HAL open science

Measuring and Evaluating Communication Intensities in Collaborative Networks

Jens Eschenbächer, Novica Zarvić, Oliver Thomas, Klaus-Dieter Thoben

To cite this version:

Jens Eschenbächer, Novica Zarvić, Oliver Thomas, Klaus-Dieter Thoben. Measuring and Evaluating Communication Intensities in Collaborative Networks. 11th IFIP WG 5.5 Working Conference on Virtual Enterprises (PRO-VE), Oct 2010, Saint-Etienne, France. pp.527-536, 10.1007/978-3-642-15961-9_63 . hal-01055950

HAL Id: hal-01055950

https://inria.hal.science/hal-01055950v1

Submitted on 25 Aug 2014

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Distributed under a Creative Commons Attribution 4.0 International License

Measuring and Evaluating Communication Intensities in Collaborative Networks

Jens Eschenbächer[1], Novica Zarvić[2], Oliver Thomas[2], Klaus-Dieter Thoben[1]
[1] BIBA – Bremer Institut für Produktion und Logistik GmbH, Hochschulring 20, 28359 Bremen, Germany
{esc, tho}@biba.uni-bremen.de
[2] Universität Osnabrück, Fachgebiet Informationsmanagement und Wirtschaftsinformatik, Katharinenstr. 3, 49069 Osnabrück, Germany
{novica.zarvic, oliver.thomas}@uni-osnabrueck.de

Abstract. Companies that are actively participating in a collaborative network (CN) need to show a high level of cooperation ability and willingness. The concept of cooperation contains various aspects that need to be considered, like e.g. communication, resource exchange, or cross-organisational processes. These aspects should become permanent subjects of analysis during the operational phase of the CN. The article at hand considers one of these aspects, namely the communication aspect. Our approach is based on a combination of fundamental concepts stemming from the Media-Richness-Theory (MRT) and Graph-Theory. It enables the analyser to firstly measure and then evaluate communication intensities in CNs. We present our approach by means of an example and discuss possible application areas and extensions.

Keywords: Communication intensity, collaborative networks, cooperation.

1 Introduction

Today, globalisation and also the tendency towards decreasing in-house production force many companies to cooperate within Collaborative Networks (CNs) [1-3]. The concept of cooperation is defined as the collaboration of systems or the merging of activities. In order to measure this concept, all aspects that can have an influence on cooperation must be taken into account. In networks of manufacturers the exchange of resources is of fundamental relevance, whereas for service networks outsourcing and offshoring of work are dominating aspects [4]. Both the exchange of resources and the external allocation of tasks are dependent on high-quality communication between the partners in the CN and are therefore crucial for the success of the network. Therefore communication must be seen as an indispensable aspect, because it does not only support but it enables cooperation. Because of this importance, the article focuses solely on the communication aspect in cooperation and provides a systematic approach for measuring and evaluating communication in CNs.

The paper is structured as follows. Section 2 gives an introduction about relevant elements that need to be considered when performing a collaborative network analysis. Then, in section 3, we present the building blocks of our approach and

provide the reader with important background information on the MRT (Media Richness Theory) [5-7]. Thereby we enrich MRT with an evaluation scheme that delivers values to be used in network graphs. Then we present in section 4 our approach on the basis of a case study. The approach itself is straightforward applicable and represents – next to resource exchanges and external task allocations – one important building block of a holistic method that is able to measure and evaluate cooperation. Finally, in section 5 we summarise our findings, discuss possible future research for extending our approach and conclude the article.

2 Elements of Collaborative Network Analysis

Firstly, a method to measure and evaluate communication in CNs must be developed. According to Wührer [8], there are four crucial elements that a so-called network analysis must incorporate. These four elements, also shown in Fig. 1, are (a) type of entity, (b) type of relationship, (c) content of relationship, and (d) level of analysis.

