Shaping the Next Incarnation of Business Intelligence

Towards a Flexibly Governed Network of Information Integration and Analysis Capabilities

Socio-technical macro trends continuously reshape the demand for integrated decision and management support (Business Intelligence, BI). The vision presented in the paper is a response to those developments. It combines five strings of innovation: New concepts for BI governance, agile and user-driven BI, BI and Business Process Management, BI across enterprise borders, and new approaches of dealing with unstructured data. Macro trends like the diffusion of cyber physical systems illustrate the relevance of bundling these five strings. For pursuing the vision in a concrete application environment we recommend a series of succeeding studies. These should lead from an exploration of the respective problem context over a screening of the solution space to a specific solution design.

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1 Relevance and Timeliness of the Topic

Management Information Systems (MIS) and Decision Support Systems (DSS) have been designed and applied with varying success since the 1970s (Hosack et al. 2012; Scott Morton 1983). This encompassed approaches as diverse as reporting-focused executive information systems, Online Analytical Processing (OLAP)-driven data exploration solutions, or model-based decision support and data mining systems (Gluchowski et al. 2008; Kemper et al. 2010). It was the addition of the Data Warehouse (DWH) concept as an integrated managerial data repository (Inmon 2005) that brought those systems together and led to the now common multi-level architectures. These also entailed the diffusion of the term *Business Intelligence* (BI). Initially being used rather heterogeneously (Mertens 2002), BI is now commonly understood to denote integrated approaches to an IT-based management and decision support (Foley and Guillemette 2010). The continued attention among business decision makers (Gartner 2007–2012) and Information Systems' academics (Steininger et al. 2009) indicates the relevance of BI. The aim of this paper is to craft a vision of the next-level of BI that brings together current research efforts under a strategic,

