Designing a supply network artifact for data, process, and people integration

Koppenhagen, Norbert; Mueller, Benjamin; Maedche, Alexander; Li, Ye; Hiller, Stephanie

Published in:
Information Systems and e-Business Management

DOI:
10.1007/s10257-015-0296-1

Publication date:
2016

Inf Syst E-Bus Manage (2016) 14:613–636
DOI 10.1007/s10257-015-0296-1

ORIGINAL ARTICLE

Designing a supply network artifact for data, process, and people integration

Norbert Koppenhagen[1,3] · **Benjamin Mueller**[1,2] · **Alexander Maedche**[1,5] · **Ye Li**[3] · **Stephanie Hiller**[4]

Received: 15 March 2015 / Revised: 30 September 2015 / Accepted: 27 October 2015 / Published online: 19 November 2015

Abstract E-procurement and supplier-relationship management systems have helped to substantially advance process execution in supply management. However, current supply network systems still face challenges of high data integration efforts, as well as the decoupling of structured data and processes from the growing amount of digitalized unstructured interactions of supply management professionals. Inspired by the room for improvement posed by this challenges, our research proposes a design for a supply network artifact in supplier qualification that addresses these problems by enabling holistic integration of data, processes, and people. The artifact is developed following an action design research approach. Building on a set of meta-requirements derived from literature and practice explorations, we

✉ Alexander Maedche
maedche@es.uni-mannheim.de; alexander.maedche@kit.edu

Norbert Koppenhagen
koppenhagen@es.uni-mannheim.de; koppenhagen@sap.com

Benjamin Mueller
mueller@es.uni-mannheim.de; b.mueller@rug.nl

Ye Li
ye.li02@sap.com

Stephanie Hiller
sthiller@googlemail.com

1 Institute for Enterprise Systems, University of Mannheim, L15, 1-6, 68131 Mannheim, Germany

2 Faculty of Economics and Business, University of Groningen, Nettelbosje 2, 9747 AE Groningen, The Netherlands

3 SAP SE, Walldorf, Germany

4 Siemens AG, Freyeslebenstraße 1, 91058 Erlangen, Germany

5 Karlsruhe Institute of Technology (KIT), Fritz-Erler-Straße 23, 76131 Karlsruhe, Germany

conceptualize two design principles and derive corresponding design decisions that have been implemented in an software artifact. Finally, we formulate testable hypotheses and evaluate the artifact and its design in the context of supplier qualification. Our results show that the proposed design reduces mental effort of supply management professionals and significantly increases efficiency when performing typical supply network tasks such as supplier qualification.

Keywords Design science · Procurement · Supply management · Supply networks · Supply network system artifact

1 Introduction

Supply networks are characterized by wide inter-organizational settings of connected entities, with the key focus on procurement and the provisioning of goods and services. As such, they describe the value generation flow of goods and services between connected business partners (Harland et al. 2001). Supporting supply management on an individual company level, the primary target of enterprise resource planning (ERP) systems is to standardize structured data and to streamline business processes within a company (Davenport 1998). Extending this scope, e-procurement and supplier-relationship management (SRM) systems focus on supply networks beyond the boundary of a single company. They enable integration across companies by establishing standards for document exchange between different systems. However, these approaches still result in costly, rigid, and complex data integration of peer-to-peer nodes in dynamic supply networks (Tarn et al. 2002; Harland et al. 2001). Also, the emergence of e-marketplaces in the early 2000s could not overcome these challenges, and many of the most promising e-marketplace providers and concepts disappeared when the.com-bubble burst—primarily because of the data integration complexity that arises when connecting dyadic and many-to-many network relationships on a single platform (Grey et al. 2005).

Besides this integration challenge, e-procurement and SRM systems are targeted on streamlining structured business processes and handling of structured data. Structured data has a fixed format and meaning described by meta-data—from start to completion of a business transaction. It is normally stored in database fields. In contrast, unstructured interactions like instant messages, feeds, or blogs for example have no or limited fixed format, are directly derived from human interactions resulting in textual data, and can hardly be computed without any prior transformation (Baars and Kemper 2008). Many of these happen before, during, and after the actual execution of structured business processes, but are rarely supported by the respective systems (Calisir 2004). This is a particular challenge as Cappuccio (2012) predicts that enterprise data will grow by 650 % over the next 5 years, with 80 % of that data being unstructured.

Addressing the challenges of (1) data integration and (2) supporting unstructured interactions, we propose an artifact design that tightly bundles both structured and unstructured data and processes perspectives. Through not looking at both independently, our overall research objective is to determine design principles (DPs) instantiated in an artifact which advance supply networks for supply management professionals, by seamlessly connecting both structured and unstructured data and processes. To reach this goal, we employ action design research (ADR) (Sein et al. 2011) based on the design science research (DSR) paradigm (Hevner et al. 2004). We conceptualize DPs which we use to derive and implement related design decisions (DDs) in an artifact. Finally, we define testable hypotheses and evaluate the utility of both the artifact and the underlying design.

This article is structured as follows: Sect. 2 provides an overview of existing research and describes the identified research gap in more detail by articulating key challenges from scientific and sources from practice. Section 3 introduces the research methodology, following an ADR approach. Section 4 explores a set of meta-requirements and DPs for a solution design and briefly presents the developed artifact. Section 5 introduces the evaluation concept and presents results of a field experiment and Sect. 6 discusses the results. Finally, Sect. 7 provides a summary by articulating contributions for science and practice and concludes with a reflection on limitations, further research opportunities and practical deployment options of the design proposed.

2 Related work

Prior research widely investigated the effects of Internet utilization on supply management and procurement processes (Tanner et al. 2008; Rai et al. 2006; Barua et al. 2004; Davila et al. 2003), in particular in the context of e-procurement (Mishra et al. 2007), e-marketplaces (public exchanges) (Grey et al. 2005), business-to-business procurement (Subramaniam and Shaw 2002), and supplier relationship management (private exchanges) (Brenner and Wenger 2007). Tanner et al. (2008), for example, examined 68 companies from multiple industries and the problems they encountered when using IT in procurement. Slow data integration is named by more than 54 %, while more than 22 % of the participants also criticize deficits in integrating systems. Other important issues are the lack of quality of master data, the fact that respective systems only address some of the procurement processes or cannot address the processes holistically, and the lack of user-friendliness and acceptance. This highlights that current solutions seem to struggle with implementing this requirements convincingly and supporting the business professionals comprehensively.

Similarly, the literature review by Awad and Nassar (2010) identifies supply management challenges that need to be taken into account when designing for this domain. Among others, the complexity of procurement processes involving a large number of process steps and a variety of different internal and external stakeholders. Moreover, "[…] the ability to seamlessly connect with customers, partners, and co-workers is vital for success" (Awad and Nassar 2010, p. 4). This research clearly stresses the mismatch between the essential demand for flexibility, interoperability, and the coverage of holistic supply network processes. Current solutions reveal shortcomings to cope with those challenges, primarily because of their focus on structured data and processes.

In a field study applying the Delphi method with 46 experts in the public sector, Moe and Päivärinta (2011) describe major challenges in procurement. For instance, they ascertain that flexibility in the qualification of suppliers, for instance for innovation generation and operational supply management are key factors to cope with the dynamics in supply networks. Their study also shows that co-operation between stakeholders and interoperability of structured and unstructured data and processes are highly important factors for success.

Carneiro et al. (2013) performed multiple case studies regarding challenges in the creation and operation of collaborative business networks, including two cases of procurement and distribution networks. Their results highlight the importance of information and competency exchange and sharing "[…] an IT platform that provides information on the negotiated conditions, in real time, with full visibility and transparency" (Carneiro et al. 2013, p. 112). Supply networks additionally need to provide support for communication, collaboration, information sharing, and supplier qualification. All of these are rarely provided by current IT system offerings.