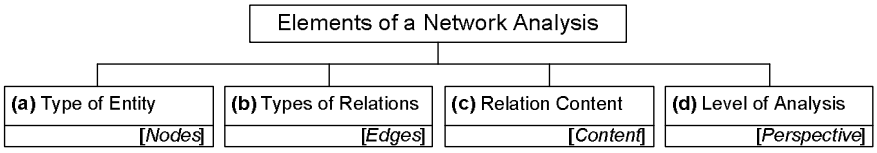

Fig. 1: Essential Elements of the Collaborative Network Analysis (cf. [8])

When looking at a CN from a graph-theoretical perspective, the *type of entity* (a) is usually represented by nodes in the graph. Every node stands for an actor of the network and could represent entities such as companies, departments within those companies, and individuals. The second element, *types of relationships* (b), describes the relationships between the nodes, which are visualised by means of edges between nodes. The *content of relationship* (c) describes the instantiation of edges, delivering content and values to the type of relationship under consideration. Finally, the *level of analysis* (d) deals with the perspective that is chosen for the examination. Nodes and edges in the graph may be analysed separately, before the attention is directed at specific pair- relationships on the next level of analysis.

3 A Reference Model for Measuring and Evaluating the Communication Aspect

3.1 ICT-Systems

First results in research underline the high importance of designing ICT (information and communication technology) infrastructures [9-11]. This section briefly introduces ICT-systems that are treated by the following investigation, where some basic ideas of Weber [12] are adopted. The term information system (IS) comprises the computer-assisted processing and presentation of information and their functional as well as

data-technical integration. The focus is though mainly on the integration and interoperability of existing information systems available for communication in and between companies. The benefit of these systems particularly depends on two distinct components: the data-structure that determines what sort of data may be computed on one side and the functional component as the actual processing-instance on the other side. Within the framework of the communication system concept, the emphasis lays on communication and is understood as information exchange. Lockermann et al. define a communication system as an exchange-oriented IS [13]. Meanwhile some authors try to develop a formal ontology for IS which have received some attention [14]. In the 80ies, the development of new telecommunication technologies led to the investigation on how these techniques could be used for handling diverse office tasks [15]. The telecommunication technologies did not continue to center exclusively on the mere information processing, but put communication itself into the spotlight. Upcoming terms like "office communication system" demonstrate this change of paradigms. Objects of interest were mainly the information flow, the communication partner, the throughput time of interactions, and finally the communication costs. In this context, IS were viewed as black boxes, while the attention was turned to both the processes and the media of communication. Key aspects of research were among others Workflow- and Groupware Systems as well as the multimedia-based communication support of distributed collaborative processes. Figure 2 shows a selection of ICT-Systems. The four-field matrix makes obvious that some ICT-Systems can be positively classified as IS, whereas others clearly are part of the group of communication systems. Besides ICT-systems, the matrix additionally discriminates between storage and output media. Criteria for the differentiation are interaction possibilities on one hand, and electronic reusability on the other hand.

From a theoretical viewpoint, there are many different approaches on how ICT-systems can be utilized effectively in collaborations. For example, Reichwald et al. [16] discussed the MRT, in which complexity is perceived as the driver of selection.

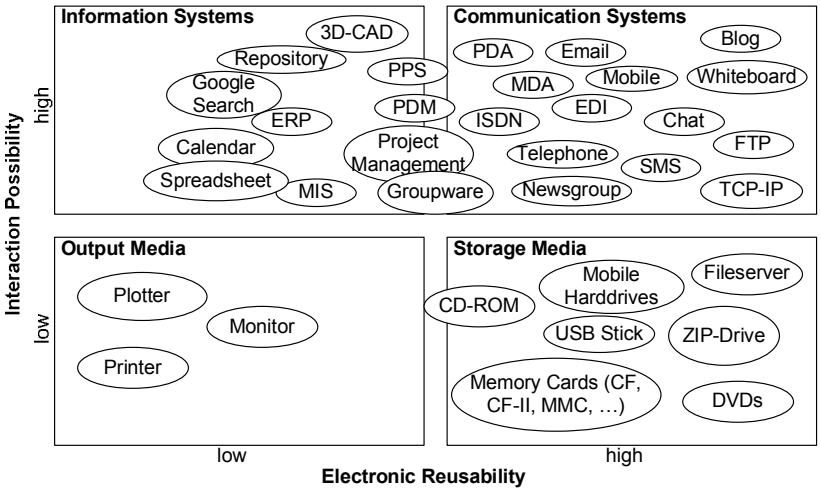

Fig. 2: Characterisation of a Selection of ICT-Systems

3.2 Theoretical Approaches for Creating Communication Processes

Some German researchers have discussed heavily theoretical approaches that support communication processes in ICT environments [17-19]. These led to diverse and even conflicting results. In this section we will not focus on this debate, but rather use one theoretical perspective, which is MRT [20, 21]. Whenever face-to-face communication is not possible, media support is required. This comes true whenever the communication partners cannot be at the same place at the same time. Fortunately, the broad spectrum of communication-supporting media ranging from the classical letter or fax to telephones and video-conferences allows users to overcome barriers of space and time and is still growing constantly.

