8-6-2011

Ubiquitous Computing – an Application Domain for Business Intelligence in the Cloud?

Henning Baars
Universität Stuttgart, baars@wi.uni-stuttgart.de

Hans-Georg Kemper
Universität Stuttgart, kemper@wi.uni-stuttgart.de

Ubiquitous Computing – an Application Domain for Business Intelligence in the Cloud?

Henning Baars
University of Stuttgart
baars@wi.uni-stuttgart.de

Hans-Georg Kemper
University of Stuttgart
kemper@wi.uni-stuttgart.de

ABSTRACT

A number of IT providers have introduced web-based services for management support that are discussed under the label "Business Intelligence (BI) in the Cloud". It has been argued that these Cloud products might become valuable complements to on-premise enterprise BI infrastructures by allowing a flexible addition of sizeable components, tools or – in selected areas – complete solutions. In this publication, it is discussed in how far a Ubiquitous Computing setting based on technologies like radio frequency identification (RFID) or sensor technology could become a relevant application domain for "Cloud-BI". The main insights come from a literature review, a series of expert interviews on BI and Cloud Computing, and a case on spare parts logistics. The results indicate that the addressed domain indeed comes with business potential and highlight the need for further design oriented research.

Keywords

Business Intelligence, Data Warehouse, Cloud Computing, Ubiquitous Computing, RFID.

INTRODUCTION

The term Cloud Computing has become remarkably popular during the last couple of years. Merging traditions of "netsourcing", i.e. a net-based IT service provision (Kern, Lacity and Willcocks 2002), and of grid computing, which addresses the exploitation of infrastructure virtualization (Ashraf, Altmann and Hwang 2010; Stanoevska-Slabeva and Wozniak 2010), Cloud Computing promises new degrees of flexibility, scalability, and robustness (Buyya, Yeo and Venugopal 2009; Weinhardt, Aadasivam, Blau, Borissov, Meinl, Michalk and Stößer 2009). It has been pointed out that companies currently use such services for well-defined, simple, and non-core applications (Benlian Hess and Buxmann 2009).

From this angle, the domain of management support is not a typical application area for Cloud Computing. Contemporary approaches to an IT-based management support, usually referred to as Business Intelligence (BI), are for a large part driven by integration objectives – on a technical, content, and organizational level (Ariyachandra and Watson 2006; Golfarelli, Rizzi and Cella 2004; Moss and Atre 2003). This entails conceptual and technical complexity on the one hand, and size on the other: In some cases, the integrated repositories for management support (Data Warehouses – DWHs) that form the core of most BI infrastructures have already surpassed the petabyte barrier. On top of that, the data stored for decision making is often highly confidential.

Nevertheless, some authors see a relevant business potential for "BI in the cloud" or "Cloud-BI" approaches because this might inject some agility into BI and alleviate problems of varying workloads (Sandler 2010; Thomson and van der Walt 2010). In fact, next to generic infrastructure-services, first dedicated Cloud-based reporting and data analysis applications have already entered the market (Evelson 2010). While such services might not (yet) be ready to replace large-scale BI infrastructures, it is very well conceivable that they complement them at the edges – either by bringing in additional services or components, by providing a development environment, or by flexibly attaching (loosely integrated) standalone management support solutions (Baars and Kemper 2010).

This contribution addresses a variant of the latter scenario. More precisely, it is analyzed in how far the application of Ubiquitous Computing (UC) technologies (in particular RFID and smart sensors) might become a viable example of Cloud-BI solutions. The results are supposed to help IS/BI practitioners to identify and explore new BI application domains and guide IS researchers in crafting further research. The relevant insights are drawn from three major building blocks: first, a reflection on the literature, second, the evaluation of selected results from a series of expert interviews on Cloud-BI, and third, a study from the field of spare part logistics.

LITERATURE REVIEW

The following section introduces and structures concepts and research results from the literature on the topics in discussion. It aims at fathoming a possible interplay between them by identifying possible coupling elements.

