Contributions to Decision Support for Wind Energy, Literature Research Processes and Towards a Better World through Information Systems

Von der Wirtschaftswissenschaftlichen Fakultät der
Gottfried Wilhelm Leibniz Universität Hannover
zur Erlangung des akademischen Grades

Doktor der Wirtschaftswissenschaften
– Doctor rerum politicarum –

genehmigte Dissertation

von

Diplom Ökonom André Koukal
geboren am 02.01.1985 in Burgwedel

2018

Betreuer und Gutachter:	Prof. Dr. Michael H. Breitner
Weiterer Gutachter:	Prof. Dr. Klaus-Peter Wiedmann
Vorsitzender der Prüfungskommission:	Prof. Dr. Stefan Wielenberg
Weiteres Mitglied (beratend):	Dr. Michelle Muraz
Tag der Promotion:	15.11.2018

This thesis is dedicated to those
who inspired and supported me,
especially my family.

I. Abstract

Decision making is an important and complex challenge for companies, organizations and individuals. Making the right operational and strategic decisions at the right time has a big influence on a successful development and the survival in competition. To make the best possible decisions it is essential to have access to aggregated and processed information which are accurate, reliable and consistent. Decision support contributes to the decision-making process by preparing and providing relevant information. Decision support systems (DSS) further contribute to decision-making processes as they embed approaches into integrated systems which aim to provide fast and easy access to decision-relevant information. This cumulative dissertation is divided into three thematic chapters according to different research areas which are presented and discussed in the context of quantitative and qualitative decision support. The first thematic chapter focusses on decision support for the wind energy sector based on quantitative financial approaches. A DSS is constructed that addresses the needs of all project stakeholders for the assessment of corresponding projects. The system integration of renewable energies (RE) in general and of wind energy represents a fundamental challenge as the unsteady electricity generation introduces variability in the electrical system. Decision support is provided by introducing a modeling approach that can help to design support schemes which promote a spatially-diversified deployment through location-based investment incentives. The second thematic chapter revolves around the enhancement of the literature research processes which is an important sub-step of a complete literature review and part of many other scientific research methods. Decision support is provided by our Tool for Semantic Indexing and Similarity Queries (TSISQ) that allows a fast and simple identification of semantically similar research articles. The third thematic chapter deals with survey-based decision support. Qualitative and quantitative data was gathered with an explorative survey among leading IS researchers. The findings can contribute to decisions regarding the future alignment of the IS research domain. In summary, it is shown that decision support based on qualitative and quantitative data contributes to decision making by providing decision-relevant information. As data amounts will continue to growth in the future, the relevance of decision support will further increase.

Keywords: Decision Support, Decision Support System (DSS), Renewable Energies, Wind Energy, Literature Research Process, Design Science, Survey Research

Zusammenfassung

Entscheidungsprozesse stellen komplexe und bedeutende Herausforderungen für Unternehmen, Organisationen und Individuen dar. Die richtigen operativen und strategischen Entscheidungen zum richtigen Zeitpunkt zu treffen hat großen Einfluss auf den eigenen Erfolg und das Bestehen im Wettbewerb. Entscheidungsunterstützung trägt zu Entscheidungsprozessen durch das Bereitstellen entscheidungsrelevanter Informationen bei, da bestmögliche Entscheidungen den Zugriff auf aufbereitete Informationen verlangen, die zuverlässig und konsistent sind. Entscheidungsunterstützungssysteme (EÜS) können einen zusätzlichen Beitrag leisten, indem sie Methoden in einem Gesamtsystem vereinen, das einen schnellen und einfachen Zugriff auf entscheidungsrelevante Informationen ermöglicht. Diese kumulative Dissertation ist in drei thematische Kapitel unterteilt, die sich mit qualitativer und quantitativer Entscheidungsunterstützung befassen. Das erste thematische Kapitel behandelt Entscheidungsunterstützung im Bereich der Windenergie basierend auf quantitativen, finanziellen Methoden. Das erstellte EÜS deckt die Anforderungen aller Steakholder eines Windenergieprojektes hinsichtlich der finanziellen Bewertung ab. Die Integration erneuerbarer Energien (EE) in die Stromnetze stellt durch die schwankende Stromerzeugung eine zentrale Herausforderung dar. Entscheidungsunterstützung wird hierzu durch einen Ansatz geboten, der die Gestaltung von Einspeisevergütungssystemen adressiert. Dazu wird eine räumliche Verteilung von EE Anlagen durch standortbezogene, finanzielle Vergütungsanreize gefördert. Im zweiten thematischen Kapitel geht es um die Erweiterung von Literaturrechercheprozessen, die ein wichtiger Bestandteil eines Literaturüberblicks und darüber hinaus Teil weiterer wissenschaftlicher Forschungsmethoden sind. Entscheidungsunterstützung wird mit Hilfe von TSISQ (*Tool for Semantic Indexing and Similarity Queries)* gegeben. Es ermöglicht die schnelle und einfache Identifizierung semantisch ähnlicher Forschungsartikel. Das dritte thematische Kapitel beschäftigt sich mit umfragebasierter Entscheidungsunterstützung. Die Ergebnisse einer explorativen Befragung führender IS Forscher können zu Entscheidungen bezüglich der zukünftigen Ausrichtung der IS Forschungsdomäne beitragen. Insgesamt wird deutlich, dass Entscheidungsunterstützung basierend auf qualitativen und quantitativen Daten zum Entscheidungsprozess durch das Bereitstellen entscheidungsrelevanter Informationen beiträgt. Durch künftig zunehmende Datenmengen wird die Bedeutung von Entscheidungsunterstützung zudem weiter steigen.

Schlagworte: Entscheidungsunterstützung, Entscheidungsunterstützungssystem, Erneuerbare Energien, Windenergie, Literaturrecherche Prozess, Design Science, Umfrageforschung

II. Management Summary

Making the right decisions at the right time is an important challenge for companies, organizations and individuals. A successful development and the survival in competition strongly depends on the quality of operational and strategic decisions. In order to make the best possible decisions it is essential to have access to aggregated and processed information which are accurate, reliable and consistent. For the preparation of relevant information, all kinds of qualitative and quantitative data that can contribute to an issue should be considered. The complexity of decision making based on diverse information and increasing amounts of data highlight the importance of approaches, models, and tools for decision support.

Decision support contributes to the decision-making process by providing relevant information based on quantitative as well as qualitative data which is collected and extracted from various data sources. Continuously increasing amounts of data e.g. through different kinds of sensors, the connection of devices or digitalization (Power, 2014) demand for the use of information systems (IS) for automatic data processing, preparation and supply. The ability to consider and use the huge amounts of publicly or internally available data for decision making can have a significant influence on how companies or organizations effectively compete in the market. Embedding decision-supporting approaches and models into decision support systems (DSS) can further contribute to corresponding decision-making processes as they aim to provide fast and easy access to aggregated, decision-relevant information in integrated systems.

In this cumulative dissertation, three major research areas are presented and discussed in the context of quantitative and qualitative decision support based on corresponding research papers. The dissertation is divided into three thematic chapters according to these research areas. Chapter 2 is the first thematic chapter and deals with decision support for the wind energy sector based on quantitative financial approaches. Chapter 3 focusses on decision support for the enhancement of literature research processes by employing quantitative approaches. Chapter 4 revolves around survey-based decision support. Figure I illustrates the research streams with corresponding conference and journal publications. Each of the three research streams finally resulted in an “A” publication according to the VHB JOURQUAL 3 ranking.

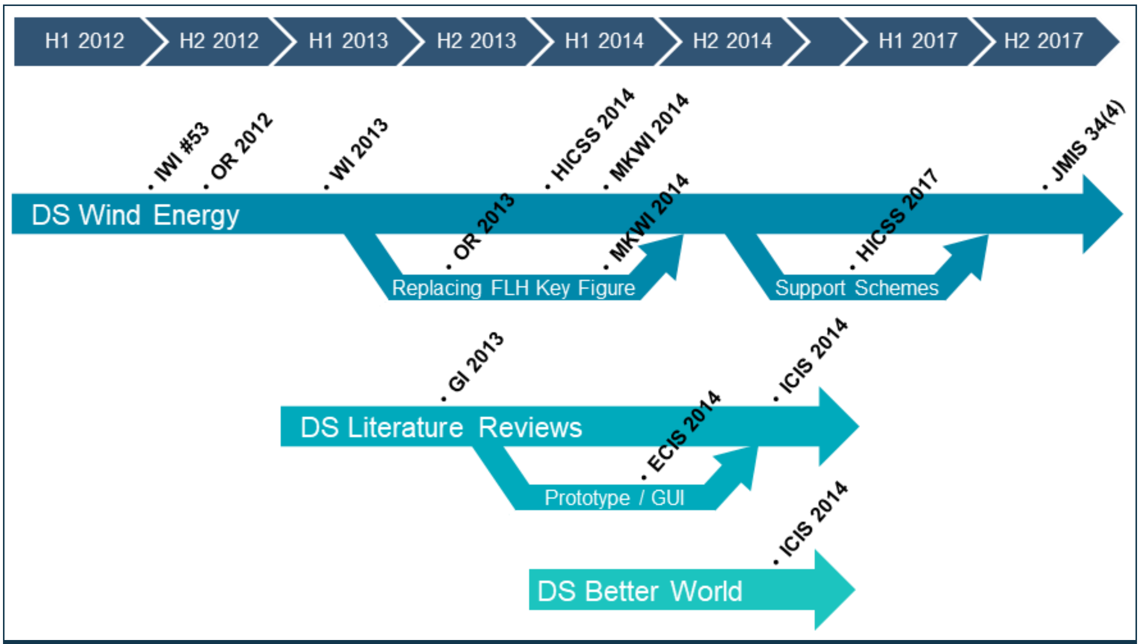


Figure I: Research Streams with related Journal and Conference Publications.

Decision Support for the Wind Energy Sector:

Considering that the energy demand is constantly increasing all over the world and climate change effects from greenhouse gas emissions are becoming more and more evident, an intensive expansion of renewable energies (RE) seems not only necessary, but mandatory. To facilitate this expansion decision support is provided for the assessment of wind energy projects. The constructed decision support system (DSS) utilizes probability distributions and a Monte Carlo simulation (MCS) to consider project risks on top of a discounted cash-flow model. The DSS addresses the needs of all project stakeholders and thus can contribute to an expansion of RE as well as environmental and economic sustainability. Figure II shows simulation results of relevant key figures for investors (project value) and lenders (DSCR, LLCR, PLCR). The applicability of the DSS and the underlying models are evaluated in two exemplary wind energy projects in Germany and Brazil.

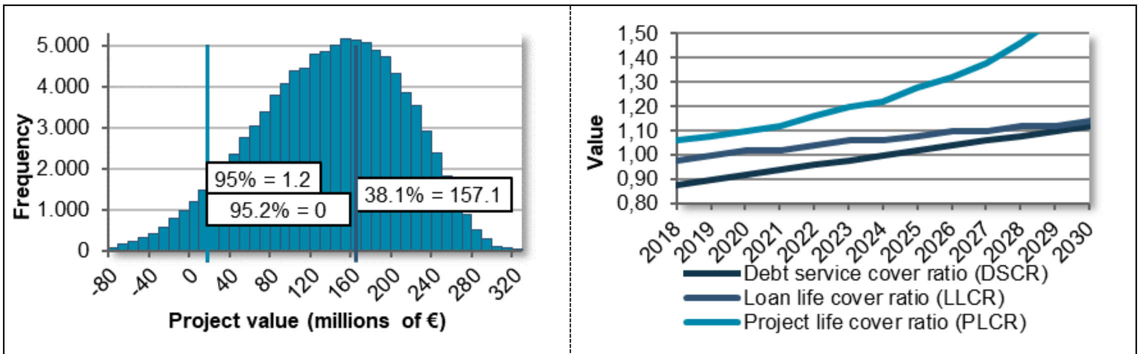


Figure II: Distribution of the Project Value and Key Figures at 95% Confidence Level based on Koukal and Breitner (2014).

Next to the assessment of individual RE projects from the perspective of investors or lenders, the system integration of RE represents an important challenge in the transition towards sustainable energy systems. Their unsteady electricity generation introduces variability in the electrical system and leads to high ancillary services costs and technical issues regarding grid stability and supply reliability. These issues can be significantly mitigated through a spatially diversified deployment of RE which smooths the variability in the electrical system over sufficiently large regions. By introducing a modeling approach that can help to design support schemes to promote a spatially-diversified deployment for RE through location-based investment incentives, decision support is provided. The modelling approach combines a consideration of favorable spatial distributions of RE capacity with current policy designs that aim at an active capacity expansion management. It is evaluated in a simulation study with focus on diversifying wind energy deployment in Mexico under an idealized auction-based support scheme. Figure III shows required feed-in compensations and potential wind farm locations in Mexico.

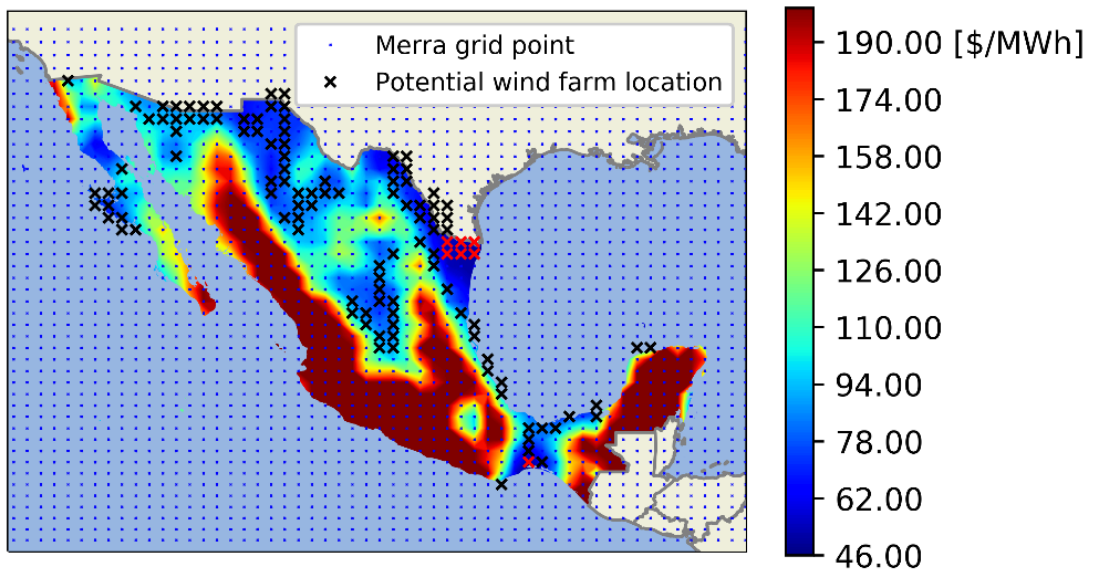


Figure III: Required Feed-In Compensations according to Piel et al. (2017).

The study demonstrates how location-based investment incentives reduce resource-dependent competition among projects and shift the competition towards the economic efficiency of projects. The underlying approach and application results provide guidance and support policy-makers to quantify and evaluate location-based incentives for RE support schemes. Design elements of the created models and artifacts offer prescriptive knowledge that can help policy-makers to assess current approaches for quantifying location-based incentives. They can further be used as a benchmark model for comparisons of different concepts for support schemes or location-based investment incentives.

Decision Support for the Enhancement of Literature Research Processes:

Literature search is an important sub-step of a complete literature review and a part of many other established scientific research methods. By addressing and enhancing this fundamental and time-consuming step in every literature research process, decision support is provided with the Tool for Semantic Indexing and Similarity Queries (TSISQ). The simplified access to a huge amount of scientific resources requires an increasing effort to conduct comprehensive literature reviews. To address this issue, TSISQ is designed to use unstructured texts, e.g. either complete scientific research papers or any kind of natural language, as query input to identify semantically similar texts. It makes use of a technique called latent semantic indexing (LSI) which belongs to the field if natural language processing and provides a web-frontend to allow a simple use and fast identification of semantically similar research articles. The components of TSISQ, their functions, and the respective data flows are presented in Figure IV.

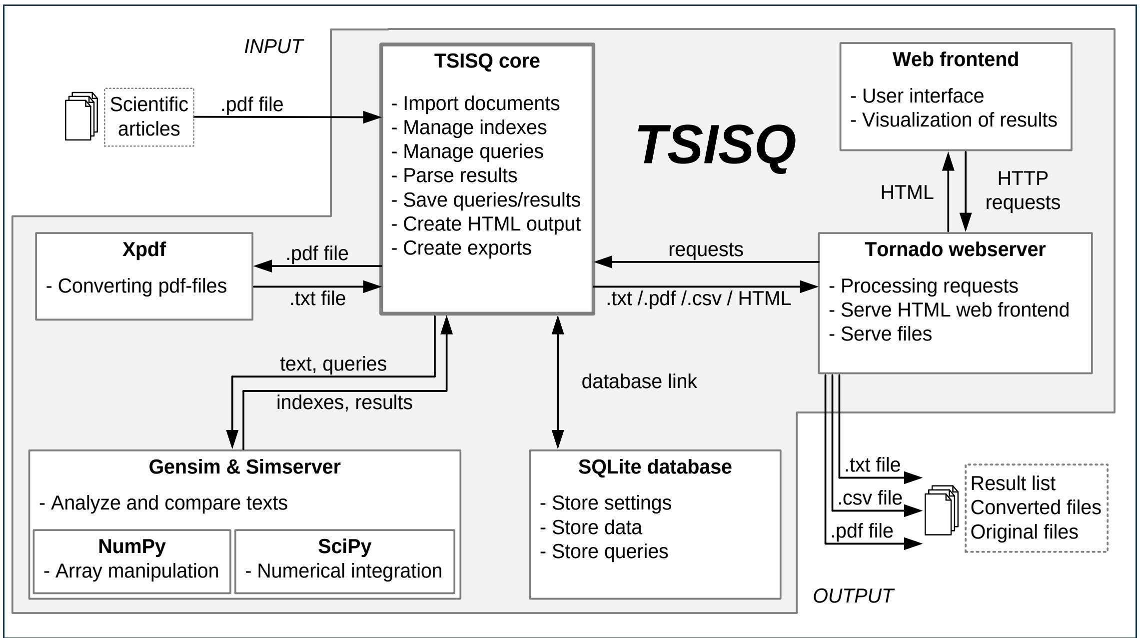


Figure IV: System Architecture of TSISQ prototype based on Koukal et al. (2014).

The applicability of TSISQ is evaluated in different environments and search cases covering realistic applications that aim at the identification of semantically similar literature. Results indicate that TSISQ can increase the efficiency of a literature search by saving valuable time in finding relevant literature in a desired research field. Additionally, it can improve the quality of search results and enhance the comprehensiveness of a review by identifying sources that otherwise would not have been considered. In summary, TSISQ can contribute to decision support and represents a useful complement to the established search engines used in scientific literature research processes. The target audience includes all researchers who need to efficiently gain an overview of a specific research field and refine the theoretical foundations of their research.

Decision Support towards a Better World through IS:

Behind the background of the Millennium Development Goals (MDGs) decision support is provided on top of survey research methodology and a questionnaire (Chapter 4). To answer the high-level and abstract question of how IS can contribute to build a better world, an explorative survey among leading IS researchers on a global scale was conducted and qualitative and quantitative data was gathered. The results show that the impact of IS is largely perceived as indirect and that the perceived contribution of different IS research streams varies considerably. The biggest contribution is seen regarding the goals universal education, environmental sustainability, and a global partnership for development. A selection of quantitative results derived from the survey data concerning the MDGs is presented in Figure V.

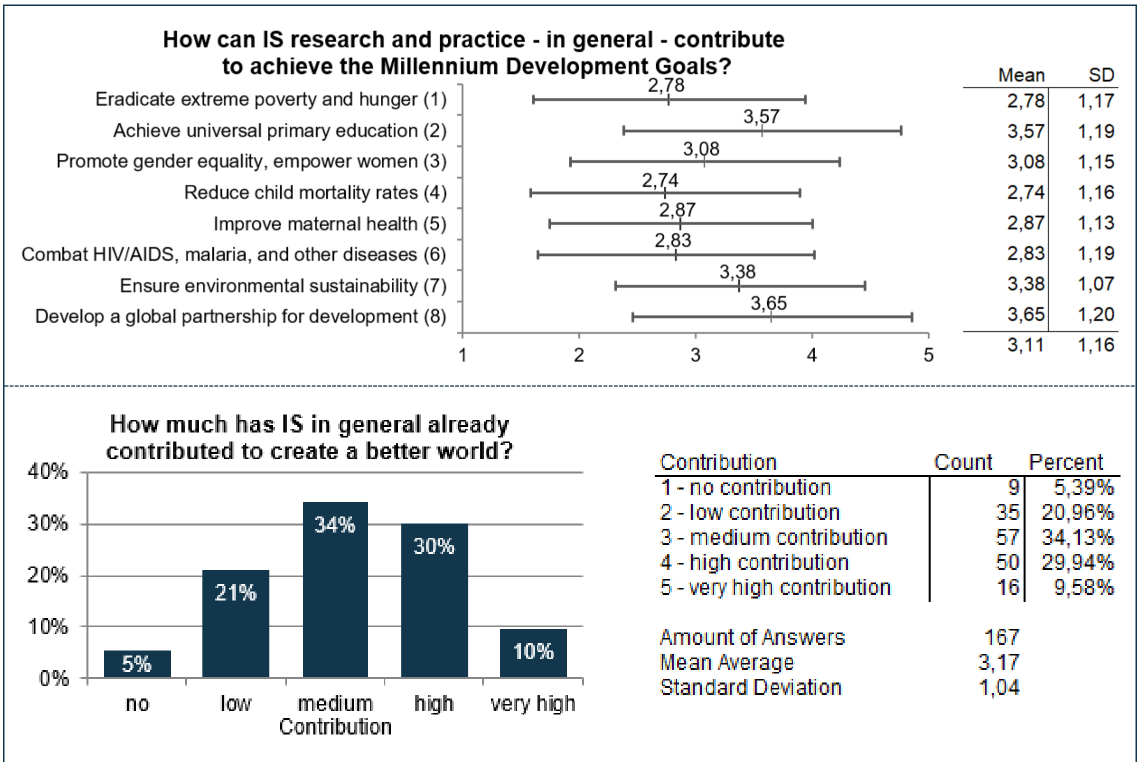


Figure V: Results of Survey among IS Researchers based on Rickenberg et a. (2014).

Besides positive aspects, the survey also reveals challenges and critique concerning IS research. It can serve as a starting point, create awareness, and stimulate further discussions and research. With the right focus and alignment, IS practice and research have the potential to take on the big questions and can help to build a better world. Significant improvements regarding high level goals like the MDGs can only be reached within an incremental progress. Structural changes to the IS research domain and involved institutions can facilitate IS researchers to really take on the big questions and build a better world. In summary, it is shown that qualitative and quantitative data gathered with surveys can contribute to decision support and improve decision making.

In this cumulative dissertation, several topics of three different research streams and corresponding research publications are investigated. The results address two objectives. On the one hand, they contribute to IS research in the area of qualitative and quantitative decision support regarding the application and enhancement of different research methods as well as the alignment of the IS research community concerning important global challenges. On the other hand, the presented findings address practical problems of investors, lenders and other stakeholders of specific wind energy projects, policy makers that are faced with issues concerning the variability in the electrical system due to renewable energies and related grid stability as well as the process to find relevant literature in a specific research field.

Different research methods were employed for the presented research. Design-orientated approaches according to Peffers et al. (2008) as well as Hevner et al. (2004, 2007) were followed for the research regarding wind energy and literature research processes by identifying domain-specific problems, specifying research objectives and formulating research question. Formal models and instantiations were designed, constructed and refined in a loop of iterations and finally demonstrated and evaluated. Survey-based approaches found application for the research concerning questions about how IS can contribute to a better world. After the research objectives have been set and a research question was posed, an explorative online survey among leading IS researchers was conducted to gather qualitative as well as quantitative data. With the help of open coding techniques and descriptive statistics, the given answers were classified and visualized to enable interpretations and the formulization of findings.

Even though the research processes presented in the thematic chapters of this dissertation mainly focused on practical problems in different IS research areas or in the IS research discipline in general, they all considered both main principles of IS research: rigor and relevance. Methodological rigor is ensured by employing research approaches that are well established in the IS research domain and by following specific guidelines in the research processes. Relevance is also addressed as the conducted research is focused on practical problems and contributions are provided that enhance existing solutions or establish new approaches.

In summary, it is shown that decision support based on qualitative and quantitative data contributes to decision makers' needs by processing and preparing data and providing aggregated information. It can lead to better decision making and aims at the goal of long-term corporate and organizational success. As data amounts will continue to growth in the future, the relevance of decision support will further increase.

III. Table of Contents

IV. Table of Figures

V. List of Tables

VI. List of Abbreviations

AIS	Association for Information Systems
AIS	Association for the Information Systems
APV	Adjusted present value
CAPEX	Capital expenditures
CAPM	Capital asset pricing model
CDM	Clean development mechanism’s
CFADS	Cash flow available for debt service
CSV	Comma-separated value
DCF	Discounted cash-flow
DSCR	Debt service cover ratio
DSR	Design science research
DSS	Decision support system
ECIS	European Conference on Information Systems
ECM	Enterprise content management
EJIS	European Journal on Information Systems
EU	European Union
FCF	Free cash-flow
GI-FB	*Fachbereich Wirtschaftsinformatik der Gesellschaft für Informatik* (German) Department of business informatics of the society for computer science
ICIS	International Conference on Information Systems
IRENA	International Renewable Energy Agency
IRR	Internal rate of return
IS	Information system
ISR	Information Systems Research
JAIS	Journal of the Association in Information Systems
JIS	Journal on Information Systems
LDA	Latent dirichlet allocation
LLCR	Loan life cover ratio
LSA	Latent semantic analysis

LSI	Latent semantic indexing
MCS	Monte Carlo simulation
MDGs	Millennium development goals
MISQ	Management of Information Systems Quarterly
NPVE	Net present value to equity
OECD	Organisation for Economic Co-operation and Development
OPEX	Operation expenditures
OWE	Onshore wind energy
OWP	Offshore wind park
PDF	Portable document format
PERT	Program evaluation and review technique
PLCR	Project life cover ratio
PV	Present value
RE	Renewable energy
RQ	Research question
SD	Standard deviation
SDGs	Sustainable Development Goals
SEM	Structural equation modeling
SVD	singular value decomposition
TFIDF	Term frequency-inverse document frequency
TSISQ	Tool for Semantic Indexing and Similarity Queries
UN	United Nations
VaR	Value-at-risk
VBA	Visual Basic for Applications
VHB	*Verband der Hochschullehrer für Betriebswirtschaft e.V.* (German) Academic Association for Business Research
VSM	Vector space model
VWF	Virtual wind farm
WACC	Weighted average cost of capital
WKWI	*Wissenschaftlichen Kommission Wirtschaftsinformatik im Verband der Hochschullehrer für Betriebswirtschaft* (German) Scientific commission for business informatics in the association of professors for business administration

0. Overall View of Publications

In this section, a short chronological overview of research publications that form the basis for this cumulative thesis is presented. Table 1 shows all published articles with the involved authors, the publication date, the journal or conference proceedings in which an article was published. Besides, it is outlined in which part of this thesis the publications are possibly considered in more detail.

The column VHB/JQ3 refers to the rating according to the VHB JOURQUAL version 3 (Hennig-Thurau et al., 2015; Hennig-Thurau und Sattler, 2015b). This is the official rating for journals and conference proceedings of the *Verband der Hochschullehrer für Betriebswirtschaft e.V.* (VHB) (German Academic Association for Business Research). It is based on the assessment and classification of the VHB members and follows methodological approaches that were created through a variety of input by the members (Hennig-Thurau and Sattler, 2015a).

The column WKWI shows a rating according to the *Wirtschaftsinformatik-Orientierungslisten der Wissenschaftlichen Kommission Wirtschaftsinformatik im Verband der Hochschullehrer für Betriebswirtschaft* (WKWI) (business informatics guidelines of the scientific commission for business informatics in the association of professors for business administration) as well as the *Fachbereich Wirtschaftsinformatik der Gesellschaft für Informatik* (GI-FB) (department of business informatics of the society for computer science. The ranking represents an assessment from the point of view of business informatics and refers to journals and conferences relevant to the information systems research domain (Heinzl et al., 2008).

In total, 16 articles are included in the publication list. All but one of them have already been published. Especially the articles that were published in conference proceedings or journals which are ranked with “A” according to the VHB JOURQUAL 3 ranking serve as important foundation for this thesis. Chapter 2.2 is largely based on paper #15 from the Journal of Management Information Systems while chapter 3 bases on paper #13 and chapter 4 on paper #12, both from the International Conference on Information Systems (ICIS 2014). Only chapter is 2.1. bases on articles ranked with a “C” according to the VHB JOURQUAL.

Table 1: Overview of Publications

#	Publication Date	Title	Authors	Conference/Journal	WKWI	VHB/JQ3	Chapter	Appendix
16	to be published	Enhancing Strategic Bidding Optimization for Renewable Energy Auctions: A Risk-Adequate Marginal Cost Model	Stetter, C. Piel, J.-H. Koukal, A. Breitner, M.H.	Operations Research Proceedings 2018		D		Appendix 16
15	12/2017	Promoting the System Integration of Renewable Energies: Toward a Decision Support System for Incentivizing Spatially-Diversified Deployment	Piel, J.-H. Hamann, J. Koukal, A. Breitner, M.H.	Journal of Management Information Systems (JMIS), 34(4), pp. 994-1022.	A	A	2.2	Appendix 15
14	01/2017	Financial Decision Support System for Wind Energy – Analysis of Mexican Projects and a Support Scheme Concept	Koukal, A. Piel, J.-H.	Proceedings of the Hawai'i International Conference on System Sciences (HICSS 2014), HI, USA, pp. 865-874.	B	C	2.2	Appendix 14
13	12/2014	Enhancing Literature Review Methods - Evaluation of a Literature Search Approach based on Latent Semantic Indexing	Koukal, A. Gleue, C. Breitner, M.H.	Proceedings of the International Conference on Information Systems (ICIS 2014), Auckland, New Zealand, pp. 1-19.	A	A	3	Appendix 13
12	12/2014	Building a Better World through Information Systems – An Explorative Survey among Leading IS Researchers	Rickenberg, T.A. Koukal, A. Breitner, M.H.	Proceedings of the International Conference on Information Systems (ICIS 2014), Auckland, New Zealand, pp. 1-19.	A	A	4	Appendix 12
11	06/2014	Enhancing Literature Review Methods - Towards more efficient Literature Research with Latent Semantic Indexing	Koukal, A. Gleue, C. Breitner, M.H.	Proceedings of the European Conference on Information Systems (ECIS 2014), Tel Aviv, Israel, pp. 1-13.	A	B	3	Appendix 11
10	03/2014	Replacing the Full Load Hours Key Figure for the Risk Assessment of Wind Energy Projects	Koukal, A. Lange, S. Breitner, M.H.	Proceedings of the Multikonferenz Wirtschaftsinformatik (MKWI 2014), Paderborn, Germany, pp. 949-961.	C	D		Appendix 10
9	03/2014	Entscheidungsunterstützungssystem zur Projektbewertung von Onshore Windenergieprojekten in Schwellenländern	Koukal, A. Kurz, L. Breitner, M.H.	Proceedings of the Multikonferenz Wirtschaftsinformatik (MKWI 2014), Paderborn, Germany, pp. 869-881.	C	D		Appendix 9
8	01/2014	Offshore Wind Energy in Emerging Countries: A Decision Support System for the Assessment of Projects	Koukal, A. Breitner, M.H.	Proceedings of the Hawai'i International Conference on System Sciences (HICSS 2014), HI, USA, pp. 865-874.	B	C	2.1	Appendix 8
7	09/2013	Enhancing Literature Research Processes: A Glance at an Approach Based on Latent Semantic Indexing	Koukal, A. Gleue, C. Breitner, M.H.	Lecture Notes in Informatics (LNI), Vol. 220, Informatik 2013 Proceedings (GI 2013), pp. 1937-1942.	B	C	3	Appendix 7
6	09/2013	Measurement of Risk for Wind Energy Projects - A Critical Analysis of Full Load Hours	Koukal, A. Lange, S. Breitner, M.H.	Operations Research Proceedings 2013, pp. 255-262.		D		Appendix 6
5	09/2013	Towards an Allocation of Revenues in Virtual Clusters within Smart Grids	Küster, B. Koukal, A. Breitner, M.H.	IWI Diskussionsbeiträge #60, Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.				Appendix 5
4	09/2013	Revenue Model for Virtual Clusters within Smart Grids	Voss, A. Koukal, A. Breitner, M.H.	IWI Diskussionsbeiträge #59, Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.				Appendix 4
3	03/2013	A Decision Support Tool for the Risk Management of Offshore Wind Energy Projects	Koukal, A. Breitner, M.H.	Proceedings of the Internationale Tagung Wirtschaftsinformatik (WI 2013), pp. 1683-1697.	A	C	2.1	Appendix 3
2	09/2012	Decision Support Tool for Offshore Wind Parks in the Context of Project Financing	Koukal, A. Breitner, M.H.	Operations Research Proceedings 2012, pp. 309-314.		D	2.1	Appendix 2
1	04/2012	Projektfinanzierung und Risikomanagement von Offshore-Windparks in Deutschland	Koukal, A. Breitner, M.H.	IWI Diskussionsbeiträge #53, Institut für Wirtschaftsinformatik, Leibniz Universität Hannover.				Appendix 1

1. Introduction

1.1. Motivation and Research Topics

Making the right decisions at the right time is an important challenge for companies, organizations and individuals as their success strongly depends on the quality of their operational and strategic decisions.

"It does not take much strength to do things, but it requires a great deal of strength to decide what to do."