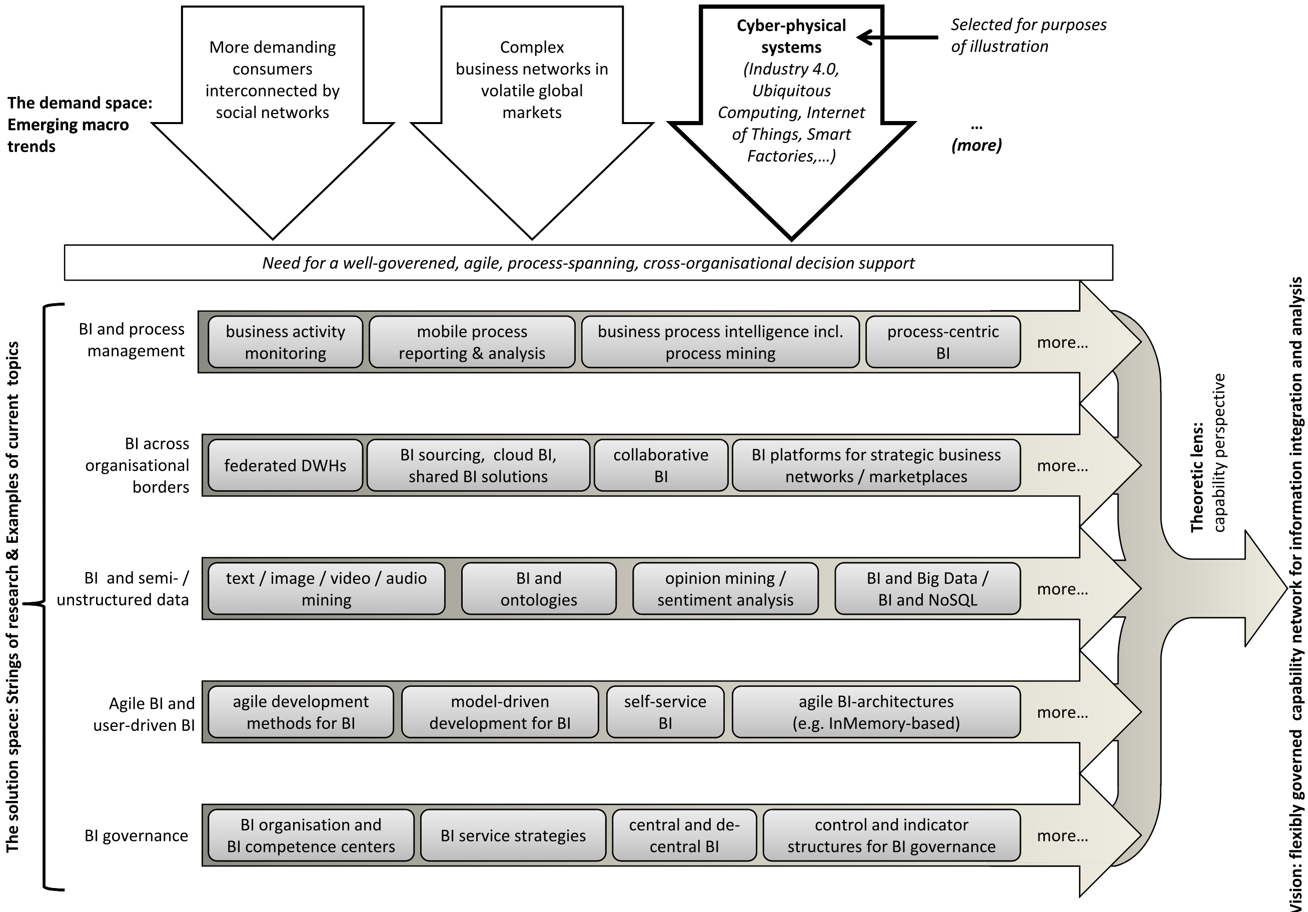

Fig. 1 Structure of the paper

capability-oriented theme with an emphasis on governance aspects. It will be argued that this is a necessary response to emerging macro trends in the business environment.

The structure of the argumentation is as follows (cf. **Fig. 1**): Changes in the demand space for BI coming from the macro trends are met on the solution side by a variety of innovations. The respective research topics were systematically gathered and bundled to general strings which in their interplay form the new vision for BI. All strings were built up on prior work and might be complemented by future topics later.

Macro trends with a potential impact on BI include an on-going increase of process complexity in volatile global markets, a more informed and demanding consumer base interconnected by social networks, or the need to include sustainability rationales into product and supply chain strategies. The following discussion will use the example of the emergence of *cyber-physical systems* (CPS) for purposes of illustration. CPS are physical systems controlled and integrated by embedded computing and networking components (Lee 2008). They are dealt with from various angles under headings like *Internet of Things*, *Ubiquitous Computing* (Kortuem et al. 2010) or (for the manufacturing industry) *Industry 4.0* (Feld et al. 2012). CPS do not only introduce complexity, but also large amounts of raw data and opportunities for an enhanced real-time steering and adaption of processes. This brings the option of a rapid succession of changes in product and process configurations – enabled by ad-hoc modifiable CPS and supported by automatically gathered CPS data. The more far-reaching those changes are (individually or as an agglomeration of seemingly minor changes), the more it is necessary to reflect their possible impacts while considering enterprise policies and strategies, available data from other business units, and possible reverberations across the value chain. Putting CPS into a consistent decision context and harness their resulting potential is still a tremendous challenge that requires a set of well-orchestrated capabilities supported by viable models, methods, technologies, and concepts.