The application domain: Business Intelligence

Business Intelligence has been defined as a class of technologies for information provision (Negash 2004), as an IT architecture (Moss et al. 2003), as an umbrella term for a variety of concepts or technologies (Turban, Sharda and Delen 2010), and as a process for knowledge generation (Golfarelli et al. 2004). While these conceptualizations clearly vary, the extensional side of the BI phenomenon is remarkably similar – the technologies and concepts discussed are all revolve around the integration and refinement of large amounts of data for management support purposes. The respective components are usually ordered in a layered fashion (Baars and Kemper 2008): A data layer which combines data extraction, transformation, and loading (ETL) with managerial data repositories (application-spanning DWHs and application-specific data marts), a data analysis and reporting layer (OLAP, data mining, executive information systems etc.), and a user access layer (typically realized with a portal). With regards to its inherent orientation towards integration, Business Intelligence is in the following understood as an integrated IT-based approach to management support.

From the vantage point of the topic in discussion, three aspects of BI are noteworthy – the prevailing relevance of "standalone" managerial support solutions, varying workloads, and the need for agility:

The relevance of *standalone solutions* provides a first handle for the discussed Cloud-BI scenarios: Despite the dominating leitmotif of integration, there will always be a reasonable demand for smaller, less complex, and more independent management support solutions – be it because solutions are only temporarily used or due to a lack of a business-case for integration. Such situations particularly arise when highly specific solutions are designed, e.g. in the areas of production or logistics that deal with specialized questions regarding *physical* objects. A deep-integration of the respective data into the more financially oriented enterprise DWH is often not advisable.

Varying workloads arise for two reasons – the seasonality of reporting and the unpredictability of ad-hoc-analysis. This trait of BI might motivate the application of Cloud technology which promises dynamic scaling.

Agility is another possible driver for Cloud-BI (Sandler 2010; Thomson et al. 2010). In the strategic management literature, the gist of the concept "agility" is its stress on the ability to quickly respond to *unforeseen* changes (Weill, Subramani and Broadbent 2002). Such changes are of particular importance for management support which inherently deals with unpredictable changes and with the discovery of unforeseen patterns. The consequences are that the BI solutions themselves need to be adapted in an agile fashion, e.g. by wiring in new data sources, providing a new analytical functionality, or offer new approaches to data presentation.

The technological platform: Cloud Computing

"Cloud Computing" is still defined heterogeneously (Stanoevska-Slabeva et al. 2010; Weinhardt et al. 2009). However, a growing consensus is that it combines a *business aspect*, namely an IT service provision on a fee basis, and an *architectural aspect* in the form of a distributed, net-based architecture where resources can be dynamically rearranged (Buyya et al. 2009; Weinhardt et al. 2009). It can be reasonably assumed that the products of the large IT vendors currently form a gravitational force towards a common understanding (Zhou, Zhang, Zeng and Qian 2010). Still, the spectrum of services sold as "Cloud services" is rather wide – from offerings available to a generic market (*public cloud*) up to a setting where all resources are kept within a group of enterprises or even the premises of a single company (*private cloud*) (Stanoevska-Slabeva et al. 2010; White 2008). The following discussion will focus on public clouds.

The types of services subsumed under the Cloud Computing umbrella are usually ordered in a stack: The foundation is a set of services for the utilization of virtualized hardware, *Infrastructure-as a-Service* (IaaS). If this is combined with a web-based (multi-tenant) application provision, the term *Software-as-a-Service* (SaaS) is used. In between, some vendors also offer middleware, database, and development platforms to craft or adapt SaaS-solutions based on an IaaS socket. This has become known as *Platform-as-a-Service* (Stanoevska-Slabeva et al. 2010; White 2008).

When it comes to Business Intelligence, the above introduced stack can be combined with the different components of a BI architecture to come to a differentiated view on Cloud-BI: It will be probably rather difficult to move a larger enterprise DWH into the Cloud. The situation is different, however, for a smaller data mart or a specialized analytical application. This leads to a variety of possible scenarios for Cloud-BI, from attaching one or several BI components, tools, or services to a central enterprise solution up to complex and completely distributed BI Mashups (Baars et al. 2010). This paper focuses on a scenario that aims at providing a complete BI solution in the Cloud and that spans all layers. Such a scenario is particularly relevant for the "standalone" solutions discussed above.