— Elbert Hubbard

Essential for making the best possible decisions are not only the willingness to fully take responsibility for any consequences but also the availability of aggregated and processed information which are accurate, reliable and consistent. All kinds of qualitative and quantitative data that can contribute to issues requiring prior decisions should be considered. The complexity to make these decisions based on diverse information and increasing amounts of data highlight the importance of approaches, models, and tools for decision support.

Decision support contributes to the decision-making process by providing relevant information based on quantitative as well as qualitative data which were collected and extracted from various data sources. Against the background of continuously growing amounts of these data, the use of information systems (IS) for automatic data preparation and supply is essential (Power, 2014). In the future, with a continued increase of publicly or internally available data, the importance of decision support will further increase as a fast and easy access to decision-relevant information is crucial for companies and organizations to effectively compete in the market.

Embedding approaches and models that contribute to decision making into decision support systems (DSS) can further improve corresponding processes and results. A DSS is an "interactive, computer-based system that help people use computer communication, data, documents, knowledge, and models to solve problems and make decisions" (Power, 2002). DSS include group support systems, executive IS, online analytical processing systems, data warehousing, and business intelligence (Arnott and Pervan, 2012). These types of DSS address different target groups or decision makers and consequently vary regarding the processed and prepared information.

This dissertation addresses qualitative and quantitative decision support in three different research areas. The research contributions of underlying research papers are thematically grouped and focus on specific questions concerning wind energy, literature research processes and the contribution of IS towards a better world. The dissertation gives an overview of research contributions addressing these issues and is divided into three thematic chapters accordingly: chapter 2 addresses questions concerning decision support for the wind energy sector. However, the chapter is again divided into two chapters regarding the focus of research questions (RQs) on different stakeholders of wind energy projects based on quantitative financial approaches. While the underlying RQs of subchapter 2.1 concern investors and lenders, the RQs of subchapter 2.2 mainly address policy makers. Chapter 3 tackles questions regarding decision support for the enhancement of literature research processes by employing approaches of natural language processing. Chapter 4 deals with survey-based decision support. Corresponding RQs of the underlying research papers are presented in Table 2.

Table 2: Investigated Research Questions.

Main Topic	Chapter	Central Research Questions
Decision Support for the Wind Energy Sector	2.1	RQ1: Does a specific offshore wind energy project provide adequate returns for investors as well as sufficient debt service coverage when critical project risks are considered? (HICSS 2014) RQ2: How can decision support be provided for stakeholders for these types of projects? (HICSS 2014)
	2.2	RQ1: How can decision support be provided for investors, lenders and policy makers to access OWE projects and corresponding support schemes to stimulate investments and a further expansion? (HICSS 2017) RQ2: How can investment incentives be quantified to improve the spatial distribution of wind energy deployment under renewable energy auctions? (JMIS 2017)
Decision Support for the Enhancement of Literature Research Processes	3	RQ1: How can a LSI-based approach be adopted and implemented to increase the efficiency of scientific literature research processes? (ECIS 2014) RQ2: How can a LSI-based approach increase the efficiency of scientific literature research processes? (ICIS 2014)
Decision Support Towards a Better World through IS	4	RQ: How can IS research and IS practice contribute to build a better world? (ICIS 2014)

1.2. Research Approaches and Methodological Overview

The IS research domain strives to gain knowledge about the management of information technology and about the use of information technology for managerial and organizational aspects (Zmud, 1997). For this purpose, two complementary but distinct research paradigms exist in the IS research domain: behavioral science and design science (March and Smith, 1995). The behavioral science paradigm has its roots in natural science research and seeks to develop, verify or justify theories that explain or predict human and organizational behavior (Hevner et al., 2004). It is passive regarding technology (Orlikowski and Iacono, 2001) as it focusses only on the description of technology's implications on individuals, groups, and organizations (Hevner et al., 2004). In contrast, the design science paradigm is rooted in engineering and sciences of the artificial (Simon, 1996). It represents a problem-solving paradigm and aims at the creation of new and innovative artifacts that represent ideas, practices, and products to extend human problem-solving boundaries as well as organizational capabilities (Hevner et al., 2004). Both research paradigms exist in parallel and complement each other (Ayanso et al., 2011). However, the focus of the Anglo-American IS research community is largely on behavioral science, while the European IS research and especially the German IS domain has a strong focus on design-orientated research, see e.g. Österle et al. (2011).

While the research publications and the underlying research projects of this dissertation followed rigorous research processes, especially the research projects of chapter 2 and 3 had also a strong practical focus and thus employed design science as research methodology due to its underlying goal of utility (Winter, 2008). Besides, the research approaches of these two chapters apply quantitative methods, while in chapter 4 qualitative as well as quantitative methods are applied.

Chapter 2 of this dissertation addresses decision support for the wind energy sector and includes two chapters both resulting from a different underlying research project. In total, these research projects resulted in five publications. The research presented in chapter 2.1 as well as in chapter 2.2 followed a design-orientated research based on a design science research (DSR) approach. This approach was chosen in both cases to design, demonstrate, and evaluate research artifacts in a clearly defined process according to Peffers et al. (2008). Besides, key recommendations of Hevner et al. (2004, 2007) and March and Smith (1995) were also considered. The lack of research about the economic potential of specific offshore wind energy projects against the background of constantly increasing electricity demands and supply difficulties triggered the research activities presented in chapter 2.1. The identification of the above-mentioned issue set the starting point for the development of a decision support system (DSS) suitable for the assessment of wind energy projects. To achieve this goal, several research artifacts were constructed. March and Smith (1995) classify the research artifacts resulting from design-oriented research into constructs, models, methods, and instantiations. The first artifact was a basic DCF model which was limited to central aspects of an offshore wind energy project. Within an iterative approach, this model was tested and extended. Finally, on top of the formal models an instantiation was implemented as an Excel/VBA prototype. In chapter 2.2 the focus was set on the construction of research artifacts that serve as a basis to assess location-based conditions for wind energy projects in a specific country. In the research process, the basic initial DCF model was enhanced by implementing a complex risk model that enables the application of an MCS. In addition to the formal models, an instantiation was created by the implementation of a prototype in MATLAB. In chapter 2.1 as well as chapter 2.2 the DSR process was completed by tests, a demonstration and an evaluation of the research artifacts.

Chapter 3 of this dissertation deals with decision support for the enhancement of literature research processes. It is based on one research project that resulted in three scientific publications. Again, design orientated research based on a DSR approach was chosen to design, demonstrate, and evaluate research artifacts. According to Peffers et al. (2008) the research design is classified as problem-centered approach as the identification of a lack of automated support in combination with a consideration of semantic concepts for text retrieval triggered the research process. This research process was followed according to guideline six, “design as a search process”, by Hevner (2004). Within an iterative approach, research artifacts were cyclically created and refined. To enable semantic indexing with the Latent Semantic Indexing (LSI) approach and similarity queries, a basic model with the mathematical processing as well as a software prototype as an instantiation were constructed. The next steps focused on an extension of the existing model and prototype with a layer for automated preparation of the content database and a web front end. To complete the DSR process, the extended model and instantiation were tested, the capabilities demonstrated, and application results evaluated.

Chapter 4 of this dissertation differs from the other thematic chapters as it deals with decision support based on surveys. It has one underlying research project that resulted in one publication. Qualitative and quantitative data was gathered with an online questionnaire among leading IS researchers to investigate how and to which extent IS can contribute to build a better world, in particular regarding the Millennium Development Goals (MDGs). The answers were analyzed within an explorative survey by employing qualitative data analysis and coding techniques.

1.3. Structure of the Dissertation

The dissertation begins with an initial overview of publications in chapter 0. It is followed by an introduction in chapter 1 and three thematic parts. Each of these three parts present research results from the underlying research projects and corresponding scientific articles. While chapter 2 is divided into two major parts, both chapter 3 and chapter 4 form a single thematic unit respectively. The thesis ends with a conclusion, limitations, and an outlook in chapter 5. The structure is illustrated in Figure 1.

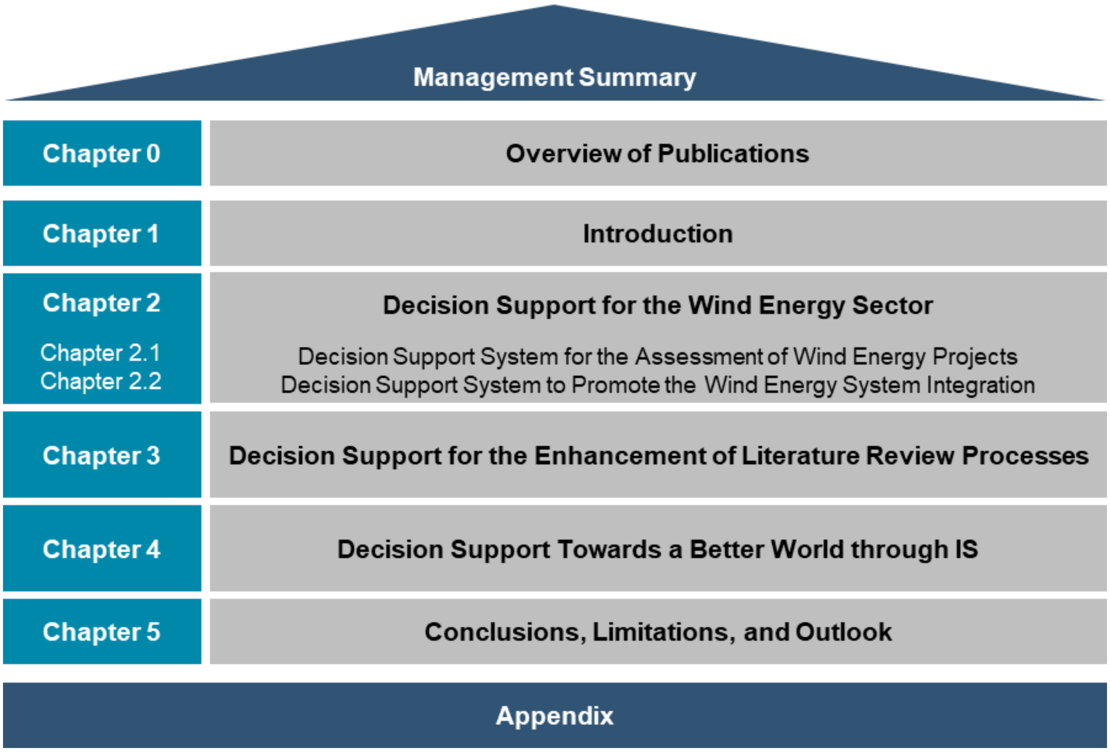


Figure 1: Structure of the Dissertation.

In the overview of publications in chapter 0 the publications that serve as foundation for this thesis are presented in chronological order in combination with a link to the chapter in which they are considered. The introduction in chapter 1 presents the motivation, overall goals, the underlying research problems and the structure of the thesis. While chapter 2 is divided into two major thematic parts, both subchapters - 2.1 and 2.2 - have the same structure as the thematic chapters 3 and 4. All of them include a motivation of the according research topic, the research background, the research design, a summary of results as well as a discussion, limitations, an outlook, and an academic classification of articles that served as foundation. An overall conclusion as well as overall limitations, and an outlook across all chapters are provided in chapter 5.

2. Decision Support for the Wind Energy Sector

2.1. Decision Support System for the Assessment of Wind Energy Projects

2.1.1. Motivation and Research Topic

The demand for energy has been increasing worldwide in the last few decades and will continue to do so in the future. However, there are major differences regarding the individual countries. While the energy consumption in OECD and non-OECD countries was roughly equal in 2007, the consumption will increase by 14 percent in OECD countries compared to 84 percent in non-OECD countries by 2035 (Wolfram et al., 2012). As the global climate change process is influenced by greenhouse gas emissions and thus by the consumption and the required generation of electricity, it seems not only necessary, but mandatory to expand renewable energies in order to limit negative ecological effects.

Wind energy is expected to make the largest contribution to the expansion of renewable energies by increasing its share on the worldwide electricity production from 2 percent in 2009 to 8 percent in 2035. The biggest further potential is in developing and emerging countries e.g. in Central and South America as there has been no intensive use so far (Chu and Majumdar, 2012). However, also the European Commission set goals regarding the reduction of greenhouse gas emissions which are widely known as the 20-20-20 targets to further international efforts of climate protection. Additionally, the current Renewables Directive defined that 20 % of the total EU energy consumption shall come from renewable energy sources (Prässler and Schaechtele, 2012). To meet these goals the member states have set up National Renewable Energy Action Plans and defined different incentive systems and feed-in tariffs to support the expansion of the installed offshore wind capacity.

Offshore wind parks produce significantly more energy in comparison to onshore wind parks and they can be placed close to population centers but out of sight to mitigate local opposition (Chu and Majumdar, 2012). Besides, the offshore wind energy sector has been developed rapidly in the last twenty years. However, technical aspects have been in the foreground for most of the time and in contrast to the technical development there has been no comparable expansion of the number of constructed offshore wind energy plants. A major reason for this are the investment costs for such projects which go up to two billion euros with a typical nominal power output of 400 MW (KPMG, 2010). Another reason is the large number of significant risk factors. Some are based on the low technical experience, others are inherent for offshore projects as the plants are difficult to access due to the great distance to the coastline or result from the higher requirements for the infrastructure, e.g. harbors, offshore power stations, high voltage power lines, and special vessels.

In the past, a majority of the few offshore wind projects was conducted in the framework of corporate finance by large energy supplying companies. Nowadays, most projects are realized in the context of project finance. This increases complexity by taking the different concerns of all involved participants into account and increases the importance of lenders as projects depend to a great part on the debt capital. Debt is only provided against the background of expected future cash-flows of a project which makes it particularly important to consider the numerous risk factors of an offshore wind project within the risk management to ensure economic success.

Within the IS research domain sustainability and green IS are becoming a major topic (Dedrick, 2010) as one factor of the increasing electricity consumption and emission of greenhouse gases is the heavy use of information technology. However, the use of IS can also contribute to higher sustainability and resource savings. Green IS enables the creation, evaluation and optimization of products and processes to increase resource efficiency. In existing literature little support for the assessment of individual (offshore) wind parks and their respective general financial conditions exist. To fill this void, a decision support system for the assessment of projects is presented and the following research questions are addressed:

RQ1: Does a specific offshore wind energy project provide adequate returns for investors as well as sufficient debt service coverage when critical project risks are considered?

RQ2: How can decision support be provided for stakeholders for these types of projects?

This chapter is largely based on Koukal and Breitner (2012), Koukal and Breitner (2013), Koukal and Breitner (2014), Appendix 2, Appendix 3, and Appendix 8.

2.1.2. Research Background

When Watson et al. called for more attention to energy informatics and eco-friendliness in 2010 the increasing interest in environmental and economic sustainability of societies also reached the IS research domain (Watson et al., 2010). However, the achievements that shaped Green IS as a subfield in the IS discipline were not followed by an adequate uptake in research (vom Brocke et al., 2012). Green IS helps to expand renewable energies and to increase environmental and economic sustainability by employing information and communication technology (Rickenberg et al., 2012). The assessment of wind energy projects and their respective general financial conditions by using IT and IS is obviously an example of Green IS.

Snyder and Kaiser evaluated the costs of offshore wind parks in Europe. They use a multiple linear regression model to describe the effect of certain parameters on investment costs (Snyder and Kaiser, 2009). Madlener et al. provide a DCF model in combination with a MCS and Value-at-Risk (VaR) principle and focus on the German offshore wind sector. A comprehensive analysis of several risk factors and their influences on wind energy projects is performed (Madlener et al., 2009). Blanco compares the operating costs and cost structures of onshore and offshore wind parks and presents forecasts of future energy prices (Blanco, 2009). Levitt et al. analyze the breakeven price of electricity for offshore wind projects in various countries with a cash-flow model. They consider different financing concepts and make use of a sensitivity analysis (Levitt et al., 2011). Prässler and Schaechtele performed a comprehensive assessment of the financial attractiveness of offshore wind power markets in Europe to evaluate the general financial conditions and feed-in tariffs of many European countries. They calculated the internal rate of return (IRR), determined different financial key figures and evaluated multiple scenarios (Prässler and Schaechtele, 2012). Schillings et al. identified the overall potential for offshore wind energy in the North Sea with a DSS (Schillings et al., 2012).

The literature research indicates that no publication addresses the assessment of an individual offshore wind energy projects by simultaneously addressing the demands of investors as well as lenders under consideration of project risks. Although several mathematical models are implemented to evaluate individual projects, in most cases they only take corporate finance into consideration. Besides, the more complex models that also consider project risks only refer to projects in Europe.

The DCF models of Madlener et al. (Madlener et al., 2009) are used as a foundation to formulate an enhanced mathematical model and construct artifacts that allows the analysis of wind energy projects in different countries under various conditions.

2.1.3. Research Design

Our research was conducted using design science research principles to address relevance and enhance rigor of the research process and results. The design-orientated research process was recommended by Offermann et al. (2009) and, in particular, Peffers et al. (2008). Also, we used key recommendations of Hevner et al. (2004, 2007) and March and Smith (1995). According to Peffers et al. (2008) the design of our research is classified as problem-centered approach, see Figure 2.

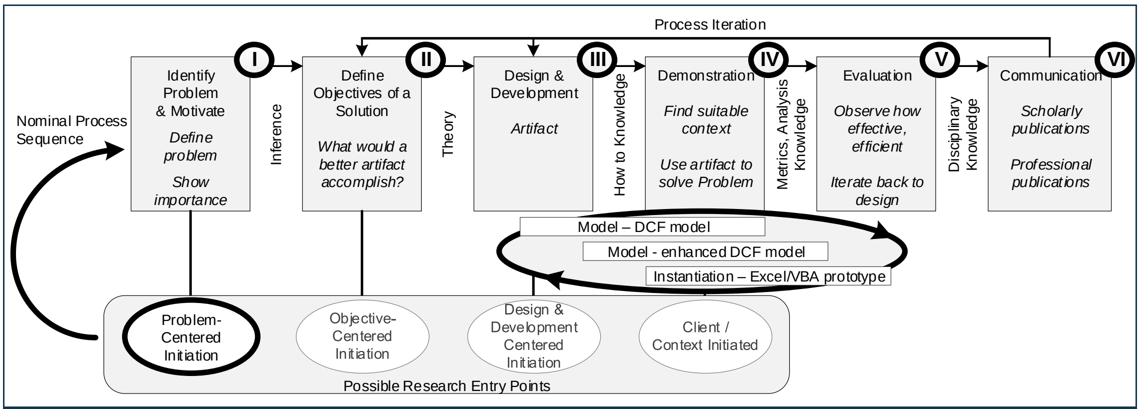


Figure 2: Research Design based on Koukal and Breitner (2014).

The lack of research about the economic potential of specific offshore wind energy projects against the background of constantly increasing electricity demands and supply difficulties triggered the development of our DSS. The research process was initiated by identifying the above-mentioned problem (I). A comprehensive literature review was conducted within the fields of energy informatics and the general finance and IS research domain. According to our research question, the design, demonstration, and evaluation of artifacts that can provide a basis to assess an individual offshore wind energy project or the general conditions in a specific country was the main objective (II). After defining the problem and specific requirements, the scientific input was used to design the first artifact (III): a basic DCF model. The model was limited to central aspects of an offshore wind energy project with its investment and operating cash-flow and the respective project value calculation. For further development, we used an iterative approach to create and refine artifacts according to guideline six, “design as a search process”, by Hevner (2004). Thus, the basic model was extended with extra parameters and the possibility to define probability distributions for the key figures, resulting in a model with an enhanced concept of the DSS. March and Smith (1995) classify the result of design-oriented research into constructs, models, methods, and instantiations. On top of the formal models, an instantiation was implemented: an Excel/VBA prototype. The DSR process was completed by tests of the artifacts and a demonstration (IV) and evaluation (V) of the capabilities of the prototype to enable documentation of research results (VI).

2.1.4. Summary of Results

2.1.4.1. Discounted Cash-Flow Model and Discounting Method

The DCF model sets the basis for the assessment of a wind energy project. Figure 3 shows the main components and the relationships within the model. The investment and operating cash-flow consists of several components that are individually considered. The revenues within the operating cash-flow directly result from selling the generated electricity which depends on the net full load hours multiplied by the nominal power output of the entire wind park. The inflation rate has an influence on multiple components and increases the electricity market price and every component of the expenditures annually. Taxes are calculated by considering operating cash-flow, depreciation of the fixed assets, and tax rate. The sum of investment cash-flow, operating cash-flow, and taxes results in the free cash-flow.

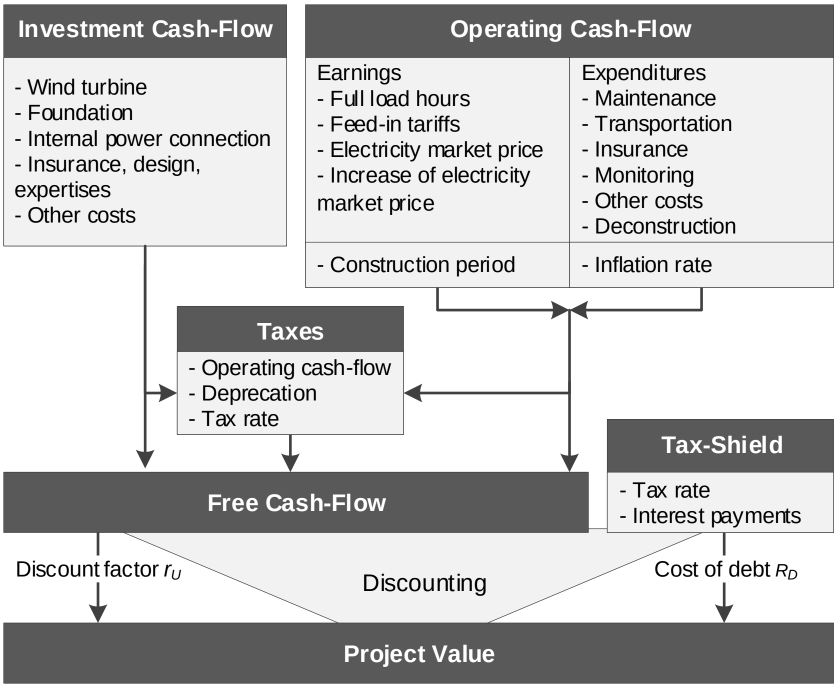


Figure 3: Components of the DCF Model based on Koukal and Breitner (2013).

The project value as well as other relevant financial key figures are calculated by discounting the future project cash-flows. Several approaches to apply this method exists and especially the weighted average cost of capital (WACC) is applied in previous research (see Madlener et al., 2009). Future projects will typically be planned and realized in the context of project finance due to high investment costs. For those projects the debt-equity ratio is not constant in the course of time and the APV method is a better choice for discounting the cash-flows (Luehrman, 1997). The calculation of the project value (PV) by applying the APV method is presented in equation (1). The first part of the equation represents the present value of all free cash-flows (FCF) and the second part determines the present value of the tax shield. The latter describes an increased project value resulting from tax savings obtained by interest payments (Fernandez, 2004).

$$PV = \sum_{t=1}^{T} \frac{FCF_t}{(1+r_U)^t} + \sum_{t=1}^{T} \frac{\tau * [r_{D,t} * D_{t-1}]}{(1+r_{D,t})^t} \tag{1}$$

The present value of the tax shield is based on the multiplication of the tax rate τ by the interest payments $[r_{D,t} * D_{t-1}]$ discounted with the cost of debt of the respective period. The FCF is discounted by applying the discount factor r_U, which is calculated as the average of the return on equity r_E and the cost of debt r_D weighted with the share of equity *E* and debt *D* on the company value *V* (equation (2)).

$$r_U = r_E * \frac{E}{V} + r_D * \frac{D}{V} \tag{2}$$

The costs of debt are determined by loan agreements, while the return on equity must be determined with the capital asset pricing model (CAPM) in equation (3):

$$r_E = r_f + (r_M - r_f) * \beta \tag{3}$$

It is based on the risk-free interest rate r_f, the market risk premium $(r_M - r_f)$, which includes the market interest rate r_M and the beta factor which expresses the systematic risk of the project compared to risks on the general market.

2.1.4.2. Financial Key Figures and Monte Carlo Simulation

Additional key figures besides the PV are determined to consider the different perspectives of project participants. The IRR of an investment is the discount factor that results in a project value of zero and thus indicates the interest yield an investor can reach with an investment (Brealey et al., 2011). The relationship between project developers and lenders is characterized by the supply of debt capital and the regular repayment of the loan. Consequently, lenders demand key figures that address the debt service coverage. The debt service cover ratio (DSCR) is one of the most important key figures for lenders and measures the debt service coverage for every single period of a project. It is the quotient of the cash flow available for debt service (CFADS) and the debt service (Pretorius et al., 2008) and is shown in equation (4).

$$DSCR_t = \frac{CFADS_t}{DS_t} \tag{4}$$

Other important key figures that provide information about the ability of debt repayments are the loan life cover ratio (LLCR) and the project life cover ratio (PLCR) which are only useful in combination with the DSCR. Both are calculated as quotient of future CFADS discounted by the cost of debt and the amount of outstanding debt of a single period. Whereas the LLCR refers to the CFADS over the remaining loan life, the PLCR refers to all outstanding CFADS of the project (see equation (5) and (6)).

$$LLCR_t = \frac{\sum_{l=t}^{L} \frac{CFADS_l}{(1+r_{D,l})^l}}{D_{t-1}} \quad (5)$$

$$PLCR_t = \frac{\sum_{p=t}^{P} \frac{CFADS_p}{(1+r_{D,p})^p}}{D_{t-1}} \quad (6)$$

An analysis of the expected values does not provide a sufficient basis for investment decisions due to an inadequate consideration of possible risks. To address this issue, the deterministic DCF model is extended by a MCS which aims at a consideration of a wide variety of different risk factors with effects on a wind energy project.

To take the effects of these risks into account, individual probability distributions are set up. Due to an insufficient database on risks in the offshore wind sector, Beta distributions are used in combination with a program evaluation and review technique (PERT) estimation because they only need a minimum, a maximum and a most likely value to be completely described (Madlener et al., 2009). One concept that considers the project risks and expresses them in one ratio is the VaR. It can be applied on all key figures including DSCR, LLCR and PLCR. Regarding the project value, the VaR shows the minimum value that is not undercut by a certain confidence level.

2.1.4.3. Decision Support System

The DSS is implemented in Visual Basic for Applications (VBA) in the environment of Microsoft Excel 2010. Excel is chosen due its wide use, usability, spreadsheet calculation functionality, and the possibility to expand it with add-ins. The DSS integrates the DCF model, the control of the MCS, visualization of results, and input and output functionality into one system to provide decision support. The architecture of the system and the data flow is illustrated in Figure 4.

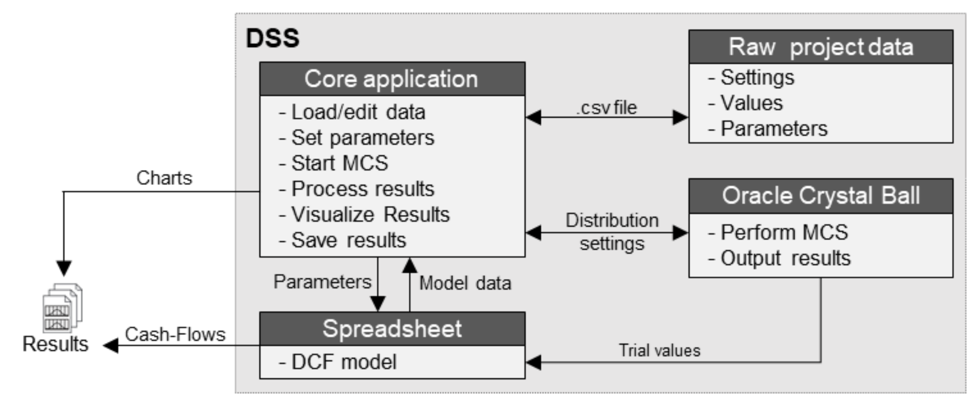


Figure 4: System Architecture of the DSS based on Koukal and Breitner (2014).

2.1.4.4. Case Study: Offshore Wind Park in Germany

To demonstrate the applicability of our research artifacts, the DSS and the underlying model are used to perform a case study of a fictitious OWP in the German North Sea. The assumptions about the wind park characteristics in Table 3 are based on German projects which have been planned in 2012 (KPMG, 2010; Madlener, et al. 2009).

Table 3: Assumptions about the Wind Park according to Koukal and Breitner (2013).

Key parameters	
Parameter	Value
Distance to coast	90 km
Depth of water	40 m
Wind energy plants	80
Nominal power output/plant	5 MW
Expected annual energy output	1540 GWh
Tax rate	35%

Additional parameters		
Parameter	Value	Disc./Sur.
Net full load hours	3850	- 25% / + 50%
Annual inflation rate	2%	- 20% / + 20%

Investment costs		
Component	Costs	Disc./Sur.
Wind turbine	682.4 M€	- 5% / + 5%
Foundation	340.6 M€	- 10% + 10%
Internal power connection	238.0 M€	- 5% / + 5%
Design/insurance/expertise	67.5 M€	- 10% / + 15%
Other costs	111.5 M€	- 25% / + 25%
Total investment costs	1440.0 M€	

Operating costs		
Component	Costs	Disc./Sur.
Maintenance	22.5 M€	- 25% / + 25%
Insurance	18.8 M€	- 5% / + 25%
Transportation	3.0 M€	- 25% / + 25%
Monitoring	1.0 M€	- 5% / + 5%
Other costs	0.9 M€	- 5% / + 5%
Total operating costs	58.7 M€	

To apply the APV method, the return on equity is calculated (equation (3)) with a risk-free interest rate of 2%, a market risk premium of approximately 10% and a beta factor of 1.8. It results in 2% + 8% × 1.8 = 16.4%. This value is similar to the result of a survey about the expectations of the return on equity of project developers. Without the consideration of a higher risk due to the compression model they require a return on equity of 14-15% (BMU, 2011). The costs of debt are determined as 6.66% by the average weighted interest rate of debt over the project lifetime. The return on equity and the costs of debt are inserted with their percentage of shares of the total capital into equation (2). This results in a discount factor of 16.4% × 40% + 6.66% × 60% = 10.56%.

To perform a MCS with Beta probability distributions and PERT estimations, a minimum, a maximum, and a most likely value are specified for every risky parameter. While all expected values of these parameters are used as most likely points of the probability distributions, the minimum and maximum points are calculated with percentage discounts from and surcharges on top of the expected values. The discounts and surcharges are presented in Table 3 and are mostly based on the research of Madlener et al., 2009. As an example, the minimum and maximum points of the probability distribution of the annual inflation rate are calculated. The annual inflation rate in Germany was between 1% and 3% in the last years. The variances of the expected value at a height of 2% are assumed to be close to the statistic values with -25% and +50%. Consequently, the minimum is 75% × 2% = 1.5% and the maximum is 150% × 2 % = 3.0%.

Table 4: Project Cash-Flows according to Koukal and Breitner (2013).

	∑	2013	2014	2015	2016	2017	…	2035
1. Investment cash-flow		-145.0	-575.0	-720.0			…	
2. Operating cash-flow				123.2	245.5	244.5	…	-89.1
2.1 Earnings				146.3	292.6	292.6	…	59.5
2.2 Expenditures				-23.1	-47.1	-48.1	…	-148.7
3. Taxes						-21,2	…	
Free cash-flow		-145.0	-575.0	-596.8	245.5	223.3	…	-89.1
Tax-shield			6.7	20.6	21.1	19.8	…	
Discounted free cash-flow	-49.8	-131.2	-470.4	-441.7	164.3	135.2	…	-8.9
Discounted tax shield	121.9		6.3	18.1	17.4	15.3	…	
Project value	72.1	-131.2	-464.2	-423.6	181.7	150.5	…	-8.9
Cumulative project value		-131.2	-595.3	-1018.9	-837.2	-686.7	…	72.1

All values of the different parameters are inserted into the cash-flow model. The results presented in Table 4 allows different statements about the OWP: (1) The project value of 72.1M€ is positive and thus, the wind park offers a return on equity which is bigger than the required 16.4%. (2) The IRR is 12.05% and the return on equity which results in this value under otherwise equal conditions is 20.14%. (3) The cumulative project value shows that the project turns into a positive investment after 14 years in 2027.

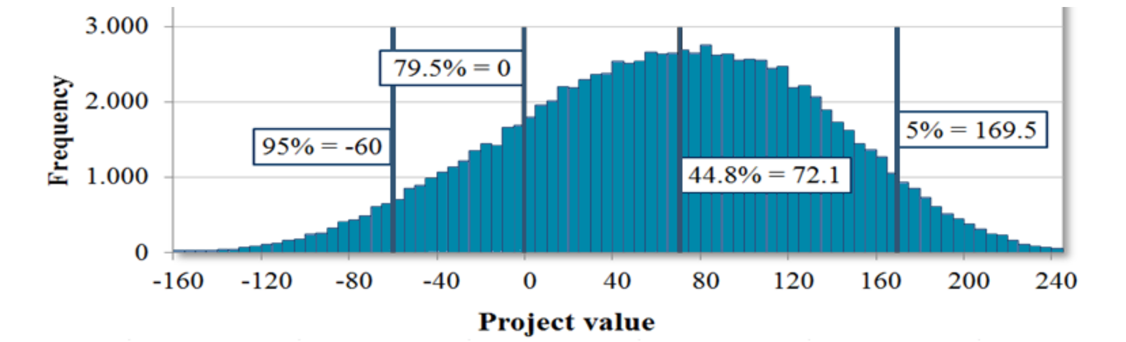


Figure 5: Distribution of the Project Value based on Koukal and Breitner (2013).