Based on a field study in the manufacturing industry Rai and Hornyak (2013) conclude in particular for sourcing use cases, that individual work performance, mediated by job satisfaction, is positively influenced by consistent and shared data. In addition they found evidence that in work processes with high interdependence between internal and external stakeholders (e.g., strategic sourcing, stakeholder collaboration) current supply management systems are too rigid, inflexible and too structured. They suppose "[…] that collaboration and negotiation technologies enabling dynamic interactions through rich media (e.g., multiple cues) are likely to be more suitable in these contexts" (Rai and Hornyak 2013, p. 34).

In summary the presented prior research provides evidence that a major source of current challenges is the focus on structured data and processes, and the non-holistic coverage of supply network processes by insufficiently addressing interoperability and people integration aspects. Data and process integration is defined as "[…] the problem of combining data [and process steps] residing at different sources and providing the user with a unified view of these […]" (Lenzerini 2002, p. 233). The term "people integration", on the other hand, is mainly found in research on social communities and the integration of people in the society or groups of people. People integration in the context of IS is motivated primarily by practical demand and corresponding product offerings for people collaboration environments, user productivity, and networking capabilities (e.g., collaboration rooms, social networks, or wikis). Accordingly, people integration can be defined as interaction between two or more people, working together to achieve shared goals, based on common or shared information (Martinez-Moyano et al. 2006). Table 1 provides a list of aggregated key challenges in supply networks and their relation to the two dimensions of data and process integration (DPI) as well as people integration (PI).

Further evidence from practice has been found in an explorative study by Koppenhagen et al. (2011). In this research supply management experts raised major challenges of current e-procurement and SRM systems in terms of the high amount of various structured procurement documents which needs to be exchanged even along straight forward processes like quote-to-invoice, and the lack of

Table 1 Aggregated key challenges in supply networks

Key challenges in supply management networks	Data/process integration (DPI)	People integration (PI)	References
(a) Support of efficient execution of holistic and dynamic supply processes (e.g., in sourcing processes)	X	X	Rai and Hornyak (2013), Moe and Päivärinta (2011), Koppenhagen et al. (2011), Awad and Nassar (2010), Tanner et al. (2008)
(b) Interoperability in terms of system integration and semantic/syntactic standardization	X		Moe and Päivärinta (2011), Koppenhagen et al. (2011), Awad and Nassar (2010), Tanner et al. (2008)
(c) Support for efficient supplier qualification and partnership creation for innovation generation and operational supply management	X	X	Rai and Hornyak (2013), Carneiro et al. (2013), Moe and Päivärinta (2011), Koppenhagen et al. (2011), Awad and Nassar (2010)
(d) Support collaboration between stakeholders, business partners, customers, service providers etc. for information/competency sharing and collaborative planning		X	Rai and Hornyak (2013), Carneiro et al. (2013), Moe and Päivärinta (2011), Koppenhagen et al. (2011)
(e) Shared IT platform providing real time visibility on accurate and relevant information	X		Rai and Hornyak (2013), Carneiro et al. (2013), Koppenhagen et al. (2011), Awad and Nassar (2010), Tanner et al. (2008)
(f) High usability and productivity of supply network user interfaces to attract business users		X	Tanner et al. (2008), Koppenhagen et al. (2011)

coverage for unstructured interactions between business stakeholders throughout the execution of structured process steps (e.g. business contact initialization, document collaboration, emails, instant messages, calls). Further challenges highlighted were high on-boarding and integration cost, heterogeneous and inflexible collaboration models, lack of real-time and consistent business status insights as basis for simulations and informed decisions, and the missing interoperability to social media tools, and consequently the context linkage between people networks and business process. Consequently supply management practitioners quoted that current systems fall short covering rather unstructured business processes holistically, like sourcing processes which are imperative to achieve strategic supply management goals like cost containment, supply base management and quality assurance.

In summary supply management practitioners state that current systems are problematic because they provide only partial coverage of unstructured business activities (Koppenhagen et al. 2011). This is in particular an issue in context of highly interactive, dynamic and ad hoc processes like sourcing, which are critically important in meeting strategic supply management goals such as cost containment, supply base management and quality assurance.

Addressing these challenges, this research work proposes a design that tightly bundles both structured and unstructured data and process perspectives. Through not looking at both challenges independently, the overarching research question of our research is:

> Which design principles connecting both structured and unstructured data and processes instantiated in an software artifact advance individual performance of supply network professionals?

3 Methodology

There seems to be relative consensus in the DSR community that the research process frequently iterates between "development and evaluation" (Kuechler and Vaishnavi 2008), "build and evaluate" (March and Smith 1995), or "generate and test" (Hevner et al. 2004). Following calls for evaluation in realistic settings when applying DSR (Hevner 2007; Pries-Heje et al. 2008), Sein et al. (2011) complemented these two process steps by proposing that the creation of an artifact is informed both by the researchers' initial design and by the continuous interaction with organizational units. They consequently propose ADR as an approach which is rooted in action research and enables the researcher to study "complex social processes […] by introducing changes into these processes and observing the effects of these changes" (Baskerville 1999, p. 4). According to Sein et al. (2011), it is crucial to include what Hevner (2007, p. 88) calls a "contextual environment" right from the start of the research project in order to ensure that the designed prototype really meets the business needs and matches the original problems. The practical aspect is thus stressed more, due to the continuous inclusion of practitioners and the iterative reciprocal shaping between building and evaluating. Figure 1 shows the overall phased approach of the ADR cycle in our research project.

In our project, this approach allowed us to iterate between the practitioners' input, the researchers' analyses, and the generation of innovative solutions to the problem space in the DSR team. Based on novel solutions, the fully functional artifact is deployed for empirical evaluation to business users with supply management responsibilities in various companies. Table 2 provides an overview of the core activities during the ADR phases.

4 Designing an supply network artifact

4.1 Meta-requirements

To address the key challenges of supply networks listed above, we argue for a stronger combination of DPI with PI in the design of corresponding supply network systems. After several iterations within the research team, starting with single requirements, continuous reflection with practice, we summarized preliminary meta-requirements. Out of those we finally condensed two meta-requirements for the design of a supply network artifact.

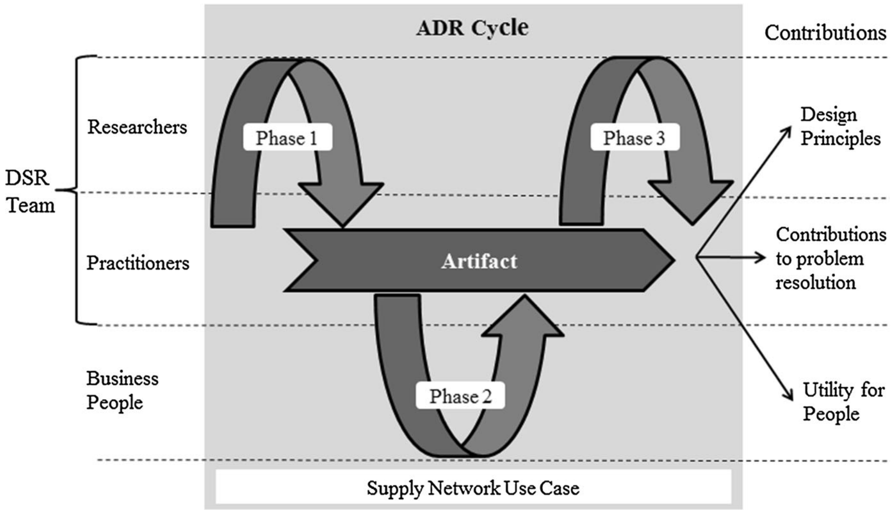

Fig. 1 Research design of artifact build, apply, and evaluation cycles (based on Sein et al. 2011)