The application context: Ubiquitous Computing and RFID

The vision of "Ubiquitous Computing" (UC) aims at embedding a large number of wirelessly interconnected IT components into the physical environment in order to jointly provide services (Weiser 1996). It thereby combines aspects of mobility and embeddedness (Lyytinnen and Yoo 2002). In the recent years, a growing number of applications that seem reasonable from a business standpoint begin to take shape – based on the proliferation of more and more Internet-enabled UC technologies (Fleisch 2010). Examples include smart machines and appliances, sensor networks, smart meters etc. One of those technologies stands out – at least going by its impact on the discussion: Radio frequency identification (RFID), a technology for the transmission of digital object data without a line of sight which can also be enhanced with sensor and tracking and tracing technologies (Curtin, Kauffman and Riggins 2007).

From the point of view of the subject in discussion, the following characteristics of UC are relevant:

UC technology can be used to collect data that is *highly interesting for managerial support*: Most UC scenarios are based on an automatic gathering of data with high degrees of accuracy, timeliness, correctness, and resolution. As a side effect of this, large volumes of data are generated that need to be handled with components designed for data integration, refinement, and analysis – BI components. Especially if combined with industry-spanning coding standards, technologies like RFID can foster data integration as they allow for tracking individual, serialized items below the logistical unit. A number of dedicated RFID-BI-solutions with RFID-DWHs have been proposed and explored (Cho 2005; Baars and Sun 2009).

Object-attached technologies like RFID foster *decentralization* and *cross-company applications*. There are two reasons for this: First, the *point of creation* of data is tied to the object (e.g. in form of an RFID tag) and therefore often lies outside of the premises of the enterprise. Second, the *Internet-compliant digitalization* allows for a comfortable transfer and exchange of this data – even across enterprise borders. This matches the architecture of larger public Cloud solutions.

Conclusions

Although they seem disjoint at the first glance, BI, Cloud Computing and UC share several complementarities: On the one hand, a Cloud solution might be an option for a "standalone" BI solution that only needs a loose integration into a larger enterprise BI environment and/or that is subject to agility pressures – especially if workloads vary. UC has been shown to be a relevant application area for BI by bringing in high-quality data sources. Eventually, the de-central "Internet nature" of contemporary UC solutions seems tailored for Cloud scenarios. The conclusions from the literature review are enlisted in Table 1 and illustrated in Figure 1.

L1	Larger enterprise BI components are technically too demanding and confidential for Cloud computing.
L2	Some smaller BI solutions only require a light degree of integration into the enterprise BI infrastructure and can be addressed using Cloud approaches (despite L1).
L3	There is a need for functional agility in BI which might be addressed with Cloud solutions (esp. with SaaS or PaaS).
L4	The variability of workloads is an issue in BI that can be addressed with Cloud solutions (esp. with IaaS).
L5	BI solutions can be used to efficiently utilize vast amount of UC data.
L6	UC provides relevant data with a high precision, accuracy, and timeliness.
L7	UC drives decentralization and out-of-premises solutions and is thereby compatible to Cloud approaches.
L8	UC fosters inter-company solutions and solutions built on shared resources that can be provided by Cloud solutions.