The solution space available for dealing with the trends is continuously expanded by a stream of innovations entering the field of BI, starting from In-Memory analytics, in which data repositories are consequently held in volatile RAM (Loos et al. 2011), via Cloud-BI, i.e. an Internet-based provision of BI components built upon virtualized infrastructures (Thomson and van der Walt 2010), up to the integration of new highly parallelized architectures capable of handling large volumes of poly-structured data (Cattell 2011). This paper argues that below the seemingly disjoint topics there is a forceful thematic trend that might change the very nature of BI: The various innovations have the potential to craft a BI that can be quickly realigned with changing requirements. The foundation of such a BI is an orchestrated network of BI capabilities in which internal and external services, contents, and infrastructure components can be merged ad-hoc and without significant compromises regarding consistency or compliance requirements. Such a BI would also support the realization of visions of IT-enabled agile enterprises (Fleisch and Österle 2004).

The chosen *capability* concept (Winter 2003) highlights a business-oriented, theory-backed stance that is seen to be particularly suited for capturing the relation between BI systems and their strategic value (Weill et al. 2002). BI supports *dynamic capabilities* that are needed to "integrate, build, and reconfigure internal and external competences to address rapidly changing environments" (Eisenhardt and Martin 2000). The focus of BI research is put on *sensing capabilities*, which enable an organization to identify strengths, weaknesses, opportunities, and threats (Overby et al. 2006). The capability concept also has the merits that the pathways between BI-based capabilities and business value have been explained before (Seddon et al. 2013) and that capabilities can be iteratively decomposed (TOGAF Group 2009). For BI, a splitting of the sensing into information integration and analysis capabilities appears reasonable as those can be associated with logical and technical structure of most BI approaches.

The chosen theoretical lens also shows the repercussions of BI research in other spheres of IS research. Examples include Information and Knowledge Management that provide further sensing capabilities (Weill et al. 2002), Enterprise Architecture Management where capabilities are applied as a conceptual tool (TOGAF Group 2009), or the design of process management systems and agile IS infrastructures for complementing *responding capabilities* (Overby et al. 2006). Our work is therefore embedded into the general IS subjects of agile enterprises, business process management, and the strategic value of IS.

2 Identifying Strings of Innovation and Research Challenges

The relevant building blocks of our vision comes from the identification of relevant research strings based on a review of 576 industry and 667 academic publications from the years 2008 to 2013. The publications were taken from 43 manually screened sources, which includes BI specific outlets as well as IS journals and conferences (cf. online Appendix A).

All identified BI publications were matched against a classification schema for BI topics. The schema was originally developed iteratively in a BI working group of the German Computer Society and iteratively expanded during the coding, cross-validation, and result consolidation. The outcomes (overview cf. online Appendix A) have been explored both qualitatively and quantitatively in a workshop. This led to the identification of five major streams of innovation that are seen to coalesce in the presented vision:

(1) A deepened interplay between *BI and Business Process Management* (BPM). This general topic has appeared 55 times in our sample, both on the academic (36) and the industry (19) side. Process-oriented DSS have a long history. The integration of BI functions into operational processes in particular has been applied for a while now under the heading *Operational BI* (Hänel and Felden 2012). The tool set for process-oriented BI features is constantly expanded, e.g. by providing operational end-users with extended analytic functionality (Bucher et al. 2009) or with features for identifying or analyzing process structures in BI based on large volumes of automatically gathered log data (*Business Process Intelligence* and *Process Mining*) (Grigori et al. 2004; Van der Aalst and Weijters 2004).

We see it as a core research challenge to come up with a framework that puts process-analysis capabilities into an overarching BI context. In this context, two relevant unanswered research questions are:

R1: To what degree should the analysis of processes be moved to an integrated BI environment, which can provide consistent cross-functional information but lacks local insights and incurs delays? This can be specified on the *technical side* by the distribution of data preparation and process analysis functionality as well as by the degree of integration of data models, elements, attributes, and meta data. On the *organizational side* this leads to questions on the degree of centralization of decision rights and responsibilities. In the context of CPS: Is it advisable to merge the decision support for a CPS-based shop-floor environment with "classical" BI systems given the need to extract massive volumes of production data and to decide in near-real-time?