Table 2 Core activities of the ADR phases

	Core activities
Phase 1	Explorative study applying literature review, field observations and practice interviews (open and semi-structured) in various industries (e.g. high-tech, chemical, pharma, telecommunication, utilities, consumer products, retail/wholesale, trade)
	(Meta-) requirements aggregation
	Design principles induction
	Design decisions deduction
	Design and development of the artifact applying user centric design methodology (Garrett 2011)
	Artifact build by applying agile/lean development methodologies (Truex et al. 1999)
Phase 2	Artifact field evaluation according the principles of action research (Baskerville 1999; Checkland and Holwell 2007; Lau 1999)
	Evaluation along defined supply network use case, applying field experiment with 26 procurement experts, cross industries
	Primarily quantitative data gathering, measuring performance and individual mental effort
	Statistical analysis of quantitative data
Phase 3	Aggregation of empirical results
	Derivation of conclusions regarding design validity, scientific and practical contributions for problem resolution and utility
	Further refinement of the artifact
	Generalizations, definition of future research, limitations and communication

Firstly, still significant efforts for enabling semantic and syntactic integration infrastructures for many-to-many system integration are required. In this regard by definition structured document distributions between systems from the logical point of view should be prevented. The physical exchange of supply management documents like quotes, purchase orders or invoices should be significantly reduced to a minimum of defined segments as needed in accordance to existing legacy system distributions. Notwithstanding on the logical level a consistent state of shared business documents should be given for all involved business partners at any point in time. Business partners who are collaborating to achieve joint business goals should have always the same data and process basis to guide decision making and to gain high consistency and transparency on the actual business status. Consequently we define the following meta-requirement:

MR1 Consistent view on shared data and processes at any time for all involved business partners.

Secondly, structured and unstructured data and processes should not be handled separately or in different systems. Instead, they should be closely interrelated and interwoven into one environment, meaning for example that it should be possible to network and exchange instant messages during order collaboration within the business context of final negotiation of the price conditions (unstructured process steps) in a year's supply contract (structured data). It should also be possible to easily anticipate extending, changing and new use cases and to collaborate with business partners in flexible collaboration environments without the need to move to another system (including project rooms, messages and news feeds for example). This is in particular important in use cases which are highly interactive, ad hoc and unstructured like sourcing processes, as required by supply management practitioners above. Consequently we define as second meta-requirement:

MR2 Simultaneous coverage for structured and unstructured data and processes to support supply management processes holistically.

4.2 Design principles

Approaching a system design for a supply network artifact, these two meta-requirements need to be transferred into DPs as underlying conceptual foundations, which guide the subsequent DDs and the development of the artifact.

To address meta-requirement MR1, we propose networked business objects (n-BOs) as our first DP (DP1). DP1 defines that all business partners should collaborate on the same shared objects on a shared virtualized platform, and document exchange is prevented by definition, leading to the avoidance of inconsistent versions and cross-referencing of documents. The status of an n-BO evolves during the course of the business process. For example, the n-BO type business partner (BP) in a supplier qualification use case naturally goes along an evolving collaboration process where a supplier data set (an instance of a business partner) is further enriched in terms of attributes and capabilities (methods). The status evolution is illustrated in Fig. 2, modelling the holistic view of the end-to-end process from generic contact to qualified business partner status.

To cover a comprehensive set of supply network processes, we suggest five necessary n-BO types to efficiently support supply network use cases: (1)

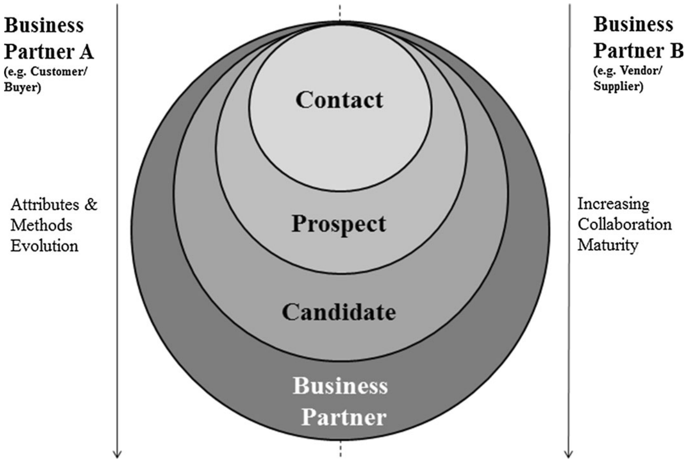

Fig. 2 Design principle networked business objects (DP1)

BUSINESS PARTNER summarizes diverse personas and roles in business networks like category manager, buyer, vendor, and sales manager. (2) ITEM describes all entities that could be the subject of collaboration in a supply network like products, articles, material, stock keeping units (SKUs), services, investment goods, etc. (3) ORDER reflects the legally binding agreement of the business partners in the network. It also incorporates both traditional purchase or sales orders and predecessor or successor states of a classical order, for example contract, quote, delivery, and invoice. We call the latter design aspect 'object evolution'. (4) PROJECT defines activities, combining resources and tasks along common business purpose, time lines and milestones. (5) DOCUMENT stands for all unstructured content like text documents, spreadsheets, presentations, technical specifications and so on, which the networked users could collaborate on.

To fulfil meta-requirement MR2, we introduce social augmentation of supply networks as design principle 2 (DP2). With this, we postulate that the increasing relevance of IT-based social interaction should not only be reflected by offering social media tools in companies, but by taking a systematic approach to integrate IT-supported social interaction in supply networks. We therefore suggest socially augmenting existing structured supply network processes by leveraging IT-based social integration. The corresponding structured data should be stored in networked business objects (DP1).

Processing all interaction activities in one environment—unstructured activities like identifying and qualifying new contacts, interacting efficiently with previously connected business partner combined with structured data such as contract proposals, quotes or invoices—will avoid media breaks and help to prevent loss of business context. The DPs, the meta-requirements and the addressed key challenges in supply networks are summarized in Table 3.

Table 3 Design principles, meta requirements and key challenges

	Design principle	Meta-requirement	Addresses key challenge(s)
DP1	Prevent dispersal data and processes by introducing *networked Business Objects (n-BO)*	*MR1* Consistent view on shared data and processes at any time for all involved business partners	a, b, c, d, e
DP2	Enable the *social augmentation* of supply networks by deeply integrating IT-supported social interaction	*MR2* Simultaneous coverage for structured and unstructured data and processes to support supply management processes holistically	a, c, d, e, f

4.3 Instantiation: the B-zone prototype

Based on the DPs, the artifact was implemented by drawing concrete DDs from the two DPs, which were incorporated as features into the functional software artifact and developed in cooperation with an international software company specifically focusing on the supplier qualification scenario. Table 4 summarizes the DDs and the interrelation to the DPs they are derived from.