Principally, the users have alternatives to choose from. This simple fact has got a considerable impact on the success of communication processes, because the media choice strongly influences interaction. The communication research tries to track down such connections. One field of communication research concentrates on the factors in media choice, namely, the reasons why people tend to use certain media in specific communication situations. Another central field, namely the media impact, examines the effects of media usage on the success of communication processes. Numerous empirical studies have dealt with these questions and produced many surprising insights [16]. At large, three classes of influence factors that determine the selection and utilisation of media are distinguished in literature:

- According to the *MRT*, objective attributes of the medium regarding the analog and digital communication content dominate the decision (Is the medium rich or lean?).
- The *theory of subjective media acceptance* assumes that the individual way of working and preferences for certain communication types determines the media choice (Does the medium support one's own preferences concerning speed, comfort, etc.?).
- The *social influence approach* argues that the media acceptance of the communication partners' (social) environment predetermines the media selection (Which medium does my interaction partner prefer?).

None of these theories is capable of explaining all forms and reasons of media decision, and even combined, they leave many questions unanswered. Nevertheless, recent research makes one thing very clear. New telecommunication media may not be considered suitable for the overcoming of borders in time and space just because of their technical potentials. Only if further influence factors and dependencies are taken into account, concrete behavior may be explained properly, like for instance, why high-cost and time-consuming personal communication (face-to-face) is often still preferred in business despite of the wide availability of telephone and other media. The most ostensive depiction for explaining such phenomena is offered by the MRT. It states that technical and non-technical communication forms have distinct transmission capacities regarding both analog and digital information and consequently can be classified as richer or leaner communication [22]. Correspondingly, face-to-face communication in personal contact is a rich communication form. It offers a multitude of so-called parallel communication channels like speech, tone, gesture, facial expression, etc., allows for direct feedback, responses, and a rich spectrum of possible expression, as well as the intermediation

and observation of mood and emotion. In contrast, the mere exchange of documents, for example by fax, represents a lean communication with a very low degree of media-richness.

3.3 Applying MRT to the Communication Aspect in CNs

Our approach is based on the MRT, which we extended by an evaluation scheme as shown in figure 3. We do so for being able later on to instantiate the edges in our network analysis with values (cf. section 2). In practice, the MRT is discussed controversially, but in our view, it constitutes a rather useful approach for the differentiation of communication processes. Acting on the assumption that the effectiveness of communication depends on the communication medium used, a direct and personal communication is defined to be most effective, while the group of unaddressed documents bears the lowest effectiveness. Because the effectiveness of communication also expresses the used media's communication intensity [23], the extended media-richness concept appears to be an appropriate reference model for the measurement and evaluation of the aspect to be investigated. Communication as such usually includes only one sender and one receiver. However, in business relationships communication cannot be unidirectional, but in most cases implies reactions and answers. The evaluation scores have been allocated to the medium type by considering the medium effectiveness. This means that the more effective the communication medium in MRT, the higher the evaluation score.

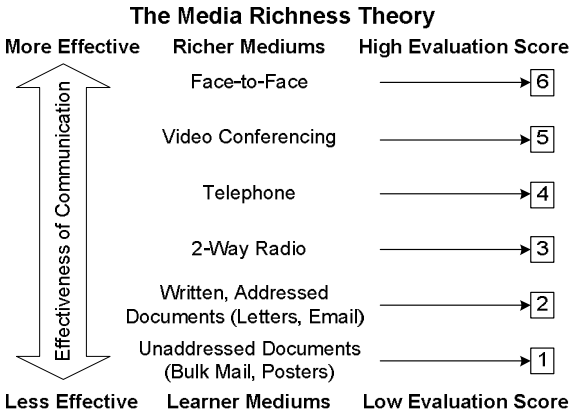

Fig. 3: Evaluation Scheme on basis of the MRT

4 Presentation of the Methodology: A Case Study

The measurement of organizational communication has been a research subject for many years [24]. Nevertheless today more research is needed to understand the exploding number of communication processes in organizations. Consequently our