The MCS is applied to the cash-flow model. It is performed with 100,000 simulation runs and needs 428 seconds on an Intel Core i7-2640M CPU with 2.80 GHz, 8GB Ram and Microsoft Windows 7 64bit as operating system. The effect on the project value is shown in Figure 5. Some statements can be derived from the distribution:

1. At a confidence level of 95 % the project value is -60 M€. Consequently, the value of the project is at this or a higher amount with a certainty of 95 %.
2. The calculation of the IRR for the project value of -60 M€ can be made analogously to point 2 of the considerations about the expected project value which results in an IRR of at least 9.26% with a certainty of 95%.
3. The minimum project value is 0 with a probability of 79.5%. Investors will get an interest yield that is at least at the same level as other investments of similar risk.
4. The probability to reach a project value of at least 72.1 M€ which correspondents with the expected project value is only 44.8 %.

2.1.4.5. Case Study: Offshore Wind Park in Brazil

For an additional demonstration of the applicability of the DSS, a case study of an OWP in an emerging country is performed. The examined wind park is subproject 8 of 23 of a project called Asa Branca located the northeast of Brazil which has been in planning status in 2013. The project characteristics are shown in Table 5. The Brazilian electricity system relies on auction-based mechanisms with an average auction winning price of 148 R$/MWh in 2009 for electricity from onshore wind parks (Porrua et al., 2010). Converted into Euro of 2013 with an exchange rate of 0.37 EUR/BRL and an inflation rate of 2%, it is about 60€/MWh.

Table 5: Assumptions about the Wind Park according to Koukal and Breitner (2014).

Key parameters	
Parameter	Value
Distance to coast	22 km
Depth of water	10 m
Average wind speed	10.5 m/s
Wind energy plants	96
Nominal power output/plant	5 MW
Expected annual energy output	1958 GWh
Tax rate	35%

Investment costs		
Component	Costs	Disc./Sur.
Wind turbine	639.7 M€	- 5% / + 5%
Foundation	319.3 M€	- 10% + 10%
Internal power connection	223.1 M€	- 5% / + 5%
Grid connection	90.0 M€	-10% / +10%
Design/insurance/expertise	63.4 M€	- 10% / + 15%
Other costs	104.5 M€	- 25% / + 25%
Total investment costs	1439.8 M€	

Additional parameters		
Parameter	Value	Disc./Sur.
Net full load hours	4080	- 20% / + 10%
Annual inflation rate	2%	- 25% / + 25%

Operating costs		
Component	Costs	Disc./Sur.
Maintenance	28.6 M€	- 25% / + 25%
Insurance	23.9 M€	- 5% / + 25%
Transportation	3.8 M€	- 25% / + 25%
Monitoring	1.3 M€	- 5% / + 5%
Other costs	1.1 M€	- 5% / + 5%
Total operating costs	58.7 M€	

To apply the APV method, the return on equity is calculated (equation (3)) with a risk-free interest rate of 2%, which refers to bonds from Germany or the USA, a market risk premium of 7.9% (Fernandez et al. 2013), and a beta of 1.5. It results in 2% + (7.9% - 2%) × 1.5 = 10.85%. Next, the cost of debt are determined. The Brazilian development bank finances large onshore wind projects with a share of up to 80% debt and an interest rate between 6.4% and 10.58% (da Silva et al. 2013). An interest rate for an offshore project of 11% is assumed due to the higher risk compared to onshore projects. Finally, the discount rate is calculated (equation (2)) with a share of debt of 70%: 10.85% ×30% + 11% × 70% = 10.96%. To perform a MCS with Beta probability distributions and PERT estimations, a minimum, a maximum, and a most likely value are set for every parameter fraught with risk. While the expected values of these parameters are used as most likely values, the minimum and maximum points are calculated by discounts from and surcharges on top of the expected values (see Table 3). They are based on the research of Madlener et al., 2009. There is no correlation between the individual probability distributions in our model.

All parameters and values are inserted into the DCF model. The resulting expected project value of -435.7M€ is highly negative and adequate returns cannot be achieved. Besides, the DSCR is at a level lower than one in every operation period and lenders will not provide debt capital. Consequently, the project will not be realized.

To demonstrate the influence of a feed-in tariff on the project value calculation, the model is adjusted and a guaranteed compensation for the produced energy of 105 €/MWh in 2014 increasing with the inflation rate is assumed. The new calculation of the expected project value is shown in Table 6. The expected project value of 157.1 M€ is positive and the investment opportunity offers a return on equity that is higher than the required 10.85%. The IRR is 13.5% and the cumulative project shows that the project turns after 16 years in 2030 for the first time into a positive investment.

Table 6: Project Cash-Flows according to Koukal and Breitner (2014).

(Millions of Euro)	∑	2014	2015	2016	2017	2018	2019	…	2036
1. Investment cash flow		-213.0	-641.2	-585.6				…	
2. Operating cash flow					159.5	162.7	166.0	…	232.4
2.1 Revenues					218.2	222.6	227.0	…	317.9
2.2 Expenditures					-58.7	-59.9	-61.1	…	-85.5
3. Taxes								…	-81.3
Free cash flow		-213.0	-641.2	-585.6	159.5	162.7	166.0	…	151.1
Tax-shield			16.8	40.7	45.1	44.1	43.0	…	
Discounted free cash flow	-109.4	-192.0	-520.8	-428.7	105.3	96.8	88.9	…	13.8
Discounted tax shield	266.5		15.1	33.0	33.0	29.1	25.5	…	
Project value	157.1	-192.6	-505.7	-395.7	138.2	125.8	114.5	…	13.8
Cumulative project value		-192.6	-697.7	-1093.4	-955.1	-829.3	-714.9	…	157.1
DSCR, LLCR, PLCR					>1,03	> 1.05	> 1.07		

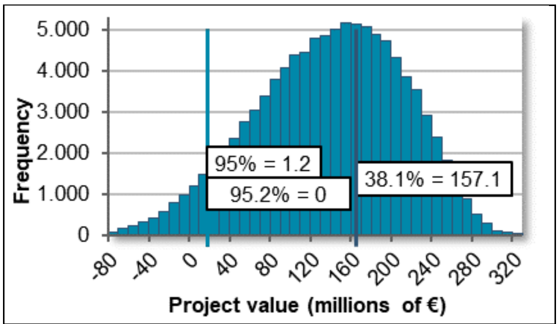


Figure 6: Distribution of the Project Value based on Koukal and Breitner (2014).

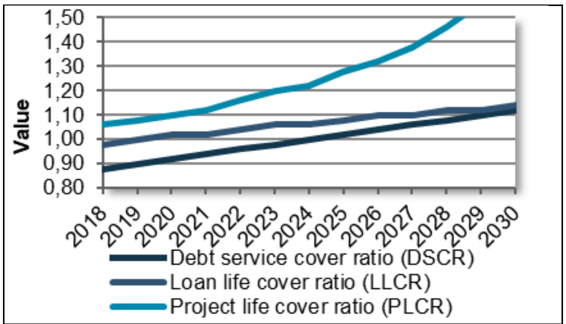


Figure 7: Results at 95% Confidence Level based on Koukal and Breitner (2014).

The MCS is applied analogously to the first case study (see Figure 6). At a confidence level of 95%, the project value is 1.2 M€ and the corresponding IRR is 11%. With a probability of 95.2% the minimum project value is 0 and investors get the required interest yield. The probability to reach the expected project value of at least 157.1 M€ is only 38.1%. The consequences of the MCS on the financial key figures are presented in Figure 7. It shows that the project offers adequate debt service coverage if a liquidity reserve is built up in the first year of operation to bridge any possible liquidity shortfalls.

2.1.5. Discussion, Limitations, and Further Research

Research artifacts that assess the economic feasibility of an offshore wind energy project and the respective general economic conditions were constructed and evaluated to provide decision support. Based on established discounting methods, a DCF model was formulated and an DSS that integrates the model and additional components in an intuitive IS was implemented. Since the offshore wind energy and renewable energies in general as well as our system aim at ecological and economic sustainability, we claim that the system is both a Green IS and a Green DSS.

The presented results of the first case study clearly indicate that an investment into an offshore project in the German North Sea is in the average profitable for project developers and lenders. In contrast, the results of the second case study for the OWP in Brazil show that an investment into an offshore wind energy project in Brazil is not an attractive investment opportunity under the current general financial conditions. However, it is also shown that a feed-in tariff that is guaranteed by law can promote an expansion of the offshore wind energy sector.

With the two example applications it is shown that the DSS can assist investors and lenders with the complex tasks of assessing possible project returns and the project's ability to cover debt service. Governments are also addressed by providing the possibility to check whether the respective general financial conditions in a country are sufficient to support the expansion of the offshore wind energy. Besides, the DSS can be applied for projects in other countries and regions when the parameters are adjusted. While expected values for every key figure are calculated and processed immediately, a new run of the MCS to consider project risks take some time. However, neither of these aspects is as time consuming as the gathering of information to adjust the project's parameters with suitable values.

Our implemented DSS has a strong practical focus and is utilized to demonstrate the use of the artifact to solve a problem (Peffers et al., 2008). It helps to check the applicability of the underlying model and can support decision makers to evaluate the economic potential of specific offshore wind energy projects. The calculation of the project value and the subsequent computation of the IRR is addressing investors demand for information about project's interest rates. The calculation of key figures like the DSCR addresses the requirements of lenders regarding the project's ability to cover debt services. Besides, the DSS helps users to understand the effects of changes in the general financial conditions like feed-in tariffs, a changed cost situation of individual cost factors, a different amount of annual full load hours, or alternative discount factors. The influence of individual risk factors on a project's success becomes clear. Against this background, the importance of a sufficient risk management is highlighted. The examination of critical risk factors allows to detect which project risks are the greatest threats and at which point of time in the planning or operating process it is most important to establish risk management methods.

Certain limitations regarding our research artifacts are identified. The research artifacts are evaluated for two offshore wind energy projects for which only rough data is available. The DCF model, the subsequently applied MCS, and the DSS should be evaluated for other regions and with practitioners as DSR aims at adopting artifacts by practitioners. However, only 13.5% of DSS design-science research artifacts are evaluated in the field yet (Arnott and Pervan, 2012). An empirical evaluation by project developers and lenders can help to increase rigor and the generalizability for our approach.

A single corporate tax rate is used by the DCF model. For countries with more complex tax systems, the model provides only an approximation. However, deviations of the real situation depend strongly on the individual case of the project and thus, the key findings of the model retain their validity. In our DCF model, the technical availability is a flat adjustment of the full load hours key figure and not an independent parameter. This aggregation leads to inaccurate results in combination with the MCS due to a rough approximation of different and independent distributions of parameters. A further developed model should consider these key figures independently as this allows to consider changes of the technical availability over the long term (Levitt et al., 2011).

The results of the MCS are based on uncorrelated Beta probability distributions with PERT estimations. The shape of the Beta distribution provides only a rough approximation of occurring risks. Additionally, certain effects that result in a specific behavior of one distribution normally have an influence on multiple components. A better consideration of critical risk factors can be realized when more and longer experiences and better scientific investigations of planning, construction, and operation of offshore wind parks are made. In this case, the Beta distributions with PERT estimations can be replaced by more realistic ones and correlations between risk factors can be considered. However, in the near future, no improvement of the data situation can be expected as this data and knowledge is protected by in associated companies.

Further research steps regarding our artifacts and addressing the identified limitations are required. Additional parameters and a better consideration of project risks can enhance our model. A deeper empirical analysis and validation of the artifacts that go beyond the application examples is also needed.

2.1.6. Academic Classification of Publications

The research paper "Decision Support Tool for Offshore Wind Parks in the Context of Project Financing" was written together with Michael H. Breitner, see Koukal and Breitner (2012) and Appendix 2. The paper was accepted after a double-blind peer review with one revision at the International Conference of the German OR Society 2012 (OR 2012) in Hannover, Germany in the "Wind Energy and other Wind Energy Sources" track. It was presented at the OR in September 2012 and has been published in the Operations Research Proceedings 2012, which are ranked in category "D" according to the VHB JOURQUAL 3 (WKWI, 2008; Hennig-Thurau and Sattler, 2015b).

The initial publication regarding a wind energy related topic from an investor's perspective was followed up by the research paper "A Decision Support Tool for the Risk Management of Offshore Wind Energy Projects". The paper was written together with Michael H. Breitner (see Koukal and Breitner (2013) and Appendix 3) and it was accepted after a double-blind peer review with one revision at the Internationale Tagung Wirtschaftsinformatik 2013 (WI 2013) in Leipzig, Germany in the "Visionäre und Interdisziplinäre Themen" (visionary and interdisciplinary topics) track. It was presented at the WI in February 2013 and has been published in the proceedings of the Internationale Tagung Wirtschaftsinformatik 2013, which are ranked in category "A" according to the WKWI and "C" according to the VHB JOURQUAL 3 (WKWI, 2008; Hennig-Thurau and Sattler, 2015b).

The two previous publications served as a basis for the next research steps that enabled further improvements of the underlying DCF model and the application within a new case study. These research steps and their findings have been published in the research paper "Offshore Wind Energy in Emerging Countries: A Decision Support System for the Assessment of Projects" which was again written together with Michael H. Breitner, see Koukal and Breitner (2014) and Appendix 8. The paper was accepted after a double-blind peer review with one revision at the 47th International Conference on System Sciences (HICSS 2014) in Waikoloa, Big Island, Hawaii, USA in the "Sustainability" track. It was presented at the HICSS in January 2014 and has been published in the proceedings of the conference which are ranked in category "B" according to the WKWI and "C" according to the VHB JOURQUAL 3 (WKWI, 2008; Hennig-Thurau and Sattler, 2015b).

2.2. Decision Support System to Promote the Wind Energy System Integration

2.2.1. Motivation and Research Topic

During the last decades, the deployment of RE technologies was mainly based on financial support mechanisms with low market integration – e.g., feed-in priorities, purchase guarantees, and fixed feed-in tariffs – as these technologies could not compete with conventional electricity generation (Abolhosseini and Heshmati, 2014). Even though these support mechanisms were effective in promoting the expansion of RE deployment in several countries, they led to significant subsidy costs (Huntington et al., 2014). To reduce these subsidies, policy-makers currently rather tend to apply market-based support mechanisms (European Commission, 2013; REN21, 2016). Auctions for RE subsidies introduce a price discovery element into the establishment of subsidy levels (Del Río and Linares, 2014) and are on the rise in many countries. They lead to significant reductions of subsidy costs as RE projects compete in them and only the most cost-efficient projects are realized (Huntington et al., 2017; Del Río and Linares, 2014).

Nevertheless, auction mechanisms also foster an accumulation of RE deployment at locations with the most resources, as these locations offer the most cost-efficient deployment (Abdmouleh et al., 2015; Del Río and Linares, 2014). The resulting spatial concentration of RE capacity intensifies the stochasticity of electricity generation because of highly correlated resource availabilities (van Kuik et al., 2016; Roques et al., 2010). Additionally, these locations with high RE resources do not necessarily match to areas with high electricity demands. The increased stochasticity and the potential mismatch between supply and demand locations result in high ancillary and electricity distribution costs as well as technical issues threatening grid stability and supply reliability (Reichenberg et al., 2017; Rombauts et al., 2011; Roque et al., 2010). Consequently, there is a trade-off between a cost-efficient and reliable electricity distribution and a cost-efficient RE electricity generation at the most resource-rich locations.

This trade-off must be taken into consideration when financial support mechanisms are designed to improve the system integration of RE by promoting an appropriate spatial distribution of new capacity (Reichenberg et al., 2017; Roques et al., 2010). Incentives must be carefully designed as the realization of this distribution is the result of the entirety of investment decisions by individual investors (González and Lacal-Arántegui, 2016). The relationship between competitiveness and in-situ resource availability must be weakened by suitable incentives to realize projects outside the most resource-rich locations. Auction mechanisms, e.g. in Germany (Lang and Lang, 2015), Mexico (IRENA, 2017), and Spain (Huntington et al., 2017), use incentives based on locations' resource availabilities to adjust the decisions of investors and thus the spatial distribution of new RE capacity (Lang and Lang, 2015). However, the design and quantification of these incentives are major challenges as inappropriate designs have strong adverse effects on the efficiency of electricity supply (Huntington et al., 2017.

As the global climate change process is influenced by greenhouse gas emissions and thus by the generation of electricity, to limit negative ecological effects, an intensive expansion of renewable energies seems not only necessary, but mandatory. Wind energy will most likely contribute to this expansion with the greatest extend by increasing its share on the worldwide energy production from 2 percent in 2009 to 8 percent in 2035 (Chu and Majumdar, 2012). The biggest potential is in the developing and emerging countries e.g. in Central and South America as there has been no intensive use so far (Chu and Majumdar, 2012). In this study, we focus on the improvement of the spatial distribution of wind energy deployment in Mexico as Mexico has many regions which offer average wind speeds that are otherwise rather typical for offshore locations. Although wind energy has the potential to contribute significantly to global electricity generation (Lu et al., 2009), the accumulation of wind energy capacity under auction mechanisms for RE subsidies is a common issue (van Kuik et al., 2016). We tackle this issue by addressing the following research questions:

RQ1: How can decision support be provided for investors, lenders and policy makers to access onshore wind energy (OWE) projects and corresponding support schemes to stimulate investments and a further expansion?

RQ2: How can investment incentives be quantified to improve the spatial distribution of wind energy deployment under renewable energy auctions?

These research questions are investigated by way of a DSR approach. A technological artifact is presented that integrates in the final version three models: (1) a resource model to describe the availability of RE resources; (2) an economic viability model to depict the decision making of economic agents; (3) a spatial distribution model to assess the effects of support mechanism designs on the spatial distribution of new capacity. The study focusses on the technical design of these models and the integration in the technological artifact. The latter is instantiated as a DSS prototype and applied in a pilot study and an extended simulation study based on real-world data to permit a proof-of-concept (Nunamaker et al., 2015).

This chapter is largely based on Koukal and Piel (2017), Piel et al. (2017), Appendix 14, and Appendix 15.

2.2.2. Research Background

The increasing interest in environmental and economic sustainability of societies also reached the IS research domain when Watson et al. (2010) called to consider energy informatics and eco-friendliness to a broader extend. However, this call was not followed by a sufficient uptake in research (vom Brocke et al., 2012).

Although auctions are becoming the predominant support mechanism for RE (REN21, 2016; Del Río and Linares, 2014), their adverse effects on spatial diversification of new capacity (Abdmouleh et al., 2015; González and Lacal-Arántegui, 2016) explain the focus of current energy policy research on extending auction designs to promote a desired distribution from a system perspective. Recently, Huntington et al. (2017) analyzed policy design elements with a focus on their effects on the trade-off between promoting and efficiently integrating RE into electricity systems. They highlighted the need to design incentives to affect the entirety of investment decisions to promote an efficient system integration and they proposed a capacity-based policy design with feed-in compensation mechanisms based on a variety of reference benchmark plants.

However, altering auction bids for location-based incentives weakens the link between the competitiveness of a project and resource availabilities. When carefully designed, they incentivize investors to develop projects outside the most resource-rich locations and thus promote a less concentrated spatial distribution of RE deployment. Consequently, location-based incentives are a useful design element to improve the spatial distribution of RE capacity due to the ability of influencing the entirety of investment decisions while still preserving competition regarding marginal costs. Additionally, this approach directly addresses the trade-off between the efficiencies of electricity generation and distribution in combination with an active expansion planning and market-based incentives to maintain cost-efficiency of supply.

Current research provides methods to identify the optimal spatial distributions of RE capacity regarding different evaluation criteria (Reichenberg et al., 2017; Roques et al., 2010; Thomaidis et al., 2016). Additionally, a significant body of research investigated design elements of RE support mechanisms and their effectiveness as well as efficiency concerning RE deployment and system integration (Huntington et al., 2017; Del Río and Linares, 2014; Wiegand et al., 2016). However, a combination of these research streams to investigate investment incentives for an appropriate system integration of RE by estimating their effect on the spatial distribution of new capacity has not been the focus of previous studies.

2.2.3. Research Design

Our research was conducted using design science research principles to address relevance and enhance rigor of the research process and results. The design-orientated research process was recommended by Offermann et al. (2009) and, in particular, Peffers et al. (2008). Also, we used key recommendations of Hevner et al. (2004, 2007) and March and Smith (1995). According to Peffers et al. (2008) the design of our research is classified as problem-centered approach, see Figure 8.

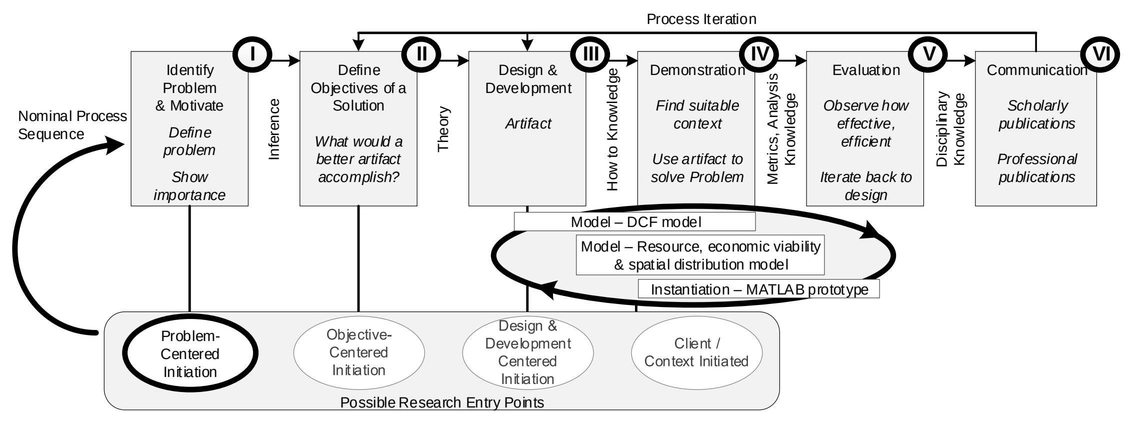


Figure 8: Research Design based on Koukal and Piel (2017).

We mainly focused on the design, demonstration, and evaluation of artifacts that can provide a basis to assess location-based conditions for wind energy projects in a specific country (II). Regarding this objective, the practical and scientific input was used to design and evaluate artifacts in a loop of iterations in the design cycle according to (Hevner, 2007). After refining the problem domain and defining detailed requirements, the first research artifact was designed (III): a basic DCF model. For a further development and a more detailed elaboration we used an iterative approach according to guideline six, “design as a search process”, by Hever (2007) and examined risk factors and enhanced our initial model by implementing a complex risk model that enables the application of an MCS (see Figure 8). The next iteration resulted in the definition of a more complex structure consisting of three models: a resource model; an economic viability model; and a spatial distribution model. In addition to the constructed formal models, an instantiation was created by the implementation of a prototype in MATLAB. The DSR process cycles were then completed by more extensive tests of the artifacts to enable the documentation of research results. According to the classification of research methodologies by Palvia et al. (2006), two case study in the form of project value and debt coverage calculations for OWE projects at different locations in Mexico in combination with the design of support scheme components were performed to demonstrate (IV) and evaluate (V) the capabilities of the DSS. Finally, we worked toward publishing our research results (VI).

2.2.4. Summary of Results

2.2.4.1. Discounted Cash-Flow, Risk Model and DSS

The basis for the assessment of projects is our DCF model. The model is used to calculate the FCF of an OWE project. It represents the after-tax cash flow available to the project's investors which must initially be used for debt service coverage. Figure 9 shows the sets, parameters, and key equations of the DCF model.

	Sets		$t=(1,\dots,T)$: *year*	$v=(0,\dots,V)$: *wind speed [m/s]*
(7)	**Para-meters**	FCF_t: *free cash flow [€]* CE_t: *capital expenditures [€]*	OE_t: *operation expenditures [€]* DE_t: *decommissioning expenditures [€]*	TAX_t: *tax payments [€]* R_t: *revenues [€]*
(8)		T^c: *planning and construction [years]* T^{dc}: *predevelopment and consenting [years]* T^{pa}: *production and acquisition [years]*	T^{fi}: *foundation installation [years]* T^{pci}: *power connection installation [years]* T^{wi}: *turbine installation [years]*	T^o: *operation [years]* T^{de}: *decommissioning [years]* T^{ds}: *debt service period [years]*
(9)		c_t^{pr}: *project rights [€]* c_t^a: *expenditures in T^{dc} period [€]* c_t^{cp}: *expenditures in T^{pa} period [€]* c_t^{fi}: *foundation installation [€]*	c_t^{pci}: *power connection installation [€]* c_t^{wi}: *turbine installation [€]* c_t^f: *foundations [€]*	c_t^{pc}: *power connection [€]* c_t^w: *turbines [€]* c_t^{ic}: *insurance (construction) [€]*
(10)		r^p: *feed-in tariff [€/MWh]* W_v: *turbines' cumulative power curve [MW]* k_t: *Weibull shape parameter*	a_t: *Weibull scale parameter* δ_t^s: *wake losses [%]*	δ_t^a: *technical failure losses [%]* δ_t^o: *other losses [%]*
(11) 12)		c_t^r: *repair [€]* c_t^m: *maintenance [€]*	c_t^o: *land lease, administration [€]* c_t^{io}: *insurance (operation) [€]*	c_t^{de}: *dismantling and disposal [€]* r_t^{de}: *component recovery value [€]*
(13)		τ: *corporate tax rate [%]* I_t: *interest payments [€]*	DEP_t: *depreciation expenses [€]* P_t: *provision expenses for decommissioning obligations [€]*	
(14) - (16)		APV: *adjusted present value [€]* i^c: *cost of capital [%]* i^d: *cost of debt [%]*	i^e: *cost of equity [%]* E: *equity capital [€]* D: *debt capital [€]*	i^f: *risk-free interest rate [%]* i^m: *market interest rate [%]* β: *beta factor*
	Key figures	APV: *adjusted present value [€]* IRR: *internal rate of return [%]*	IRR^e: *equity internal rate of return [%]* $DSCR_t$: *debt service cover ratio*	$LLCR_t$: *loan life cover ratio* $PLCR_t$: *project life cover ratio*

$$FCF_t = R_t - \left(CE_t + OE_t + DE_t + \begin{cases} TAX_t, & if\ TAX_t > 0 \\ 0, & if\ TAX_t \le 0 \end{cases}\right) \qquad \forall\, t = 1,\dots,T \tag{7}$$

$$T = \overbrace{T^{dc} + T^{pa} + T^{fi} + \max(T^{pci}, T^{wi})}^{T^c} + T^o + T^{de} \tag{8}$$

$$CE_t = c_t^{pr} + c_t^a + c_t^{cp} + c_t^{fi} + c_t^{pci} + c_t^{wi} + c_t^f + c_t^{pc} + c_t^w + c_t^{ic} \qquad \forall\, t = 1,\dots,T^c \tag{9}$$

$$R_t = r^p * \left(\left[\int_{v=0}^{V} \left(\frac{k_t}{a_t} * \left(\frac{v}{a_t}\right)^{k_t - 1} * e^{\left(\frac{v}{a_t}\right)^{k_t}} * W_v\right) dv\right] * 8{,}760 * (1 - \delta_t^s * \delta_t^a * \delta_t^o)\right) \qquad \forall\, t = T^c,\dots,T \tag{10}$$

$$OE_t = c_t^r + c_t^m + c_t^o + c_t^{io} \qquad \forall\, t = T^c,\dots,T \tag{11}$$

$$DE_t = c_t^{de} - r_t^{de} \qquad \forall\, t = T^c + T^o,\dots,T \tag{12}$$

$$TAX_t = (R_t - OE_t - I_t - DEP_t - P_t) * \tau \qquad \forall\, t = 1,\dots,T \tag{13}$$

Figure 9: DCF Model Parameters and Equations based on Koukal and Piel (2017).

According to equation (7), the FCF is specified as difference between revenues and the sum of capital expenditures (CAPEX), operation expenditures (OPEX), decommissioning expenditures, and tax payments. Equation (8) describes the structure of the entire project life cycle. Equation (9) shows the calculation of the CAPEX and equation (10) the determination of revenues. Equation (11) determines the OPEX. Decommissioning expenditures at the end of the project are calculated via equation (12) and represent the difference between the dismantling and disposal expenditures and the components' recovery values. Equation (13) calculates the tax payments.

Most OWE projects are financed via special purpose vehicles which are characterized by debt-to-equity ratios that vary during the project life. Consequently, we use the APV method since it is a better choice when these conditions apply (Luehrman, 1997).

The APV is calculated according to equation (14) by adding the discounted FCFs and tax shields among the project life. While the FCFs are discounted by the cost of capital, the tax shields are discounted by the cost of debt. The cost of capital is specified by equation (15) and represents the average of the costs of equity and debt, weighted with the shares of equity and debt. As shown in equation (16), the cost of equity is determined according to the CAPM by estimating the expected return of an alternative investment into a diversified and risk-adjusted market portfolio (Da et al., 2012). Additional important key figures for lenders are provided as they need key figures that evaluate the debt service coverage. The DSCR determines the debt service coverage for every single period of a project. It is the quotient of the CFADS and the debt service (Pretorius et al., 2008), see equation (17).

$$APV = \sum_{t=1}^{T} \frac{FCF_t}{(1+i^c)^t} + \frac{\tau * I_t}{(1+i^d)^t} \tag{14}$$

$$i^c = i^e * \frac{E}{E+D} + i^d * \frac{D}{E+D} \tag{15}$$

$$i^e = i^f + (i^m - i^f) * \beta \tag{16}$$

$$DSCR_t = \frac{R_t - (OE_t + TAX_t)}{DS_t} \qquad \forall\, t = T^c + 1, \dots, T^{ds} \tag{17}$$

As a pure contemplation of expected values does not provide a sufficient basis for investment decisions due to an insufficient consideration of project risks (Koukal and Breitner, 2014), investments must always be assessed against the background of the investor's individual risk aversion and risk-bearing capacity. A risk model was developed which considers five risk factors and lead to 27 probabilistic parameters in the DCF model. As certain parameters are interrelated (Kitzing and Weber, 2015), it also considers correlations by the implementation of the Iman-Conover method. Rank order correlation can be induced between randomly distributed variables regardless of their distributions and without changing their shape (Imam and Conover, 1982). On top of the DCF model a MCS is applied. The MCS results in distributions that represent approximations of parameters and key figures and allows the application of VaR analyses. The VaR determines the maximum monetary loss that is not exceeded within a fixed period of time and an explicit confidence level. E.g. applied to the APV, the VaR expresses the minimum project value that is not undershot by a certain probability (confidence level).

The DSS is a MATLAB-based desktop application that is compatible with multiple operating systems. The DSS integrates the DCF model, the control of a MCS, visualization of results as well as input and output functionality to provide decision support. The system's architecture and the data flow are presented in Figure 10. Users must initially specify a dataset that represents the case study and serves as the necessary input for the MCS. All parameters of an OWP can be im- and exported from .mat files.

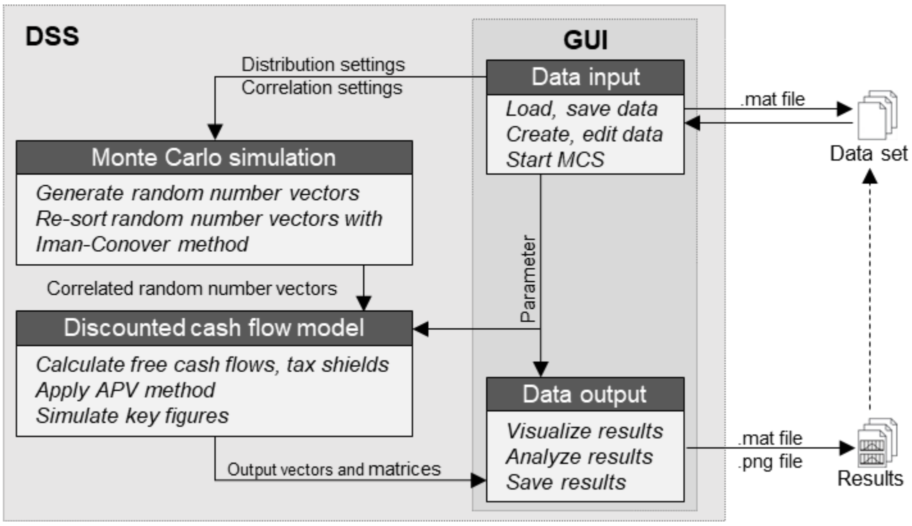


Figure 10: System Architecture based on Koukal and Piel (2017).

2.2.4.2. Pilot Study of Mexican Wind Energy Projects

To demonstrate the applicability of our research artifacts, the DSS is used to assess fictional OWE projects located at five different locations in Mexico. The locations and their corresponding average wind speed as well as parameters for the distributions of wind speeds are presented in Table 7. The projects are fictitious but based on data of real projects in Oaxaca. They consist of 41 turbines from Gamesa with 2.5 MW nominal power output. The planning and construction periods are set to 2 years in total. Within this timeframe the installation of turbines and power connection is also performed. The project lifetime is 20 years.

Table 7: Assumptions of Mexican projects according to Koukal and Piel (2017).

Location	Average wind speed [m/s]	Scale factor k	Shape factor c
La Venta, Oaxaca	12.54	1.906	13.573
La Laguna, BCS	8.65	2.394	9.193
San Quintin, BCN	7.43	2.578	7.803
Telchac Puerto, Yucatan	7.25	2.739	7.581
Matamoros, Tamaulipas	6.67	1.883	6.925

To apply the APV method, discount rates must be determined. The return on equity (equation (14)) is calculated with a risk-free interest rate of 0.8%, which is based on long term bonds from Germany, a market risk premium of 7.4% (Fernandez et al. 2014), and a beta factor of 1.27. The latter is derived from the average unlevered beta of 1.07 for companies operating in the Mexican onshore wind market. Consequently, the return on equity results in 0.8% + (7.4% - 0.8%) × 1.27 = 9.18%. Next, the cost of debt is determined. In the past, the Inter-American Development Bank or the World Bank supported Mexican OWE projects. Thus, a participation on the debt of 40% at 7.2% is assumed. Other banks provide 60% of the debt at 8.9% interest rate which results in a weighted cost of debt of 8.22%. Finally, the discount rate is calculated (equation (15)) with a total debt share of 70%: 9.18% × 30% + 8.22% × 70% = 8.51%.