The artifact maps a complete supplier qualification use case, from initial contact between supplier and buyer to a well-established relationship between them in the 'business partner' stage. DD1 refers to the evolutionary aspect of the status evolvement of networked business objects. In the supplier qualification use case, this involves the status sequence from initial contact, to prospect, to candidate and finally to business partner. This goes hand-in-hand with increasing access rights to data attributes and the option of including a business partner into structured processes like order or contract collaboration. DD2 highlights the key design decision related to DP1 that business partners involved in structured business processes and who are sharing structured data should have a common view of the same data according to their access rights, to any point in time. There is no delay in updating certain business object data and documents, and them becoming visible to all effected business partners. When a shipment location of a business partners is changed by the supplier for example, all affected buyer and service provider are notified and have immediate access to the new conditions stored in an n-BO of type BUSINESS PARTNER. With DD3 used to tightly bundle unstructured and structured data/processes, we propose business templates that are accessible in business template pools, which define the structured data set and entry fields according to the state of the actual unstructured people interaction. When for example communication between buyer and potential supplier via (instant) messaging arrives at the stage where the supply qualities, standards, incoterms etc. need to be exchanged, the business partners could select or define a business template to enter the necessary structured data. With DD4, the artifact is able to provide contact recommendation based on previous supply activities that the vendor performed for other connected business partners. It can also offer advanced ad hoc and extended search capabilities ('and', 'or', 'not', phrase search) as well as administration and status management capabilities for connected business partners.

Table 4 Design decisions derived from design principles

Design decision (DD)	Design principle(s) (DP)
DD1: Status evolvement of n-BOs	DP1
DD2: Transparency and consistency of data for all involved business partners	DP1
DD3: Business templates for embedding of structured data and processes	DP1, DP2
DD4: Contact recommendation, ad hoc and advanced search, administration	DP2
DD5: Asynchronous and synchronous (instant) messages	DP2
DD6: News feeds and watch-list alerts	DP2
DD7: Social connections between business partners with various stages	DP2

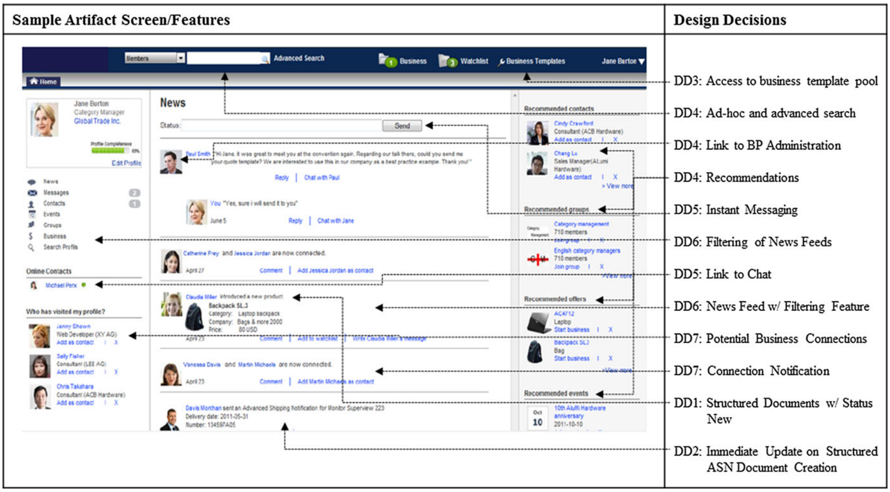

Fig. 3 Design decisions reflected in artifact features of home view

DD5 allows users to create instant messages, (micro) blogs, chat entries etc. with selected partners or to the complete personal supply network of connected business partners. Similarly, with DD6, users can integrate various news feed channels, from supply management forums and public social networks for instance, or to define personal watch-lists which automatically notify when certain events or price changes occur for particular products of interest. Finally, DD7 allows the supply network user to connect to business contacts continuously and receive feeds or messages when connected partners broadcast news, instant messages or blogs, or update certain important structured supply documents.

The sample screen in Fig. 3 shows the home view of the artifact, where business users receive continuous feeds related to structured and unstructured data updates and related data filters for example. The system provides actual recommendations, messaging possibilities and extended search and watch-list capabilities etc.

5 Evaluation of phase 2

This section presents the underlying evaluation model, the experiment design as well as results of the artifact evaluation in phase 2 of the overall ADR project. For that purpose, we applied supplier qualification (SQ) as sample use case following an experimental evaluation because within supply network processes, "identifying, selecting and managing suppliers for a strategic, long-term partnership is a 'key ingredient' to the success of a supply chain" (Wu and Blackhurst 2009, p. 4593). Relationships of this kind will improve a company's competitiveness, because of the reduction of purchase cost and time (Choi and Kim 2008). Wu and Blackhurst (2009) even consider supplier qualification to be the most important phase in procurement. SQ includes all process steps to define, develop and maintain the supply base for diverse product categories, covering for instance initial supplier identification, categorization and evaluation. It is a use case which is strongly characterized by the key challenges and meta-requirements defined above and consequently is an appropriate candidate to measure the design effects as recommended by related work, industry experts and supply management practitioners (Rai and Hornyak 2013; Carneiro et al. 2013; Koppenhagen et al. 2011).

5.1 Evaluation model

To test the artifact design, we focused on the individual level of supply network professionals. Individual performance in supply networks as the dependent variable can be divided into two variables, namely task efficiency and task effectiveness (Sharda et al. 1988; Fuller and Dennis 2009), an approach similar to the by Benbasat and Schroeder (1977), Allen (2006), and Vessey and Galletta (1991). With the artifact providing solutions for the integration of unstructured and structured data and for the prevention of document exchange, we expect that buyers using the artifact will perform a supply network task faster than with a comparison tool, as they do not need to integrate different sources of information manually and do not have to keep track of the latest version of a document. We therefore suggest that:

H1 Using the artifact results in higher task efficiency than using a comparison tool.

Task effectiveness can be measured by decision-making quality. Making the right decision that meets most pre-defined requirements from a set of choices results in high task effectiveness. Prevention of document exchange also results in the reduced risk of making mistakes because of obsolete document versions. If integration of unstructured and structured activities results in more clearly presented information, this is expected to result in better decisions because it is less likely that important pieces of information are missing. Thus, we hypothesize that:

H2 Using the artifact results in higher task effectiveness than using a comparison tool.

Beyond these outcome-oriented measurements, we suggest that individuals who are utilizing advanced supply network systems are directly effected as well. An appropriate kernel theory which addresses such effects is the Cognitive Load Theory (CLT) from cognitive psychology first introduced by Sweller (1988). It proposes that a human's short-term memory is limited in its capacity and can therefore be hindered in problem solving and learning when excessive cognitive load is imposed (Sweller 1993; Miller 1956). The instructional design how information is presented plays an important role in this. Cognitive load can be conceptualized in the dimensions of mental load and mental effort (Paas et al. 2003; Paas and Merrienboer 1994). Mental load accounts for the amount of intrinsic cognitive load that is fixed by a given task. Mental effort represents the human-centred aspect of cognitive load and accounts for the cognitive capacity that is actually allocated to perform the task (Paas et al. 2003; Rey and Buchwald 2011). When mental load is kept at a constant level by applying the same task to an individual while using different tools, mental effort can be used to assess cognitive load as a whole (Paas et al. 1994, 2003; Rey and Buchwald 2011).

It is therefore proposed that the artifact lowers the mental effort compared to a comparison tool frequently used today in supply management. We therefore suggest that:

H3 Using an artifact results in lower mental effort required to perform a task as compared to using a comparison tool.

With this operationalization, the resultant research model consists of constructs that can be measured for evaluation. By deriving testable hypotheses, it is possible to evaluate the artifact as a design product (Walls et al. 1992; Pries-Heje et al. 2008). The research model with the relations between the variables is shown in Fig. 4.