R2: How can distributed process-oriented capabilities be coordinated? This entails questions regarding the design of functionality for facilitating, monitoring and possibly confining cross-functional data access and usage. E.g. for CPS: How can sensor data generated during the maintenance of "smart products" be utilized for the analysis of spare part supply chains given the different sets of systems, models, competencies, and mind-sets in the affected business units (logistics, product design, maintenance)?

(2) Interest in solutions that *cross organizational borders* (9) and/or that are *cooperatively developed and operated* (11). The on-going academic research conducted in the field of Computer Systems on federated DWHs and data marts (4) is of particular relevance in this regard. In the same vein, Cloud-based BI (20) enables shared BI resources and supports higher degrees of professionalization. Cross-border solutions bear the promise to foster the alignment of sensing capabilities. It needs to be highlighted that the subject of BI across enterprise borders remains under-explored both from the business and the technology side. The core research challenge remains in the design and exploration solutions and their impact on business value. This encompasses the following research questions:

R3: How can cross-border BI solutions be designed so that all partners are willing to participate? CPS example: Which features of a (possibly Cloud-based) solution for supply chain optimization would foster the willingness of a provider of smart objects to feed in production data (e.g. anonymization functionality, industry benchmarks, provision of feedback information on customer behavior, or access to high-performance analytics for local analysis)?

R4: What business models for cross-border BI systems are viable considering the platform providers, the data providers, and all users involved? E.g.: Can features like usage analysis or benchmarks enabled by smart machine data become features customers are willing to pay for?

(3) *New approaches dealing with semi- or unstructured data*, particularly collected outside enterprise borders. While this

subject has been a focal point of (academic) BI research before (Baars and Kemper 2008), it has eventually entered industry interest with the appearance of new and distributed architectures for data storage and analysis that are designed to deal with large volumes of poly-structured data (*Big Data*) (Cattell 2011; Buhl et al. 2013). In our sample 89 sources addressed the topic of Big Data with a significant part being industry publications (71 compared to 18 academic). It is interesting to note that there is relevant research in the field of applying ontologies to BI (20). This might lead to additional impulses in the future.

Relevant research questions include:

R5: With what methods and tools can information requirements be elicited in a highly unstructured Big Data context? E.g.: How do process and data models need to be designed in order to support the exploitation of the almost unmanageable variety, volume, and complexity of CPS data, e.g. during the search for product enhancements? Which attributes and sensor measurements can be cut off, combined, or summarized before entering the analysis of product usage?

R6: How can specified capabilities for handling unstructured data be efficiently sourced and integrated? E.g.: Can resources used to prepare sensor and video data for the analysis of a security breach in a smart production environment be quickly drawn from outside service providers, e.g. by the use of Cloud solutions? What integration approaches would guarantee their seamless integration?

(4) Advances in the *agility of providing BI solutions* and *user-driven BI development*. A total of 26 of the selected publications explicitly discuss agile development methods for BI. However, in the realm of BI with its complex multi-layered architectures, development is only one facet of agility, which is next to BI organizations (6) and BI architectures (9) (Zimmer et al. 2012). In the medium-term, the growing body of academic work on model-driven development for BI might come into play here as well (11). Besides, several other innovations have been connected with BI agility, e.g. self-service BI that promises a user-driven, yet controlled BI development (Imhoff and White 2011) (3) or In-Memory BI (12), which is expected to allow for ad-hoc analysis with reduced modeling overhead.

The related approaches harness the business-oriented capabilities of the user departments more thoroughly and more quickly. However, the following fundamental research question is still unanswered:

R7: How can the various technical, organizational, and functional measures be put into a consistent BI agility framework that is malleable enough to include future innovations? E.g.: Does the BI system provide relevant data and analysis functionality quick enough for dealing with unpredicted catastrophic events in CPS-enabled supply chains – given the possibility to track all relevant objects and logistic resources and their status, as well as for bringing this data together and analyzing it ad-hoc with high-performance In-Memory solutions?

