inflation of daily live and environments with computing power comes the broad availability of infrastructure (e.g. Wireless LAN, UMTS).
The Internet of Things provides great opportunities for information systems as they can access manifold information and therefore develop own 'senses'. However, a world with tremendous numbers of connected things might question traditional management approaches. Especially in organisations, where top-down approaches are common, huge challenges could arise. It can be assumed that the Internet of Things combined with other discussed trends like the prosumer and a culture of knowledge sharing will lead to a *decline of hierarchies* and the *decentralisation* of information creation, management and usage. Bottom-up and systemic management approaches might be an appropriate answer.

Internet of Services

The Internet is developing towards services orientation on all levels. At the technological basis *Cloud Computing* can be considered a main trend for the next years. The complete virtualisation of content hosting and computer power in a global cloud or grid allows application developers to think beyond capacity and bandwidth restrictions.
On the application level, service orientation is on its way to be standard for new information systems. *Open API*s and especially the REST paradigm are key parts of the web 2.0 definition. Well-known services like Facebook and Twitter but also small and highly specialised services like the todo-list service "Remember the milk" provide their functionality via open interfaces. Combined with the possibility of *mashups* this also leads to a service-orientation on the end-user level. Users do not have to choose a complete suite of functionalities. They can pick highly specialised applications which fit their needs and combine them to their personal application landscape. These developments enable whole new business models for small services which do not have high value stand-alone but in combination with others (Facebook or Twitter applications are an example for such application ecosystems).

An explanation model for these developments can be found in the concept of the *Long Tail* (Anderson, 2006). Due to the low costs of providing a service in the Internet and the broad availability of possible service consumers, even highly-specialised services can be successful and fill a niche. As a result of this trend it seems reasonable, that consumers will develop more specialised wishes and demands (Brynjolfsson, Hu and Smith, 2006).

THE ROLE OF BI IN FUTURE BUSINESS SERVICES

Business Intelligence and Future Internet have a two-sided, intertwined relationship with both concepts mutually influencing and impacting each other. First of all, technologies, applications and individual as well as organizational behaviours accompanying the Future Internet might change the way BI is done in a radical manner. On the other side, we argue that BI, proliferating its analytical methods and applications, is an enabler for the Future Internet, which could not develop without BI. In order to elaborate these two theses we are going to discuss the presented four fields of Future Internet in the context of BI. We will include current research and, where existing, examples from real-world applications.

BI and People

Business Intelligence is intended to provide management and decision support. Therefore it has always been targeting users i.e. 'people'. Hence, the massive developments towards a people-based Future Internet can be expected to have significant impact on BI. From a BI point of view, the prosumer can be seen as great chance to develop analysing and report quality. If users contribute their knowledge like explanations for KPIs, reasons for local developments and future predictions, a BI system using these contributions could benefit. However, this implies that the conditions for prosumer activities are complied. In section 3 we discussed that users a) have to be able and b) have to be motivated to contribute information. Both represent great challenges.