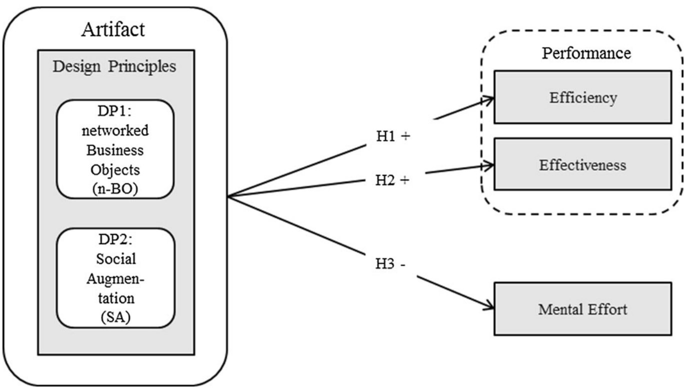

Fig. 4 Evaluation model

5.2 Experiment design

To evaluate the effect of the two DPs embedded in the artifact, we deployed a field experiment as suggested by Hevner and Chatterjee (2010) and collected quantitative data. In our experimental evaluations, the alteration of the independent variable ‘tool’ occurs either by using the artifact incorporating the DPs or by using a comparison tool not incorporating the two DPs. In our experiment, task efficiency is measured using the amount of time consumed by a participant when executing the supplier qualification task. The unit of measurement is seconds. Task effectiveness is measured using ‘decision quality’. In supply management, the task of qualifying suppliers is a decision process that is dependent on multiple criteria and potentially on subjective assessments (de Boer et al. 2001). With these complex conditions in mind, measuring quality is difficult. Decision criteria are often formulated beforehand and involve information like cost, quality of products and delivery performance (Choi and Kim 2008). In order to come to a concurrent decision, the criteria are weighted according to their importance which varies across companies or whole industries. Weighting methods can range from simple scoring methods to complex mathematical programming models (de Boer et al. 2001; Choi and Kim 2008) or decision models such DEA (Wu and Blackhurst 2009). Besides hard facts, like cost, delivery time or compliance of quality standard guidelines (like ISO norms), also soft facts may play a role when qualifying potential suppliers, although they can be considered subordinate. With these complex conditions in mind and as most attention in literature has been paid to the choice phase within the supplier qualification process, we applied a procedure for quality measurement similar to the approach used by Vessey and Galletta (1991) with awarding scores at certain decision points based on hard and soft facts. As the SQ use case was applied to serve as the task that has to be performed during the experiment it therefore determines the mental load.

5.3 Participant selection

Participants were recruited using two criteria: (1) a minimum level of experience in either supplier qualification or supply management/procurement in general and (2) not having previously taken part in any related pre-studies. A judgment sampling combined with a snowball sampling was used to recruit participants (Diekmann 2009). A total of 26 participants from various companies and industries met the criteria as described above, 18 male and 8 female. The average age was 38.08 years (SD 8.8), with a relatively high average experience in supply management (8.23 years). This illustrates the high level of experience present among the members of our sample. The individuals were also quite experienced in performing supplier qualification tasks. As indicated by the median of 4.0 in ‘supplier qualification tasks performed’ 50 % of them have conducted this kind of task more than 5–10 times. In fact, 38.5 % have already performed it more than 10 times. Table 5 provides the descriptive statistics of the participant sample.

Table 5 Descriptive sample statistics for age and work experience

	Age of participants	Years of experience in supply management	Experience supplier qualification	Supplier qualification task performed	Amount of supervised suppliers
N valid	26	26	26	26	26
Mean	38.08	8.231	4.2688	3.54	654.62
Median	37.00	6.500	4.6700	4.00	10
SD	8.80	5.0144	1.52,928	1.449	2361.921
Variance	78.154	25.145	2.339	2.098	5578,671.846
Minimum	24	0.0	1.00	1	0
Maximum	54	20	6.67	5	12,000

5.4 Experimental procedure, task and material

The experimental factor is the tool used for supplier qualification tasks. Two values are possible: Either the participants in our experiment were asked to use the artifact (incorporating the two DPs), or they were asked to perform the same task using a comparison tool (which does not incorporate the DPs). All participants experienced both levels of the experimental factor.

The selection of the comparison tool is based on two criteria: Firstly, the tool needs to provide the most commonly used functions for supplier qualification tasks in a conventional sense. Secondly, the tool should not provide more functions beyond the conventional needs and should not provide any functions that relate to the DPs. To elicit the commonly used functions for supplier qualification tasks, we consulted 16 procurement experts. They identified Microsoft Excel (81 %) and email (75 %) as the most typical tools they used in the supplier qualification tasks. Considering the other selection criteria, we therefore chose a web-based working environment that incorporates email accounts, tabular contact storage, as well as spread sheet online storing and editing functions as the comparison tool for the experiment. When setting up the experiment, both the artifact and the comparison tool were configured with the same amount and type of data for conducting the task. Profiles of prospective suppliers, including names, email addresses, locations, and portraits were generated randomly from feasible sets, without foreseeable bias. To counter any carryover effects (Field and Hole 2003; Jones 1985), the presentation sequence of the two tools was counterbalanced.

In a within-subject approach, participants were randomly assigned to one of the presenting sequences. Individuals in group one used the artifact first and the comparison tool second to execute the same supplier qualification task, while the second group did the opposite. The experiment was carried out in a web-based virtual meeting environment, which offered screen sharing as well as text-based and vocal communication channels. Participants took part in the experiment in their own, familiar working environment and dialled into the virtual meeting. The naturally occurring environment for the experiment has been applied to avoid rather unaccustomed side effects of an artificial laboratory setting, and because of the possibilities of a virtual experiment room which still allows to concentrate on the given tasks without disturbance.

Each experiment lasted about 90 min, which is a manageable duration for participants according to Diekmann (2009). The same researcher provided guidance for all the experimental sessions. At the beginning of each experimental session, the researcher introduced the goal of the experiment, the expected duration and the option of quitting the experiment at any time without explanation. Afterwards, the participants were instructed to fill in a pre-experiment survey covering a few personal details and task experience. They then began the experimental task with the artifact or with the comparison tool, depending on their group assignment. Each session was started with a 2-min video introducing the key features of the tool in question. The participants were then instructed by the researcher via a text-based communication channel to perform the supplier qualification task. Similar amounts of instructions were provided for the artifact and the comparison tool. Once the participants had completed the task, they were asked to fill in a post-task questionnaire about their mental effort during the experimental task. Afterwards, they were instructed to start the second experimental task with the comparison tool. Two different sets of prospective suppliers were used in the two consecutive supplier qualification tasks to reduce the carryover effects. All experimental sessions were screen recorded to allow for further analysis.

During the experimental task of the supplier qualification use case, participants were instructed to imagine themselves as category managers in a purchasing department. In this role, their task was to find new suppliers and to present their selected, final supplier to the company's board. The participants needed to find new suppliers by asking their established contacts and by searching through unknown contacts. Once they had found five suppliers, they had to add them to their contact list and mark them as prospects. They were then asked to send these five prospects a qualification questionnaire where the participants had to flag one criterion as a show-stopper before sending it. After the prospects had filled in the questionnaires, the participants analysed the results. At the first decision point, they had to reject two prospects, notify them and mark the remaining prospects as candidates. At the second decision point, they had to choose one candidate, notify him or her and set his/her connection level to business partner. During the experimental tasks, the researcher played the role of prospective suppliers and wrote emails and sent back the completed questionnaires to the participants. This experimental design ensures that every participant receives the same responses from the prospective suppliers, thus rendering the participants' performance comparable.