(5) New concepts for *BI Governance* that define specific structures for a strategy-driven steering and controlling of BI (Dinter et al. 2008). This subject was addressed in 32 of the screened publications. BI governance concepts are currently evolving to responsive frameworks that built up on results in String 4. The core research challenge is to deal with the inclusion of new participants in the development and operation of BI solutions: Line-of-business BI experts, end-users, units responsible for operational BI solutions, BI units from cooperating businesses, external BI suppliers – all contributing individual capabilities. In our view, the relevant research question is:

R8: How can a BI Governance be designed and enforced despite highly decentralized BI responsibilities? E.g.: To what extent should production and logistics units be included into the definition of a BI Governance and to what extent are they a subject to the resulting rules and regulations (esp. regarding the design of de-central indicator systems, reports, and the use of heterogeneous tools)?

The derived strings are in line with conclusions of similar literature reviews, which mostly focus on subsets of Strings 4 and 5 (Chen et al. 2012; Hosack et al. 2012), leaving the fields of agility and governance unmentioned, which we see as constituent for our vision: Agility brings additional value. Governance is needed to marshal the variety of capabilities.

3 Methodological Position, Academic Disciplines, Initial Results, and Conclusions

Many of the discussed innovations lead to an increased division of labour with an increased participation of end user departments, the involvement of operational units, Cloud providers, and/or cooperating enterprises. The result is a *BI supply network* that interconnects capabilities from various partners. Due to the fact that these networks do not exist, we propose an active involvement of IS researchers in their evolution. As the orientation of the presented framework is kept deliberately open and broad, this requires a translation of the presented general research questions into a series of concrete activities. For this purpose, we suggest a succession of projects that follows the general structure depicted in **Fig. 1**:

1. Instantiation of one or several research questions based on a selected macro trend and a concrete problem context. Aims of respective projects would be identifying, delineating, and specifying a given application setting. An example for R5 would be "search for product enhancements with sensor data in the automotive industry". This type of research is explorative in nature (e.g. case studies and grounded theory, expert interviews, or descriptive quantitative studies) and requires a strong input from domain experts – in the example experts for the automotive industry and embedded car systems.
2. As soon as the application context is well-defined, succeeding studies can tackle an in-depth analysis of gaps in information supply and their economic relevance. In case of the CPS example for R7, this would mean specifying what information is needed under which time constraints in order to cope with catastrophic events. Besides a necessary cooperation with domain experts, additional input from economics can provide handles for assessing the value of an adequate information supply. Next to case studies, empirical research might support testing the relevance of identified lacks of information supply for the purpose of results generalization.
3. While the first two steps cover the information demand, the third and fourth address the supply side. Step 3

subsumes scanning the available solution space in a given string, selecting the most suitable *solution components*, as well as possibly identifying gaps that require further developments. For the R6 example, this would mean testing and comparing alternative analytical methods or tools. Where multiple overlapping solutions for the same problem are proposed, experiments appear to be suited. In the case of the lack of solutions (e.g. for video analysis), design research is needed. In this case, it is advisable to seek the cooperation with scientific domains that specialize on crafting possible solution components, e.g. computer science for data integration methods or data exchange architectures, the data base and OR community for the analytical toolset, as well as Cognitive Psychology, Information Design, and Human Computer Interaction for data visualization. Note that particularly in the case of Strings 2 and 5 that also deal with organizational components (e.g. frameworks) additional input from organizational and business strategy research is required.

4. The fourth step falls into the core domain of IS: The combination of the components from step 3 to solution blueprints. Considering the example of R2, this could be the design of a Cloud solution for the analysis of a spare part supply chain based on data generated by smart objects. Design research would be suited here for obvious reasons. The implementation and evaluation of the developed solutions can be supported by methods from the field of Action Research. As in steps 1 and 2, a tight interaction with domain experts is needed again for tailoring the solution for the giving setting. In case of Strings 2 and 3, additional legal issues arise (data privacy, data ownership, and intellectual property) especially when analytic (Big Data) solutions are shared across organizational borders.
5. Ultimately, fundamental conceptual work is needed in order to bring those proposed five strings together based on the results from the preceding five steps.