Table 1. Conclusions from the literature review

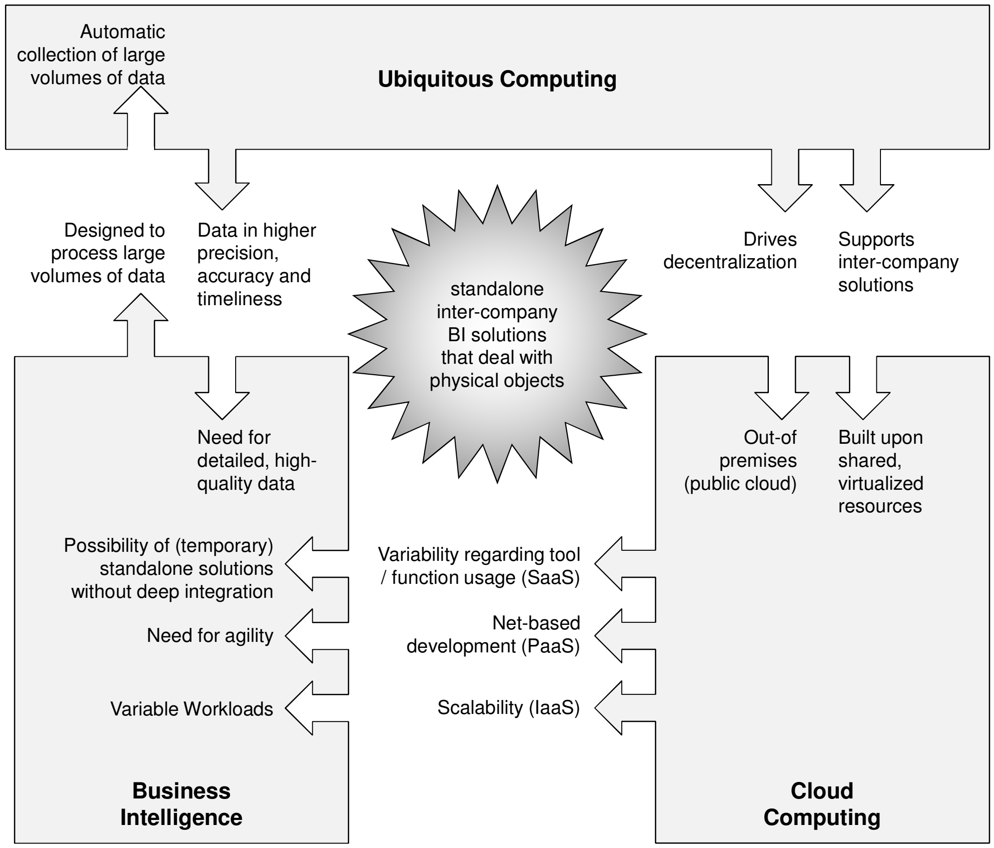

Figure 1. Coupling elements between the concepts

Methodology for the further exploration of the subject

In order to further enrich and deepen the discussion, selected results from a series of qualitative expert interviews (Myers and Newman 2007) on BI strategy and BI infrastructure management from June 2010-January 2011 are evaluated. Participants were managers from the BI units of 8 large organizations with mature BI installations (cf. Table 2).

	Industry	**Position**
Organization A	IT and BI service provider for insurances	Manager IT
Organization B	Chemical industry group	Team leader BI and project manager “BI framework”
Organization C	Passenger and cargo logistics (railroad)	Manager of the BI unit + BI consultant
Organization D	Holding company / textile services subsidiary	Program manager BI, formerly BI manager in the subsidiary
Organization E	Packaged food	Team leader information management
Organization F	Industry chemicals	Manager Business Intelligence (global)
Organization G	Chemicals	Team leader BI (part of the IT governance unit)
Organization H	IT daughter of a chemical group	Unit manager BI and data management + manager for logistics data

Table 2. Participants in the BI study

Each interview lasted between 70 and 100 minutes and was based on a semi-structured interview guideline with 45 (open) questions that covered 6 areas (background and context, BI strategy, BI applications, BI architecture, BI organization, BI virtualization & BI in the Cloud). The interview guideline was derived from a theoretical framework that drew from IT strategy, BI, and Cloud literature. All interviews have been recorded and fully transcribed. Due to the open-ended nature of the questions and the dynamics in the interviews it was necessary to apply further steps to deal with the amount of material: First, the transcripts were fractured and re-ordered. Afterwards, open coding was applied jointly by the two authors. Third, a constant comparison approach led to preliminary concepts and assumptions regarding their interplay (Locke 2001; Miles and Huberman 1994).

The conclusions from the above discussion and the additional input from the interviews were further explored by the means of a smaller interpretative case study (Walsham 1995; Yin 2008) on spare parts logistics at a larger machinery manufacturing company. It has primarily been gathered in a two-hour interview conducted in June 2010, a workshop in February 2011 that included process visualization and prototyping techniques, and additional phone-based exchanges on the results in April 2011. Participants were the manager of a unit for strategic logistics as well as two further experts.

The richness of the material as well as the familiarity of the authors with most of the cases ensured internal validity. The generalizations and therefore the external validity are primarily based on plausibility rationales that are grounded in the theoretical and practical background of the authors. A limitation of the BI study in this respect lies in the focus on larger enterprises – some of the conclusions might need to be adjusted for smaller enterprises.