approach for measuring and evaluating communication shall now be illustrated with the help of a concrete case study. The developed methodology consists of five steps (cf. Figure 4) that will be explained in this section. The first step presumes the knowledge of the company network's structure. In accordance with *types of entities* (a) and *types of relationships* (b) introduced within the framework of the collaborative network analysis, such a structure consists graph-theoretically of nodes and edges, where nodes symbolize the companies and edges the relationships (here in terms of the communication aspect as communication channels) within the network. In a second step, the existing interaction types within the network are identified and assigned to the respective edges. This step describes the element *relationship content* (c) of the network analysis. We discriminate the following interaction types [25-29]:

1. Material-related interactions
2. Juridical interactions
3. Financial interactions
4. Human resource interactions
5. ICT interactions

The third step is the alignment of the graph with so-called bidirectional multi-edges, which means that each edge (step 1) is duplicated and aligned in order to mirror both interaction directions in the communication of the respective companies. In the next step, the interaction type to be examined must be determined.

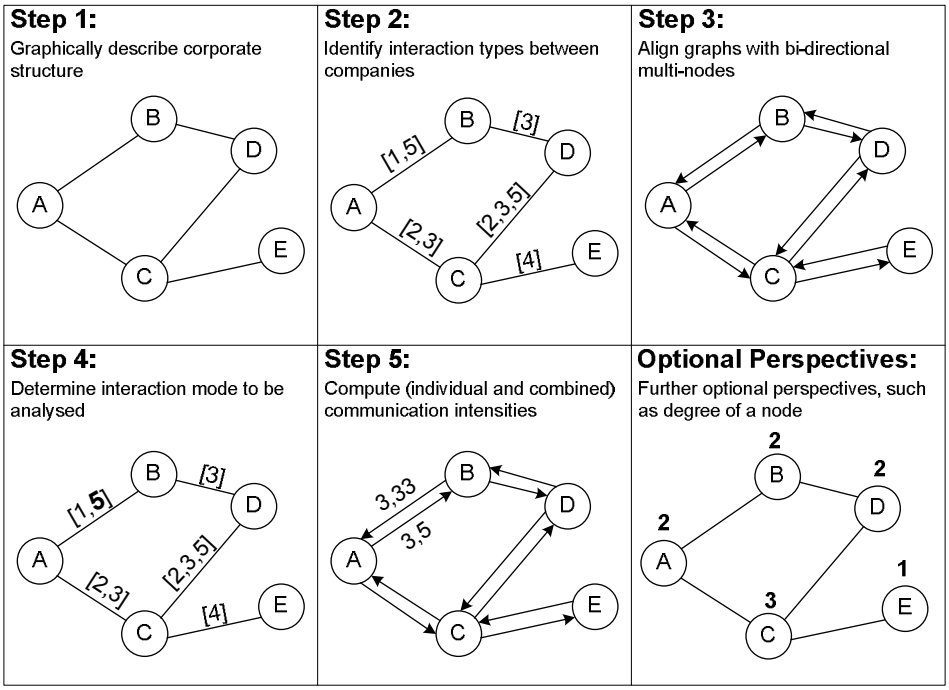

Fig. 4: Methodology for the Measurement and Evaluation of Communication

In our case study, we analyse the ICT-interaction type (interaction type 5) in more detail. At this point, we exemplarily focus on the communication aspect of this interaction type.

Business Case Description. The challenge of this case study is the development of a car driver assisting system that heavily improves driving safety. It is based on the idea to design and implement touch screen functionalities for applications in cars. The innovation to be developed displays essential information like velocity, navigation data, and the control panel directly upon the surface of the windshield and therewith within the driver's field of view. The driver controls the display with his finger tips and may conduct such adjustments at the make-believe distance of the menu elements. This simple mechanism avoids the eye adjustment in the case that the driver switches its eye focus and attention from "infinite distance" (observation of the road) to "2-foot" (usual distance to the front panel) and back. This bears the advantage that the driver hasn't got to turn his eyes from the road anymore - a tremendous safety advance. The information is additionally presented on the front panel. The front seat passenger could furthermore enjoy from entertainment functions like a movie player without distracting the driver.