In procurement, the task of qualifying suppliers is a decision process that depends on multiple criteria (de Boer et al. 2001). Anticipating this, multi-objectivism was accounted for by designing a qualification business template that incorporated differently weighted criteria with five indications to be considered by the participants. The range of possible points was scaled from 0 to 5. To check if suppliers were rejected or chosen for the right reasons, the participants were asked at each decision point why they decided the way they did.

Mental effort was measured in the post-task questionnaire using the NASA Task Load Index (TLX) (Rubio et al. 2004; Hart and Staveland 1988). The un-weighted version was used, as it does not differ much from the weighted version and is easier for the participants to follow (Wiebe et al. 2010). It consists of six categories: mental demand, physical demand, temporal demand, performance, effort and frustration level (Hart and Staveland 1988; Rubio et al. 2004). Each question is connected to a scale from 0 to 100 points representing the corresponding demand level.

5.5 Results

SPSS version 15.0 was used for the analysis of the experiment data. Cronbach's alpha for the mental effort scale was 0.849 for the comparison tool and 0.845 for the artifact, which indicate high internal reliability of the scale (Nunnally and Bernstein 1994). The average scores on the scales were thus taken as the measurements for participants' mental effort. We used repeated measures analysis of variance (rANOVA) to test hypothesis 1, 2, and 3 (Jones and Kenward 2003). Before testing, violations of relevant statistical assumptions were explored. Firstly, the normality of all dependent variables was examined using the Kolmogorov–Smirnov test and the Shapiro–Wilk test. No violation of normality on the variable 'time' and 'mental effort' was detected at the significant level of 0.05. The variable 'quality' violated the normality assumption, and was thus tested with the non-parameter method (Wilcoxon's test). Secondly, Levene's test was performed on the variables 'time' and 'mental effort', and no violation of homogeneity of variance was detected at the significant level of 0.05 (Hair 2010). We then examined which covariates should be taken in the hypothesis testing. Since within-subject design was used in the experiment, no demographic variables (such as gender or age) or individual experience had to be taken as covariates in the hypothesis testing. A correlation between the order of the tools and the dependent variables reveals that the order is significantly correlated to the time needed to perform the task with the artifact.

We performed repeated measures MANOVA with 'tool' (the artifact vs. comparison tool) as the independent variable and 'time' and 'mental effort' as dependent variables. For both sequences in which the tools have been used, the results indicate that significantly less time was required in order to complete the supplier qualification task when using the artifact than when using the comparison tool ($p < 0.001$). Using the artifact also resulted in significantly lower mental effort than using the comparison tool when performing the supplier qualification task ($p < 0.001$). Hypothesis 1 and Hypothesis 3 are thus supported. Evaluated with Cohen's d, the effect size for 'time' and 'mental effort' were 0.877 and 0.847 respectively, classified as a large effect according to Cohen (1962, pp. 273–288).

To test proposition 2, Wilcoxon's test was applied as an equivalent test of the parametric *t* test (Field and Hole 2003; Toutenburg and Heumann 2008). The null hypothesis cannot be rejected at the significance level of 0.05 ($p = 0.739$), which indicates that there is no significant difference in quality points achieved with the artifact versus the comparison tool. Hypothesis 2 is therefore not supported.

Table 6 Statistical results

	Significance 2-Tailed (p)	Correlation Pearson (r)	Comparison tool (N = 26)		B-zone artifact (N = 26)	
			Mean	SD	Mean	SD
Time (s)	0.000	0.628	1810.81	397.78	1263.73	283.88
Quality (points)	0.739	0.026	3.54	0.706	3.58	0.809
Mental effort	0.000	−0.598	51.05	19.96	26.62	13.12

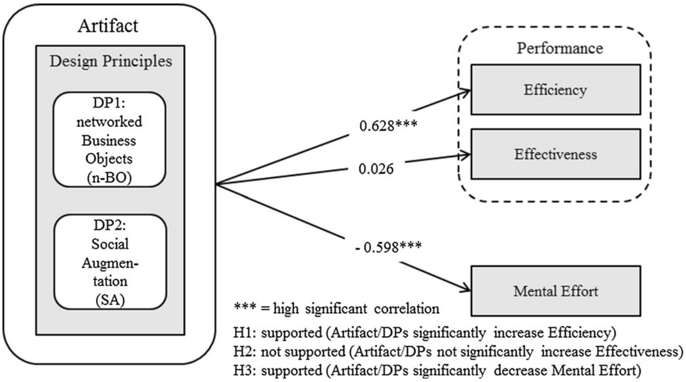

Fig. 5 Hypothesis testing results

Table 6 presents the statistical results of the dependent variables in various experimental conditions.

Figure 5 provides an overview of the evaluation results.

6 Discussion

With the support of hypothesis 3 we first of all could show that our artifact significantly contributes to the reduction of the mental effort of a supply professional that has to be invested for a given task compared to a comparison tool. By ensuring that different types of structured and unstructured data are tightly connected and displayed in one platform, and are not distributed in different applications like email, ERP and SRM systems, the DP social augmentation reduces the information split that is responsible for cognitive (over)load. N-BO as the first DP supports users in automating administrative tasks and providing a single, harmonized version of a data document (such as qualification criteria sheets), thereby freeing cognitive space for important decision tasks.

Furthermore, hypothesis 1 is supported, thereby contributing to one key target of this research, namely that the artifact with its underlying DPs improves individual efficiency. This result can be generalized using causal explanations and surface similarities (Shadish et al. 2002). First, there are no differences between subjects in the experiments and the desired target group of practitioners. Supply management experts participated in the experiment that can be regarded as a representative sampling of the target group in supply networks, as they came from different companies, operated in different departments and purchased different goods, with a high subject matter exposure and background. Strictly speaking, the snowball and judgement sampling method does not constitute a truly probabilistic sample (Bhattacherjee 2012). Compared to a simple convenience sample however, this expert selection has a higher external validity and provides relevant insight to the problem solution. Secondly, individual efficiency, which is measured in this experiment, is a part of group performance. Unless the performance of suppliers, at the other side of a supply relationship, would decrease by using a network like the artifact, it is reasonable to assume that the overall network performance would also improve when using the artifact as a supply network environment. Finally, if DPs, n-BOs and social augmentation reduced the time needed to perform a supplier qualification use case, they could also help to reduce time in other use cases where the combination of different types of data and exchange of documents play an important role.

Finally, despite there being a higher quality indication using the artefact, hypothesis 2 was not supported, no significant difference in the mean values of quality compared to the comparison tool. The average quality score achieved was relatively high, with a score of 3.54 (comparison tool) and 3.58 (our artifact) out of 5, but did not differ much between the comparison tool and our artifact. There are a number of explanations for this. One reason for the equal means could be that the use case designed for the experiment was finally not complex enough to yield substantially different results in terms of quality. The assumption that the supplier qualification task in general imposes high intrinsic load thus continues to hold true, but the mental load in this designed experimental task might not have been high enough to influence quality. It is very likely that individuals tend to adjust the time effort rather than to compromise on a high quality outcome. Nevertheless, complicating the use case by increasing the amount of suppliers to be qualified and adding more decision rounds to it would have easily exceeded the original time plan of maximum 90 min per experiment. Some individuals could also still have compensated the higher complexity with a higher time investment. Related to this is the fact that quality is an aspect of performance that is very difficult to control in an experiment, on account of its high level of subjectivity. From the questionnaires at the decisions points it appeared that while the question of where the supplier was located (Singapore as opposed to Kuala Lumpur for example) was more important for some participants in the experiment, others considered it more important for suppliers to be rated well or recommended by others, or for some suppliers to be more experienced in their job (senior trade agents as opposed to junior trade agents for example). Some even stated nationality, native language or gender as decisive factors.