RESULTS FROM THE BUSINESS INTELLIGENCE STUDY

It is noteworthy that only two of the organizations had already gathered first-hand experience with Cloud-BI-solutions – despite (or maybe because of) the fact that each of the companies had an established BI organization and a mature BI infrastructure. The exceptions were companies A and H: A is already offering a sort of a “Private-Cloud-SaaS”-solution to affiliated insurance companies (albeit without virtualization in its data center). H is currently running first pilot projects for selected BI components.

Despite the occurrence of varying workloads in almost all organizations (except G), they were surprisingly considered to be a rather manageable nuisance than a critical problem (which weakens conclusion L4). In some cases, peak loads were dealt with by building up buffer capacities, in others by tolerating “some slowdowns”. Scalability was classified as a “nice to have” (A and B). Company H already uses virtualization in its data center for rearranging computing or data base capacity in times of peak demand.

Some technical limitations were stated regarding virtualization and Cloud solutions that detail conclusion L1: Especially high-end components that require dedicated hardware were not considered to be easily virtualized (use of in-memory processing technology for data analysis (A), dedicated DWH appliances (B, G), high-data-volumes in ETL (B), larger tool suites not yet ready for virtualization (D)). Rather unsurprisingly, most participants voiced concerns regarding data security and data privacy. Furthermore, the ability to pinpoint errors and bottlenecks was considered limited in case of a data transfer over the public Internet. However, the participant from H highlighted that most the above mentioned issues will probably be dealt with mid-term – either by technical or contractual measures. Despite that optimistic outlook, as a first preliminary conclusion it can be stated that Cloud-BI might be problematic for high-performance or high-availability BI components.

Relevant application areas for Cloud-BI were seen for front end analysis and reporting components that sometimes need to be added or taken out flexibly (B, C, D, E) as well as for the access layer – especially under consideration of the growing demand for supporting a variety of heterogeneous mobile devices (D, G, H). Furthermore, Cloud solutions were considered feasible and relevant for administrative components that are not directly visible on the user side, e.g. backup and archiving (F and H). Company H regards such components as an ideal starter for Cloud-BI as it “*doesn’t involve impassable emotional barriers. From there you can go on*“. And: “*Later we can say to the user: Your data is already out there!*” Eventually, Cloud solutions were seen as an ideal way of dealing with requirements to develop, test, and operate pilot solutions in an agile fashion (A, C, D).

Both a problem and a potential driver for Cloud-BI is reflected in an answer of the interviewee from company D who reported that in the textile company, a SaaS Customer Relationship Management software was introduced that brought reporting functionality with it which became popular among the users. This example shows how operational Cloud solutions might eventually drag out BI with them. This argument was complemented by referring to the general trend towards decentralization. In a similar vein, the participant from organization H made the following point: “*I think that the majority of the data [on our company] is already outside of [our company’s] premises*.” – referring to external statistics, newspaper reports, opinion statements, data of business partners. “*One day we have to follow”*

In conclusion, Cloud-BI might be particularly applicable for running or piloting non-high-end solutions where the data sources and operational functionality are already distributed. Table 3 summarizes those conclusions and relates them to those from the literature review.

B1	Cloud-BI is not applicable for solutions that come with high-performance and/or confidentiality requirements.	Supports L1.
B2	Cloud-BI is particularly relevant for front end and analysis components.	Details L3.
B3	Dynamic workloads are not considered a core issue.	Weakens L4.
B4	Cloud-BI is particularly relevant for development and piloting.	Details L3.
B5	Data sharing with external partners facilitates Cloud-BI.	With L7: Bridge to UC.
B6	Distributed data sources facilitate Cloud-BI.	With L8: Bridge to UC.

Table 3. Selected conclusions from the BI study

EXPLORATION BASED ON A SPARE PARTS LOGISTICS CASE

The participants in the case study come from a strategic logistic unit that has been formed during the end of 2009 in order to control spare parts logistics from a unit-wide and strategic perspective. The unit was already able to reap significant benefits by analyzing data on the performance of the attached logistics service providers (LSPs), the transportation modes, the chosen service levels etc. The basic model of the spare parts chain in discussion is shown in Figure 2. It is designed for stability rather than flexibility and follows a three-level hub-and-spoke approach with defined routes (called “autobahns”) and relatively high inventory levels.