Application of the Methodology. In the above described business case – within the phase of the innovation project – a communication exchange between two suppliers in the CN appears, where supplier A needs to know the project management competency from supplier B. This represents a realistic example of a typical communication exchange within the project [30]. An excerpt of a communication between supplier A and supplier B is represented by means of a communication transcript on the left (Fig. 5a) and message flows in a BPMN-like model on the right (Fig. 5b). Every outbound message is evaluated on basis of the evaluation scheme from figure 3 and consequently given a certain value. These values are finally summed up and divided by the total number of outbound communication. The results shown in step 5 reveal a communication intensity of 3.5 for supplier A and slightly lower value for supplier B (3.33). These thoughts are in line with the initially introduced collaborative network analysis element *level of analysis* (d). On the subsequent level, namely the aggregated level of pair-relationships, we receive a mean value of 3,415 for the communication intensity of suppliers A and B. Our simple approach towards the measurement and evaluation of communication in collaborative business networks is concluded by the fifth step.

It should be noted here that suppliers sometimes tend to hold back important information among each other, because of competitive reasons and the like. Such behaviour could lead to distortions and mistakes. It is therefore expected that the need for social presence is much higher in such cooperations than inside a single company, which in turn requires a richer medium for achieving high communication intensity. This is, of course, also subject to the task to be achieved. Nevertheless, inter-personal and inter-organisational trust issues, but also inter-cultural cooperations, are representing a particular characteristic of CNs, where effective communication can help to overcome hindrances.

Certainly, additional examination of further graph-theoretical attributes is possible and might add valuable insights [31]. One possible extra-perspective would be the

degree of nodes. This perspective shows how many other nodes a node is connected with, that is, how many participants a member has interactions or communication with. This is of major importance, if the communication of an entire company and CN respectively is to be examined.

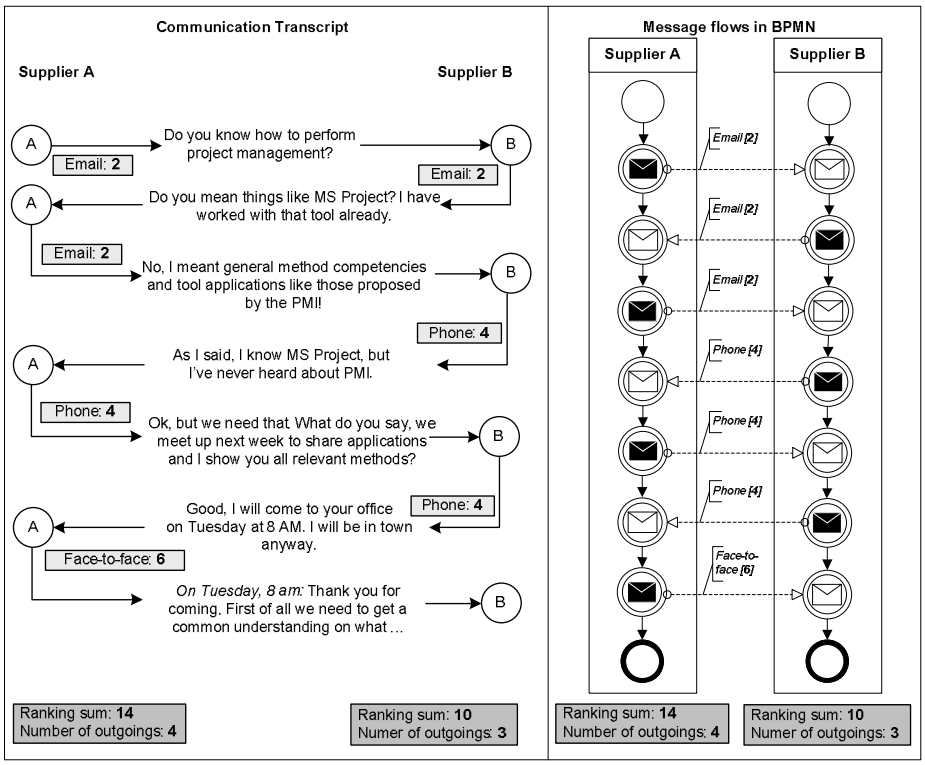

Fig. 5: a) Communication Transcript, and b) BPMN-like representation of communication