7 Conclusions

In this article, we introduce a design innovation to support business professionals in supply networks. Based on the conceptualization of two DPs, networked business objects and social augmentation, we develop an software artefact instantiating these

DPs. Based on a conceptualization of performance and cognitive load as key dependent variables, we propose a set of testable hypotheses for evaluating the artifact. In the field experiment we conducted, the artifact outperformed a comparison tool (simulating supply management professionals' current tool support) both in terms of time needed to complete the task (efficiency) and the mental effort imposed on the professionals participating on our experiment. This leads us to conclude that an artifact incorporating the DPs we are proposing is in fact able to increase the performance of procurement professionals and, ultimately, supply networks overall. As the positive evaluation we conducted suggests, n-BO (DP1) and social augmentation (DP2) are key ingredients of these improvements.

The object sharing possibility and the reduction of document exchange enabled by DP1 make it possible for business partners to digest, control and act on critical business developments, based on common information, real-time, without any data barriers and process integration impediments, such as inconsistent status, conditions or difficult identifications of structured business data. In terms of PI, DP2 also provides users with an interaction environment which reduces split-attention effects, allows instant communication, information flow, collaboration on structured documents, reaction to changed conditions and an easy way to build and maintain business connections. The artifact design tightly bundles both DPs and therefore both structured and unstructured data and processes to execute supply network tasks like supplier qualification faster and with less mental effort.

Before turning to a discussion of our contributions, we want to highlight that these need to be carefully evaluated in light of the limitations our research bears. In particular the focus on the buyers' perspective of the supplier qualification use case is an aspect to consider. Fully evaluating the artifact would make it necessary to not just have experimental subjects on the buyers' side, but to also include suppliers. For the evaluation presented here, we did however decide to focus on the buyers' side and keep the suppliers' side constant by having a researcher simulate it. This was necessary to avoid any undesired dynamic reciprocal effects various actions of the supply site might have caused on the buyers side and vice versa. Another aspect to consider is the fact that, as mentioned above, the prototype was developed in close collaboration with a leading vendor of enterprise software products. This introduces risk that the outcome of the evaluation is influenced by the personal bias of certain participants towards the artifact's branding. We accounted for this by not just sampling companies and participants from the software company's customer database. In particular, more than 70 % of the participants had so far no direct interaction with the software products of the respective brand. Also, individuals with prior brand experience and those without it do not seem to behave differently in performance, mental effort and their rating of the artifact in the evaluation.

The artifact we designed and refined on the basis of the evaluation has been crafted into a functioning prototype. More than this though, it is also in the process of becoming a commercial software product, as part of the supply solution of an international software vendor. The artifact design and its principles actually influence future enterprises software concepts, designs and developments in practice. As more and more customers will draw upon the artifact to manage supplier qualifications as well as an increasing range of other supply network tasks, we expect further potential contributions to both research and practice. By evaluating its utility in real life, further challenges with both parties of a supply network and differences in quality might become visible, and it might be possible to confirm differences in time and mental effort.

In addition there are indications that the DPs can be deployed in other areas of enterprises systems beyond supply networks to improve efficiency, effectiveness and reduce mental effort of people using such systems. In particular a high applicability can be assumed in areas where flexible, open and extensible collaboration, simulation and iterative decision making is of high importance to achieve business goals, for example in project management, collaborative design, innovation and production, and supply chain design and planning.

With respect to the design product (the artifact), suggestions regarding future research came up during the evaluation. The open feedback of the participants has revealed the need for further enrichment of the artifact with features like automated recommendations that allow the system or other buyers to recommend or rate certain suppliers. A functionality to invite colleagues to a particular supplier–buyer lifecycle process in order to make a joint decision was also mentioned. Another innovation suggestion is a neutral mediating company role so that the relationship between two companies is not dependent upon dyadic individual procurement experts. Implementing functionalities like these would serve to further increase the practical relevance for the target group of supply management experts. Another source of potential further research is the extension of tested use cases into additional success-critical business processes, beyond supply management and procurement like supply chain planning, product innovation and project management scenarios. It might also be worth considering additional methods for measuring quality. For example, a multiyear study could try to determine how the effective quality of a supplier choice is determined in supplier evaluations after completion of multiple order processes (de Boer et al. 2001).

From the scientific perspective we contribute with the underlying research topical insights to the knowledge base of understanding of the constructs which influence task performance and how future supply network systems could be conceptualized and designed to address performance impediments, based on prior research, practical grounding and by applying rigor research methodology. Beyond the topical aspects, our research contributes to the methodological discourse in the IS community. By applying the ADR approach as described by Sein et al. (2011) we follow the call of various IS scholars (e.g., Hevner 2007) to adequately achieve a balance between rigor and relevance. By conducting the entire ADR project in cooperation with a software vendor and supply management practitioners, the research results are practically relevant, while in parallel methods are applied that have been demonstrated in the IS community as rigorous. Specifically, our detailed and step-by-step presentation of an actual ADR project, combining DSR with qualitative evaluation measures in an experimental setting also contributes to the science community. We believe that we provide a comprehensive picture that eventually may help other researchers to successfully implement and follow the ADR methodology.

Relevance is achieved by grounding the problem definition by intense explorations of challenges practitioners are facing when using current supply management systems, and continuous interaction with practice throughout the complete ADR cycle, from design, build and evaluation of the artifact. By including supply management experts as the evaluation sample, their answers directly depict the opinion of the target group. In summary, we expect in real work life that knowledge workers who are responsible for qualifying suppliers would be highly familiar with the company-specific qualification procedures. The artifact would thus make them significantly faster, as it is especially useful for people who already have a stable and high learning curve regarding the task. Implications for practice are therefore that a supply network environment like the proposed artifact and its underlying DPs improves individual efficiency and is also likely to increase overall network performance. It also significantly reduces procurement professionals' mental effort, freeing up more cognitive resources for learning and thorough decision-making. While hoping that these perceived potentials will hold true for the finalized version of the design product, we consider them encouraging indications with respect to the utility of the design for supply network systems.

References

Allen G (2006) The effects of state-based and event-based data representation on user performance in query formulation tasks. MIS Q 30(2):269–290

Awad HA, Nassar MO (2010) Supply chain integration: definition and challenges. In: Proceedings of the international multiconference of engineers and computer scientists, vol 1

Baars H, Kemper H-G (2008) Management support with structured and unstructured data—an integrated business intelligence framework. Inf Syst Manag 25(2):132–148

Barua A, Konana P, Whinston AB, Yin F (2004) An empirical investigation of net-enabled business value. MIS Q 28(4):585–620

Baskerville RL (1999) Investigating information systems with action research. Commun Assoc Inf Syst 2(19):1–31

Benbasat I, Schroeder RG (1977) An experimental investigation of some MIS design variables. MIS Q 1(1):37–49

Bhattacherjee A (2012) Social science research: principles, methods, and practices, 2nd edn. Open Access Textbooks, Tampa

Brenner W, Wenger R (2007) Anforderungen an Electronic Sourcing Systeme. Elektronische Beschaffung, Brenner W, Wenger R (eds), Springer, Berlin, pp 1–21

Calisir F (2004) The relation of interface usability characteristics, perceived usefulness, and perceived ease of use to end-user satisfaction with enterprise resource planning (ERP) systems. Comput Hum Behav 20(4):505–515

Cappuccio D (2012) 10 critical tech trends for the next five years. In: Gartner symposium IT Expo 2012, 21–25 Oct 2012, Orlando, FL

Carneiro LM, Soares AL, Patrício R, Azevedo AL, Pinho de Sousa J (2013) Case studies on collaboration, technology and performance factors in business networks. Int J Comput Integr Manuf 26(1–2):101–116