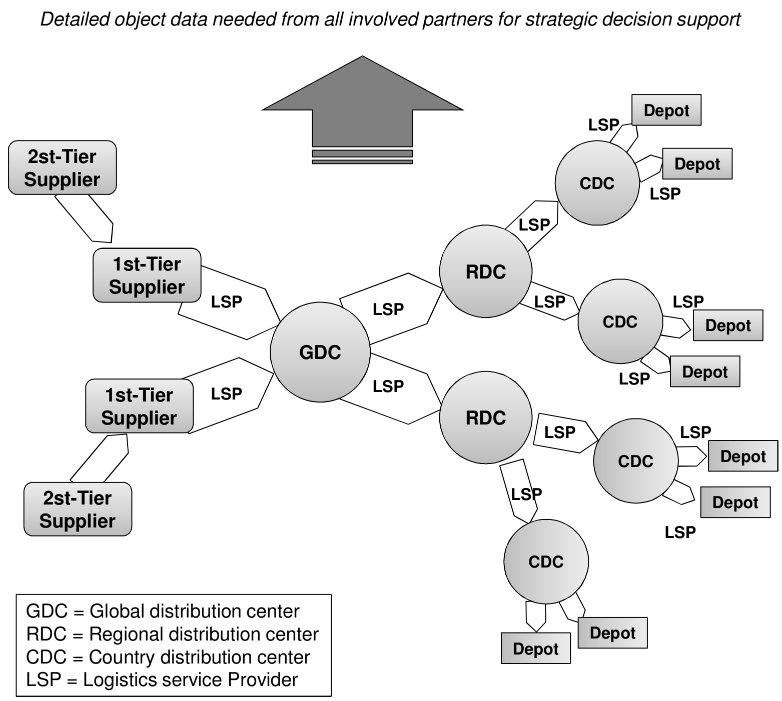

Figure 2. Structure of the supply chain in the case study

Most of the analyses in the unit are currently conducted by spreadsheets with manual data integration. The primary data sources are an enterprise DWH, an inventory management system, and data from the partners. Major limitations of the current approach are limits in the timeliness, granularity, and in parts correctness of the data.

The *granularity issue* manifests in a lack of "drill down capability" for pinpointing issues. This leads to ad-hoc requests for data from the LSPs – an approach that is both costly and time-consuming. Furthermore, the data is sometimes not sufficiently detailed – a problem especially for more expensive spare parts, some with price tags of several 1000 Euros per item.

Issues with *data correctness and precision* are currently dealt with by confining responsibility contractually to the LSPs and 2nd tier suppliers. *Timeliness* of data provision becomes crucial if a machine stops working because of missing spare parts. In such cases, costly transportation modes are chosen.

During 2010, the decision was made to move to a "fast-moving logistics" model which would have made the introduction of RFID inevitable. However, due to rising energy costs, the decision was put on hold – currently the trend is to rather avoid transportation and accept high inventory levels. Also, it was decided to introduce a new logistics hub in Asia. Yet, again due to rising energy costs, the already selected location is now challenged. In the ongoing process, a need to consider a broad spectrum on historical data besides those classically applied in optimization models surfaced, e.g. experiences with violating service levels, situations like unrest or strike etc.

The given situation supports the *design of a BI approach* for the following reasons: Data collection, integration, refinement, and analysis are obviously rapidly gaining in relevance. The current manual processes are not only inefficient but also too limited regarding timeliness, precision, and data richness. A SCM-DWH-based solution with automatic data integration from the LSPs would definitely be preferable.

The addition of the UC technologies *RFID with sensor capabilities* could enhance granularity and unleash additional efficiency gains – at first for the most expensive spare parts, later possibly for other goods as well. This would also be an enabler for switching to a "fast moving" scenario. In conjunction with the DWH, the RFID data could not only be used for an enhancement of transparency but also for pattern recognition e.g. when parts are delayed or defect. This supports the conclusions from the literature review on the potential of combining BI and UC (L5 and L6).

A *Cloud-based* realization of the DWH-solution would be advisable for the following reasons: Much of the relevant data is distributed among different sites and partners (LSPs) already. To build a joint solution would not only take this into account but also open the possibility for the LSPs to monitor, steer, and optimize their processes with respect to overarching performance indicators. This is in line with the results from the literature and the BI study (L7/L8/B5/B6).