5. RESULTS AND CONCLUSIONS

The measurement and evaluation of communication intensities in CNs poses a major problem in practice. Especially the spatial distribution and the particular form of inter-organisational cooperation remain obstacles. In this context, approaches of the telecooperation help understand and pinpoint the challenges of communication. The introduced graph-theoretical approach explains a model that facilitates a simple measurement of communication-intensities in five steps [30]. Overall, the approach might appear at first a bit simplistic, but it represents a combination of fundamental elements that are coming from two different and distinct theories. Secondly, it is straightforward applicable and delivers fast material for discussion inside CNs. And thirdly, it represents just an extensible building block of the envisioned cooperation measurement, which still needs some extensions like for instance semi-automation of creating and evaluating the communication transcripts or the handling of multiple

inbound and outbound messages and their dependencies from different partners in the CN. As mentioned above, the objectives of measuring and evaluating cooperation in CNs also include further aspects like resource exchange or external allocation of tasks over and above communication. This is why this article only shows a first concept that indeed includes the communication intensities, but must be expanded by more attributes. The assumptions of MRT have been intensively discussed in theory, and, due to broad experience in inter-organisational cooperations, the authors are certain that they can be validated in practice as well. Nevertheless, facing the multitude of new forms and instruments of communication [33], there is a great need for further research.

References

1. Ahuja, G.: Collaboration Networks, Structural Holes, and Innovation: A Longitudinal Study. Administrative Science Quarterly. Vol. 45, No. 3, 425-455 (2000)
2. Camarinha-Matos, L., Afsarmanesh, H.: Collaborative networks: a new scientific discipline. Journal of Intelligent Manufacturing. Vol. 16, 439–452 (2005)
3. Newman, M.E.J.: The structure of scientific collaboration networks. PNAS, Vol. 98, No. 2, 404-409 (2001)
4. Lacity, M.C., Willcocks, L.: Global Information Technology Outsourcing: In Search of Business Advantage. John Wiley & Sons, Inc. (2000)
5. University of Twente: Media Richness Theory. Accessed at: www.tcw.utwente.nl/theorieenoverzicht/Theory%20clusters/Mass%20Media/Media_Richness_Theory.doc/
6. Dennis, A.R., Kinney, S.T.: Testing the Media Richness Theory in the New Media: The Effect of Cues, Feedback and Task Equivocality. In: Information Systems Research. Vol. 9, No. 3, 256-274 (1998)
7. El-Shinnawy, M., Lynne Markus, M.: The poverty of media richness theory: explaining people's choice of electronic mail vs. voice mail. Int. J. Human-Computer Studies. Vol. 46, No. 4, 443-467 (1997)
8. Wührer, G.: Internationale Allianz- und Kooperationsfähigkeit österreichischer Unternehmen: Beiträge zum Gestaltansatz als Beschreibungs- und Erklärungskonzept. Linz Trauner, 1995.
9. Proakis, J.G., Masoud, S.: Communication Systems Engineering. Prent. Hall (2002)
10. Roberts J.: From Know-how to Show-how? Questioning the Role of Information and Communication Technologies in Knowledge Transfer. Technology Analysis and Strategic Management, Vol. 12, No. 4, 429-443 (2000)
11. Lankhorst, M. et al: Enterprise Architecture at Work: Modelling, Communication and Analysis. Springer, Berlin; 2nd ed. (August 2009)
12. Weber, F.: Formale Interaktionsanalyse - Ein Beitrag zur systematischen Gestaltung von Informations- und Kommunikationsstrukturen im Concurrent Enterprise durch die Berücksichtigung von Informationseigenschaften, Dissertation, Universität Bremen, Bremer Schriften zur Betriebstechnik und Arbeitswissenschaft, Vol. 61, Verlag Mainz (2009)
13. Lockermann, P., Krueger, G., Krumm, H.: Telekommunikation und Datenhaltung, Carl-Hanser Verlag, München (1993)
14. Guarino, N.: Formal Ontology and Information systems. In: N. Cuarino (Ed.) Proc. of FOIS´98, Trento, Italy, 6-8 June, IOS Press, Amsterdam, pp. 3-15 (1998)
15. Krcmar, H.: Informationsmanagement, 4. Auflage, Springer, Berlin (2006)