Checkland P, Holwell S (2007) Action research: its nature and validity. In: Kock N (ed) Information systems action research. Springer, New York, pp 3–17

Choi JH, Kim JW (2008) A hybrid decision support model for selecting highly qualified suppliers. J Comput Inf Syst 49(1):90–100

Cohen J (1962) The statistical power of abnormal-social psychological research: a review. J Abnorm Soc Psychol 65(3):145–153

Davenport TH (1998) Putting the enterprise into the enterprise system. Harvard Bus Rev 76(4):121–132
Davila A, Gupta M, Palmer R (2003) Moving procurement systems to the Internet: the Adoption and use of E-procurement technology models. Eur Manag J 21(1):11–23
de Boer L, Labro E, Morlacchi P (2001) A review of methods supporting supplier selection. Eur J Purch Supply Manag 7(2):75–89
Diekmann A (2009) Empirische Sozialforschung: Grundlagen, Methoden, Anwendungen, 20th edn. Rowohlt, Reinbek bei Hamburg
Field A, Hole G (2003) How to design and report experiments, 1st edn. Sage, London
Fuller RM, Dennis AR (2009) The impact of task-technology fit and appropriation on team performance in repeated tasks. Inf Syst Res 20(1):2–17
Garrett J (2011) The elements of user experience: user-centered design for the Web and beyond, 2nd edn. New Riders, Berkeley
Grey W, Olavson T, Shi D (2005) The role of e-marketplaces in relationship-based supply chains: a survey. IBM Syst J 44(1):109–123
Hair JF (2010) Multivariate data analysis: a global perspective, 7th edn. Pearson, Upper Saddle River
Harland CM, Lamming RC, Zheng J, Johnsen TE (2001) A taxonomy of supply networks. J Supply Chain Manag 37(4):21–27
Hart S, Staveland L (1988) Development of NASA-TLX (task load index): results of empirical and theoretical research. In: Hancock P, Meshkati N (eds) Human mental workload. North Holland Press, Amsterdam, pp 239–250
Hevner AR (2007) The three cycle view of design science research. Scand J Inf Syst 19(2):87
Hevner A, Chatterjee S (2010) Design research in information systems: theory and practice. Springer, New York
Hevner A, March ST, Park J, Ram S (2004) Design science in information systems research. MIS Q 28(1):75–105
Jones RA (1985) Research methods in the social and behavioral sciences. Sinauer Associates, Sunderland, p 1985
Jones B, Kenward MG (2003) Design and analysis of cross over trials, vol 98. CRC Press, Boca Raton
Koppenhagen N, Mueller B, Katz N, Maedche A (2011) How do procurement networks become social? Design principles evaluation in a heterogeneous environment of structured and unstructured interactions. In: ICIS 2011 proceedings, pp 1–19
Kuechler B, Vaishnavi V (2008) On theory development in design science research: anatomy of a research project. Eur J Information Syst 17(5):489–504
Lau F (1999) Toward a framework for action research in information systems studies. Inf Technol People 12(2):148–176
Lenzerini M (2002) Data integration: a theoretical perspective. In: Proceedings of the twenty-first ACM SIGMOD-SIGACT-SIGART symposium on principles of database systems, pp 233–246
March ST, Smith GF (1995) Design and natural science research on information technology. Decis Support Syst 15(4):251–266
Martinez-Moyano IJ, Rich EH, Conrad SH (2006) Exploring the detection process: integrating judgment and outcome decomposition. In: Intelligence and security informatics, pp 701–703. Springer, Berlin. Culture of Collaboration. The International Association of Facilitators Handbook 4(69)
Miller G (1956) The magical number seven, plus or minus two: some limits on our capacity for processing information. Psychol Rev 63(2):81–97
Mishra AN, Konana P, Barua A (2007) Antecedents and consequences of Internet use in procurement: an empirical investigation of U.S. manufacturing firms. Inf Syst Res 18(1):103–120
Moe CE, Päivärinta T (2011) Challenges in information systems procurement in the Norwegian public sector. In: Electronic Government. Springer, Berlin, pp 404–417
Nunnally JC, Bernstein IH (1994) Psychometric theory, 3rd edn. McGraw-Hill, New York
Paas F, Merrienboer J (1994) Instructional control of cognitive load in the training of complex cognitive tasks. Educ Psychol Rev 6(4):351–371
Paas F, Merrienboer J, Adam J (1994) Measurement of cognitive load in instructional research. Percept Mot Skills 79(1):419–430
Paas F, Tuovinen JE, Tabbers H, Van Gerven P (2003) Cognitive load measurement as a means to advance cognitive load theory. Educ Psychol 38(1):37–41
Pries-Heje J, Baskerville R, Venable JR (2008) Strategies for design science research evaluation. In: Proceedings of the 16th European conference on information systems (ECIS 2008)

Rai A, Hornyak R (2013) The impact of sourcing enterprise system use and work process interdependence on sourcing professionals' job outcomes. J Oper Manag. doi:10.1016/j.jom.2013.07.005
Rai A, Patnayakuni R, Seth N (2006) Firm performance impacts of digitally enabled supply chain integration capabilities. MIS Q 30(2):225–246
Rey GD, Buchwald F (2011) The expertise reversal effect: cognitive load and motivational explanations. J Exp Psychol Appl 17(1):33–48
Rubio S, Daz E, Martn J, Puente JM (2004) Evaluation of subjective mental workload: a comparison of SWAT, NASA-TLX, and workload profile methods. Appl Psychol 53(1):61–86
Sein M, Henfridsson O, Purao S, Rossi M, Lindgren R (2011) Action design research. MIS Q 35(1):37–56
Shadish W, Cook T, Campbell D (2002) Experimental and quasiexperimental designs for generalized causal inference. Houghton Miin Company, Boston
Sharda R, Barr SH, Mcdonnell JC (1988) Decision support system effectiveness: a review and an empirical test. Manag Sci 34(2):139–159
Subramaniam C, Shaw MJ (2002) A study on the value of B2B E-commerce: the case of web-based procurement. In: Shaw MJ (ed) E-business management. Kluwer, Boston, pp 439–461
Sweller J (1988) Cognitive load during problem solving. Cogn Sci 12(2):257–285
Sweller J (1993) Some cognitive processes and their consequences for the organisation and presentation of information. Aust J Psychol 45(1):1–8
Tanner C, Woelfle R, Schubert P, Quade M (2008) Current trends and challenges in electronic procurement: an empirical study. Electron Mark 18(1):6–18
Tarn JM, Yen DC, Beaumont M (2002) Exploring the rationales for ERP and SCM integration. Ind Manag Data Syst 102(1):26–34
Toutenburg H, Heumann C (2008) Deskriptive Statistik: eine Einführung in Methoden und Anwendungen mit R und SPSS, 6th edn. Springer, Berlin
Truex D, Baskerville R, Klein H (1999) Growing systems in emergent organizations. Commun ACM 42(8):117–123
Vessey I, Galletta D (1991) Cognitive fit: an empirical study of information acquisition. Inf Syst Res 2(1):63–84
Walls JG, Widmeyer GR, El Sawy OA (1992) Building an information system design theory for vigilant EIS. Inf Syst Res 3(1):36–59
Wiebe EN, Roberts E, Behrend TS (2010) An examination of two mental workload measurement approaches to understanding multimedia learning. Comput Hum Behav 26(3):474–481
Wu T, Blackhurst J (2009) Supplier evaluation and selection: an augmented DEA approach. Int J Prod Res 47(16):4593–4608