The data for strategic SCM is heavily inventory-centered without a need to integrate it into the financially-oriented enterprise DWH. Due to the strategic and non-operational nature of the analysis, high-end performance and availability requirements are not (yet) relevant.

Most importantly, the Cloud approach offers the possibility to respond to changes in the set of the involved LSPs, network structures, or even business models and the following changes in data fallout by ensuring an adequate scalability and flexibility on the infrastructure side. From a functional standpoint, agility could be guaranteed by the possibility for a short term inclusion of tools for advanced analysis, simulation, planning, or optimization functionality.

Table 4 summarizes the most relevant conclusions from the case. By matching the conclusions from the studies, both the potential business case and the applicability of Cloud-BI in a UC context can be derived.

C1	Cross-border UC applications can efficiently provide relevant management support data.	Corroborates L5 and L6.
C2	Strategy oriented UC applications are candidates for standalone BI solutions.	Details L2.
C3	Strategy oriented UC applications do not come with high-end requirements regarding performance.	L1 and B1 are not always relevant.
C4	UC-based solutions foster decentralized solutions and thereby (BI-)Cloud scenarios.	Combines L7/L8 and B5/B6.
C5	BI solutions based on UC applications are sensitive to changes in the operational business processes and require scalability.	Corroborates L3 and weakens B4.
C6	In order to react to unexpected changes in the environment, BI solutions based on UC applications need to be able to flexibly include specific analysis features.	Corroborates and exemplifies L3 and B2.

Table 4. Selected conclusions from the logistics case

DISCUSSION AND CONCLUSIONS

As has been shown, the seemingly disjoint subjects Business Intelligence, Cloud Computing and Ubiquitous Computing might indeed fit together – the coupling elements being agility requirements in BI, the value of UC for managerial support, and UC's distributed and de-central nature. The case study especially illustrates how a typical UC setting can become subject to heavy and hardly predictable variations in basic requirements that can be addressed adequately in a cloud environment.

The contribution of this paper lies in opening the discussion on a potentially new BI application domain. While it is clearly exploratory and the conclusions drawn are of course preliminarily, the presented results are understood to be a starter both for a further practical exploration and for additional research. Of particular relevance are design science and action research– with the need to craft and evaluate solutions and architectures in a real life setting like the one described.

Considering the ever increasing degree of permeation of the physical environment with internetworked IT components, the ongoing virtualization of IT infrastructures and the growing need for analysis and reporting tools to exploit the vast amount of data generated in such environments, UC, BI, and Cloud Computing does not seem to be such an exotic combination after all but much rather a set of converging trends.