16. Reichwald, R., Möslein, K., Sachbacher, H., Englberger, H., Oldenburg, S.: Telekooperation: Verteilte Arbeits- und Organisationsformen, Springer, Berlin (1998)
17. Stadlbauer, F.: Zwischenbetriebliche Anwendungsintegration - IT Management in Unternehmensnetzwerken, Dissertation, Universität München, Wiesbaden, Deutscher Universitäts-Verlag (2007)
18. Wittenberg, S.: Gestaltung interner Märkte in Unternehmensnetzwerken, Dissertation, LMU München, Lohmar Köln, Josel Eul Verlag (2006)
19. van's Gravesande, B.S.: Internetbasierte Anwendungen in der F&E-Kooperation: Eine empirische Analyse basierend auf der Adaptive Structuration Theory, Dissertation, Universität Witten-Herdecke, Wiesbaden, Deutscher Univ.-Verlag (2006)
20. Daft, R.L., Lengel, R.H.: Organizational information requirements, media richness and structural design. Management Science, Vol. 32, No. 5, 554-571 (1986)
21. Trevino, L., Lengel, R., Bodensteiner, W., Gerloff, E., Muir, N.: The richness imperative and cognitive style: The role of individual differences in media choice behavior. Management Communication Quarterly, Vol. 4, No. 2, 176-197 (1990)
22. Zack, M.H.: Interactivity and Communication Mode Choice in Ongoing Management Groups. Information Systems Research, Vol. 4, No. 3, 207-239 (1993)
23. Dawes, P.L.: Communication Intensity in Large Scale Organizational High Technology Purchasing Decisions. Business-to-Business Marketing. Vol. 3, No. 3, 3-38 (1996)
24. Roberts, K. H.; O'Reilly, C. A.: Measuring organizational communication. Journal of Applied Psychology. Vol. 59, No. 3, 321-326 (1974)
25. Weber, D.: Strategische Planung im Unternehmensnetzwerk am Beispiel industrieller Dienstleistungen im Industrieanlagenbau Elektronikfertigung. Dissertation, Technische Universität Braunschweig, Aachen, Shaker Verlag (2005)
26. Liebhart, U.-E.: Strategische Kooperationsnetzwerke: Entwicklung, Gestaltung und Steuerung. Dissertation, Universität Klagenfurt, Deutscher Universitäts-Verlag (2002)
27. Preece, J.; Rogers, Y., Sharp, H.: Interaction Design: Beyond Human-Computer Interaction. John Wiley (2002)
28. Madhok, A., Tallman, S.B.: Resources, Transactions and Rents: Managing Value Through Interfirm Collaborative Relationships. Organization Science, Special Issue: Managing Partnerships and Strategic Alliances, Vol. 9, No. 3, 326-339 (1998)
29. Eschenbächer, J.: Gestaltung von Innovationsprozessen in Virtuellen Organisationen durch Kooperationsorientierte Netzwerkanalyse, Dissertation, Universität Bremen, Bremer Schriften zur Betriebstechnik und Arbeitswissenschaft, Band 64, Verlag Mainz (2009)
30. Zarvić, N.; Eschenbächer, J;, Thoben, K.-D.: Messen und Bewerten von Kommunikationsintensitäten in Unternehmensnetzwerken. Information Management und Consulting. Vol. 24, No. 4, 19- 24. (2009)
31. Zarvić, N.: Considering Structural Properties of Inter-organizational Network Fragments during Business-IT Alignment, TR-CTIT-08-12, Centre for Telematics and Information Technology, University of Twente, ISSN 1381-3625 (2008)
32. O'Brien, G.: The measurement of cooperation. Organizational Behavior & Human Performance. Vol. 3, No. 4, 427-439 (1968)
33. Watson-Manheim, M.B.; Bélanger F.: Communication Media Repertoires: Dealing with the Multiplicity of Media Choices. MIS Quarterly. Vol. 31, No. 2, 267-293 (2007)