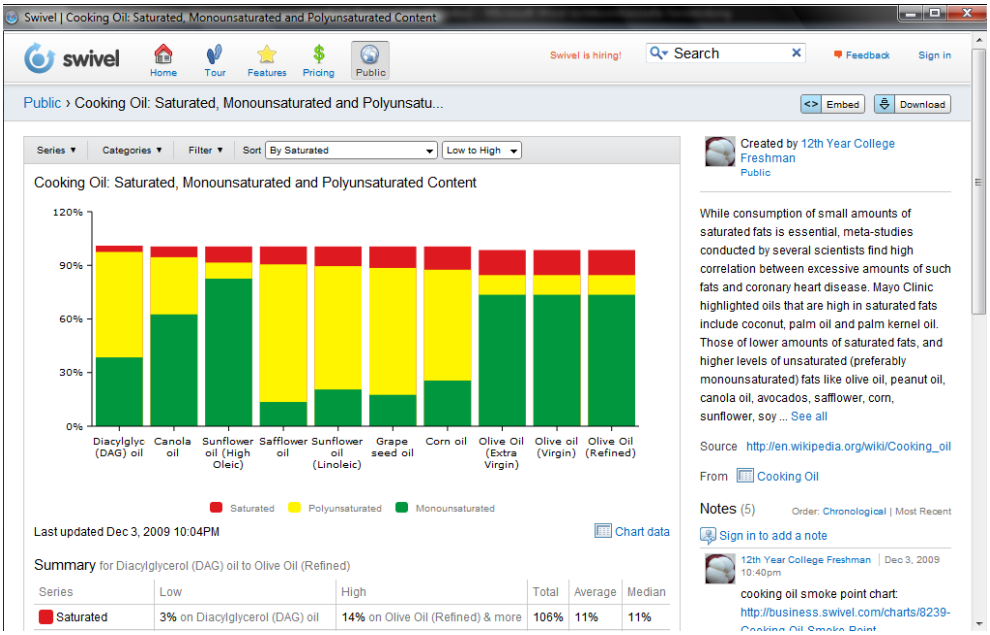

Fig. 2. 'YouTube for data', a possible approach for BI crowdsourcing.

How can user-created and therefore possible incorrect and inexact content be integrated with well-structured and proven financial data? If people only are allowed to give comments, is this enough motivation for them to participate? The particular value of the prosumer idea lies in Crowdsourcing. However, in thinking of financial planning this would imply that a broad user base can have access to these numbers and the right to change or at least annotate them. Who is responsible for this data? Is it acceptable that the numbers have been created by the 'crowd'? This trend of *BI crowdsourcing* raises many questions. A possible solution could be to crowdsource not the whole BI process but different parts of it. For example, figure 2 shows a screenshot of Swivel (http://swivel.com), a service which can be described as 'YouTube for data'. Everybody can upload data and – more important – a broad range of users can analyse and comment it as the underlying data sources are publicly available. A similar approach is the foundation of data.gov (http://data.gov), the information platform of the American government.

Another way of BI recognising the growing importance of people in the Future Internet could be the explicit usage of the Wisdom of the Crowds principle. In increasing extent peoples activities will be visible in web-based media like wikis, social networking services or microblogs. There lies an obvious benefit in utilizing this data for BI. A good example for the future roadmap in this topic is the microblogging service Socialcast (http://socialcast.com). Figure 3 shows an approach which Socialcast has called *Social BI*. This BI solution provides analyses like current trends and most active users based on microblogging postings. It can be easily thought of extended use cases till extreme scenarios like real-time company monitoring using emotion recognition and opinion mining (Pang and Lee, 2008).

Finally, to meet the trend towards digital natives future BI applications might have to include other concepts known from web 2.0 like recommendations, social networking (between BI users) and tagging. An existing research work with a prototype for such a vision of *BI Social Software* can be found in (Böhringer, Gluchowski, Kurze and Schieder, 2009).