To perform a MCS with Beta distributions and PERT estimations, a minimum, a maximum, and a most likely value for every risky parameter must be specified. The expected values of these parameters are used as most likely values and the minimum and maximum points are calculated by discounts and surcharges to the expected values.

All relevant parameters and values are inserted into the DCF model. The MCS is performed with 20,000 iterations and requires 43 minutes for each location using MATLAB R2016a on an Intel® Core™ i7-4710MQ CPU with 2.5 GHz, 20 GB RAM and Microsoft Windows 7 64-bit as the operating system. Simulation results are presented for the 90% confidence levels at different equity shares in Table 8. The results allow different statements about the analyzed OWE projects:

1. Only the project in La Venta, Oaxaca provides very positive returns for investors and sufficient debt service coverage regardless of the equity share.
2. In all other regions the revenues are too low to meet requirements of investors and lenders. Thus, higher compensations are required to promote the wind energy.
3. The project in La Laguna, BCS shows that an OWE project which is attractive in economic terms is not necessarily financeable (positive APV but DSCR lower than 1 at 30% equity) and vice versa (negative APV but DSCR of 1 at 40% equity).

Table 8: Key figures at 90% confidence level according to Koukal and Piel (2017)

	30% equity		35% equity		40% equity	
Location	APV	Min DSCR	APV	Min DSCR	APV	Min DSCR
La Venta, Oaxaca	814.7 M$	1.07	744.0 M$	1.15	665.4 M$	1.25
La Laguna, BCS	10.4 M$	0.86	-31.2 M$	0.92	-77.8 M$	1.00
San Quintin, BCN	-794.2 M$	0.65	-832.0 M$	0.70	-687.9 M$	0.76
Telchac Puerto, Yucatan	-931.9 M$	0.61	-964.3 M$	0.66	-1013.9 M$	0.71
Matamoros, Tamaulipas	-1390.3 M$	0.45	-1436.9 M$	0.49	-1466.8 M$	0.53

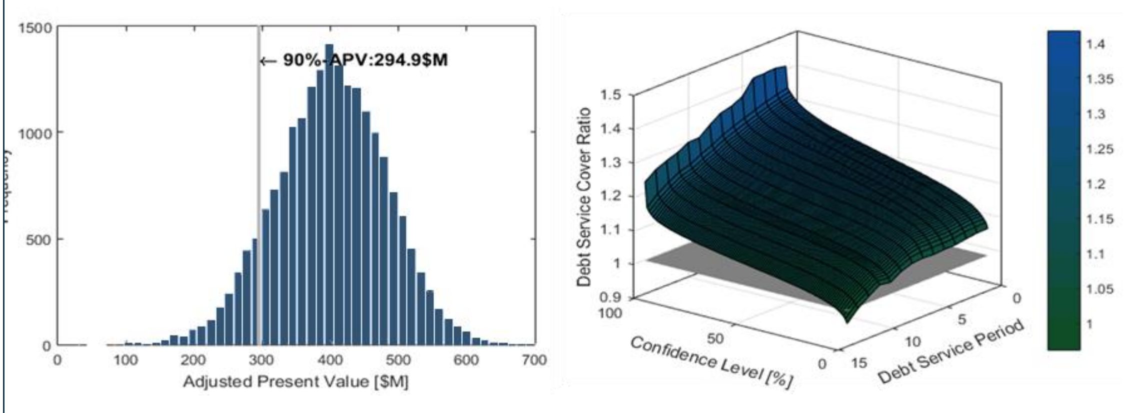


Figure 11: APV and DSCR for La Laguna, BCS with 35% equity based on Koukal and Piel (2017).

Based on these results, a concept of a uniform support scheme from Germany is adopted which offers transparent conditions that fits for all projects in a country. The support scheme is based on a site quality adjustment factor that considers certain conditions of any location compared to a 100% reference site. For an easy application to the Mexican case, the 100% reference site refers to the average wind speed. As the project in La Laguna, BCS is almost financeable and profitable with a 35% equity share (see Table 8), the compensation for the produced electricity of this project was increased in iterative steps to determine the minimum compensation that fulfills the needs of investors and lenders at a 90% confidence level. Figure 11 shows that a minimum DSCR of 1 and an APV greater than 0 is achieved when the compensation is set to 1,225 MXN/MWh. Although this result does not apply for other equity shares, we define the site conditions of La Laguna, BCS with an average wind speed of 8.65 m/s as the 100% reference site.

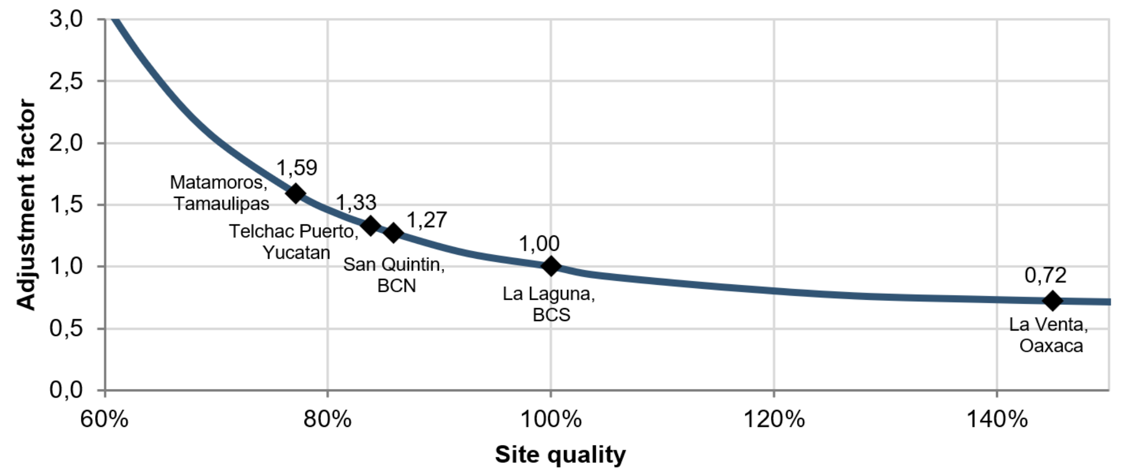


Figure 12: Site quality adjustment curve based on Koukal and Piel (2017).

Next, the minimum electricity compensations for projects with other site qualities which barely make them financeable as well as profitable were identified. Thus, the compensations of the other projects were increased or decreased. The last step was a normalization of the minimum compensations. All identified compensations were divided by 1,225 MXN/MWh which is the identified compensation of the 100% reference site at La Laguna, BCS to calculate adjustment factors. The result of this process is a list of projects with average wind speed, corresponding site quality factor, minimum required compensation, and adjustment factor. Major parts of the result list are visualized in Figure 12. By connecting the data points of the adjustment factors for all site qualities, the site quality adjustment curve (SQAC) becomes visible. The results show that the required compensation for electricity is not linearly depending on the average wind speed. Instead, the adjustment factor increases exponentially with decreasing site qualities which is similar to the SQAC implemented in the German OWE support scheme.

2.2.4.3. Resource, Economic Viability and Spatial Distribution Models

Based on the pilot study, the underlying model is extended and reorganized. The extended model for the quantification of locations-based incentives consists of three components: (1) a resource model; (2) an economic viability model; and (3) a spatial distribution model. The integration of these models represents our technological artifact which is instantiated as a DSS prototype and presented in Figure 13.

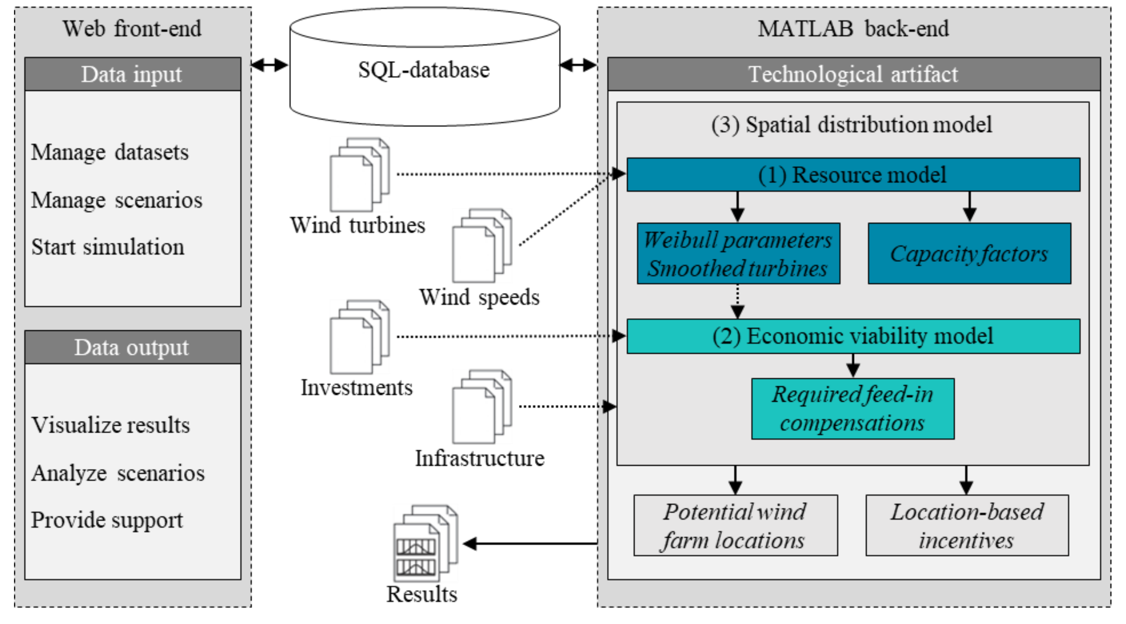


Figure 13: System Architecture and Developed Artifact based on Piel et al. (2017).

The resource model provides estimates of resource availabilities at arbitrary locations necessary to determine the economic viability of RE projects. It is oriented toward the Virtual Wind Farm (VWF) model by Staffell and Green (2014). The VWF model uses NASA's Modern-Era Retrospective analysis for Research and Applications (MERRA-2) dataset which is an ex-post simulation model that combines simulated and globally-observed data into a gridded meteorological dataset (Rienecker et al., 2011). Figure 14 illustrates the modified VWF model process: (1) acquisition of wind speeds at each grid point at 2m, 10m, and 50m above ground; (2) interpolation of wind speeds to the geographic coordinates of arbitrary locations using LOESS regression; (3) extrapolation of wind speeds to turbines' hub height using the logarithmic profile law; (4) conversion of wind speeds to electricity generation using smoothed wind turbines' power curves (5). The location of a potential wind farm and turbine characteristics are used by the resource model and yields the annual Weibull parameters, its aggregated power curve, the estimated average annual capacity factor as well as the corresponding wind time series.

The economic viability model is responsible for simulating the investment decisions of RE investors. To simulate the cash-flow streams of wind energy projects, it

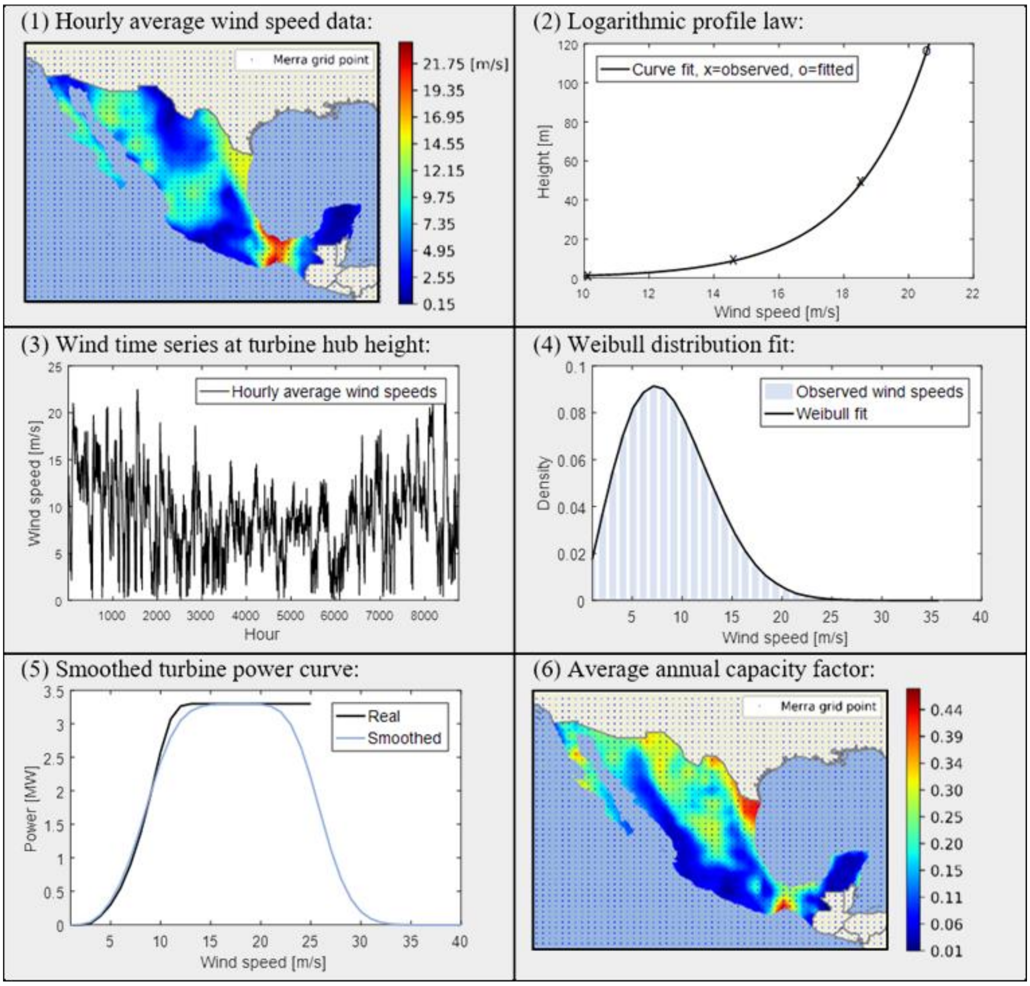


Figure 14: Underlying Modified VWF Model Process based on Piel et al. (2017).

uses the annual Weibull parameters and the smoothed power curve provided by the resource model. Besides, a variety of investment and technical data is fed into the model. The majority of this data is provided in the form of stochastic parameters which is quantified by means of a MCS.

As the actual realization of RE projects depends on balancing the interests of equity investors and lenders the economic viability model considers both perspectives. The flow-to-equity valuation approach is utilized to calculate the net present value to equity (NPVE) to measure a project's profitability. The flow-to-equity valuation approach was chosen because it is robust regarding the uncertain debt-share over the project life cycle which simplifies the valuation in comparison to the WACC and APV approaches. However, all of these approaches would lead to the same value of equity if consistently applied. Further, the bankability of a project was measured from the lender perspective by way of the DSCR. The explicit consideration of bankability is required due to the high debt-shares and the independence of project financed companies which must provide debt service entirely from their cash flows.

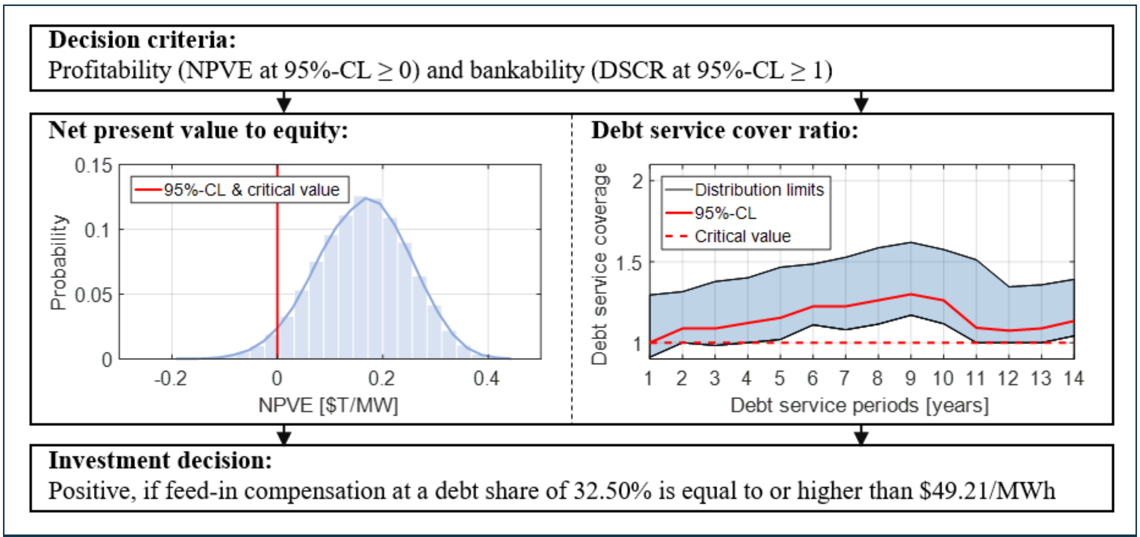


Figure 15: VaR Application to NPVE and DSCR according to Piel et al. (2017).

Figure 15 shows the application of the VaR approach to the distributions of NPVE and DSCR by specifying critical values for both key figures. Investors typically use these 95%-confidence levels to determine investment decisions and which are also crucial to lenders providing debt capital (Koukal and Breitner, 2013). In an auction mechanism, investors need to determine the minimum feed-in compensation for which the project is both profitable and bankable. This compensation corresponds to the optimal non-strategic bid price in a competitive auction and is determined by adjusting both compensation and debt share by means of a numerical optimization procedure.

The combination of resource and economic viability model enables to evaluate the competitiveness of projects at arbitrary locations which is utilized by the spatial distribution model. It is responsible for simulating the entirety of investment decisions and the influence of policy designs on these decisions. The resulting information can be used to quantify location-based incentives and adjust the spatial distribution of RE deployment. The model assumes an auction mechanism, which could be oriented toward the implementation proposal of Del Rio and Linares (2014). Comparable auction designs were recently implemented in several countries (IRENA, 2017; Klessmann et al., 2013).

Del Rio and Linares (2014) suggested using location-based incentives to foster a regional coordination of RE deployment by adjusting bid prices according to resource availabilities. To quantify these adjustments, the spatial distribution model was applied according to the following process: (1) definition of potential wind farm locations and projects; (2) application of the resource and economic viability models to each location and project; (3) definition of a resource availability measure and application to each location; (4) regression of required feed-in compensations against resource availability measures among all projects to determine location-based incentives.

2.2.4.4. Simulation Study: Diversifying Wind Energy Deployment in Mexico

Mexico has a high but heterogeneous wind resource availabilities (Carrasco-Díaz et al., 2015; Hernández-Escobedo et al., 2014; Jaramillo and Borja, 2004; Jaramillo et al., 2004) with an estimated capacity potential of at least 40,000 MW (Cancino-Solórzano et al., 2011). In particular, the Isthmus of Tehuantepec in the state of Oaxaca offers very high wind speeds that are otherwise typical at offshore locations (Jaramillo and Borja, 2004). However, Mexico has other regions with high resource potentials and most of them have only slightly positive or even negative correlations with the wind resource availabilities in the Isthmus of Tehuantepec. Besides, Mexico has recently introduced auctions for RE subsidies with location-based incentives to mitigate spatial concentration of deployment and thus serves as an ideal subject of study for demonstrating and evaluating our technological artifact.

To assess wind resource availabilities for random locations in Mexico the resource model was fed with data from NASA's MERRA-2 database. The obtained dataset consisted of 109,725,000 (2,508 x 8,760 x 5) observations corresponding to 2,508 MERRA-2 grid points at which hourly wind speed data from the years 2011 to 2015 was gathered. To calculate the electricity generation at each grid point a reference wind farm was parametrized which is assumed to be installed at each grid point with a smoothed power curve of a Vestas V112-3.3 wind turbine with a nominal power output of 3.3 MW and a hub height of 117 m (see Figure 14(2)).

Investment data for the economic viability model was derived from the reference wind farm using the clean development mechanism's (CDM) project database which contains project characteristics and investment analyses for twenty Mexican wind farms. Additionally, the renewable energy cost database provided by the International Renewable Energy Agency (IRENA) was used and results of the first Mexican auction were applied for comparison and evaluation.

To apply the spatial distribution model, a set of potential wind farm locations based on wind resource availabilities and electricity grid infrastructure was preselected. In includes locations within a radius of 50 km around power substations, which usually serve as grid connection points for wind farms. Wind resource availability was determined by calculating the capacity factor of the reference wind farm at every location with a minimum capacity factor of 0.22. This value was chosen as the average capacity factor of all remaining locations of 0.2866 almost equals to the simulated average capacity factor of Mexico's current wind fleet. Further, a uniform distribution of capacity among these locations reduce the standard deviation of hourly capacity factors by 15.92%.

Based on the prepared dataset, the resource and economic viability models were applied to the locations of each of the 2,508 MERRA-2 grid points. The investment decisions for the reference wind farm at each grid point were simulated by running the MCS of the economic viability model with 100,000 iterations and resulted in the required feed-in compensation for every MERRA-2 grid point. Then, the spatial distribution model and the calculated feed-in compensations were applied and used to determine location-based incentives. The application of filters for capacity factors and distances to grid infrastructure according to our selection process led to 115 potential wind farm locations remaining in the set. A scatterplot of the filtered capacity factors and the corresponding required feed-in compensation of each location is presented in Figure 16. It shows that few locations have very high resource availabilities (capacity factor >= 0.4) and therefore require very low feed-in compensations.

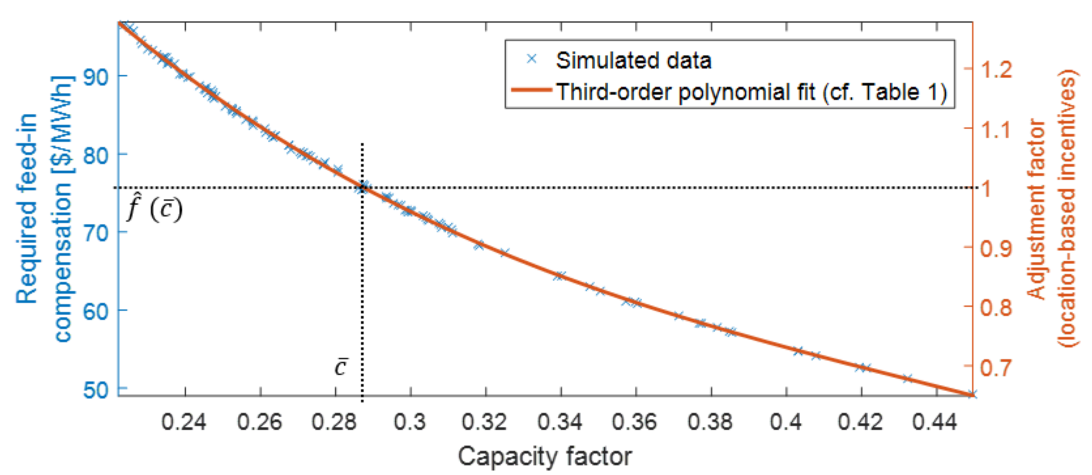


Figure 16: Capacity Factor and Required Compensations according to Piel et al. (2017).

To further investigate these findings, Figure 17 presents a heatmap of the required feed-in compensations in Mexico after filtering by capacity factors and grid infrastructure. Potential wind farm locations in the selected set are marked with black crosses. The rare wind farm locations with capacity factors higher than 0.4 are marked with red crosses. Figure 17 shows that the locations with such high capacity factors are concentrated in two regions, namely, the neighboring states of Tamaulipas and Nuevo Leon in the northeast and the Isthmus of Tehuantepec in the southeast of Mexico. Projects in these locations have a competitive advantage in auction mechanisms without suitable location-based incentives and, thus, it is likely that potential wind energy capacity would be accumulated in these regions. However, the heatmap further shows that there are many other regions in Mexico with high resource availabilities. Consequently, it highlights the potential for improving spatial distribution of new capacity towards a more diverse deployment.

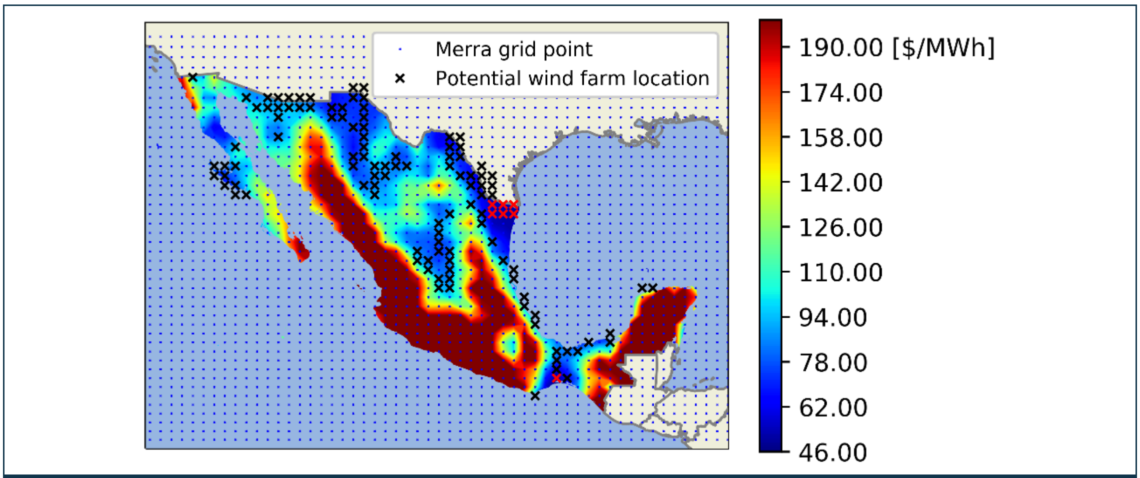


Figure 17: Required Feed-In Compensations according to Piel et al. (2017).

To illustrate how the results can be implemented in the Mexican auction mechanism, the effects on the competition between five projects are presented. The projects differ regarding their capacity factors as well as their bidding strategy and marginal costs. It is shown how location-based incentives eliminate resource-based competition while preserving competition regarding bidding behavior and marginal costs. The projects are presented in Table 9 with resource availability (capacity factor), bid price, adjustment factor (location-based incentive), and adjusted bid price. The latter are used to award projects in the auctions. However, in accordance with the pay-as-bid rule, awarded projects receive compensations at the level of their original bid prices (Del Río et al., 2014).

While project I has the average capacity factor, project II and III correspond to capacity factors' 25% and 75% quantiles in the selected set. Project I, II, and III are assumed to bid their marginal costs and only differ regarding their resource availabilities. The adjusted bid price of project II is lower than its original bid price, due to a lower capacity factor than the average project. For project III it's the opposite. After adjusting the bid prices, projects I, II, and III are equally competitive even though their capacity factors differ. Thus, resource availabilities no longer affect their relative competitiveness. Project IV and V have the same capacity factor as project III but differ regarding their bid prices. After considering the adjustment factor, the projects' competitiveness still differs. Further, even though project IV has a higher capacity factor and lower bid price than projects I and II, its adjusted bid price is higher and thus its competitiveness is lower.

Table 9: Exemplary location-based incentives according to Koukal and Piel (2017).

Project	Capacity factor c	Bid price bid	Adjustment factor $\hat{f}(\bar{c})/\hat{f}(c)$	Adjusted bid price bid_{adj}
Project I	0.2870	$75.80/MWh	1	$75.80/MWh
Project II	0.2472	$87.61/MWh	0.8652	$75.80/MWh
Project III	0.3061	$71.18/MWh	1.0649	$75.80/MWh
Project IV	0.3061	$73.00/MWh	1.0649	$77.74/MWh
Project V	0.3061	$69.00/MWh	1.0649	$73.48/MWh

2.2.5. Discussion, Limitations, and Further Research

The results of the simulation study show a non-linear relationship between in-situ wind resource availabilities (capacity factors) and the competitiveness of wind energy projects. The lower the capacity factor of such projects, the higher the marginal required feed-in compensation. Due to this correlation, location-based incentives for wind energy projects cannot directly be derived from wind resource assessments as this would not match the required compensations of projects. Instead this would cause over- or under-compensation of investors, lead to inefficient supply, and adversely affect the spatial distribution of deployment. Consequently, it is necessary to conduct economic assessments in addition to wind resource assessments for an adequately large set of projects in the area to be investigated in order to determine the relative competitiveness of these projects as well as appropriate location-based incentives.

As shown in the application examples, location-based incentives depending on capacity factors can be used to eliminate resource-based competition among projects while maintaining competition regarding bidding behavior and marginal costs. Resulting location-based incentives imply a uniform distribution of new capacity among all considered locations and consequently facilitate geographic smoothing of electricity generation from wind energy. The potential locations were filtered to achieve an average capacity factor that is almost equal to the capacity factor of Mexico's current wind fleet. By homogeneously distributing wind energy projects among these locations, the total variability of electricity generation can be reduced by 15.92% in comparison to the current wind fleet. However, projects that would have been uncompetitive without location-based incentives due to resource availabilities can now compete in the auction process which results in higher average feed-in compensations. Location-based incentives lead to higher subsidy costs, but the reduced variability can decrease ancillary costs of electricity supply and therefore promotes a better system integration of wind energy. By varying the preselection of projects and the parametrization of location-based incentives, policymakers can adjust the distribution of new wind energy capacity to utilize the trade-off between additional subsidies and reduced ancillary costs to achieve a desired balance.

This study integrates knowledge on finding desirable distributions of RE deployment from the literature on sustainable energy planning with the knowledge on RE auction design from energy policy literature. Former research on sustainable energy planning demonstrated that suitable spatial distributions of RE capacity reduce the variability of electricity generation and improve the system integration of large shares of intermittent RE (i.e. Reichenberg et al., 2017; Thomaidis et al., 2016). While the focus of respective publications lies on the identification of optimal capacity distributions regarding several evaluation criteria, it is not addressed how such distributions could be implemented through support mechanism designs. Compared with this, a large stream of energy policy research focuses on support mechanism designs to incentivize the efficient expansion of RE capacity but do not explicitly consider effects on the spatial distribution of new capacity. Recent energy policy literature recommends the implementation of location-based incentives in RE support mechanisms to affect the spatial distribution of capacity (i.e. Huntington et al., 2017; Del Río and Linares, 2014). However, this is usually described qualitatively, while an explicit design and a quantification are not addressed.

Our research combines both literature streams and provides an integrated modeling approach that allows to quantify investment incentives in order to promote a desired spatial distribution of capacity. Quantified incentives can be used to extend auction mechanisms by keeping favorable attributes but preventing adverse effects on the spatial distribution. Moreover, support mechanism designs for wind energy can be evaluated regarding the expected spatial distribution of new capacity as estimations of the competitiveness of wind energy projects at arbitrary locations are provided.

This research further contributes to the Green IS literature as it addresses an important issue of the transition towards sustainable energy systems. It is responded to the demand postulated by Gholami et al. (2016) for more solution-oriented IS research on environmental sustainability issues. Former Green IS research on the integration of intermittent RE into electricity systems is primarily positioned within the energy informatics framework with a major focus on the demand side of energy systems in smart grids (Goebel et al., 2014; Strueker and van Dinther, 2012).In contrast, we designed an IS solution that supports policy decision making regarding the incentivization of a system integration of intermittent RE and can mitigate issues on the system supply side, which is currently underrepresented in Green IS research.

In the process of this research, the need for practical assistance for policy-makers and other decision-makers regarding environmental issues and climate change was addressed, as outlined by Dedrick (2010). The quantification and implementation of location-based incentives in current support mechanisms is a substantial practical challenge as indicated by the frequent and major changes of the support mechanism. If countries apply quantified location-based incentives the detailed design is publicly available in corresponding laws (e.g., in Germany (Land and Lang, 2015), Mexico (IRENA, 2017), and Spain (Huntington et al., 2017)). However, the underlying approaches of the quantification are specific to individual countries and not published. This research provides guidance for policy-makers for a quantification and evaluation of location-based incentives for RE support mechanisms. The design elements of the presented artifact provide knowledge that can help policy-makers to assess current approaches for quantifying these incentives. Further, it can be used as a benchmark model for comparisons.

With the simulation study, an alternative approach for quantifying location-based incentives for wind energy deployment in Mexico was explored. Following Del Río and Linares (2014), auctions that do not mix technologies were assumed. However, current auctions in Mexico include solar and wind energy and thus, respective projects receive the same location-based incentives regardless of differences in resource availabilities. This auction design distorts the effect of location-based incentives on the spatial distribution of new capacity, which may have been a reason for recent changes in the Mexican auction system. As demonstrated in the simulation study and application example, the technology-specific approach can diversify the spatial distribution of wind energy capacity and can be a feasible alternative to the current auction design in Mexico.

This study is subject to two main limitations. At first, the approaches for the quantification of location-based incentives in RE support mechanisms are neither published nor available for validation. Thus, the presented modeling approach can only be evaluated against the actual distribution of RE deployment and the few published results of auction-mechanisms which make use of such incentives. This lack of data on auctions with location-based incentives significantly limits the possibility to evaluate the models. However, it is likely that this lack of data decreases in the future as the implementation of auctions increases, and more auction results will be available. Due to this limitation, this study addressed a proof-of-concept (Nunamaker et al., 2015, Nunamaker et al., 1990) of the modeling approach in a simulation study based on real-world data.

At second, there is a lack of incorporation of stakeholders into the process of developing artifacts. Only the economic viability model was developed together with stakeholders as this model is an extension of an artifact from previous design cycles (Koukal and Piel, 2017; Koukal and Breitner, 2014; Koukal and Breitner, 2013) that was previously evaluated with practitioners in the field of wind energy investments. Further research steps will need to put a stronger focus on the collection of requirements from relevant stakeholders and on the adaption of the current design to meet these requirements. Particularly policy-makers will need to be incorporated into the design process of the artifact to enable supporting them with actual decision support. Future research need to implement the artifact in a complete DSS to allow the evaluation and further development of both the models and the actual user-side of such a system.