REFERENCES

1. Ariyachandra, T. and Watson, J. (2006) Which Data Warehouse Architecture is the Most Successful? *Business Intelligence Journal*, 11, 1, 2-4.
2. Ashraf, B.M., Altmann, J. and Hwang, J. (2010) Cloud Computing Value Chains - Understanding Businesses and Value Creation in the Cloud, TEMEP Discussion Paper No. 2010:61, Seoul, University of Seoul.
3. Baars, H. and Kemper, H.G. (2008) Management Support with Structured and Unstructured Data – An Integrated Business Intelligence Framework, *Information Systems Management,* 25, 2 132-148.
4. Baars, H. and Kemper, H.G. (2010) Business Intelligence in the Cloud? in *Proceedings of the 14th Pacific Asia Conference on Information Systems (PACIS)*, July 9-12, Taipeh, Taiwan, 1529-1539.
5. Baars, H. and Sun, X. (2009) Multidimensional Analysis of RFID Data in Logistics. In *Proceedings of the 42. Hawaii International Conference on System Sciences (HICCS-42)*, January 5-8, Hawaii.
6. Benlian, A., Hess, T. and Buxmann, P. (2009) Drivers of SaaS-Adoption – An Empirical Study of Different Application Types, *Business & Information Systems Engineering (BISE),* 1, 5, 357-369.
7. Buyya, R., Yeo, C.S. and Venugopal, S. (2009) Market-Oriented Cloud Computing: Vision, Hype and Reality for Delivering IT Services as Computing Utilities, *Future Generation Computer Systems*, 25, 6, 599-616.
8. Cho, D.Y. (2005) Ubiquitous Data Warehouse: Integrating RFID with Multidimensional Online Analysis, *Proceedings of the San Diego International Systems Conference*, July 08-10, San Diego.
9. Curtin, J., Kauffman, R.J. and Riggins, F.J. (2007) Making the 'Most' out of Rfid Technology: A Research Agenda for the Study of the Adoption, Usage and Impact of Rfid, *Information Technology and Management*, 8, 2, 87-110.
10. Evelson, B. (2010) BI In The Cloud? Yes, And On The Ground, Too," URL: http://blogs.forrester.com/business_process/2010/01/bi-in-the-cloud-yes-and-on-the-ground-too.html, January 26, 2010.
11. Fleisch, E. (2010) What is the Internet of Things? An Economic Perspective" Auto-ID Labs White Paper WP-BIZAPP-053, January, Auto-ID Labs, St. Gallen.
12. Golfarelli, M., Rizzi, S. and Cella, I. (2004) Beyond data warehousing: what's next in business intelligence? *Proceedings of the 7th ACM international workshop on Data warehousing and OLAP*, November 8-13, Washington.
13. Kern, T., Lacity, M.C. and Willcocks, M.P. (2002) Netsourcing: renting business applications and services over a network, Prentice Hall, Upper Saddle River.
14. Locke, K. (2001), Grounded Theory in Management Research, Sage, London et al.
15. Lyytinnen, K. and Yoo, Y. (2002), Issues and Challenges in Ubiquitous Computing, *Communications of the ACM*, 45, 12, 42-65.
16. Miles and Huberman (1994) Qualitative data analysis – An extended sourcebook, 2nd ed., Sage, Thousand Oaks.
17. Moss, S.T. and Atre, S. (2003) Business Intelligence Roadmap – The Complete Project Lifecycle for Decision Support Applications, Addison-Wesley, Boston.

18. Myers, M.D. and Newman, M. (2007), The qualitative interview in IS research: Examining the craft, *Information and Organization,* 17, 1, 2-26.
19. Negash, S. (2004), Business Intelligence, *Communications of AIS,* 13, 177-195.
20. Sandler, D. (2010), Best Practices for Applying Agile Techniques to Data Warehouses, *Business Intelligence Journal*, 15, 4, 17-27.
21. Stanoevska-Slabeva, K. and Wozniak, T. (2010) Cloud Basics – An Introduction to Cloud Computing, in: Stanoevska-Slabeva, K., Wozniak, T. and Ristol, S. (Eds.) *Grid and Cloud Computing*, Springer Berlin and Heidelberg, 2010, 47-61.
22. Thomson, W.J.J. and van der Walt, J.S. (2010), Business intelligence in the cloud, *South African Journal of Information Management*, 12, 1.
23. Turban, E., Sharda, R. and Delen, D. (2010) Decision Support and Business Intelligence Systems, 9^{th} ed., Pearson, Boston et al.
24. Walsham, G. (1995), Interpretive case studies in IS research: nature and method, *European Journal of Information Systems,* 4, 1, 74-81.
25. Weill, P., Subramani, M. and Broadbent, M. (2002), Building IT Infrastructure for Strategic Agility, *MIT Sloan Management Review,* 44, 1, 57-65.
26. Weinhardt, C., Aadasivam, A., Blau, B., Borissov, N., Meinl, T., Michalk, W. and Stößer, J. (2009), Cloud Computing – A Classification, Business Models, and Research Directions, *Business & Information Systems Engineering (BISE)*, 1, 5, 391-399.
27. Weiser, M. (1996) Ubiqutious Computing, URL: http://sandbox.xerox.com/ubicomp/, last updated 17^{th} of March 1996.
28. Yin, R.K. (2003), Case study research: Design and methods, 4^{th} ed., Sage, Thousand Oaks (CA), USA, 2008.
29. Zhou, M., Zhang, R., Zeng, D. and Qian, W. (2010) Services in the Cloud Computing Era: A Survey, in: *Proceedings of the 4th International Universal Communication Symposium (IUCS)*, October 18-19, Beijing, 40-46.