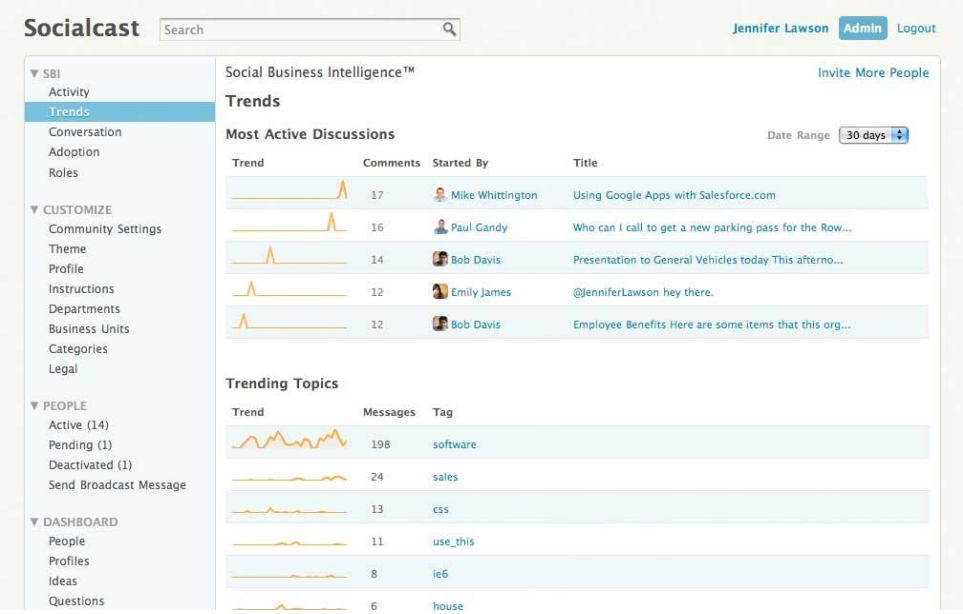

Fig. 3. An example for a Social Business Intelligence.

BI and Content and Knowledge

The integration of BI and knowledge management has been announced in existing research work (Cody, Kreulen, Krishna and Spangler, 2002). We expect this trend to broaden in future. More precisely, in a people-enhanced BI system as described earlier, BI is part of Knowledge Management (*Knowledge Intelligence*) as it provides a platform for the externalisation of people's knowledge.

We propose that developments of the Future Internet of Content and Knowledge on a technical side will have significant impact on classic BI. BI traditionally deals with well-structured data. Of course it will need to adopt approaches from Semantic Web if it wants to leverage and integrate user-created content.

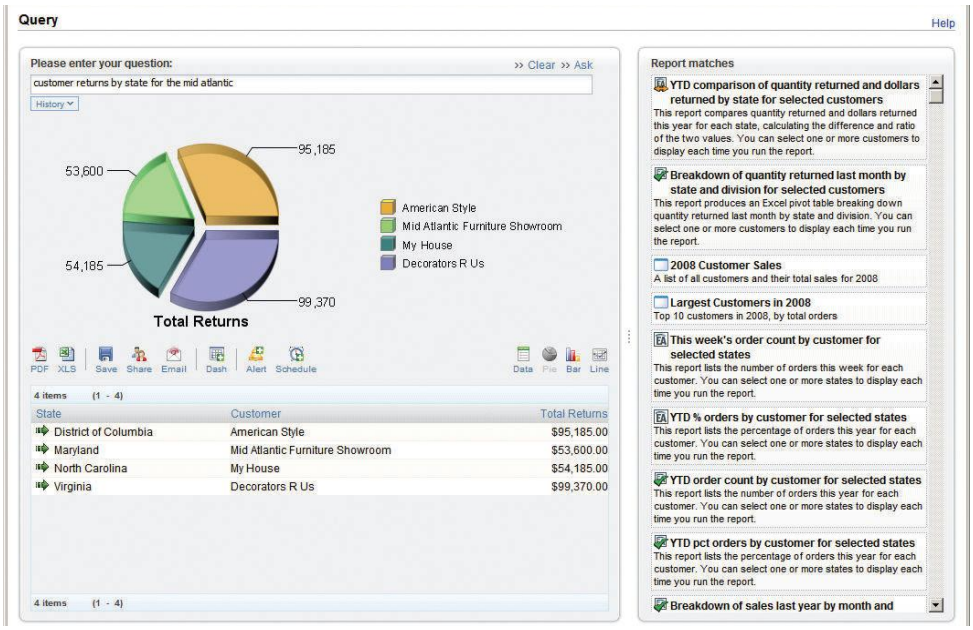

Fig. 4. An example of a BI interface for natural language queries.

However, in saying that BI at its core is very well-structured, it might be surprising that only slowly user-friendly interfaces occur. The SAP BusinessObjects Explorer (Elliott, 2009) or the Progress EasyAsk BI Studio (see figure 4) are examples which provide similar functionality as Wolfram Alpha for business data. We expect increasing activity towards such easy-to-use *Answer-focussed BI* applications which provide content-based answers instead of forcing the user to think in technical concepts like cubes and dimensions. The technology side of BI, though, will benefit from Semantic Web developments. A number of research works already exist in this area of *Ontology-based BI* which mainly aims at managing BI architectures using meta-models and semantic concepts (Kurze, Gluchowski and Böhringer, 2010; Sell, Silva, Beppler, Napoli, Ghisi, Pacheco and Todesco, 2008).