In all cases, the largest methodological challenge comes from the highly integrated nature of BI, the double-role of sub-systems like a DWH as application system and infrastructure component, and the fact that there is no clear plan-development-run cycle. This impedes the separation of a clear unit of study and becomes even more problematic in the envisioned dynamic and multi-partner environments.

This paper derived and discussed the vision of a network of distributed BI capabilities that can be dynamically connected in order to support organizations that operate, thrive, and prosper in an increasingly integrated world of data. In order to turn this vision into reality, joint effort with inputs from various disciplines and a multi-method research approach would be required.

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Abstract

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The body of knowledge generated by Business Intelligence (BI) research is constantly extended by a stream of heterogeneous technological and organizational innovations. This paper shows how these can be bundled to a new vision for BI that is aligned with new requirements coming from socio-technical macro trends. The building blocks of the vision come from five research strings that have been extracted from an extensive literature review: BI and Business Process Management, BI across enterprise borders, new approaches of dealing with unstructured data, agile and user-driven BI, and new concepts for BI governance. The macro trend of the diffusion of cyber-physical systems is used to illustrate the argumentation.

The realization of this vision comes with an array of open research questions and requires the coordination of research initiatives from a variety of disciplines. Due to the embedded nature of the addressed topics within general research areas of the Information Systems (IS) discipline and the linking pins that come with the underlying Dynamic Capabilities Approach such research provides a contribution to IS.

Keywords: Business intelligence, decision and management support, data warehousing, literature review, dynamic capability approach, organizational agility

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Anhang (verfügbar online über http://springerlink.com)

Appendix

Table 1 Classification scheme and number of papers (only two levels of the hierarchy)

		Academic	Industry	Total
BI strategy and structures / BI governance				
	BI strategy	2	6	8
	BI governance	7	25	32
	BI Competence Centers (BICC)	7	9	16
	Central vs. decentral BI steering	7	4	11
	BI sourcing / BI sourcing strategies	2	2	4
	Managerial control for BI / indicator systems	4	2	6
	Structures for agile BI	2	4	6
	Role concepts for BI	3	1	4
	Other / general	2	10	12
BI architectures				
	Architecture frameworks for BI and Data Warehousing	26	25	51
	BI architectures for handling unstructured data	10	4	14
	Real time and active Data Warehousing	9	8	17
	BI appliances and In-Memory BI	2	10	12
	Cloud BI and BI architectures	10	10	20
	NoSQL Repositories / BI and Big Data	18	71	89
	Architectures for mobile BI	6	10	16
	BI and service-oriented architectures	5	1	6
	BI and Ubiquitous Computing	7	2	9
	BI and Master Data Management	2	11	13
	Other / general	10	13	23
BI application domains				
	BI for SME	1	6	7
	BI across enterprise borders	8	1	9
	Industry specific BI applications	98	51	149
	Business function specific BI applications	108	42	150
	Other / general	3	2	5
Operational BI and BI for Process Management				
	Application areas for operational BI	5	2	7
	Integrating BI into operational processes and applications	8	3	11
	BI in process management	21	8	29
	Other / general	2	6	8
BI development and operations				
	BI development	63	62	125
	BI operations	14	13	27
	Both development and operations	1	8	9
Data and Information quality				
	Measuring Data and Information Quality	9	3	12
	Metrics	4	3	7
	Data quality for unstructured data	1	1	2
	Data Quality Management (DQM) tools	9	12	21
	DQM organisation	2	8	10
	Other / general	6	19	25
Modeling and component design for BI				
	Data modeling and BI	40	39	79
	Ontologies and BI / BI and the Semantic Web	20	0	20
	Meta data modeling	3	2	5
	BI-oriented process modeling	2	1	3
	Service-oriented models for BI	4	0	4
	BI and reference modeling	7	1	8
	ETL modeling	9	3	12
	Design of BI components	98	68	166
	Other / general	1	1	2
Analytics				
	OLAP based analytics	28	1	29
	Data Mining	139	33	172
	Web Mining	14	1	15
	Text Mining / analysis of un- and semistructured data	69	5	74
	Procss Mining	16	0	16
	Social Network Analysis	52	15	67
	Spatial BI / BI and geodata	10	7	17
	Data visualisation and visual analytics	9	8	17
	Analysis of stream data and Complex Event Processing	4	0	4
	Other / general	19	20	39
BI and general IS themes				
	BI and IS theory	18	2	20
	Evaluation of BI approaches	43	17	60
	User behaviour and its steering	23	7	30
	Acceptance and Diffusion of BI	16	1	17
	BI and culture	8	8	16
	BI and knowledge management	15	2	17
	Collaborative BI / CSCW and BI	6	5	11
	Technology and innovation management and BI, BI trends	4	14	18
	Other / general	14	7	21