2.2.6. Academic Classification of Publications

The publications regarding the assessment of wind energy projects from investors perspectives served as basis for the next research projects with a focus shift towards policy makers. The research paper “Financial Decision Support System for Wind Energy – Analysis of Mexican Projects and a Support Scheme Concept” was written together with Jan-Hendrik Piel, see Koukal and Piel (2017) and Appendix 14. The paper was accepted after a double-blind peer review with one revision at the 50th International Conference on System Sciences (HICSS 2017) in Waikoloa, Big Island, Hawaii, USA in the “Sustainability” track. It was presented at the HICSS in January 2017 and has been published in the proceedings of the conference which are ranked in category “B” according to the WKWI and “C” according to the VHB JOURQUAL 3 (WKWI, 2008; Hennig-Thurau and Sattler, 2015b).

The initial publication regarding a wind energy related topic for policy was followed up by the research paper “Promoting the System Integration of Renewable Energies: Toward a Decision Support System for Incentivizing Spatially-Diversified Deployment”. The paper was written together with Jan-Hendrik Piel, Julian Hamann and Michael H. Breitner (see Piel et al. (2017) and Appendix 15) and it was accepted after a double-blind peer review with one revision in the Journal of Management Information Systems (JMIS) which is ranked in category “A” according to the WKWI and VHB JOURQUAL 3 (WKWI, 2008; Hennig-Thurau and Sattler, 2015b).

3. Decision Support for the Enhancement of Literature Research Processes

3.1. Motivation and Research Topic

Literature research is a complex and highly important task (Wolfswinkel et al., 2013) and the whole literature research process represents an "essential first step and foundation when undertaking a research project" (Baker, 2000). It is crucial to be aware of what is already known in a specific scientific discipline's body of knowledge before attempting to contribute to any research field (Hart, 1998; Levy and Ellis, 2006). In 2002 Webster and Watson observed that specifically in the relatively young field of IS research, there is a lack of a proper theoretical foundation for quality literature reviews (Webster and Watson, 2002). To strengthen IS as a field of study, they state that effective literature review methods may provide great value to the discipline and that well-founded and rigorously conducted literature reviews have a higher chance of getting published. Considering the rising number of scientific publications worldwide, as well as facilitated access to broad scientific resources triggered by new technologies (Mabe and Amin, 2001; Park and Lee, 2011) and the resulting complex information environment (Bawden and Robinson, 2009; Manwani et al., 2001), a manually conducted, extensive literature review, is an increasingly time-consuming task.

To tackle this task and improve efficiency, we developed TSISQ, our "Tool for Semantic Indexing and Similarity Queries". It is designed to use unstructured texts as query input, e.g. complete scientific research papers or any kind of natural language, and can identify semantically similar texts in a large index of scientific publications. As TSISQ can help overcome the limitations of "classic" keyword searches while enhancing and facilitating the research process, we posit that it is a valuable addition to several stages of well-established literature review methods (Okoli and Schabram, 2010; Levy and Ellis, 2006; Webster and Watson, 2002). Besides, TSISQ can be used to support every research method that implicitly demands an extensive literature review, such as design science research according to Hevner with his claim for research rigor (Hevner et al., 2004) or the rigor cycle (Hevner, 2007). Following a design science research approach, we design and implement a prototype of our tool. Then, the prototype will be used to evaluate the capabilities of a latent semantic indexing (LSI) based approach for literature review methods. Hence, we seek to answer the following research questions:

RQ1: How can a LSI-based approach be adopted and implemented to increase the efficiency of scientific literature research processes?

RQ2: How can a LSI-based approach increase the efficiency of scientific literature research processes?

This chapter is largely based on Koukal et al. (2014a), Koukal et al. (2014b), Appendix 11 and Appendix 13.

3.2. Research Background

3.2.1. Literature Reviews

Literature reviews are the most basic, yet very important concept to set a theoretical basis. Their quality and usefulness significantly depend on the literature research process (vom Brocke et al., 2009). In the IS community, various well-established methods exist for properly conducting a quality literature review. Although different sets of guidelines are proposed by their authors, it seems to be the common opinion that it is of importance to get and provide a broad understanding of the pursued research topic. Consequently, the identification of relevant related literature is an important subtask in every literature review (Wolfswinkel et al., 2013). Webster and Watson (2002) claim that relevant prior literature in IS and related areas must be reviewed to write an ideal article and, thus, an examination of past research is required. Levy and Ellis (2006) propose a data-processing approach consisting of a three-stage framework. The first stage is the gathering and screening of “inputs”. This includes the identification and analysis of quality literature in the respective field to ensure the validity and reliability of the study and its results. Okoli and Schabram (2010) point out that a literature review must be systematic in terms of following a specific method and, more importantly in our case, comprehensive in its scope, including all relevant material (see also Fink, 2010; Rousseau et al., 2008). The need for comprehensiveness is underlined in step three, “searching for the literature,” in the presented “eight-step-guide to conducting a [scientifically rigorous] systematic literature review.” Considering the above-mentioned guidelines and proposals, our aim is not to introduce a completely new method for literature reviews, but to facilitate certain steps of existing, well-established ones by proposing a tool-supported similarity search process. In the following, a short overview of retrieval approaches for addressing our underlying challenge of identifying semantic similarities between texts is given.

3.2.2. Related Work

To the best of our knowledge, the research gap we seek to address, put precisely, comparing a query formulated in natural language and a large body of published, complete IS research papers using LSI or a related method, has not been reported in scientific literature. A publication from Sidorova et al. (2008) appears to be closest to our study. They present an approach based on LSI to determine the “intellectual core of the information systems discipline” by examining the abstracts of published IS research articles from 1985 through 2006 in three high quality research journals: MIS Quarterly, Information Systems Research and the Journal of Management Information Systems. Referring to the work of Sidorova et al., Hovorka et al. (2009) analyzed semantic relationships in 24,841 abstracts from core business journals to derive possible convergences between IS and other business disciplines. Blake (2010) followed a similar approach by identifying core topics and themes of data and information quality research. Another similar approach was applied by Homayouni et al. (2004) in the field of bioinformatics. They showed that the automatic extraction of relationships between genes from abstracts and titles in biomedical literature can be performed with high precision by using LSI.

However, the text-corpus we want to analyze is much larger than the one examined by Sidorova et al. (2008) and also larger than the collection utilized by Homayouni et al. (2004) as it contains full texts of all publications from the highest ranked IS research journals (the “AIS basket of eight”) plus the four most important global IS conferences (AMCIS, ECIS, HICSS, ICIS) from 2007 to 2014. The corpora analyzed by the already mentioned scientific studies, who followed similar approaches, are also composed of abstracts only.

One of the challenges of our intent is that almost all common algorithms compute very large matrices as a result of a high amount of unique terms and documents directly in memory. This is a memory-intensive application which demands a lot of computing power. It is desirable to keep the technical requirements as low as possible while not having to reduce the tools’ performance significantly. To address this issue, the framework “genism” that serves as one of the main foundations for TSISQ uses an algorithm for a memory-efficient incremental process proposed by Brand (2006) (Řehůřek and Sojka, 2010). Řehůřek and Sojka (2010) state that, to their best knowledge, their Python-based implementation of Brand’s algorithm is the only publicly available implementation of LSI that is independent of the index size. This allows an execution of TSISQ on an average, up-to-date computer or notebook.

3.3. Research Design

Our research was conducted using design science research principles to address relevance and enhance rigor of the research process and results. The design-orientated research process was recommended by Offermann et al. (2009) and, in particular, Peffers et al. (2008). Also, we used key recommendations of Hevner et al. (2004, 2007) and March and Smith (1995). According to Peffers et al. (2008) the design of our research is classified as problem-centered approach, see Figure 18.

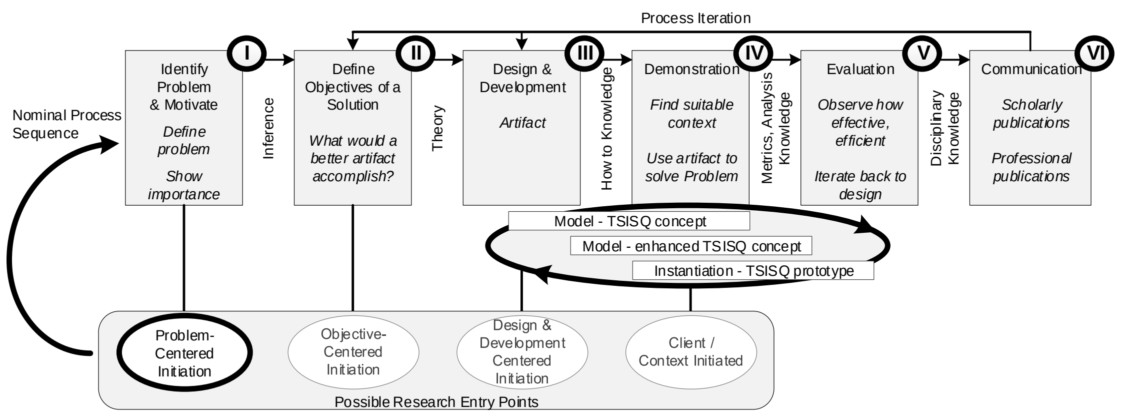


Figure 18: Research Design based on Koukal et al. (2014).

The lack of automated support in combination with a consideration of semantic concepts for text retrieval makes the literature search process slow and time consuming. The need for a more efficient approach triggered the development of the TSISQ prototype. The research process was initiated by identifying the above-mentioned problem (I). A comprehensive literature review was conducted within the fields of methods for conducting literature reviews in the IS, information retrieval, and NLP domain. According to our research question, the design, demonstration, and evaluation of artifacts that can enhance the literature research process were the main objectives (II). After defining the problem and specific requirements, the scientific input was used to design the first artifact (III): a basic model for TSISQ. This model was limited to the central aspects of semantic indexing and similarity queries. For further development, we used an iterative approach to create and refine artifacts cyclically according to guideline six, “design as a search process”, by Hevner (2004). Thus, the basic model was extended with a layer for automated preparation of the content database and a web front end, resulting in an enhanced model for TSISQ. March and Smith (1995) classify the result of design-oriented research into constructs, models, methods, and instantiations. On top of the formal models, an instantiation was implemented: a prototype of TSISQ. The DSR process was then completed by tests of the artifacts and a demonstration (IV) and evaluation (V) of the capabilities of the prototype to enable documentation of research results (VI).

3.4. Summary of Results

3.4.1. Enhancing the literature research process with TSISQ

Three fundamental stages can be derived from the different guidelines for conducting a systematic literature review in the IS field that should be addressed in every literature research process. We understand them as important sub-steps of a complete literature review. The first stage is the search space definition, e.g. the selection of a scientific database. The second stage is the search process with identification of articles that possibly fit the author's needs. The third stage is the screening of the identified papers to check the content for relevant aspects. TSISQ allows an enhancement of the second stage by providing a search method that addresses the lack of not taking semantic concepts into consideration when performing keyword-based searches (see Figure 19). Besides that, it may reduce efforts in the third stage due to less irrelevant articles that must be filtered out of search results.

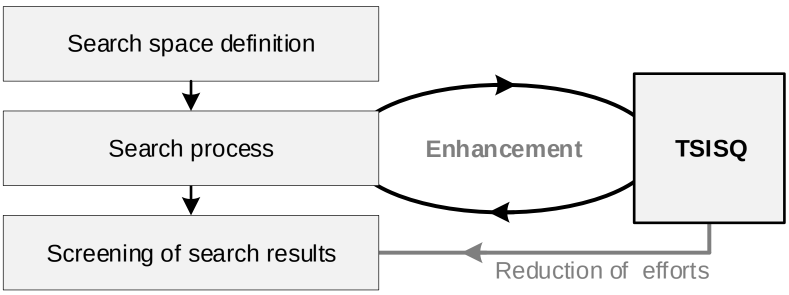


Figure 19: Literature Research Process' Enhancement based on Koukal et al. (2014).

3.4.2. Underlying Theoretical Concepts and Applied Methods

The conversion of documents into its representation in the vector space model (VSM) is a main concept to permit computer-aided processing of contents (Salton et al., 1975). In TSISQ, this concept represents the initial step of the processing of any document. Each document is defined as a t-dimensional vector in Euclidean space, where t corresponds to the amount of different terms of a document. This is combined with a weighting of each term to quantify its importance and relevance. We apply the term frequency-inverse document frequency (TFIDF) concept (Salton and McGill, 1986) which is the most common approach that determines term weights (Yandell and Majoros, 2002). It improves the performance of retrieval systems (Maas et al., 2011) by discounting the influence of more common non-stopwords and promoting of amount of rare terms (Sidorova et al., 2008). The conversion into VSM and the application of the TFIDF concept results in a term-by-document matrix in which the columns contain the weighting of terms for each document. The conversion of documents to fixed-length lists of numbers does not result in a greater reduction of the dimension of content nor in a greater consideration of the statistical structure of a document or a corpus, Thus, the problem of the VSM of not being able to deal with synonymy (e.g. “required” and “substantial”) and polysemy (e.g. read a “book” and “book” a journey) persist.

To deal with these shortcomings and reduce the dimension, LSI can be applied. It uses co-occurrences of terms to take advantage of an implicit higher-order structure in the association of terms with documents (“semantic structure”) (Zhang et al., 2011). For this purpose, TSISQ decomposes the term-by-document matrix into three other matrices in a process called singular value decomposition (SVD) (Forsythe, 1977). To avoid conflicts with memory limits, TSISQ uses an incremental SVD processing algorithm by Brand (2006). Next, the three matrices are reduced in their dimensions to provide the best rank-k approximation of the original term-by-document matrix (Kontostathis, 2007).

The reduction of matrices’ dimensions is illustrated in Figure 20: Reduced Singular Value Decomposition based on Koukal et al. (2014).. The columns of the third reduced matrix are used for comparisons and similarity queries. Each column of matrix D’ represents a vector that characterizes the aggregated semantic concept of a document. To compare a query with documents, TSISQ initially converts each query input into its representation in the VSM and subsequently transforms it into the same space as the document vectors. This comparison of queries and documents is performed with the help of the cosine measure. Instead of determining the angle between query and document vectors, the cosine of the angle is calculated. The cosine measure is perhaps the most frequently applied measure for comparison of document similarities (Korenius et al., 2007). TSISQ returns the absolute value of the cosine that expresses the similarity between query and documents within an interval of [0, 1]. The higher this value, the higher is the similarity.

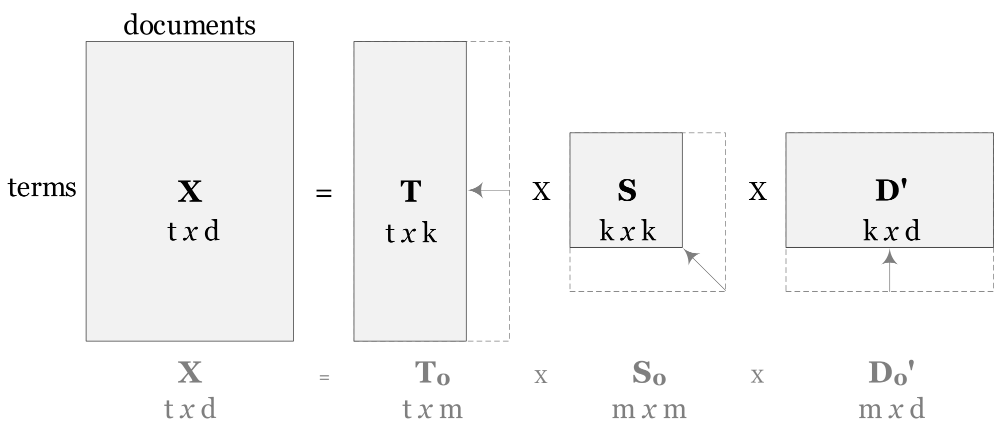


Figure 20: Reduced Singular Value Decomposition based on Koukal et al. (2014).

3.4.3. Implementation and Architecture of TSISQ

To enable cross-platform use, the TSISQ prototype is implemented in the Python programming language. The system components, their functions, and the respective data flow are presented in Figure 21: System Architecture of TSISQ prototype based on Koukal et al. (2014). As basic input scientific articles in PDF file format are used. These files are converted into plain text files with Xpdf. For the application of the presented methods of VSM, TFIDF, and SVD the software framework Gensim is used in combination with a higher-level control layer called Simserver. Gensim is a NLP software framework which is based on the idea of document streaming (Řehůřek and Sojka, 2010) and requires the open source NumPy and SciPy libraries for array manipulation as well as numerical integration and optimization. Since the term-by-document matrix does not have to be stored in memory Gensim provides memory-independent fast processing of large datasets. Additionally, it enables the direct application of the SVD concept on a term-by-document matrix with term-frequency weightings or with a previous application of the TFIDF weighting scheme as used by TSISQ. The initial training and the indexing process are computationally expensive and took about half an hour each for 12,300 documents on a system with an Intel Core i7-2640M CPU with 2.80 GHz, 8GB Ram. The indexing process results in an index corpus file for further processing. TSISQ stores information about indexes, contents, file sizes of PDF and text files, and the query history in a SQLite database. For the processing of user request and responses from TSISQ, the Python based Tornado web framework is used. User requests are passed to TSISQ core and responses are served to the HTML web front end. The graphical representation of the web front end is based on the Twitter Bootstrap framework.

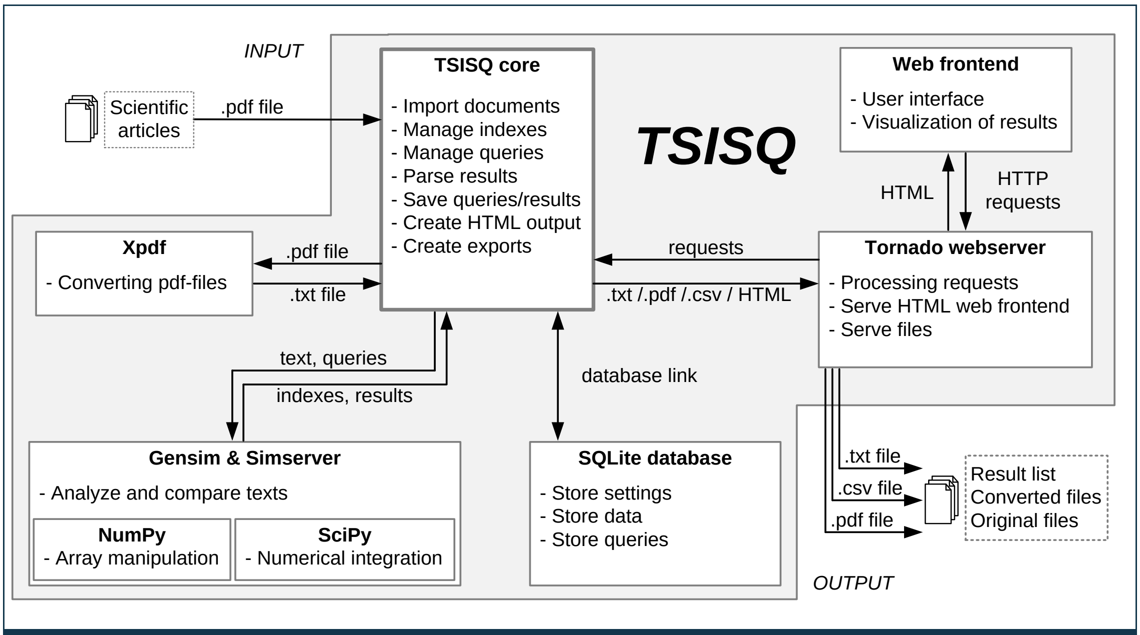


Figure 21: System Architecture of TSISQ prototype based on Koukal et al. (2014).

3.4.4. Demonstration and Evaluation

To demonstrate and evaluate the applicability of the constructed artifacts in the DSR process, we compare TSISQ with a keyword-based search engine with the help of domain experts and a laboratory experiment. As it makes sense to start a literature review with the leading journals, because any major contribution is likely to be found in them (Webster and Watson, 2002), our data base consists of eight journals and four conferences of important IS research, see Table 10.

Table 10: Database of Collected Research Articles according to Koukal et al. (2014).

Journal	Total	EJIS	ISJ	ISR	JAIS	JIT	JMIS	JSIS	MISQ
Articles	1,685	372	166	323	219	223	280	147	326
Share in %	13.7%	3.0%	1.4%	2.6%	1.8%	1.8%	2.3%	1.2%	2.6%
Conference	**Total**	**AMCIS**	**ECIS**	**HICSS**	**ICIS**				**Total**
Articles	10,647	3,604	1,599	3,681	1,763				12,332
Share in %	86.3%	29.2%	13.0%	29.9%	14.3%				100%

3.4.4.1. Comparison of TSISQ with a Keyword-based Search Engine

To be able to recommend the use of TSISQ, it is not sufficient to only prove that search results are suitable, but also to verify their quality in comparison to an established scientific search engine. For a comparison, AISel was chosen as search engine as it is one of the leading databases in IS research, and three different research fields were selected: (1) Enterprise content management (ECM) as it is a relatively well-defined research domain within the IS field, (2) IS security and privacy as it is, in contrast, a vast research field which spreads to various domains from IT to e.g. psychology; and (3) structural equation modeling (SEM) to include a research method which is frequently applied to manifold topics within the IS domain and not only research topics. Next, a set of keywords was prepared for each of the three domains which were used as an input for (a) the search with AISel and (b) the TSISQ keyword search. In addition, we selected suitable natural language inputs for (c) the TSISQ text search. Table 11 shows the different keywords and texts used for the queries with AISel and TSISQ.

Table 11: Input for Comparison of Search Engines according to Koukal et al. (2014).

Research Area	AISel and TSISQ keyword search	TSISQ text search
Enterprise content management (ECM)	- Enterprise content management - ECM	Abstract of a literature review by Rickenberg et al. (2012)
IS security and privacy	- IT security, IS security - IT privacy, IS privacy	Description of “IS Security and Privacy” track from ICIS 2014.
Structural equation modeling (SEM)	- Structural equation models - Structural equation modeling - Structural equation modelling - SEM	Abstract of article about evaluation of indicators in SEM by Bollen (2011)

The focus of our analysis was on the relevance of results to the targeted research field as this is the most important quality criterion for a researcher performing a literature review. To allow a comparison of the results with respect to their quality, a three-point Likert scale was chosen for the quantification: A ranking of “0” classifies an article as being irrelevant to the initial query, while “1” means it is considered relevant, and “2” is highly relevant to a search topic. To ensure the independence of this classification, domain experts in the respective fields of research were provided with up to 50 top results for each search and asked to rank each result on the above-mentioned scale.

The results in the field of ECM (Figure 22a) show only a small difference regarding the quality of results using TSISQ in contrast to AISel. However, Figure 22b shows a quality improvement, especially in the class of highly relevant literature, in which TSISQ highly outperforms AISel. Further, the TSISQ output did not contain irrelevant literature at all. In the field of SEM (Figure 22c), TSISQ-keyword search delivered almost exclusively irrelevant articles while the search with natural language input again outperforms AISel regarding relevant and highly relevant literature. Finally, aggregates results in Figure 22d show that the search results of AISel are distributed similarly in all three. Though the TSISQ-keyword search delivers a high number of irrelevant articles, a high number of highly relevant articles are identified as well. In contrast, the use of topic-related, natural language input for the TSISQ-text search delivers a significant number of relevant and, especially, highly relevant articles and only few irrelevant articles.

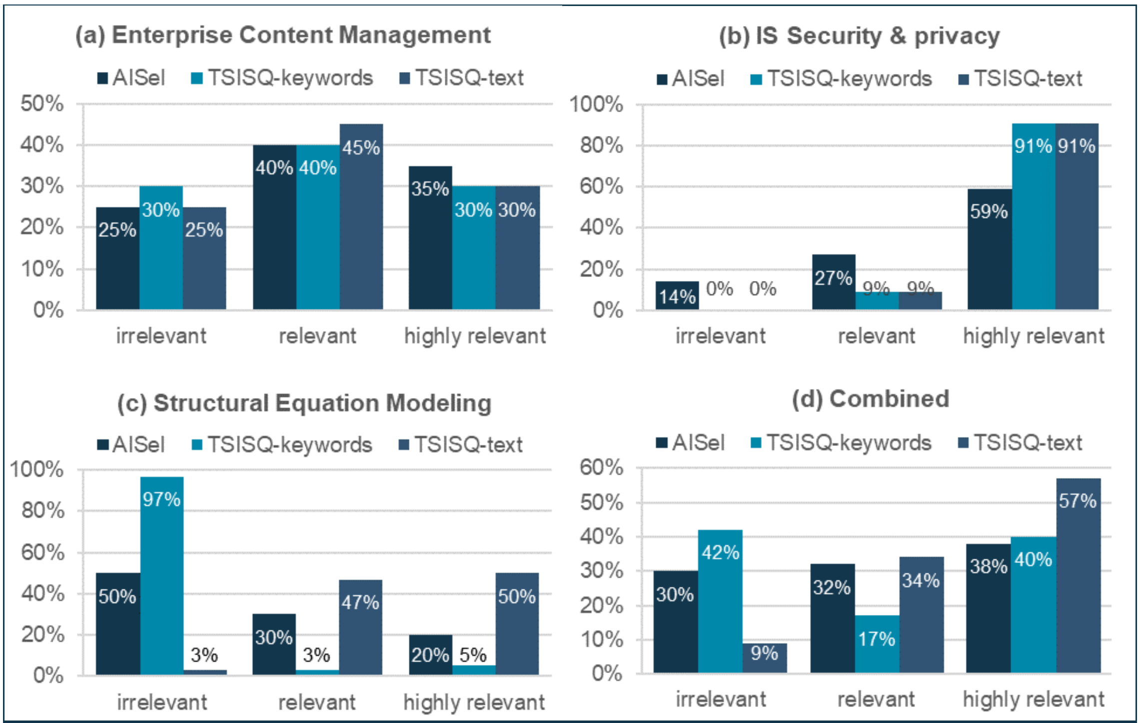


Figure 22: Evaluation of Search Results based on Koukal et al. (2014).

3.4.4.2. Identification of False-Positive and False-Negative Errors

The intention of the laboratory experiment is to further evaluate TSISQ and underline our theoretical assumptions about the applicability and advantages of LSI. Since an LSI-based similarity search can deal with the issues of synonymy and polysemy it considerably reduces the amount of false-positive and false-negative errors, i.e. finding non-relevant papers or missing relevant ones. While “false-positive hits” are easy to identify, “false-negative” errors, i.e. thematic mismatches in the upper ranks or outside of our search results, are hard to detect. To address this issue, a comprehensive understanding of the considered contents is required before analyzing the search results.

As first findings led us to the assumption that the majority of a query’s most relevant papers can be found within the top 25 results (Koukal et al., 2013), we built a manipulated index composed of only 100 scientific papers. Each of the articles was manually selected and classified into two categories to receive significant results in a controlled environment. The first category only contained 25 articles concerning “IS security and privacy” and, thus, they are likely to be semantically similar. The selection of these articles was based on the domain experts’ classification of our case study. The second category comprised 75 publications that were selected randomly but manually screened to ensure that they deal with topics different from those in the first category. As query input, we chose the complete description from the 2014 ICIS “IS Security and Privacy” track.

TSISQ delivered an output of 28 results, even though only 25 articles of 100 belong to the target domain of “IS Security and Privacy”. The 28 results contain 23 relevant and 5 irrelevant articles. Consequently, 2 of the 25 relevant articles were not identified which corresponds to a false-negative error rate of 8 percent. While the top nine search results are most accurate with a hit rate of 100 percent (see Figure 23) and the average false-positive error rate in the range of the top 20 results is still at an acceptable level between 10 and 15 percent, this rate increases up to 19 percent for all 28 search results.

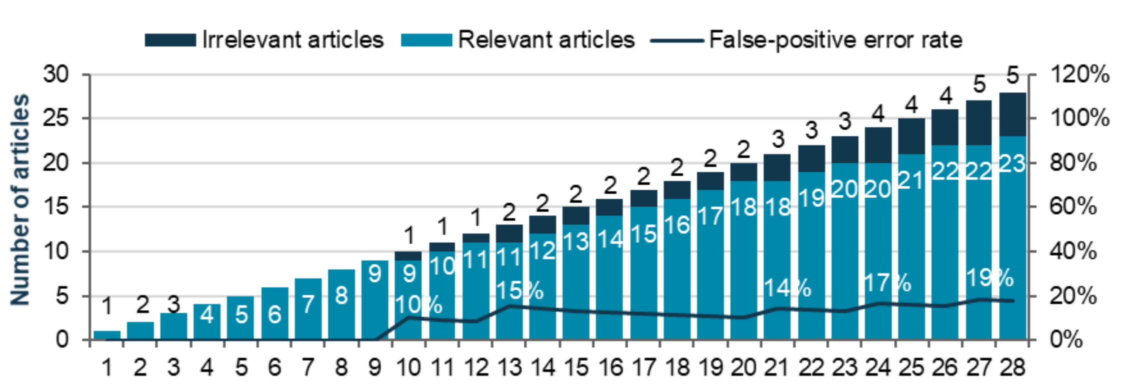


Figure 23: Results of the Laboratory Experiment based on Koukal et al. (2014).

3.5. Discussion, Limitations, and Further Research

The research was conducted to gain insight on how an LSI-based approach can be adopted and implemented to increase the efficiency of scientific literature research processes and how well such an approach performs in comparison to an established, keyword-based search engine. The presentation of the enhanced concept for the literature research process, the architecture of TSISQ, and the respective underlying theoretical concepts and applied methods directly address the first research question. Based on established approaches of the document retrieval domain, we created a prototype of our "Tool for Semantic Indexing and Similarity Queries" to address the tasks of performing semantic analysis of texts and subsequently searching for similar content. From a technical perspective, the whole application of an LSI-based literature search tool like TSISQ is complex. While the effort of an implementation into an existing infrastructure is low, it requires considerable computing power to create index corpora. However, this process is only necessary when further documents are added to an index corpus. It can be performed automatically by scheduled background tasks. From the perspective of a researcher, preparing and conducting any query with TSISQ requires the same time as the use of conventional techniques. Beyond that, using natural language as query input without the need to further define search terms or to meet formal requirements regarding a search engines' syntax can reduce time and effort for the user.

The second research question is addressed by the demonstration and evaluation of TSISQ's capabilities. The results indicate that the application of an LSI-based approach is very well suited for enhancing scientific literature research processes, especially if natural language texts related to the target domain are used as query inputs. In all presented search cases (Figure 22a-c), the TSISQ-text search generates at least the same quality of results regarding the relevance of articles, when relevant and highly relevant articles are considered. In search cases (b) and (c), it significantly outperforms the keyword-based approaches (AISel and TSISQ-keywords). Regarding search case (a) in the ECM domain, the quality of results of all search approaches is almost identical. However, TSISQ-text search performs worse in comparison to the other search cases.

To provide a better understanding of why the individual outcomes show those large differences, the query inputs must be analyzed in detail as the database and the setup of the searches used in the three search cases was identical. Two possible reasons for the outcomes have been identified: Firstly, the field of ECM is narrow compared to SEM or IS security and privacy, for which many articles exist containing applications and discussions about their type and conduct in various fields within the IS domain.

Secondly, the query input of search case (c) obviously contains more specific content (terms, semantic concepts) regarding the target domain of SEM and, thus, in search case (c), TSISQ-text delivers significantly better results.

The performance of TSISQ-text search in search case (c) is particularly to be emphasized as SEM is a method and not necessarily a research field itself and can be applied to almost every research field. It can be expected that the research domain analyzed with an SEM approach in an SEM-related article also dominates the semantic concepts extracted by TSISQ. The results of search case (c) do not reflect this aspect as the abstract used as query input for TSISQ-text search describes a meta-research article, dealing with SEM as a method and not its application in a different research domain. Consequently, TSISQ does not seem to be feasible for the identification of articles following a certain methodology but the initial assumption that TSISQ is useful for the identification of topic-related texts is confirmed.

TSISQ handles phrases like „structural equation modeling" not as one single search term (see section 3.4.2) but converts the terms into their representation in the VSM, determines their weights by the application of the TFIDF concept, and transforms them by LSI. In search case (c) of the TSISQ-keyword search for SEM, the terms "model", "modeling" and "modelling" receive relatively low TFIDF-weights but together they form a comparably strong semantic concept which is found in a high number of documents in the database. A "modeling" process usually results in a "model", and even if the term "modeling" is consistently used in the same spelling (which is often not the case), both spellings ("modeling" and "modelling") are likely to be found in articles' references section. Consequently, TSISQ identifies articles which contain all these terms as semantically similar to the query with the result that, e.g., literature about business process modeling or any statistical model is a potential but unwanted result to the SEM query. Accordingly, as the terms "model" and "modeling" appear in almost every IS research field in different contexts, TSISQ keyword search leads to diffuse results.

In contrast, TSISQ keyword search finds only relevant articles for the search case of IS security and privacy (b), because (1) the database exclusively consists of IS literature, (2) the spelling of the terms "security" and "privacy" is unique, (3) the terms "IS" and "IT" are identified as stop-words and filtered out as there is no distinction between upper and lower case spelling and (4), the aggregation of the terms "security" and "privacy" to a semantic concept is likely to exactly deliver the expected search results. If the database was expanded with non-domain-specific literature, less accurate search results could be expected. This must be kept in mind when using TSISQ solely with keywords.

The overall results of the different search cases show that the search results of TSISQ text search will most likely outperform those of a keyword-based search without the need to follow specific conventions for the formulation of query inputs. In keyword-based search engines like AISel search results are likely to be useless when search-engine-specific conventions are not considered. For example, a full abstract used as query input for AISel will either deliver no results if “AND”-conditions are applied or deliver totally random results if “OR”-conditions are applied. The definition of a set of suitable keywords that not only covers an entire research field but the specific target subdomain of it (by including all relevant synonyms or related terms) would require additional time and effort. However, considering the focus of this research on enhancing the literature research process by identifying semantically similar literature, it can be assumed that at least one scientific article or text regarding the target domain is known to the researcher who uses TSISQ. Against the background of at least identical or even better quality of the search results (see Figure 22a-d), it can be stated that particularly the TSISQ text search approach which does not require any special transformation of existing texts for the query increases the efficiency of the literature research process.