BI and Things

Obviously, a world of Ubiquitous Computing will lead to *Ubiquitous Sensing.* Massive amounts of data on customers, employees and all kinds of business activities will be available at mirco-level and in real-time (Fano and Gershman, 2002). This trend demands for new methods of integration and Information Fusion (Xiong and Svensson, 2002). Such methods could become part of BI requirements which lead to the need for ubiquity of BI support to control and monitor things (Gagnon and Cakici, 2008). First impressions of these developments show current RFID-based solutions for stock monitoring or goods tracking. While very detailed data analyses are possible, such applications face challenges when it comes to large data volumes and dynamic changes (Wang and Liu, 2005).
We label this trend *Ubiquitous BI*. This concept works two-ways: not only will BI have to source information ubiquitously, it will also have to deliver context information in manifold scenarios, which includes usage with mobile devices at the front-end side.
We already discussed implications of the massively increased numbers of information sources in the Internet of Things. Decentralised management approaches might be an appropriate answer which therefore would also impact BI (Fisher, 2008; Ischy and Simoni, 2002). The resulting trend of *BI decentralisation* in the understanding of 'democratised' information creation, classification, analysis and usage corresponds with our findings in the Internet of People section. In a further step this leads to the demand that also 'things' have access to BI functionality and are able to conduct analyses and react independently. Learning-enhanced Rule-based systems could be an appropriate answer.

BI and Services

The trend towards Cloud Computing already has arrived in the BI domain. Several vendors provide *Cloud BI* in form of SaaS offerings (e.g. http://kapowtech.com/, http://www.gooddata.com/) or specialised cloud services (e.g. http://zementis.com/, http://www.strikeiron.com/). Especially the latter can be also seen as examples for Embedded BI, which means the availability of (highly specialised) Business Intelligence functionality in other applications via APIs. Ad-hoc-orchestration of functionality with mashups is one possible future scenario.

On the user-side this might to the availability of BI functionality to a much broader user base (*BI as a Service*). Following the principle of the Long Tail it can be subsumed that this must lead to more specific solutions for individual users and therefore the need for customised or customisable applications. Based on this observation, it can be subsumed that the architecture of future BI solutions will change significantly. Due to the Long Tail approach it seems unlikely that we will see monolithically BI suites by big vendors dominating the market like today. In contrary, we expect future BI applications being ecosystems of highly-specialised components which can be combined for individual needs. As a result, this leads to a need for new business models and consulting strategies in the long term.

DISCUSSION AND OUTLOOK

Table 1 summarises our findings. To sum up our discussion, the most important driver for future BI seems to be the Future Internet of people. Especially the top-down thinking and expert-centric BI domain will see a tremendous challenge to meet these developments. On the other hand it can be argued, that such expected masses of available data only can be managed appropriately using BI. The existence of BI technology in a picture of future business therefore cannot be questioned. However, the right question is whether BI will act as supportive and therefore secondary technology or as the central element for managing future business. The examples in the section 'BI and People' showed, that the latter might be possible. In saying that, referring to the other sections it also can be stated that different application domains will be coupled narrower in ad-hoc mergers like mashups or API-based new meta-applications. Again, this leads to the question if we will talk about 'Business Intelligence' in future.

Trend	Organisational perspective	Functional perspective	Technological perspective
Future Internet for People	BI crowdsourcing	Social BI	BI Social Software
Future Internet of Content	Knowledge Intelligence	Answer-based BI	Ontology-based BI
Future Internet of Things	BI decentralisation	Ubiquitous BI	Ubiquitous sensing
Future Internet of Services	BI as a service	Embedded BI	Cloud BI

Tab. 1. Business Intelligence perspectives on Future Internet.

After discussing trends of the Future Internet, a comparison to current discussed trends in the BI community (section 3) showed that important aspects might be missing in these discussions. Against the background of the advanced development of some of the discussed trends, the BI community should acknowledge them soon. This especially is the case for BI research. While this paper naturally can only be a snap-shot of the current situation, we hope to give an interesting overview and to provide useful links stimulating further research on the intersection of Business Intelligence and the Future Internet.

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