Table 2 Screened sources

Type	Name
BI, Academic	ACM International Workshop On Data Warehousing and OLAP (DOLAP)
BI, Academic	Business Intelligence Journal (not TDWI)
BI, Academic	Decision Support Systems
BI, Academic	International conference on Very large data bases (VLDB)
BI, Academic	International Journal of Business Intelligence and Data Mining
BI, Academic	International Journal of Business Intelligence Research
BI, Academic	Journal of Management Information Systems (JMIS)
BI, Academic	Workshop BI (FG BI, GI e.V.)
BI, Industry	BI Spektrum
BI, Industry	BI Journal TDWI
BI, Industry	http://www.b-eye-network.com/
BI, Industry	DW, EA (2010, 2012)
BI, Industry	http://www.information-management.com/ (formerly DMReview)
BI, Industry	TDWI Conference (conference)
IS & Business, Academic	ACM Transactions on Information Systems
IS & Business, Academic	Americas Conference on Information Systems (AMCIS)
IS & Business, Academic	Annual Conference der European Marketing Academy (EMAC)
IS & Business, Academic	Communications of the ACM
IS & Business, Academic	European Conference on Information Systems (ECIS)
IS & Business, Academic	European Journal of Information Systems
IS & Business, Academic	Hawaii International Conference on System Sciences (HICSS)
IS & Business, Academic	HMD Praxis der Wirtschaftsinformatik
IS & Business, Academic	Human-Computer Interaction
IS & Business, Academic	IEEE Software
IS & Business, Academic	Information and Management
IS & Business, Academic	Information Systems Journal (ISJ)
IS & Business, Academic	Information Systems Research (ISR)
IS & Business, Academic	INFORMS Journal on Computing
IS & Business, Academic	International Business Review
IS & Business, Academic	International Conference on Information Systems (ICIS)
IS & Business, Academic	Journal of Business Logistics
IS & Business, Academic	Journal of Information Technology
IS & Business, Academic	Journal of International Business Studies
IS & Business, Academic	Journal of Strategic Information Systems (JSIS, Journal)
IS & Business, Academic	Journal of the Association for Information Systems (JAIS)
IS & Business, Academic	Management Science
IS & Business, Academic	Multikonferenz Wirtschaftsinformatik (MKWI)
IS & Business, Academic	MCIS
IS & Business, Academic	Mediterranean Conference on Information Systems (MCIS)
IS & Business, Academic	MIS Quarterly
IS & Business, Academic	Pacific Asia Conference on Information Systems (PACIS)
IS & Business, Academic	Wirtschaftsinformatik / Business & Information Systems Engineering (BISE) (Journal)
IS & Business, Academic	Wirtschaftsinformatik (Conference)