The results of the pilot study (Koukal et al., 2013) showed that the chance to achieve good results in the top 25 entries of the output is potentially high. However, if the number of articles dealing with target-related content is unknown, e.g. due to the large size of the index, no statement about the performance of the search engine can be made. Consequently, in the case of a comparatively large number of adequate articles in the index (e.g. 250), search results with heavily decreasing accuracy after the top 25 results would not be satisfying. In contrast, if the number of adequate articles in the same index is comparably low, e.g. 20, the detection of 16 articles within the top 25 search results would be a remarkably good search accuracy.

While the search accuracy and quality of results in comparison to the established, keyword-based search engine of AISel was evaluated in the case study, the laboratory experiment allows a quantification of the false-positive and false-negative error rate. Additionally, it addresses the question if the promising results of the case study simply arise from an unexpectedly large number of ECM-, IS security and privacy- or SEM-related articles in the index or from a good performance of TSISQ. In the laboratory experiment’s controlled environment, the average search accuracy is at least 81% within the top 28 results. Consequently, the expected value from our pilot study (75%) is outperformed by TSISQ which underlines the overall remarkable results of the case study.

Even though there is a lot of positive feedback in many publications that deal with LSI in various contexts and the related algorithms in detail, some limitations exist. LSI is suitable for addressing the issue of synonymy but the performance in solving problems with polysemy is limited due to the orthogonal characteristic of factors in the term-by-document-matrix (Lee et al., 2010; Bhandari et al., 2008). Besides, the simplifying assumption that the calculated text-representing vector is the centroid of its word vectors is criticized by Kintsch (2010). An example provided by him shows that the sum of the vectors is identical for the two phrases “the lion killed the deer” and “the deer killed the lion”. The substantial different meaning of those two sentences would be missed by LSI. However, it is highlighted that for texts of a minimum length of 100 to 150 words (e.g. abstracts), LSI provides a surprisingly good approximation and useful results.

The database is a critical spot for the examination of results. In our study, a wide range of top IS articles in diverse fields of research is covered. If a comprehensive literature review is to be conducted, the considered period of about seven years could be insufficient. However, to evaluate the feasibility of TSISQ for conducting the literature research process the specified period is sufficient. To date, our tool and the whole approach to support the literature review process is only applicable if all textual content is available in English. This arises from the fact that a dictionary of stop-words is required. Those dictionaries do not exist for many languages as it takes a lot of time and effort to create such resources (Furlan et al., 2013). However, as most of the top IS literature is published in English, this aspect does not negatively influence the outcomes of our study. Besides, a deeper analysis concerning the effects on the output might be necessary when query inputs for the same target domain are slightly adjusted, similar to a sensitivity analysis. Measuring the effects on the search results for SEM in search case (c) when e.g. the terms “models”, “modeling”, and “modelling” are left out one at a time could help to outline more detailed guidelines on how to formulate a query.

Further research steps are required regarding our approach. First, the index must be extended to cover more conferences and journals in a longer period. Second, to improve the validity of evaluation results, more extensive tests and assessments of more domain experts should be included in the future. Third, to elaborate how an aggregated and focused query should be formulated, a controlled adjustment of individual search terms should be performed. Fourth, the establishment of clear guidelines concerning the composition of query inputs should be addressed. Based on the third and fourth step and according to our recommendations, embedding the presented approach into a structured and well-designed iterative-process cycle can be a promising additional expansion.

3.6. Academic Classification of Publications

The research paper "Enhancing Literature Research Processes: A Glance at an Approach Based on Latent Semantic Indexing" was written together with Christoph Gleue and Michael H. Breitner, see Koukal et al. (2013) and Appendix 7. The paper was accepted after a double-blind peer review with one revision at the Annual Meeting of the Association for Informatics 2013 (GI 2013) in Koblenz, Germany in the "Applications of Semantic Technologies" track. It was presented at the GI in September 2013 and has been published in the proceedings of the Lecture Notes in Informatics, GI Edition 2013, which are ranked in category "B" according to the WKWI and "C" according to the VHB JOURQUAL 3 (WKWI, 2008; Hennig-Thurau and Sattler, 2015b).

The initial publication regarding a LSI and literature research related topic was followed up by the research paper "Enhancing Literature Review Methods – Towards more efficient Literature Research with Latent Semantic Indexing". The paper was written together with Christoph Gleue and Michael H. Breitner (see Koukal et al. (2014a) and Appendix 11) and it was accepted after a double-blind peer review with one revision at the 22nd European Conference on Information Systems (ECIS 2014) in Tel Aviv, Israel in the "Research Methods and Philosophy" track. It was presented at the ECIS in June 2014 and has been published in the conference proceedings which are ranked in category "A" according to the WKWI and "B" according to the VHB JOURQUAL 3 (WKWI, 2008; Hennig-Thurau and Sattler, 2015b).

The findings presented in both previous publications served as a basis for the next research steps that addressed further improvements of the TSISQ prototype and an extended evaluation of its applicability. These research steps and their findings have been published in the research paper "Enhancing Literature Review Methods - Evaluation of a Literature Search Approach based on Latent Semantic Indexing" which was again written together with Christoph Gleue and Michael H. Breitner, see Koukal et al. (2014b) and Appendix 13. The paper was accepted after a double-blind peer review with one revision at the 35th International Conference on Information Systems (ICIS 2014) in Auckland, New Zealand in the "Research Methods" track. It was presented at the ICIS in December 2014 and has been published in the proceedings of the conference which are ranked in category "A" according to the WKWI and the VHB JOURQUAL 3 (WKWI, 2008; Hennig-Thurau and Sattler, 2015b).

4. Decision Support Towards a Better World through IS

4.1. Motivation and Research Topic

In 2014 Grover stated that *"most of our research doesn't take on the big questions"* (Grover, 2014). The United Nations (UN) defined the Millennium Development Goals (MDGs) which specify major global challenges and big questions of our century. The MDGs include the eradication of poverty and hunger, universal and affordable access to healthcare and education, environmental sustainability, gender equality, and a global partnership for development (UN, 2014a). While the information systems (IS) community is well positioned to assist in addressing these challenges, the underlying research discipline has been criticized to lack impact on important issues with high visibility, such as the MDGs (Agarwal and Lucas, 2005; Wang et al., 2010). IS have major contributions on increasing global productivity (Watson et al., 2010) and advancing individual lifestyle and thus can contribute – and are already contributing – to building a better world. However, IS research is still deemed to lack relevance to IS practice (see e.g. Benbasat and Zmud, 1999, 2003; Rosemann and Vessey, 2008; Straub and Ang, 2011).

Leading IS researchers discussed this issue and called for more relevance (Rosemann and Vessey, 2008), sustainability (Watson et al., 2010; Seidel et al., 2013), responsibility, reverberation, and impact (Desouza et al., 2006a, 2006b, 2007). Besides, IS research should improve current systems with respect to certain goals (Frank, 2014) by being active, original and asking unique questions in order to increase the value of IS research (Hassan, 2014; Chiasson, 2014). Hasan and Watson (2014) state positive actions of IS – such as facilitating communication for accessing education, connecting diaspora, participating in politics, as well as optimizing the production and distribution of food and energy – which are in need of further investigation and research. To tackle these topics and set a starting point for discussion and further research about the potential of the IS research domain to take on the big questions and help to build a better world, the following research question is addressed:

RQ: How can IS research and IS practice contribute to build a better world?

This chapter is largely based on Rickenberg et al. (2014) and Appendix 12.

4.2. Research Background

4.2.1. Millennium Development Goals

In 2000, several statements about values, principles, and objectives for the international agenda for the twenty-first century were made by world leaders at the so called United Nations Millennium Summit. They aimed at a reduction of extreme poverty and set out a series of time-bound objectives with a deadline in 2015. These objectives have become known as the MDGs and contain eight goals: (1) Eradicate extreme poverty and hunger, (2) achieve universal primary education, (3) promote gender equality and empower women, (4) reduce child mortality, (5) improve maternal health, (6) combat HIV/AIDS, malaria, and other diseases, (7) ensure environmental sustainability, (8) develop a global partnership for development (UN, 2014). To set a baseline for our survey and a common understanding of the term 'better world', we employ and refer to the MDGs as they address a wide variety of global issues concerning a big majority of all people. Although other goals may improve certain issues, we chose the MDGs as they are supported by most countries and are globally accepted, thus, achieving these goals results in a '*better world'* from a global perspective.

4.2.2. Related Work

Some articles exist in the IS research domain that directly refer to the MDGs (Afridi and Farooq, 2011; Calloway, 2011; Ditsa and Ojo, 2011; Ezenwa and Brooks, 2013; Ramiller and Pullman, 2008; Wang et al., 2010). Wang et al. (2010) state that millions of people die in the developing world due to poor information management. They show the potential of IS regarding this issue and provide a solution based on a combination of technologies to improve vaccination management in developing countries. Goal (5) of the MDGs is directly addressed by Afridi and Farooq (2011). They present a tool that can be used to increase the quality of care in rural areas to improve maternal health by using data mining techniques for a risk classification of pregnant women. Calloway (2011) reports about a sustainability learning model which relates information and communication technologies with the MDGs. Ramiller and Pullman (2008) describe their efforts in a project that aimed at building a system to support sustainable community development.

To the best of our knowledge, no study exists that focuses on examining the value of IS research for humanity's goals by involving leading IS researchers from all areas of the research domain. For the IS community it is time to solve some humanity's grand challenges and suggest practical solutions (Hassan et al., 2013).

4.3. Research Design and Data Collection

Surveys are a popular method used by the IS research community as they provide an epistemological way to obtain and validate knowledge (Newsted et al., 1998). For empirical exploration, a cross-sectional survey was designed to explore in which ways and to which extent IS can help to build a better world. Survey research in exploration is used to become familiar with a relatively new topic, to try out preliminary concepts about it, and to discover and raise new possibilities and dimensions (Pinsonneault and Kraemer, 1992). Our research design consists of five phases and is presented in Figure 24.

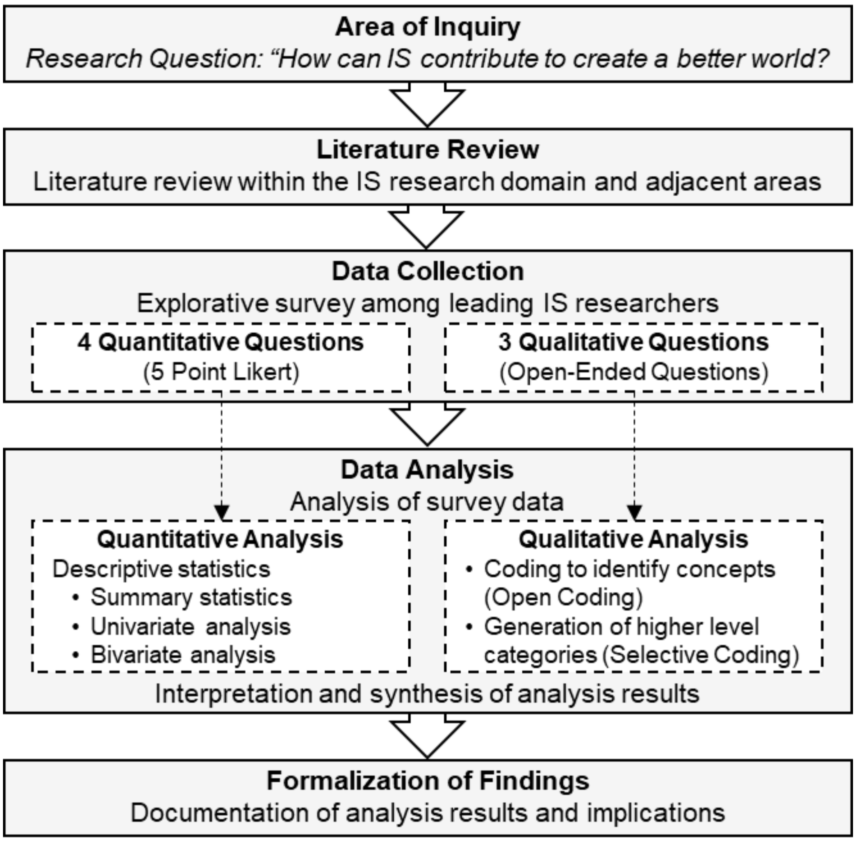


Figure 24: Research Design based on Rickenberg et al. (2014).

The definition of the area of inquiry and the problem domain set the starting point for our investigation. Then, we conducted a literature review within the IS research domain and adjacent areas according to Webster and Watson (2002), Levy and Ellis (2006) and vom Brocke et al. (2009) and created a questionnaire using survey research methodology (Pinsonneault and Kraemer, 1992; Babbie, 1990; Schutt, 2011; Punch, 2005). We collected 2,877 email addresses from track chairs of international IS conferences, sent 1,506 emails and received 171 answers, which where analyzed using qualitative and quantitative methods (Punch, 2005; Glaser and Strauss, 1967; Strauss and Corbin, 1998). Finally, the results were synthesized, interpreted, and documented.

4.4. Summary of Results

The survey is divided in two parts. Within the first part, the participants were asked how much IS – research and practice – can generally contribute to build a better world (Question 1; Q1) and how much it already has contributed (Q2). Concerning the first question, we employed the MDGs to measure the perceived contribution of IS.

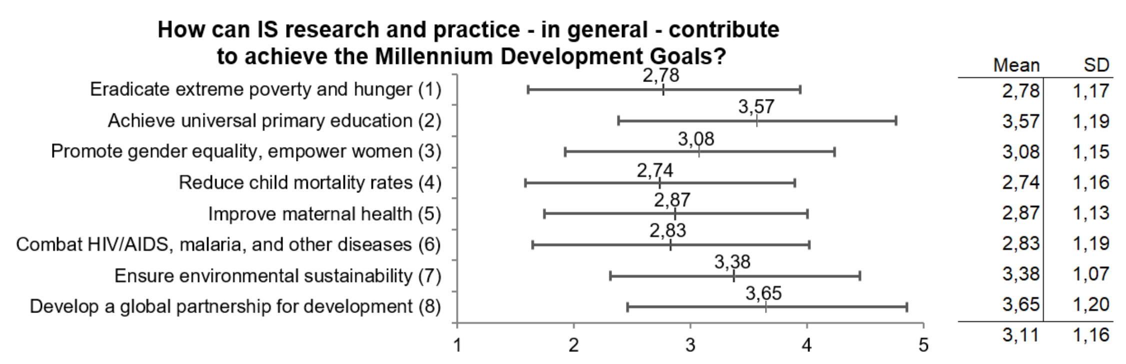
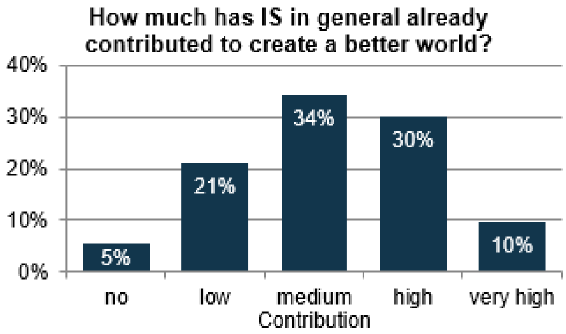


Figure 25: Results of Survey Question Q1 based on Rickenberg et a. (2014).

The results of Q1 are presented in Figure 25 and show the highest perceived contribution of IS on the MDGs on the goal ‘Develop a global partnership for development’ (3.65), followed by ‘Achieve universal primary education’ (3.57) and ‘Ensure environmental sustainability’ (3.38). Consequently, the two goals that can be achieved by facilitating access, communication, and participation via IS received the highest ratings by the participants. The contribution concerning ‘Promote gender equality and empower women’ was rated medium (3.08). The impact of IS on the goal ‘Eradicate extreme poverty and hunger’ as well as on the three goals related to health (‘Reduce child mortality rates’, ‘Improve maternal health’, and ‘Combat HIV/AIDS, malaria, and other diseases’) were estimated below average (~2.8). While the potential of IS in high-tech healthcare is widely considered as high, the impact of IS on these three rather basic but fundamental goals was rated quite low. However, the average impact of IS on these goals was still rated close to ‘3 - medium contribution’. The mean contribution of IS on all goals has a value of 3.11 and is therefore between ‘3 - medium contribution’ and ‘4 - high contribution’ while the standard deviation (SD) concerning the particular goals and in general is slightly over one (~1.1). Concerning all goals on average, 75% of the participants rate the contribution of IS as ‘low’ (23%), ‘medium’ (28%), or ‘high’ (24%), while 10% see ‘no’ and 15% a ‘very high’ contribution. This leads to the assessment of the contribution of IS that has already been realized (Figure 26).

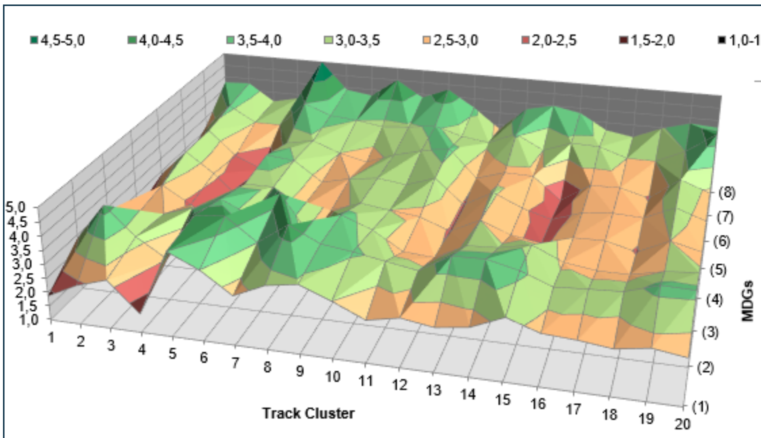
Most of the participants rated the amount of how much IS in general already contributed to a better world as medium (34%). In total, 85% of the participants rated it as ‘low’ (21%), ‘medium’ (34%), or ‘high’ (30%), while 5% see ‘no’ and 10% a ‘very high’ contribution. The mean average of the realized contribution has a value of 3.17 and is higher than the estimation of how much IS can contribute concerning the MDGs (3.11, Figure 25) since the investigated area (IS in general) is wider than the eight MDGs.



Contribution	Count	Percent
1 - no contribution	9	5,39%
2 - low contribution	35	20,96%
3 - medium contribution	57	34,13%
4 - high contribution	50	29,94%
5 - very high contribution	16	9,58%
Amount of Answers	167	
Mean Average	3,17	
Standard Deviation	1,04	

Figure 26: Results of Survey Question Q2 based on Rickenberg et a. (2014).

Figure 27 shows an initial overview about the divergence of participants' perception concerning the contribution of IS to the MDGs. Each participant was assigned to one of 20 track clusters in relation to specific tracks of IS conferences and, thus, insights about the participants' perceived contribution of IS depending on the individual track can be gained. The perceived contribution of IS regarding the individual MDGs shows a big divergence. While the overall mean of goal (8) is 3.65, the participants assigned to track cluster 5, 8, and 10 have an average perception of at least 4.0. In contrast, the participants assigned to track cluster 12 have an average perception of not more than 3.0. The other dimension of the graph illustrates the participants' perception regarding the individual MDGs within a track cluster. While the courses of the curves for track clusters 16 and 18 are relatively flat and show only slight peaks regarding goal (3) and (8), a more variable curve characterizes track cluster 1, where e.g. a mean value of lower than 2 refers to goal (1) and another mean value of at least 3.5 refers to goal (8).



No.	n	Track Cluster
1	8	Economy and Commerce
2	5	E-Government
3	11	Human Behavior and Computer Interaction
4	3	Human Capital and IS
5	5	ICTs in global development
6	9	Innovation
7	4	IS Education
8	4	IS Governance
9	6	IS in Society and Culture
10	6	IT and Business Services
11	7	IT in Healthcare
12	11	Knowledge Management and Decision Support
13	18	Organizational IS and Technology
14	6	Project Management
15	4	Regional Topics and Issues
16	11	Research Theory, Methods and Philosophy
17	4	Security and Privacy
18	13	Social Media and Collaboration
19	8	Software and System Engineering
20	11	Sustainability and Green IS

Figure 27: Results of Q1 according to Track Clusters based on Rickenberg et al. (2014).

Within the second part of the survey, the participants were asked about the general contribution (Q3), already achieved contribution (Q5), as well as potentials and challenges (Q7) of particular research streams within the IS domain with regard to building a better world through IS. Table 12 shows the amount of answers and the mean of Q4 (How much can the track contribute?) and Q6 (How much has the track already contributed?) for each track cluster. The perceived contribution of the track clusters varies considerably. While the overall mean concerning the contribution of a track (Q4) is 3.25, it is lower (2.63) for the already achieved contribution (Q6). The highest perceived ability to contribute shows 'ICT in Global Development' (4.40) which is closely connected with goal (8) of the MDGs with a large gap to the next track cluster. The lowest perceived ability shows 'Economy and Commerce' (2.25) followed by 'Research Theory, Methods, and Philosophy' and 'IS Governance' (~2.7). Particularly the contributions of 'Research Theory, Methods, and Philosophy' to building a better world through IS are of indirect nature. Concerning the perceived contribution that has already been realized, 'ICT in global development' (3.60), 'E-Government' (3.20) also show the highest values followed by 'IS Education' (3.00). This indicates that, as proposed by Hasan and Watson (2014), facilitating communication for accessing education and participation in government are opportunities to build a better world through IS. The lowest perceived realized contribution is shown by 'Research Theory, Methods, and Philosophy' (2.18), 'Security and Privacy' (2.25), and 'Sustainability and Green IS' (2.36). Regarding the largest gap between the ability to contribute and the already realized contribution, 'Security and Privacy', 'Sustainability and Green IS', and 'IT and Business Services' show a gap of one or more (≥1).

Table 12: Results for Track Clusters according to Rickenberg et a. (2014).

No.	Track Cluster	Ø Q4	Ø Q6	Answers
1	Economy and Commerce	2,25	2,38	8
2	E-Government	3,60	3,20	5
3	Human Behavior and Computer Interaction	3,09	2,64	11
4	Human Capital and IS	3,33	2,67	3
5	ICTs in global development	4,40	3,60	5
6	Innovation	3,00	2,89	10
7	IS Education	3,50	3,00	4
8	IS Governance	2,75	2,75	4
9	IS in Society and Culture	3,43	2,67	7
10	IT and Business Services	3,50	2,50	7
11	IT in Healthcare	3,57	2,71	8
12	Knowledge Management and Decision Support	2,80	2,55	11
13	Organizational IS and Technology	3,61	2,67	18
14	Project Management	3,29	2,50	7
15	Regional Topics and Issues	3,00	2,75	5
16	Research Theory, Methods and Philosophy	2,73	2,18	11
17	Security and Privacy	3,50	2,25	4
18	Social Media and Collaboration	3,45	2,92	14
19	Software and System Engineering	3,22	2,38	10
20	Sustainability and Green IS	3,40	2,36	11
	Total	3,25	2,63	162

Due to recent violations of privacy rules, e.g. by the US National Security Agency with the PRISM program (De Goede, 2014), the perceived realized contribution of 'Security and Privacy' is low (2.25) – even though the general ability to contribute was rated high (3.50). The IS research steam 'Sustainability and Green IS' is still in its early stages which results in a remarkable gap between the ability to contribute (3.40) and the realized contribution (2.36). As opposed to this, 'Economy and Commerce', 'IS Governance', and 'Innovation' show a marginal gap (~0). While the ability to contribute and the realized contribution is equal (2.75) for 'IS Governance', the gap is negative for 'Economy and Commerce' (-0.13), which suggests that the heyday of this area is over. While it is widely accepted and often stated by the participants that 'Knowledge Management and Decision Support' and 'IT in Healthcare' can significantly contribute to build a better world, the perception of the domain experts is lower (2.80 respectively 3.57).

4.5. Discussion, Limitations, and Further Research

The aim of this study is not to provide final solutions of how to build a better world through IS, but to set a basic starting point, create awareness, and provide a basis for further discussion and research. We identified certain relevant topics from the answers of the participants concerning (1) areas with high contribution, (2) general challenges, (3) negative aspects and risks of IS, (4) the indirect impact of IS, (5) value of conferences in IS research, and (6) criticism about IS research and IS conferences.

Based on the survey and the findings, several implications and recommendations can be drawn. We were able to show that the perceived contribution of IS concerning particular MDGs is lower than for others, for instance for the three goals related to health ('Reduce child mortality rates', 'Improve maternal health', and 'Combat HIV/AIDS, malaria, and other diseases'). It is important to further investigate (a) why the contribution of IS concerning these goals is rather low and (b) how the impact of IS regarding these goals can be raised. Based on quantitative analyses from the survey, we indicated that some IS research track clusters have a lower perceived impact on building a better world through IS than others. The MDGs or a 'better world' are complex and high-level goals which are certainly not the main goals to be addressed by all IS research streams. Nevertheless, we still argue that it is necessary to (a) analyze why the impact on these goals is lower of certain streams and (b) take action to raise the contribution of these streams corresponding to the track clusters. Additionally, we showed that some IS research streams do not tap the full potential, yet. According to the participants of the survey 'Sustainability and Green IS', for example, can contribute a great deal to building a better world, however, it was not able to contribute notably, yet. This potential should be exploited through appropriate, targeted research. *'Money makes the world go around'* (see e.g. Agnew, 2010) and even in research many aspects still focus on financial gains and not the societal value, although it is assumed that "science must ultimately serve humanity" (vom Brocke et al., 2013). Holistic approaches that are not focused on economic aspects are needed to address the big questions, grand challenges, and humanity's goals. This implies that IS researchers need to promote the use of social and sustainable goals and metrics to measure the impact and contribution of our research instead of using common economic metrics. Consequently, we recommend considering additional review criteria next to rigor and relevance: social impact and sustainable development. These criteria can be applied for IS conferences and journals that aim to create a sustainable impact on society, humanity, and environment. Another implication is the need of interdisciplinary approaches since broad goals ('better world') and challenges (MDGs) cannot be accomplished by single research disciplines on their own.

We identified certain limitations regarding the survey. Due to the limited amount of responses (n=171), there is only a decent amount (~8) of responses for each track cluster. There are some clusters with a lower amount of answers which are less representative, but they can be used to form a consistent overall first impression and overview of the clusters and the underlying research streams. Regarding the responses, a bias cannot be excluded due to three reasons. First, some groups of researchers are more likely to volunteer to be in the sample than others. In general, systematic selection biases are inherent in non-probability samples and cannot be excluded here. Second, we intentionally only asked IS researchers to participate in our survey. Other groups most likely have different perceptions of the contribution of IS to building a better world. Third, only leaders of the IS research field were asked but other stakeholder groups could offer different insights. Concerning the understanding of the survey, not all respondents were familiar with the MDGs. An introduction would have helped to build a better understanding. Moreover, some participants stated that 'building a better world' is a relatively vague idea and is too broad to be discussed directly. We agree that this is a rather broad and complex construct and that the open questions are complex and far from trivial to answer but this follows the explorative and intentionally broad character of our study. Based on numerous high-quality answers within the survey, we argue that a subsequent study is useful to verify our initial results. Further, few participants found the distinction between IS research and practice not sharp enough and that an answer concerning the impact of IS research is almost unrelated to an answer about IS practice. However, we asked for answers that concern both, IS research and practice, since relevant IS research needs to address important topics of IS practice and deepen the understanding of it.

Next research steps should aim for additional survey responses that will allow more comprehensive statistical analysis (e.g. using SPSS) which enables further generalization of the findings. The variance and fit between the track clusters and the corresponding answers can be analyzed by using ANOVA. Besides, we intend to enrich and extend important answers and results by involving more IS researchers with the use of an online portal which can facilitate discussions like the living scholarship approach according to Newsted et al. (1998) on the AIS website (http://aisnet.org/?MISSurvey). Other fields and disciplines can be included in future surveys to set up a differentiation of the IS field perspective and the external to the field perspective. Other target groups can bring fresh and important insights, represent a counterpoint, and should therefore be considered in future sampling decisions. A systematic descriptive or explanatory survey based on the results of our explorative survey can be conducted (Pinsonneault and Kraemer, 1993). After 2015, the Sustainable Development Goals (SDGs) generally serve as universal development agenda (UN, 2014b) and should form an important foundation for the future development of the IS domain in general. Addressing these goals can help to create a strong and sustainable impact of IS research towards building a better world.

4.6. Academic Classification of the Publication

The research paper "Building a Better World through Information Systems – An Explorative Survey among Leading IS Researchers" was written together with Tim Rickenberg and Michael H. Breitner, see Rickenberg et al. (2014) and Appendix 12. The paper was accepted after passing a double-blind pear review process (associate editor and two full reviews) with one revision at the International Conference on Information Systems (ICIS) 2014 in the track "Building a Better World through Information Systems".

The ICIS is the most prestigious IS conference in the world and the most important event for of IS academics and research-oriented practitioners organized by the Association for the Information Systems (AIS). The conference has more than 1,000 participants each year and more than 800 submissions. However, the acceptance rate is comparably low and varies between 25 and 30 percent. (see AIS Electronic Library). According to the VHB, the proceedings of the ICIS are ranked in category "A" according to the VHB JOURQUAL 3 (Hennig-Thurau and Sattler, 2015b).

5. Conclusion, Limitations, and Outlook

5.1. Summary of Results and Overall Conclusion

A variety of decisions with different impact are made on a daily basis and all kinds of data are processed to find the best solutions. The complexity to make these decisions based on diverse information highlight the importance of approaches, models, and tools for decision support. Within this dissertation, several studies are presented and discussed in the context of qualitative and quantitative decision support. Quantitative data in the form of financial key figures and similarity scores as well as qualitative and quantitative data based on surveys are processed to support decisions. For each thematic chapter, the key contributions and conclusions of the underlying research articles regarding the specific RQs are presented in the following.

Chapter 2 as first thematic chapter deals with decision support in the wind energy sector from different perspectives. The demand for energy is constantly increasing all over the world and climate change effects resulting from greenhouse gas emissions are becoming more and more evident. It is not only necessary but mandatory to expand RE in order to limit negative ecological effects. Subchapter 2.1 addresses the expansion of RE by introducing a DSS that allows a detailed consideration of project risks and the calculation of important financial key figures for the assessment of wind energy projects. It is shown that the DSS can contribute to decision making regarding the realization of individual wind energy projects as the requirements of investors and lenders for project assessments are fulfilled simultaneously. Subchapter 2.2 focuses on challenges of policy makers. The system integration of RE poses a central challenge in the transition towards sustainable energy systems as the variability of electricity generation leads to high ancillary services costs and technical issues impairing grid stability and supply reliability. The introduced modeling approach addresses these issues by providing a framework for the quantification of location-based investment incentives in RE support mechanisms to promote a spatially-diversified deployment of RE by reducing resource-dependent competition among projects. It is shown that decision support can be provided for capacity expansion management and the design of support mechanisms.

Chapter 3 as second thematic chapter deals with decision support regarding the identification of relevant articles when performing a literature search. The rising number of scientific publications as well as facilitated access to scientific resources triggered by new technologies (Mabe and Amin, 2001) and the resulting complex information environment (Bawden and Robinson, 2009) make a manually conducted, extensive literature review, a more and more time-consuming task. To tackle this task a natural language processing technique named LSI is utilized in a tool which processes texts like scientific research papers as query input to identify semantically similar texts in a large index of scientific publications. It is shown that the application of methods and tools that increase the efficiency of literature research processes can contribute to decision support. Valuable time can be saved finding relevant literature, the quality of search results can be raised, and the comprehensiveness of a review can be increased by identifying sources that otherwise would not have been considered.

Chapter 4 as third thematic chapter deals with survey-based decision support. Qualitative and quantitative data was gathered with an online questionnaire from leading IS researchers to address the high-level and abstract question of how IS can contribute to build a better world. The term “better world” was specified by employing the broad targets of the MDGs due to their critical influence on the life of billions of people. Concerning these targets, IS practice and research has - with the right focus and alignment - the potential to take on the big questions and, thus, can help to build a better world. IS researchers need to promote the use of social and sustainable goals and metrics to measure the impact and contribution of research instead of using common economic metrics. It is shown that the survey research methodology and survey-based research presented in chapter 4 can contribute to decision support. Processed information derived from qualitative and quantitative survey data can be used as basis for decision making.

The success of companies and organizations strongly depends on the quality of their strategic and operational decisions. An important prerequisite for making the best possible decisions are aggregated and processed information which are reliable and easily available. Against the background of continuously increasing amounts of data, the use of IS for automatic data preparation and supply is necessary in order to extract and collect the relevant information. Decision support based on qualitative and quantitative data optionally provided by DSS addresses these requirements. It can lead to a better decision making and aims at the goal of long-term corporate and organizational success. Besides, it seems obvious that the importance of decision support will increase simultaneously with the growth of data amounts that are available for consideration.

5.2. Overall Limitations

In this section, a critical assessment and evaluation of this dissertation is performed. The examination is especially focused on the employed research designs, applied methods and processes as well as generated results and drawn conclusions. In each chapter of this dissertation specific, identified limitations are presented. They are described and discussed in detail in the corresponding, underlying research articles. The presented publications, results and the underlying research designs are critically discussed here from an overall perspective.

Several fundamentally different research topics are presented and discussed in this dissertation against the background of the overarching topic of qualitative and quantitative design support. Various research questions from the corresponding research articles of different research fields as well as research streams are addressed which show the wide range of opportunities to contribute to decision support. However, this simultaneously outlines that the presented research in the field of wind energy, literature research processes and survey-based research towards a better world through IS illustrate only exemplary contributions to decision support research. The presented studies and the dissertation in general do not cover or explain the decision support research in its entirety but also do not make a claim to do so. To provide a better coverage of the numerous facets of this research area, future research should aim at a more comprehensive investigation of overall questions and relationships within this research field.

The research question of how IS can contribute to a better world in chapter 4 is at a high abstract level. Even though the corresponding research project was intended to be a starting point for future research that focusses on high level goals like the MDGs, it is necessary to break down high level research agendas into small projects that can be independently investigated. However, keeping the big picture in mind while investigating certain aspects can enhance researcher's motivation and stimulate discussions.

The long-lasting debate about relevance and rigor in the IS research discipline (e.g. Straub and Ang, 2011; Desouza et al., 2006; Benbasat and Zmud, 1999, 2003) outlines the importance of these fundamental aspects for thorough research. Even though the research studies presented in the thematic chapters of this dissertation mainly focus on practical problems in different IS research areas or in the IS research discipline in general, they all followed a rigorous research process. However, the quantitative and qualitative research approaches as well as the employed research designs are subject to several limitations concerning relevance and rigor. In the following, central aspects of identified limitations are discussed.

Concerning DSR approaches, certain limitations can be identified. These design-orientated research approaches focus on the development of research artifacts like constructs, models, methods and instantiations (Hevner et al., 2004) and thus, on practical aspects and the goal of utility (Winter, 2008). However, no overarching concepts or theories are addressed by these research methods and the presented research studies in chapter 2 and 3 following a DSR methodology also lack theory contributions. Besides, applicability checks from a practitioner's perspective are missing for the constructed DSR artifacts. Although a demonstration and an evaluation were conducted for the models and instantiations regarding the financial assessment of specific wind energy projects, the spatial allocation of RE as well as the enhancement of literature research processes, these assessments cover only a theoretical perspective. No in-field demonstrations and evaluations have been performed even though these applications would have led to additional uncovered issues and comprehensive findings.

While the application of survey-based research methods allows to collect a broad range of qualitative and quantitative data in a comparably comfortable way, the reliability of survey data can be critical. The design of the study, especially the type of questions like open- or closed-ended or the specified inclusion and exclusion criteria, significantly influences participants' answers and thus, the survey results and findings. Survey respondents might also provide knowingly, unknowingly, consciously or unconsciously wrong answers as they do not feel encouraged to answer honestly or do not want to contribute to personally unwanted results. For the survey presented in chapter 4, a huge number of top IS researchers was contacted and asked to participate. However, the number of contacted experts who choose not to respond to the survey might be different from the respondents due to various reasons, e.g. the personal interest regarding the research topic or similar research of the participants, which results in a selection bias. Besides, a lack of awareness concerning specific survey questions can lead to distorted results and derived findings.

The different applied research approaches which are critically discussed in this section have been separately applied in the presented articles of the thematic chapters in this dissertation. While in chapter 2 and 3, design-orientated research approaches were applied, chapter 4 employs a mainly qualitative method. However, at least a partial combination of qualitative and quantitative research approaches could improve findings and put them on a more robust foundation. Overall, the identified limitations should be used as a starting point for further research. Upcoming studies should focus on overcoming the outlined critical aspects and address them in future research projects.

5.3. Outlook

While in each thematic chapter of this dissertation implications for further research are presented, and are described in detail in the corresponding, underlying research articles, an overall outlook is provided here.

Environmental and economic sustainability as well as Green IS are of increasing interest for the IS research community as they address important societal issues (Seidel et al., 2013, Watson et al., 2010). As an example, decision support for the wind energy sector can address these issues in different ways. The assessment of specific wind energy projects and respective general financial conditions from the perspective of investors and lenders contributes to environmental and economic sustainability as it helps to increase the electricity production from RE resources. The quantification of location-based investment incentives in RE support schemes to promote a spatially diversified deployment of capacity and thus to improve the system integration of renewable energies also contributes to an increase of electricity production but simultaneously improves the efficiency of RE system integration. Beyond that, it combines the kernel theories for identifying favorable spatial distributions of RE capacity with current policy designs. More IS researchers should focus on Green IS and research topics that can solve issues by developing new approaches or combining and applying existing ones to increase sustainability in different application domains.

The development and improvement of DSS for the identification of relevant literature can foster research across all kinds of research domains as it can increase the efficiency of the underlying literature research process. Consequently, IS research should make greater efforts to develop methods, enhance models, and improve systems that can have huge impacts for research approaches and processes.

In addition to environmental issues and aspects regarding the efficiency of research processes, IS research and practice should focus more on humanity's goals, grand challenges and societal issues to take on the big questions It is time for the IS research community to engage in this challenge and suggest some practical solutions (Rickenberg et al., 2014, Hassan et al., 2013). The underlying broad social implications need to be translated into a research agenda with specific concepts and tangible actions to increase the impact of corresponding IS research for the society. To measure the impact and contribution of IS research, social and sustainable goals and metrics as well as holistic approaches which are not centered on common economic aspects, must be established and promoted. Following these aspects, the IS research community can really take on humanity's great challenges and address high level goals.

References

Abdmouleh, Z., Alammari, R. A. M., and Gastli, A. 2015. “Review of policies encouraging renewable energy integration & best practices,” *Renewable and Sustainable Energy Reviews* (45), pp. 249-262.

Abolhosseini, S. and Heshmati, A. 2014. “The main support mechanisms to finance renewable energy development,” *Renewable and Sustainable Energy Reviews* (40), pp. 876-885.

Afridi, M. J. and Farooq, M. 2011. “OG-Miner: An Intelligent Health Tool for Achieving Millennium Development Goals (MDGs) in m-Health Environments,” in *Proceedings of the 44th Hawaii International Conference on System Sciences.*

Agnew, J. 2010. "Money games: Currencies and power in the contemporary world economy," *Antipode* (41), pp. 214-238.

Agarwal, R. and Lucas, H. C. 2005. “The information systems identity crisis: focusing on high-visibility and high impact research,” *MIS Quarterly* (29:3), pp. 381-398.

Arnott, D., and Pervan, G. 2012. “Design Science in Decision Support Systems Research: An Assessment using the Hevner, March, Park, and Ram Guidelines,” *Journal of the Association for Information Systems* (13:11), pp. 923-949.

Ayanso, A., Lertwachara, K., and Vachon, F. 2011. “Design and behavioral science research in premier IS journals: evidence from database management research,” In *International Conference on Design Science Research in Information Systems*, pp. 138-152.

Babbie, E. 1990. *Survey Research Methods, 2nd Edition*. Wadsworth Inc. Fulfillment, Belmont, CA.

Baker, M. J. 2000. “Writing a Literature Review,” *Marketing Review* (1:2), pp. 219-247.

Bhandari, H., Shimbo, M., Ito, T., and Matsumoto, Y. 2008. “Generic Text Summarization Using Probabilistic Latent Semantic Indexing,” in *Proceedings of the 6th International Joint Conference on Natural Language Processing*, pp. 133-140.

Bawden, D., and Robinson, L. 2009. "The Dark Side of Information: Overload, Anxiety and Other Paradoxes and Pathologies," *Journal of Information Science* (35:2), pp. 180-191.

Benbasat, I. and Zmud, R. W. 1999. “Empirical research in information systems: the practice of relevance," *MIS quarterly*. pp. 3-16.

Blake, R. 2010. “Identifying the core topics and themes of data and information quality research,” in *Proceedings of the 16th Americas Conference on Information Systems.*

Blanco, M. I. 2009. “The economics of wind energy,” *Renewable and Sustainable Energy Reviews* (13:6-7), pp. 1372-1382.

BMU 2011. “Preparation and support of the creation of the experience report 2011 according to §65 EEG. Project IIe Wind Energy”, „Vorbereitung und Begleitung der Erstellung des Erfahrungsberichts 2011 gemäß §65 EEG. Vorhaben IIe Windenergie“ (in German).

Brand, M. 2006. “Fast low-rank modifications of the thin singular value decomposition,” *Linear Algebra and its Applications (*415:1), pp. 20-30.

Brealey, R. A., Myers, S. C., Allen, F. 2011. *Principles of corporate finance*, McGraw-Hill/Irwin, New York, NY, USA.

Calloway, L. J. 2011. "Teaching Sustainability Concepts: Information and Communications Technologies and the United Nations Millennium Development Goals," Proceedings of SIGGreen Workshop. *Sprouts: Working Papers on Information Systems* (11:8).

Cancino-Solórzano, Y., Gutiérrez-Trashorras, A.J., and Xiberta-Bernat, J. 2011. "Current state of wind energy in Mexico, achievements and perspectives," *Renewable and Sustainable Energy Reviews* (15:8), pp. 3552-3557.

Carrasco-Díaz, M., Rivas, D., Orozco-Contreras, M., and Sánchez-Montante, O. 2015. "An assessment of wind power potential along the coast of Tamaulipas, northeastern Mexico," *Renewable Energy* (78), pp. 295-305.

Chiasson, M. W. 2014. "Let's Start Fooling Ourselves: Strategies for Manoeuvring Within the Micro-Political Influences Surrounding Our Research Practices," *Communications of the Association for Information Systems* (34:1), Article 46.

Chu, S. and Majumdar, A. 2012. "Opportunities and challenges for a sustainable energy future," *Nature* (488), pp. 294-303.

Da, Z., Guo, R-J., and Jagannathan, R. 2012. "CAPM for estimating the cost of equity capital: interpreting the empirical evidence," *Journal of Financial Economics* (103:1), pp. 204-220.

Dedrick, J. 2010. "Green IS: concepts and issues for information systems research", *Communications of the Association for Information Systems* (27:1).

Desouza, K. C., Ein-Dor, P., McCubbrey, D. J., Galliers, R. D. and Myers, M. D. 2006b. "Social Activism in IS Research: Making the World a Better Place," in *Proceedings of the 27th International Conference on Information Systems*.

Desouza, K. C., Ein-Dor, P., McCubbrey, D. J., Galliers, R. D. and Myers, M. D. 2007. "Social Activism in Information Systems Research: Making the World a Better Place," *Communications of the Association for Information Systems* (19), Article 13.

Desouza, K. C., El Sawy, O. A., Galliers, R. D., Loebbecke, C. and Watson, R. T. 2006a. "Beyond Rigor and Relevance Towards Responsibility And Reverberation: Information Systems Research That Really Matters," *Communications of the Association for Information Systems* (17), Article 16.

Ditsa, G. E. and Ojo, S. O. 2011. "E-Health Technologies in Attainment of the Millennium Development Goals for Africa Healthcare System," in *Proceedings of the 22nd Australasian Conference on Information Systems*.

European Comission. 2013. *Delivering the internal electricity market and making the most of public intervention*. Brussels.

Ezenwa, C. and Brooks, L. 2013. "Using Mobile Technology to Facilitate the Health Agenda in Nigeria: Issues and Opportunities," in *Proceedings of the UK Academy for Information Systems Conference*.

Fernandez, P. 2004. "The value of tax shields is NOT equal to the present value of tax shields," *Journal of Financial Economics* (73), pp. 145-165.

Fernandez, P., Aguirreamalloa, J., and Avendaño, L. C. 2013. "Market Risk Premium Used in 82 Countries in 2012: A Survey with 7,192 Answers," SSRN.

Fernandez, P., Aguirreamalloa, J., and Avendaño, L. C. 2014. "Market risk premium used in 88 Countries in 2014: a survey with 8,228 answers," SSRN.

Fink, A. 2010. Conducting Research Literature Reviews: From the Internet to Paper (3rd edition), Thousand Oaks, California: Sage Publications.

Forsythe, G. E., Malcolm, M. A., and Moler, C. B. 1977. *Computer methods for mathematical computations*, Englewood Cliffs, NJ: Prentice-Hall.

Furlan, B., Batanović, V., and Nikolić, B. 2013. “Semantic Similarity of Short Texts in Languages with a Deficient Natural Language Processing Support,” *Decision Support Systems* (55:3), pp. 710-719.

Frank, U. 2014. “Higher Value of Research by Promoting Value for Researchers." *Communications of the Association for Information Systems* (34:1), Article 43.

Glaser, B. G. and Strauss, A. L. 1967. *The Discovery of Grounded Theory: Strategies for Qualitative Research*. Aldine Publishing Company, Chicago, IL, USA.

Gholami, R., Watson, R. T., Hasan, H., Molla, A., and Bjorn-Andersen, N. 2016. “Information systems solutions for environmental sustainability: How can we do more?,” *Journal of the Association for Information Systems* (17:8), pp. 521-536.

Goebel, C., Jacobsen, H.-A., del Razo, V., et al. 2014. “Energy informatics - Current and future research directions,” *Business & Information Systems Engineering* (6:1), pp. 25-31.

González, J. S. and Lacal-Arántegui, R. 2016. “A review of regulatory framework for wind energy in European Union countries: Current state and expected developments,” *Renewable and Sustainable Energy Reviews* (56), pp. 588-602.

Grover, V. 2014. “Value of IS Research: Let’s Not Talk Crisis – but We Can Do Better,” *Communications of the Association for Information Systems* (34), Article 45.

Hart, C. 1998. Doing a literature review: Releasing the social science research imagination. London: Sage.

Hasan, H. and Watson, R.T. 2014. Conference Theme Track: Building a Better World Through IS.

Hassan, N. R. 2014. “Value of IS Research: Is there a Crisis?,” *Communications of the Association for Information Systems* (34), Article 41.

Hassan, N. R. et al. 2013. “Benefitting from IS Research -- Who and How? A Panel on the Value of IS Research,” in *Proceedings of 19th Americas Conference on Information Systems.*

Hennig-Thurau, T.; Sattler, H.; Dyckhotf, H.; Pranke, N.; Schreyögg, G. 2015. “VHB-JOURQUAL3. Verband der Hochschullehrer für Betriebswirtschaft e.V.,“ Online http://vhbonline.org/VHB4you/jourqual/vhb-jourqual-3/ (accessed 2017-12-17).

Hennig-Thurau, T.; Sattler, H. 2015a. “Begleitdokumente zu VHB-JOURQUAL3. Verband der Hochschullehrer für Betriebswirtschaft e.V.,“ http://vhbonline.org/VHB4you/jourqual/vhb-jourqual-3/begleitdokumente/ (accessed 2017-12-17).

Hennig-Thurau, T.; Sattler, H. 2015b. “VHB-JOURQUAL3: Teilrating Wirtschaftsinformatik. Verband der Hochschullehrer für Betriebswirtschaft e.V.,“ http://vhbonline.org/VHB4you/jourqual/vhb-jourqual-3/teilrating-wi/ (accessed 2017-12-17).

Hernández-Escobedo, Q., Saldaña-Flores, R., Rodríguez-García, E.R., and Manzano-Agugliaro, F. 2014 “Wind energy resource in northern Mexico,” *Renewable and Sustainable Energy Reviews* (32), pp. 890-914.

Hevner, A. R., March, S. T., Park, J. and Ram, S. 2004. “Design Science in Information Systems Research,” *MIS Quarterly* (28:1), pp. 75-105.

Hevner, A. R. 2007. “A Three Cycle View of Design Science Research,” *Scandinavian Journal of Information Systems* (19:2), pp. 87-92.

Homayouni, R., Heinrich, K., Wei, L. and Berry, M. W. 2004. “Gene Clustering by Latent Semantic Indexing of MEDLINE Abstracts,” *Bioinformatics* (21:1), pp. 104-115.

Hovorka, D. S., Larsen, K. and Monarchi, D. 2009. “Conceptual convergences: Positioning information systems among the business disciplines,” in *Proceedings of the 17th European Conference on Information Systems.*

Huntington, S. C., Rodilla, P., Herrero, I., and Batlle, C. 2017. “Revisiting support policies for RES-E adulthood: Towards market compatible schemes,” *Energy Policy* (104), pp. 474-483.

Imam, R. L., Conover, W. 1982. ”A distribution-free approach to inducing rank correlation among input variables,” *Communications in Statistics-Simulation and Computation* (11:3), pp. 311-334.

IRENA, 2017. “Renewable energy auctions: Analysing 2016,” Abu Dhabi.

Jaramillo, O.A. and Borja, M.A. 2004. “Wind speed analysis in La Ventosa, Mexico: A bimodal probability distribution case,” *Renewable Energy* (29:10), pp. 1613-1630.

Jaramillo, O.A., Saldaña, R., and Miranda, U. 2004. “Wind power potential of Baja California Sur, México,” *Renewable Energy* (29:13), pp. 2087-2100.

Kintsch, W. 2010. “Modeling Semantic Memory,” in *Mobile Ad-hoc NETworkS (MANETS)*, S. Jhean-Larose and G. Denhière (eds.).

Kitzing, L., and Weber, C. 2015. ”Support mechanisms for renewables: how risk exposure influences investment incentives,” *International Journal of Sustainable Energy Planning & Management* (7), pp.117-134.

Klessmann, C., Rathmann, M., de Jager, D., et al. 2013. „Policy options for reducing the costs of reaching the European renewables target,” *Renewable Energy* (57), pp. 390-403.

Kontostathis, A. 2007. “Essential dimensions of latent semantic indexing (LSI),” in *Proceedings of the 40th Hawaii International Conference on System Sciences*, pp. 73-73.

Korenius, T., Laurikkala, J. and Juhola, M. 2007. “On principal component analysis, cosine and Euclidean measures in information retrieval,” *Information Sciences* (177:22), pp. 4893-4905.

Koukal, A. and Breitner, M. H. 2012. “Decision Support Tool for Offshore Wind Parks in the Context of Project Financing,” in *Operations Research Proceedings 2012*, pp. 309-314.

Koukal, A. and Breitner, M. H. 2013. “A Decision Support Tool for the Risk Management of Offshore Wind Energy Projects,” in *Proceedings of the 11th International Conference on Wirtschaftsinformatik*, pp. 1683-1697.

Koukal, A. and Breitner, M. H. 2014. “Offshore Wind Energy in Emerging Countries: A Decision Support System for the Assessment of Projects,” in *Proceedings of the 47th Hawaii International Conference on System Sciences*, pp. 865-874.

Koukal, A., Gleue, C., and Breitner, M. H. 2013. “Enhancing Literature Research Processes: A Glance at an Approach Based on Latent Semantic Indexing,” in *Lecture Notes in Informatics Proceedings*, pp. 1937-1942.

Koukal, A., Gleue, C., and Breitner, M. H. 2014a. “Enhancing Literature Review Methods – Towards More Efficient Literature Research with Latent Semantic Indexing,“ in *Proceedings of the 22nd European Conference on Information Systems*, pp. 1-13.

Koukal, A., Gleue, C., and Breitner, M. H. 2014b. "Enhancing Literature Review Methods – Evaluation of a Literature Search Approach based on Latent Semantic Indexing," in *Proceedings of the 35th International Conference on Information Systems*, pp. 1-19.

Koukal, A. and Piel, J.-H. 2017. "Financial Decision Support System for Wind Energy – Analysis of Mexican Projects and a Support Scheme Concept," in *Proceedings of the 50th Hawaii International Conference on System Sciences*, pp. 865-874.

van Kuik, G.A.M., Peinke, J., Nijssen, R., et al. 2016. "Long-term research challenges in wind energy – A research agenda by the European Academy of Wind Energy," *Wind Energy Science* (1:1), pp. 1-39.

KPMG, 2010. "Offshore Wind in Europe. 2010 Market Report".

Lang, M. and Lang, A. 2015. „The 2014 German Renewable Energy Sources Act revision – From feed-in tariffs to direct marketing to competitive bidding," *Journal of Energy & Natural Resources Law* (33:2), pp. 131-146.

Lee, S., Baker, J., Song, J., and Wetherbe, J. C. 2010. "An Empirical Comparison of Four Text Mining Methods," in *Proceedings of the 43rd Hawaii International Conference on System Sciences*.

Levitt, A. C., Kempton, W., Smith, A. P., Musial, W., and Firestone, J. 2011. "Pricing offshore wind power", *Energy Policy* (39), pp. 6408-6421.

Levy, Y. and Ellis, T. J. 2006. "A systems approach to conduct an effective literature review in support of information systems research," *Informing Science* (9), pp. 181-212.

Lu, X., McElroy, M. B., and Kiviluoma, J. 2009. "Global potential for wind-generated electricity," *Proceedings of the National Academy of Sciences of the United States of America* (106:27), pp. 10933-10938.

Luehrman, R. 1997. "Using APV: A better tool for valuing operations", *Harvard Business Review* (75), pp. 145-154.

Maas, A. L., Daly, R. E., Pham, P. T., Huang, D., Ng, A. Y., and Potts, C. 2011. "Learning word vectors for sentiment analysis," in *Proceedings of the 49th Annual Meeting of the Association for Computational Linguistics: Human Language Technologies-Volume 1*, pp. 142-150.

Mabe, M. and Amin, M. 2001. "Growth dynamics of scholarly and scientific journals," *Scientometrics* (51:1), pp. 147-162.

Madlener, R., Siegers, L., and Bendig, S. 2009. "Risk Management of Offshore Wind Energy Plants", "Risikomanagement und -controlling bei Offshore-Windenergieanlagen" (in German), *Zeitschrift für Energiewirtschaft* (33), pp. 135-146.

Manwani, S., Bech, H. and Dahlhoff, J. 2001. "Managing information overload: Is technology the answer?," in *Proceedings of the 7th Americas Conference on Information Systems*, pp. 34-38.

March, S. T., and Smith, G. S. 1995. "Design and Natural Science Research on Information Technology," *Decision Support Systems* (15:4), pp. 251-266.

Newsted, P., Huff, S. and Munro, M. 1998. "Survey Instruments in Information Systems," *MIS Quarterly* (22:4).

Nunamaker, J. F., Briggs, R. O., Derrick, D. C., and Schwabe, G. 2015. "The last research mile: Achieving both rigor and relevance in information systems research," *Journal of Management Information Systems* (32:3), pp. 10-47.

Nunamaker, J. F., Chen, M., and Purdin, T. D. M. 1990. "Systems development in information systems research," *Journal of Management Information Systems* (7:3), pp. 89-106.

Offermann, P., Levina, O., Schönherr, M., and Bub, U. 2009. "Outline of a Design Science Research Process," in *Proceedings of the 4th International Conference on Design Science Research in Information Systems and Technologies*, Philadelphia.

Okoli, C. and Schabram, K. 2010. "A Guide to Conducting a Systematic Literature Review of Information Systems Research," in *Sprouts: Working Papers on Information Systems* (10:26).

Österle, H., Becker, J., Frank, U., Hess, T., Karagiannis, D., Krcmar, H., Loos, P., Mertens, P., Oberweis, A., and Sinz, E. J. 2011. „Memorandum on design-oriented information systems research," *European Journal of Information Systems* (20:1), pp. 7-10.

Park, J. and Lee, J.-N. 2011. "The Impact of Information Overload on Decision Quality in the Web 2.0 Environment: A Cognitive-Emotional Dichotomy Perspective," in *Proceedings of the 2011 International Conference on Information Resources Management,* paper 22.

Peffers, K., Tuunanen, T., Rothenberger, M. A. and Chatterjee, S. 2008. "A design science research methodology for information systems research," *Journal of Management Information Systems* (24:3), pp. 45-77.

Piel, J.-H., Hamann, J., Koukal, A., and Breitner, M. H. 2017. "Promoting the System Integration of Renewable Energies: Toward a Decision Support System for Incentivizing Spatially-Diversified Deployment," in *Journal of Management Information Systems* (34:4), pp. 994-1022.

Pinsonneault, A. and Kraemer, K. L. 1993. "Survey research methodology in management information systems: an assessment," *Journal of Management Information Systems* (10:2), pp. 75-105.

Porrua, F., Bezerra, B., Barroso, L. A., Lino, P., Ralston, F., and Pereira, M. 2010. "Wind power insertion through energy auctions in Brazil", *Power and Energy Society General Meeting*, IEEE, pp. 1-8.

Power, D. J. 2002. *Decision Support Systems: Concepts and Resources for Managers.* Westport, CT: Greenwood Publishing Group.

Power, D. J. 2014. "Using 'big data' for analytics and decision support," *Journal of Decision Systems* (23:2), pp. 222-228.

Prässler, T. and Schaechtele, J. 2012. „Comparison of the financial attractiveness among prospective offshore wind parks in selected European countries," *Energy Policy* (45), pp. 86-101.

Pretorius, f., Chung-Hsu, B. F., McInnes, A., Lejot, P., Arner, D. 2008. *Finance for Construction and Infrastructure: Principles and Case Studies*, Wiley, 2008.

Punch, K. F. 2005. *Introduction to Social Research*. Sage, London.

Ramiller, N. C. and Pullman, M. 2008. "Good Works and Networks: Information System as Nexus for the Promotion of Sustainable Community Development," in *Proceedings of the 14th Americas Conference on Information Systems*.

Řehůřek, R. and Sojka P. 2010. "Software Framework for Topic Modelling with Large Corpora," in *Proceedings of LREC 2010 workshop New Challenges for NLP Frameworks*, pp. 46-50.

REN21 2016. *Renewables 2016 global status report*. Paris.

Reichenberg, L., Wojciechowski, A., Hedenus, F., and Johnsson, F. 2017. "Geographic aggregation of wind power-an optimization methodology for avoiding low outputs," *Wind Energy* (20:1), pp. 19-32.

Rickenberg, T. A., Koukal, A., and Breitner, M. H. 2014. “Building a Better World through Information Systems – An Explorative Survey among Leading IS Researchers,“ in *Proceedings of the 35th International Conference on Information Systems*, pp. 1-19.

Rickenberg, T. A., Neumann, M., Hohler, B., and Breitner, M. H. 2012. “Towards a process-oriented approach to assessing, classifying and visualizing Enterprise Content Management with Document Maps,” *Proceedings of the 20th European Conference on Information Systems*.

Rienecker, M. M., Suarez, M. J., Gelaro, R., et al. 2011. ”MERRA: NASA’s modern-era retrospective analysis for research and applications,” *Journal of Climate* (24:14), pp. 3624-3648.

Del Río, P. and Linares, P. 2014. “Back to the future? Rethinking auctions for renewable electricity support,” *Renewable and Sustainable Energy Reviews* (35), pp. 42-56.

Rombauts, Y., Delarue, E., and D’haeseleer, W. 2011. “Optimal portfolio-theory-based allocation of wind power: Taking into account cross - border transmission-capacity constraints,” *Renewable Energy* (36:9), pp. 2374-2387.

Roques, F., Hiroux, C., and Saguan, M. 2010. “Optimal wind power deployment in Europe-A portfolio approach,” *Energy Policy* (38:7), pp. 3245-3256.

Rosemann, M. and Vessey, I. 2008. “Toward Improving the Relevance of Information Systems Research to Practice: The Role of Applicability Checks,” *MIS Quarterly* (32:1).

Rousseau, D.M., Manning, J. and Denyer, D. 2008. “Evidence in Management and Organizational Science: Assembling the Field’s Full Weight of Scientific Knowledge Through Syntheses,” *The Academy of Management Annals* (2:1), pp. 475-515.

Salton, G. and McGill, M. J. 1986. *Introduction to modern information retrieval*, New York, NY: McGraw-Hill.

Salton, G., Wong, A., and Yang, C. S. 1975. “A Vector Space Model for Automatic Indexing,” in *Communications of the ACM* (18:11), pp. 613-620.

Schillings, C., Wanderer, T., Cameron, L., van der Wal, J. T., Jacquemin, J., and Veum, K. 2012. “A decision support system for assessing offshore wind energy potential in the North Sea”, *Energy Policy* (49), pp. 541-551.

Schutt, R. K. 2011. Investigating the social world: The process and practice of research. Pine Forge Press.

Seidel, S., Recker, J. and vom Brocke, J. 2013. “Sensemaking and Sustainable Practicing: Functional Affordances of Information Systems in Green Transformations,” *MIS Quarterly* (37:4), pp. 1275-1299.

Sidorova, A., Evangelopoulos, N., Valacich, J. S., and Ramakrishnan, T. 2008. “Uncovering the intellectual core of the information systems discipline,” *MIS Quarterly* (32:3), pp. 467-482.

da Silva, N. F., Rosa, L. P., Freitas, M. A. V., Pereira, M. G. 2013. “Wind energy in Brazil: From the power sector's expansion crisis model to the favorable environment,” *Renewable and Sustainable Energy Reviews* (22), pp. 686-697.

Simon, H. A. 1996. *The Sciences of the Artificial*, 3rd ed., MIT Press, Cambridge, MA.

Snyder, B., Kaiser, M. J. 2009. “Ecological and economic cost-benefit analysis of offshore wind energy,” *Renewable Energy* (34:6), pp. 1567-1578.

Staffell, I., and Green, R. 2014. “How does wind farm performance decline with age?,” *Renewable Energy* (66), pp. 775-786.

Straub, D. W. and Ang, S. 2011. “Rigor and Relevance in IS Research: Redefining the Debate and a Call for Future Research,” *MIS Quarterly* (35:1), pp.iii-xi.

Strauss, A. and Corbin, J. 1998. Basics of Qualitative Research: Techniques and Procedures for Developing Grounded Theory, 2nd Edition. Thousand Oaks: Sage Publications.

Strueker, J. and van Dinther, C. 2012. “Demand response in smart grids: Research opportunities for the IS discipline,” in *Proceedings of the 18th Americas Conference on Information Systems (AMCIS)*, pp. 1-10

Thomaidis, N.S., Santos-Alamillos, F.J., Pozo-Vázquez, D., and Usaola-García, J. 2016. “Optimal management of wind and solar energy resources,” *Computers & Operations Research* (66), pp. 284-291.

UN - United Nations 2014a. “United Nations Millennium Development Goals,” http://www.un.org/millenniumgoals/

UN – United Nations 2014b. “The Millennium Development Goals Report 2014,” available online at http://mdgs.un.org/unsd/mdg/Resources/Static/Products/Progress2014/English2014.pdf

vom Brocke, J., Simons, A., Niehaves, B., Riemer, K., Plattfaut, R. and Cleven, A. 2009. “Reconstructing the giant: On the importance of rigor in documenting the literature search process,“ in *Proceedings of the 17th European Conference on Information Systems*.

vom Brocke, J., Fridgen, G., Hasan, H., Ketter, W., and Watson, R. 2013. Energy informatics: designing a discipline (and possible lessons for the IS community),” in *Proceedings of the 34th International Conference on Information Systems*.

vom Brocke, J., Watson, R. T., Dwyer, C., Elliot, S., and Melville, N. 2012. “Green Information Systems: Directives for the IS Discipline,” *Proceedings of the 33rd International Conference on Information Systems*.

Wang, W., Elliot, S., and Williams, M.-A. 2010. “An IS contribution to the UN Millennium Development Goals: Next Generation Vaccination Management in the Developing World,” in *Proceedings of the 21st Australasian Conference on Information Systems*.

Watson, R. T., Boudreau, M. C., and Chen, A. J. 2010. “Information systems and environmentally sustainable development: energy informatics and new directions for the IS community,” *MIS Quarterly* (34:1), pp. 23-38.

Webster, J. and Watson, R. T. 2002. “Analyzing the Past to Prepare for the Future: Writing a Literature Review,” *MIS Quarterly* (26:2), pp. xiii-xxiii.

Wigand, F., Förster, S., Amazo, A., and Tiedemann, S. 2016. *Auctions for renewable energy support: Lessons learnt from international experiences*. Lyngby.

Winter, R. 2008. ”Design Science Research in Europe,” *European Journal of Information Systems* (17:5), pp. 470-475.

Wolfram, C., Shelef, O., and Gertler, P. J. 2012. “How will energy demand develop in the developing world?,” National Bureau of Economic Research.

Wolfswinkel, J. F., Furtmueller, E. and Wilderom, C. P. M. 2013. “Using grounded theory as a method for rigorously reviewing literature,“ *European Journal of Information Systems* (22:1), pp. 45-55.

Yandell, M. D. and Majoros, W. H. 2002. “Genomics and Natural Language Processing,” in *Nature Reviews Genetics* (3:8), pp. 601-610.

Zhang, W., Taketoshi, Y. and Xijin, T. 2011. “A comparative study of TF* IDF, LSI and multi-words for text classification,” *Expert Systems with Applications* (38:3), pp. 2758-2765.

Zmud, R. 1997. “Editor’s Comments,” *MIS Quarterly* (21:2), pp. xxi-xxii.

Appendices

Appendix 1: Projektfinanzierung und Risikomanagement von Offshore-Windparks in Deutschland

Appendix 2: Decision Support Tool for Offshore Wind Parks in the Context of Project Financing

Appendix 3: A Decision Support Tool for the Risk Management of Offshore Wind Energy Projects

Appendix 4: Revenue Model for Virtual Clusters within Smart Grids

Appendix 5: Towards an Allocation of Revenues in Virtual Clusters within Smart Grids

Appendix 6: Measurement of Risk for Wind Energy Projects - A Critical Analysis of Full Load Hours

Appendix 7: Enhancing Literature Research Processes: A Glance at an Approach Based on Latent Semantic Indexing

Appendix 8: Offshore Wind Energy in Emerging Countries: A Decision Support System for the Assessment of Projects

Appendix 9: Entscheidungsunterstützungssystem zur Projektbewertung von Onshore Windenergieprojekten in Schwellenländern

Appendix 10: Replacing the Full Load Hours Key Figure for the Risk Assessment of Wind Energy Projects

Appendix 11: Enhancing Literature Review Methods - Towards more efficient Literature Research with Latent Semantic Indexing

Appendix 12: Building a Better World through Information Systems – An Explorative Survey among Leading IS Researchers

Appendix 13: Enhancing Literature Review Methods - Evaluation of a Literature Search Approach based on Latent Semantic Indexing

Appendix 14: Financial Decision Support System for Wind Energy – Analysis of Mexican Projects and a Support Scheme Concept

Appendix 15: Promoting the System Integration of Renewable Energies: Toward a Decision Support System for Incentivizing Spatially-Diversified Deployment

Appendix 16: Enhancing Strategic Bidding Optimization for Renewable Energy Auctions: A Risk-Adequate Marginal Cost Model

Appendix 1

Projektfinanzierung und Risikomanagement von Offshore-Windparks in Deutschland

André Koukal, Michael H. Breitner

Outlet: IWI Diskussionsbeiträge #53, 2012, Hannover, Germany.

Abstract

In der vorliegenden Arbeit werden zunächst die aktuellen Rahmenbedingungen für die Offshore-Windenergie in Deutschland betrachtet, um in Verbindung mit der Darstellung relevanter technischer und wirtschaftlicher Aspekte von Offshore-Windparks die Grundlagen zu schaffen, sich mit dem Problemfeld der Projektfinanzierung und dem Risikomanagement von Offshore-Windenergieprojekten auseinanderzusetzen. Die Projektfinanzierung erweist sich insbesondere vor dem Hintergrund hoher Investitionssummen von über 1 Mrd. Euro für einen Offshore-Windpark mit 400 MW Leistung als eine Möglichkeit zur Realisierung entsprechender Projekte. Vor diesem Hintergrund wird ein Discounted Cash-Flow-Modell in Kombination mit einer Monte Carlo-Simulation zur Bewertung von Offshore-Windenergieprojekten sowie zur Messung und zum Management von Risiken vorgestellt. Um die speziellen Anforderungen der Fremdkapitalgeber bei Projektfinanzierung abzudecken, werden Finanzkennzahlen wie der Schuldendeckungsgrad berechnet. Abschließend wird ein Fallbeispiel eines fiktiven Offshore-Windparks in der deutschen Nordsee simuliert, um das entwickelte Modell zu validieren und generelle Aussagen über die Wirtschaftlichkeit deutscher Offshore-Windenergieprojekte zu treffen.

Appendix 2

Decision Support Tool for Offshore Wind Parks in the Context of Project Financing

André Koukal, Michael H. Breitner

Outlet: Proceedings of the International Annual Conference of the German Operations Research Society (OR 2012)**,** Hannover, Germany, pp. 309-314.

Abstract

Offshore wind energy has developed rapidly in the last twenty years. However, the development of the technical aspects has been in the foreground for most of the time. Due to high costs of more than e1 billion the majority of the realized projects has been implemented within the framework of corporate finance. Further goals concerning the expansion of renewable energies have been set by governments in various countries.

In this context the importance of the economic viability of alternative financing concepts like project financing is becoming increasingly evident. This paper provides a decision support tool (DST) for analyzing and evaluating the project value of offshore wind energy projects within the framework of project financing. The DST is based on a cash-flow model in which the project value is calculated by applying the discounted cash-flow (DCF) method. A Monte Carlo-simulation is used to take the project risks into consideration. In the course of that the cash-flow-at-risk (CFaR), an adjustment of the VaR approach, is used to quantify the influence of risk factors and the effects on the project value. In order to be able to consider the requirements of debt capital providers in the context of project financing key figures like the debt service cover ratio (DSCR) are calculated. Therefore, a data base that supports decisions of many project participants is provided.

Finally, a case study for a fictitious offshore wind park in the German North Sea is conducted. It is shown that in the framework of the existing feed-in tariff in Germany an offshore wind park project generates adequate returns for investors and provides sufficient debt service coverage.

Appendix 3

A Decision Support Tool for the Risk Management of Offshore Wind Energy Projects

André Koukal, Michael H. Breitner

Outlet: Proceedings of the 11th International Conference on Wirtschaftsinformatik (WI 2013), Leipzig, Germany, pp. 1683-1697.

Abstract

This paper provides a decision support tool (DST) to analyze and evaluate the project value of offshore wind energy projects within the framework of project finance. The DST is based on a discounted cash-flow model in combination with a Monte Carlo simulation (MCS) to measure project risks and manage these risks. To consider the special requirements of debt capital providers in this con-text, key figures like the debt service cover ratio (DSCR) are calculated. The DST is realized in Excel/VBA with the Excel Add-In Oracle Crystal Ball. An offshore wind park example in the German North Sea is simulated to validate the underlying simulation model and the DST

Appendix 4

Revenue Model for Virtual Clusters within Smart Grids

André Voss, André Koukal, Michael H. Breitner

Outlet: IWI Diskussionsbeiträge #59, 2013, Hannover, Germany.

Abstract

The concept of smart grids and virtual clusters become more and more significant in regard of the energy transition of the German and the European network. Obviously, the market entrance barriers for such a system are enormously high. Not least the investment costs for an implementation of the necessary structures are one of the most relevant impediments. It is important to have a possibility to quantify the cost-benefit structure of virtual clusters. In this paper a dynamic optimization model is designed and tested to answer the question of the profitability potentials of virtual clusters in a regional context within a low voltage network. Additionally, different extension possibilities are considered.

Appendix 5

Towards an Allocation of Revenues in Virtual Clusters within Smart Grids

Benjamin Küster, André Koukal, Michael H. Breitner

Outlet: IWI Diskussionsbeiträge #60, 2013, Hannover, Germany.

Abstract

The energy transition in various countries implies a reorganization of the energy sector, related voltage networks and the associated participants. Smart grids will in future play an increasingly important role. Virtual clusters within these networks must meet the economic challenges. We provide support for the allocation of revenues for the participants of those clusters. To that end, research artifacts are constructed and evaluated according to the design science research (DSR) principles. A mathematical model for the allocation of revenues is formulated and forms the basis for an implementation of a software prototype. The applicability of the prototype and the underlying model is demonstrated and evaluated within a case study of a small virtual cluster. According to Green information systems (IS), our DSS contributes to economic sustainability.

Appendix 6

Measurement of Risk for Wind Energy Projects - A Critical Analysis of Full Load Hours

André Koukal, Stefan Lange, Michael H. Breitner

Outlet: Proceedings of the International Annual Conference of the German Operations Research Society (OR 2013), Rotterdam, Netherlands, pp. 255-262.

Abstract

In scientific literature, profitability analyses of on- and offshore wind energy projects and assessments of general conditions for such projects usually make use of the full load hours (FLH) key figure to determine the annually produced energy. They also serve for the calculation of the project value and other financial key figures. This procedure leads to accurate results if only the expected value of each parameter is taken into account. However, it is difficult to choose an adequate type of distribution and to define suitable distribution parameters for the FLH when project risks are considered. In this paper, a different approach using the more basic parameter of the average wind speed and a Weibull distribution in combination with the technical availability and other discounts is provided. It aims at estimating the annual electricity generation by simultaneously taking uncertainties into account. This approach is integrated into a discounted cash flow (DCF) model on which a Monte Carlo simulation is applied. Finally, a case study for a fictitious offshore wind park in the German North Sea is conducted. It is shown that the application of the presented approach leads to more precise distributions of the outcomes than the standard analysis with FLH.

Appendix 7

Enhancing Literature Research Processes: A Glance at an Approach Based on Latent Semantic Indexing

André Koukal, Christoph Gleue, Michael H. Breitner

Outlet: Lecture Notes in Informatics (LNI), Vol. 220, Informatik 2013 Proceedings (GI 2013), pp. 1937-1942.

Abstract

Literature search as a fundamental, complex and time-consuming step in a literature research process is part of many established scientific methods. It is still predominantly supported by search techniques based on conventional term-matching methods. We address the lack of semantic approaches in this context by proposing an enhancement of the literature research process with a prototype of our Tool for Semantic Indexing and Similarity Queries (TSISQ), which is based on latent semantic indexing (LSI). Its applicability is evaluated in two cases. Results indicate that our approach can help to save valuable time discovering relevant literature in a desired research field or to increase the comprehensiveness of a review by identifying sources that otherwise would not have been considered. The target audience for our findings includes researchers who need to efficiently gain an overview of a research field, deepen their knowledge and refine the theoretical foundations of their research.

Appendix 8

Offshore Wind Energy in Emerging Countries: A Decision Support System for the Assessment of Projects

André Koukal, Michael H. Breitner

Outlet: Proceedings of the 47th Annual Hawai'i International Conference on System Sciences (HICSS 2014), Big Island of Hawai'i, USA, pp. 865-874.

Abstract

Energy consumption is constantly on the increase all over the world. Especially fast-growing economies in emerging countries contribute to this increase. In addition, the climate change effects of greenhouse gas emissions are becoming more and more evident. Today it has become necessary to expand renewable energies, and offshore wind energy in particular to emerging countries. We provide decision support for assessing projects and general financial conditions, respectively. To that end, research artifacts are constructed and evaluated according to the design science research (DSR) principles. A discounted cash flow (DCF) model in combination with a Monte Carlo simulation (MCS) to consider critical project risks forms the basis of our decision support system (DSS). The applicability of the DSS is evaluated with an offshore wind project in Brazil. According to Green information systems (IS), our DSS contributes to economic sustainability.

Appendix 9

Entscheidungsunterstützungssystem zur Projektbewertung von Onshore Windenergieprojekten in Schwellenländern

André Koukal, Larissa Kurz, Michael H. Breitner

Outlet: Proceedings der Multikonferenz Wirtschaftsinformatik (MKWI 2014**),** Paderborn, Germany, pp. 869-881.

Abstract

Der globale Energiebedarf steigt kontinuierlich, insbesondere in Schwellenländern. Ein Umdenken im Bereich der Erzeugung von Strom ist erforderlich. Windenergie ist eine bedeutsame Möglichkeit emissionsfrei Strom zu erzeugen. Daher wird ein Entscheidungsunterstützungssystem (EUS) vorgestellt, mit dessen Hilfe Onshore Windenergieprojekte in Schwellenländern hinsichtlich ökonomischer Kriterien unter Berücksichtigung von Risiken bewertet werden können. Methodisch wird dem Design-Science Research (DSR) Ansatz gefolgt. Basierend auf einem Discounted Cash Flow (DCF) Modell werden Risiken mittels einer Monte Carlo Simulation (MCS) in das EUS einbezogen. Die Evaluation des EUS erfolgt anhand eines Onshore Windparks in Mexiko. Das EUS gehört zum Feld Green Information Systems (IS) und leistet damit einen Betrag zur ökonomischen und ökologischen Nachhaltigkeit.

Appendix 10

Replacing the Full Load Hours Key Figure for the Risk Assessment of Wind Energy Projects

André Koukal, Stefan Lange, Michael H. Breitner

Outlet: Proceedings der Multikonferenz Wirtschaftsinformatik (MKWI 2014), Paderborn, Germany, pp. 949-961.

Abstract

In scientific literature, profitability analyses of on- and offshore wind energy projects and assessments of general conditions for such projects usually make use of the full load hours (FLH) key figure to determine the annually generated electricity. This procedure leads to adequate results, if only the expected value of each parameter is taken into account. However, it is difficult to choose an adequate type of distribution and to define suitable distribution parameters for the FLH when project risks are considered. In this paper, a multi factor model using the more basic parameter of the average wind speed and a Weibull distribution is provided. This approach is integrated into a discounted cash flow (DCF) model on which a Monte Carlo simulation is applied. Finally, a case study for an offshore wind park in the German North Sea is conducted. It is shown that the application of the presented approach leads to more precise distributions of the outcomes than the standard analysis with FLH.

Appendix 11

Enhancing Literature Review Methods - Towards more efficient Literature Research with Latent Semantic Indexing

André Koukal, Christoph Gleue, Michael H. Breitner

Outlet: Proceedings of the 22nd European Conference on Information Systems (ECIS 2014), Tel Aviv, Israel, pp. 1-13.
https://aisel.aisnet.org/ecis2014/proceedings/track19/1/

Abstract

Nowadays, the facilitated access to increasing amounts of information and scientific resources means that more and more effort is required to conduct comprehensive literature reviews. Literature search, as a fundamental, complex, and time-consuming step in every literature research process, is part of many established scientific methods. However, it is still predominantly supported by search techniques based on conventional term-matching methods. We address the lack of semantic approaches in this context by proposing an enhancement of established literature review methods. For this purpose, we followed design science research (DSR) principles in order to develop artifacts and implement a prototype of our Tool for Semantic Indexing and Similarity Queries (TSISQ) based on the core concepts of latent semantic indexing (LSI). Its applicability is demonstrated and evaluated in a case study. Results indicate that the presented approach can help save valuable time in finding basic literature in a desired research field or increasing the comprehensiveness of a review by efficiently identifying sources that otherwise would not have been taken into account. The target audience for our findings includes researchers who need to efficiently gain an overview of a specific research field, deepen their knowledge or refine the theoretical foundations of their research.

Appendix 12

Building a Better World through Information Systems – An Explorative Survey among Leading IS Researchers

Tim A. Rickenberg, André Koukal, Michael H. Breitner

Outlet: Proceedings of the International Conference on Information Systems (ICIS 2014), Auckland, New Zealand, pp. 1-19.
https://aisel.aisnet.org/icis2014/proceedings/ConferenceTheme/15/

Abstract

IS research and practice needs to take on the big questions and global challenges. While the IS community is well positioned to assist in addressing these challenges, IS research has been criticized to lack relevance. We investigate how and to which extent IS can con-tribute to build a better world, in particular with regard to the Millennium Development Goals (MDGs). We therefore conduct an explorative survey among leading IS research-ers on a global scale. Based on 171 responses, we employ qualitative and quantitative analy-sis methods to synthesize the survey data, document and discuss results, and derive im-plications. Besides positive aspects, the survey also reveals challenges and critique con-cerning IS research. We provide a starting point, create awareness, and stimulate further discussions and research. With the right focus and alignment, IS prac-tice and research has the potential to take on the big questions and can help to build a better world.

Appendix 13

Enhancing Literature Review Methods - Evaluation of a Literature Search Approach based on Latent Semantic Indexing

André Koukal, Michael H. Breitner

Outlet: Proceedings of the International Conference on Information Systems (ICIS 2014), Auckland, New Zealand, pp. 1-19.
https://aisel.aisnet.org/icis2014/proceedings/ResearchMethods/9/

Abstract

Literature search, as a fundamental and time-consuming step in a literature research process, is part of many established scientific research methods. The facilitated access to scientific resources requires an increasing effort to conduct comprehensive literature reviews. We address the lack of semantic approaches in this context by proposing and evaluating our Tool for Semantic Indexing and Similarity Queries (TSISQ) for the enhancement of established literature review methods. Its applicability is evaluated in different environments and search cases covering realistic applications. Results indicate that TSISQ can increase efficiency by saving valuable time in finding relevant literature in a desired research field, improve the quality of search results, and enhance the comprehensiveness of a review by identifying sources that otherwise would not have been considered. The target audience includes all researchers who need to efficiently gain an overview of a specific research field and refine the theoretical foundations of their research.

Appendix 14

Financial Decision Support System for Wind Energy – Analysis of Mexican Projects and a Support Scheme Concept

André Koukal, Jan-Hendrik Piel

Outlet: Proceedings of the 50th Annual Hawai'i International Conference on System Sciences (HICSS 2017), Big Island of Hawai'i, USA, pp. 865-874.
https://aisel.aisnet.org/hicss-50/da/grand_challenges/2/

Abstract

Energy consumption is constantly on the increase all over the world. Especially fast-growing economies in emerging countries contribute to this increase. Governments need to promote the expansion of renewable energies in these countries by providing adequate general conditions and suitable support schemes. We provide decision support for the assessment of wind energy projects and their financial conditions. Following design science research (DSR) principles, a discounted cash flow (DCF) model in combination with a Monte Carlo simulation (MCS) to consider project risks was created. On this basis, a decision support system (DSS) was implemented in MATLAB. The applicability of the DSS is evaluated in the course of an analysis of onshore wind projects in Mexico. Based on the analysis' results, a concept of a support scheme is designed to promote an expansion of onshore wind energy across Mexico.

Appendix 15

Promoting the System Integration of Renewable Energies: Toward a Decision Support System for Incentivizing Spatially-Diversified Deployment

Jan-Hendrik Piel, Julian Hamann, André Koukal, Michael H. Breitner

Outlet: Journal of Management Information Systems (JMIS), 2017, 34(4), pp. 994-1022.

Abstract

The system integration of intermittent renewable energies (RE) poses an important challenge in the transition toward sustainable energy systems. Their intermittency introduces variability into electricity generation leading to high ancillary service costs and technical issues impairing grid stability and supply reliability. These issues can be mitigated through spatially-diversified capacity deployment, as RE intermittency can be geographically smoothed over sufficiently large regions. Following a design science research approach, we develop a model for the quantification of location-based investment incentives in RE support mechanisms to foster spatially-diversified capacity deployment. We evaluate the modeling approach in a simulation study with focus on diversifying wind energy deployment in Mexico under an idealized auction mechanism and demonstrate how location-based investment incentives reduce resource-dependent competition among projects. Our research contributes a nascent design theory that combines the kernel theories for identifying favorable spatial distributions of RE capacity with current policy designs to support capacity expansion management.

Appendix 16

Enhancing Strategic Bidding Optimization for Renewable Energy Auctions: A Risk-Adequate Marginal Cost Model

Chris Stetter, Jan-Hendrik Piel, André Koukal, Michael H. Breitner

Outlet: To be published in Proceedings of the International Annual Conference of the German Operations Research Society (OR 2017), Brussels, Belgium.

Abstract

In recent years, there has been a rapidly increasing number of countries adopting auctions for the allocation of permissions and financial support to renewable energy projects. The shift toward auction mechanisms has introduced competitive price discovery of financial support levels for new projects. In common auction mechanisms, project developers compete by specifying their required sales price per unit of electricity (in €/MWh) as well as a capacity to be installed (in MW) and only the most cost-competitive projects with the lowest required financial support are granted until the auction volume (in MW) is reached. An optimal bidding strategy for these mechanisms always depends on the country-specific auction design. Such strategies commonly propose to obscure the true cost of a project by adding certain premiums on top of the marginal cost in order to maximize the expected profit.

Consequently, the starting point of finding an optimal bidding strategy must always be a reliable determination of the marginal cost, which is the minimum sales price per unit of electricity required to permit an economically viable project construction and operation at an acceptable level of risk. In this study, we thus focus on enhancing the strategic bidding by integrating a holistic financial modelling approach for a risk-adequate quantification of the marginal cost into a strategic bidding optimization model. The latter typically consider traditional discounted cash-flow models without incorporating project-specific risks and uncertainties and, thus, result in a biased and unprecise bidding strategy. We enhance current estimation approaches for the marginal cost by providing a derivative of the adjusted present value with respect to the sales price per unit of electricity. The adjusted present value is based on a state-of-the-art cash-flow calculation combined with a Monte Carlo simulation accounting for project risks.

In order to permit a proof-of-concept and in-depth understanding of our model enhancement, we conducted a simulation study of a wind farm in Lower Saxony, Germany with a prototypical implementation in Python. In particular, the simulation study focuses on the comparison of current estimation approaches and our enhanced approach incorporating the manifold risks and uncertainties into the estimation of cash-flows that determine the optimal bidding strategy to a large extend. The results show significant differences, with quantifiable advantages of our risk-considering adjusted present value method. As our modelling approach permits the direct quantitative incorporation of risks and uncertainties within strategic auction bids, we contribute to an enhanced strategic bidding optimization and comprehensive methodological support for project developers in competitive renewable energy auctions.

Enhancing Strategic Bidding Optimization for Renewable Energy Auctions: A Risk-Adequate Marginal Cost Model

Chris Stetter, Jan-Hendrik Piel, André Koukal, and Michael H. Breitner

Information Systems Institute, Leibniz University Hannover,
Königsworther Platz 1, 30167 Hannover, Germany
stetter@iwi.uni-hannover.de
piel@iwi.uni-hannover.de
koukal@iwi.uni-hannover.de
breitner@iwi.uni-hannover.de

Abstract. The shift toward auction mechanisms for renewable energies has introduced competitive price discovery of financial support levels for new projects. The starting point of finding an optimal bidding strategy in these auctions must always be a reliable determination of the marginal cost, which is the minimum sales price per unit of electricity required to permit an economically viable project realization at an acceptable level of risk. We focus on enhancing strategic bidding by introducing a holistic financial modelling approach for a risk-adequate quantification of the marginal cost, which serves as the basis for strategic bidding optimization models. In order to permit a proof-of-concept and in-depth understanding of our model enhancement, we conduct a simulation study of an onshore wind farm in Germany. The results of our study show that our modelling approach enables quantifying bid prices that are both cost-competitive and sustainable in terms of a likely project realization.

Keywords: renewable energy auctions, strategic bidding, competitive bidding, valuation, discounted cash flow, risk analysis

1 Introduction

In recent years, there has been a rapidly increasing number of countries adopting auctions for the allocation of permissions and financial support to renewable energy projects [8]. In Germany, competition for subsidized feed-in compensation for renewable electricity, where project developers participate in auctions and rival for tendered electricity volumes, was introduced with the latest amendment of the Renewable Energy Sources Act (EEG) in 2017. The German auction-mechanism for solar and onshore wind energy is designed as a tender, where project developers compete by specifying their required sales price per unit of electricity (in ct/kWh) as well as a capacity (in MW) to be installed. In the auction process only the most cost-competitive projects with the lowest required financial support are granted until the tendered capacity is reached. From project developers' perspective, competitive pricing in auctions significantly decreases profit margins, which highly increases the sensitivity to risks and uncertainties and thus decreases acceptable valuation errors. In existing literature little support focuses on deriving bid price quantification methods in the realm of renewable energy auctions, in particular from a strategic perspective considering project exogenous factors such as the occurring competition. Some rare examples are the research articles from Anatolitis et al. [1] and Voss and Madlener [4].

An optimal bidding strategy always depends on the country-specific auction design [8]. Such strategies commonly propose to obscure the true cost of a project by adding certain premiums on top of the marginal cost c_t in order to maximize the expected profit. Given the competitive situation and the complex auction design, different optimal bidding strategies evolve for the German auction mechanism [1]. It distinguishes between two pricing rules - pay-as-bid and uniform pricing - depending on the source of energy and the participant's legal form. The dominant strategy in a repeated pay-as-bid auction is to choose the bid b that maximizes the expected profit:

$$E(\pi(b)) = \sum_{i=t}^{T} \delta^{i-t} \cdot (b_i - \boldsymbol{c}) \cdot p_i \cdot \prod_{x=1}^{i-t} (1 - p_i) \quad (1)$$

where π is the profit, δ the discount factor and p_i the probability of the bid being successful in round i. In contrast, the weakly dominant strategy for the uniform pricing rule is to bid exactly the agent's marginal cost:

$$b = \boldsymbol{c} \quad (2)$$

Both strategies feature the same starting point of finding an optimal bidding strategy, the marginal cost c, which is the minimum sales price per unit of electricity required to permit an economically viable project construction and operation at an acceptable level of risk. We focus on enhancing the strategic bidding optimization model by proposing a holistic financial modelling approach for a risk-adequate quantification of the marginal cost.

Section 2 presents the proposed methodology. In order to evaluate our model enhancement, we conduct a simulation study of a wind farm in Lower Saxony, Germany in Section 3. Finally, conclusions are drawn in Section 4.

2 Methodology

Existing strategic bidding optimization models typically consider traditional discounted cash flow models for the quantification of the marginal cost without incorporating project-specific risks and uncertainties and, thus, result in a biased and imprecise bidding strategy. We enhance current estimation approaches for the marginal cost by providing a derivative of the adjusted present value with respect to the sales price per unit of electricity. The presented methodology is based on the model of Piel et al. [3], reformulated as an optimization problem. Its main characteristic is a risk-constrained optimization approach minimizing the required sales price per unit of electricity while considering investment criteria of both equity and debt investors.

Firstly, a probabilistic state-of-the-art cash flow calculation for renewable energy projects is performed. Utilizing Monte Carlo simulations (MCS) allows to simulate uncertain cash flows stemming from identified risks and uncertainties such as capital (CAPEX) or operational expenditures (OPEX). Table 1 presents an income statement and a cash flow statement, which are simulated for each year of the project life cycle $t = (1, ..., T_i)$ and each MCS iteration $i = (1, ..., I)$. For the sake of simplicity, we only consider the electricity yield $Y_{i,t}$ to be risky in this study. Due to the revenues $R_{i,t} = c \cdot Y_{i,t}$ depending on the electricity yield, it results in probability density function (PDF) estimations for the unlevered free cash flow (FCF), which are the FCF before interest payments are taken into account and serve as the basis for the optimization model.

Secondly, the debt sculpting method is applied to the unlevered FCF in order to optimally utilize the leverage effect of debt financing while a minimum debt service cover ratio (DSCR) is maintained throughout all debt service periods.

Table 1. Income and cash flow statements

Income statement	cash flow statement
Revenues	**EBIT**
− OPEX	− Taxes on EBIT
= EBITDA	+ Depreciation
− Depreciation	− CAPEX
= EBIT	**= Unlevered free cash flow**

The DSCR evaluates the debt service coverage by the cash flow available for debt service and is determined as follows:

$$DSCR_{i,t} = \frac{FCF_{i,t}}{INT_t + P_t}; \quad \forall i \in I, t \in T_{Debt} \tag{3}$$

where INT_t is the interest payment, P_t is the principal repayment, and T_{Debt} is the length of the entire debt service period. Based on a predefined minimum

DSCR target β that is maintained throughout all debt service periods at the confidence level $1-\alpha$, the maximum debt service capacity is derived as follows:

$$DSC_t = \frac{F^{-1}_{FCF,t}(\alpha)}{\beta}; \quad \forall t \in T_{Debt} \tag{4}$$

The interest payments are estimated as the difference of the maximum debt service capacity and the principal repayments, assuming that the debt capital is raised in the form of zero coupon bonds, where r_d is the cost of debt:

$$INT_t = DSC_t - P_t = DSC_t - \frac{DSC_t}{(1+r_d)^t}; \quad \forall t \in T_{Debt} \tag{5}$$

Thirdly, the adjusted present value (APV) is utilized for evaluating the profitability. Following Myers [2], each iteration of the unlevered FCF is discounted to the valuation date:

$$APV_i = \sum_{t=1}^{T_i} \frac{FCF_{i,t}}{(1+r_e)^t} + \frac{\tau \cdot INT_t}{(1+r_d)^t}; \quad \forall i \in I \tag{6}$$

where T_i is the maximum total project life cycle length for all iterations, r_e is the unlevered cost of equity and τ is the corporate tax rate. The use of the APV approach is the best choice, due to its explicit tax-shield consideration [2].

Fourthly, the optimization model minimizes the sales price per unit of generated electricity c under consideration of risk factors, the optimal capital structure and the risk-attitude of involved parties. The latter is determined through the investment criteria of equity investors, by means of the expected APV being zero and debt investors, by means of the DSCR being greater or equal to a target rate β at a certain confidence level $1-\alpha$. Thus, our optimization problem can be formulated in mathematical terms as follows:

$$\boldsymbol{Minimize}\ c \qquad \text{subject to} \tag{7}$$

$$E(f_{APV}) \geq 0 \tag{8}$$

$$F^{-1}_{DSCR,t}(\alpha) \geq \beta; \quad \forall t \in T_{Debt} \tag{9}$$

where f_{APV} is the PDF of the APV and $F^{-1}_{DSCR,t}$ is the inverse cumulative distribution function at percentage point α of the DSCR. As a first step, assuming an initial guess $c_{initial} \in \mathbb{R}^+ \setminus \{0\}$, the cash flow simulation, debt sculpting and present value method are performed. Subsequently, the first derivative of the expected APV with respect to c is determined as follows:

$$\frac{dE(f_{APV})}{dc} = (1-\tau) \cdot \sum_{t=1}^{T} \frac{E(f_{Y,t})}{(1+r_e)^t} + \frac{\tau - \tau^2}{\beta} \cdot \sum_{t=1}^{T_{Debt}} \frac{F^{-1}_{Y,t}(\alpha)}{(1+r_d)^t} \cdot (1-(1+r_d)^{-t}) \tag{10}$$

where $E(f_{Y,t})$ is the expected electricity yield and $F^{-1}_{Y,t}(\alpha)$ the αth percentile of the electricity yield. In a final step, the minimum sales price per unit of generated electricity c that exactly meets the investment criteria of all stakeholders is calculated as follows:

$$c = c_{initial} - \frac{E(f_{APV})}{\frac{dE(f_{APV})}{dc}} \tag{11}$$

3 Case-Study and Results

This section demonstrates the application of our risk-adequate marginal cost model to an onshore wind farm in Lower Saxony, Germany using a prototypical implementation in Python. Table 2 presents its project characteristics [5–7].

The electricity yield is calculated as follows using the annual Weibull wind speed PDF $f_{Weibull,i,t}(v)$, which was estimated using NASA's MERRA-2 dataset:

$$Y_{i,t} = \int_{v=0}^{V} f_{Weibull,i,t}(v) \cdot P(v)dv \cdot NOH \cdot \delta; \quad \forall i \in I, t \in T_i \tag{12}$$

where $P(v)$ is the turbine's cumulative power curve, V is the cut-out wind speed, NOH is the net operating hours and δ is the farm efficiency.

Applying our model with 10,000 MCS iterations to the fictive onshore wind farm yields marginal cost of 5.97 ct/kWh. Figure 1 demonstrates that the decision criteria of equity capital investors is fulfilled on average as the expected value of the APV is equal to or greater than zero. Likewise, a project is considered financially viable from lenders' perspective if a target ratio is covered for in every debt service period with a certain probability. Figure 2 shows that for every debt service period, the mean DSCR is equal to or greater than the target of 1.2 in 75% of the iterations. Consequently, the investment criteria of both equity and debt investors are exactly fulfilled at the estimated marginal cost.

Table 2. Project characteristics of the onshore wind farm project under investigation

Wind turbines	5 Nordex N131-3.3	Project duration	20 years
Total capacity	16.5 MW	CAPEX	1513 €/kW
Farm efficiency	87 %	OPEX (Year 1-10)	21,71 €/MWh
Net operating hours	7.635 h/turb.	OPEX (Year 11-20)	23,60 €/MWh
Corporate tax	30 %	Unlev. cost of equity	3.18 %
Straight line depreciation	16 years	Cost of debt	3.5 %
DSCR target	1.2 at 1-α=75 %	Debt service period	14 years

Fig. 1. Histogram of adjusted present value after optimization

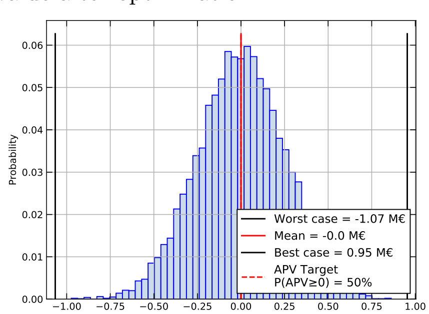
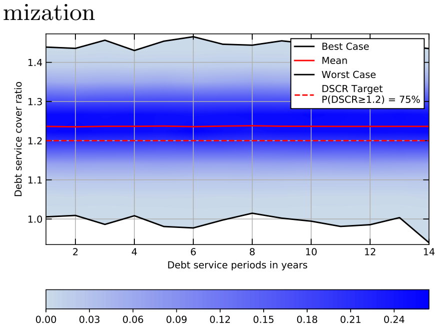


Fig. 2. Debt service coverage after optimization



4 Conclusion

Determining bid prices that are cost-competitive and sustainable in terms of a likely project realization is a major challenge that results from the shift toward auction mechanisms. It follows, that the investment criteria of all project stakeholders comprising equity and debt investors should be considered in the bid price quantification process. We have proposed an enhanced, risk-adequate estimation approach for the marginal cost, which is the starting point for strategic bidding optimization, by providing a derivative of the adjusted present value with respect to the sales price per unit of electricity. For the analyzed project it was demonstrated that the quantified marginal cost are sustainable due to the investment criteria being fulfilled, and at the same time cost-competitive as it is below the average market clearing price of 6.29 ct/kWh of the three last German onshore wind auctions. Hence, starting from the marginal cost, the simulated project developer would have had additional room for bidding strategically.

In contrast to the levelized cost of electricity, which has a similar meaning [3], our approach not only allows for the consideration of risk factors as well as specific project finance characteristics. Most importantly, as our modelling approach permits the direct quantitative incorporation of investment criteria within strategic auction bids, we contribute to an enhanced strategic bidding optimization and comprehensive methodological support for project developers in competitive renewable energy auctions. Our introduced modeling approach aims at accounting for the risk-attitude of all involved parties, which is indispensable for successful realizations of future renewable energy projects.

References

1. Anatolitis, V., Welisch, M.: Putting Renewable Energy Auctions Into Action–An Agent-Based Model of Onshore Wind Power Auctions in Germany. Energy Policy 110, 394–402 (2017)
2. Myers, S.C.: Interactions of Corporate Financing and Investment Decisions–Implications for Capital Budgeting. The Journal of finance 29(1), 1–25 (1974)
3. Piel, J.H., Hamann, J.F., Koukal, A., Breitner, M.H.: Promoting the System Integration of Renewable Energies: Toward a Decision Support System for Incentivizing Spatially Diversified Deployment. Journal of Management Information Systems 34(4), 994–1022 (2017)
4. Voss, A., Madlener, R.: Auction Schemes, Bidding Strategies and the Cost-Optimal Level of Promoting Renewable Electricity in Germany. FCN Working Paper (2017)
5. Wallasch, A.K., Lüers, S., Rehfeldt, K.: Weiterbetrieb von Windenergieanlagen nach 2020. Deutsche WindGuard, Tech. Rep (2016)
6. Wallasch, A.K., Lüers, S., Rehfeldt, K.: Kostendruck und Technologieentwicklung im Zuge der ersten Ausschreibungsrunden für die Windenergie an Land. Deutsche WindGuard, Tech. Rep (2017)
7. Wallasch, A.K., Lüers, S., Rehfeldt, K.: Wirtschaftlichkeit unterschiedlicher Nabenhöhen von Windenergieanlagen. Deutsche WindGuard, Tech. Rep (2017)
8. Winkler, J., Magosch, M., Ragwitz, M.: Effectiveness and Efficiency of Auctions for Supporting Renewable Electricity–What Can We Learn From Recent Experiences? Renewable Energy 119, 473–489 (2018)