Essays on Business Analytics, Digital Transformation, and Improved Literature Searches

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Abstract

This cumulative dissertation describes research on digital transformation, business analytics, and research methods in information systems research. Within the research methods section, a method for the assessment of research projects is discussed and an article is presented, which examines literature search methods. The article should improve the current practice of literature search in information systems research by presenting seven literature search recommendations. In the second part, participatory design in digital transformation is addressed, privacy concerns in bring your own device initiatives are examined, different aspects of chatbots are analyzed, and a taxonomy for predictive maintenance business models is developed. Part three covers different facets of self-service business intelligence, a hybrid machine learning approach and a process model for data science projects, as well as operations research models in industry 4.0. In addition, a research agenda is presented, in which examples for further research opportunities of the respective parts of the dissertation are presented.

Keywords: Literature Search, Industry 4.0, Digital Transformation, Chatbots, Business Analytics, Self-Service Business Intelligence, Data Science

Management Summary

Information systems research (ISR) is characterized, among other things, by its interdisciplinarity. Topics can be examined from different perspectives and with different methods. In this cumulative dissertation, different topics are investigated and different research designs are used. The topics described are all based on articles that have either been published or are in a review process. The dissertation is divided into three major parts. The parts cover research methods of ISR, digital transformation, and business analytics. After describing the three parts, a research agenda is presented, which presents opportunities for further research for each of the topics covered.

Part A presents two articles that deal with the assessment of research and the search for literature. A framework for the assessment of research is presented, which allows the planning for a research project to be presented in a structured way on one page (Passlick et al. 2018). Figure I shows the different boxes of this page.

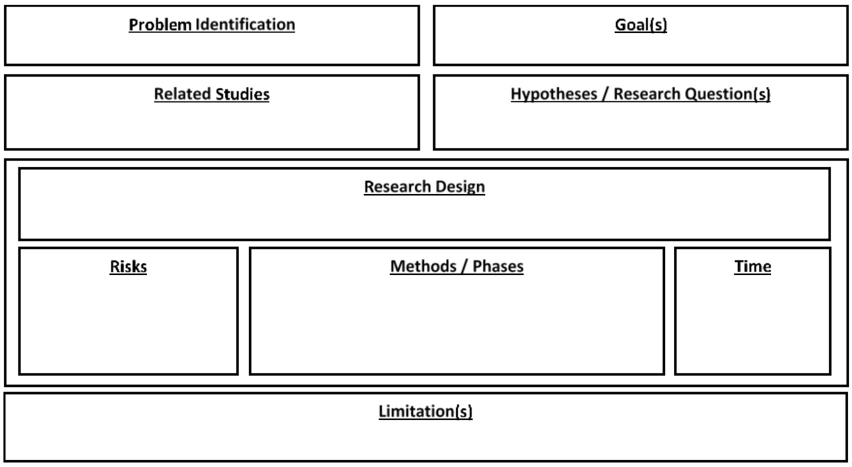

Figure I. The modified Version of the Framework (Passlick et al. 2018)

Roughly, the aspects can be divided into two parts. The boxes for problem identification, the objectives, related studies, and the hypotheses / research questions form the first part, which roughly represents the problem definition of the research project. The second part describes how the questions should be approached and what problems might occur.

The amount of literature is constantly growing, which makes finding relevant literature an increasing challenge. Accordingly, the use of literature search techniques must improve to meet this challenge. The second article of Part A is dedicated to this goal (Passlick et al. 2021b). First of all, it describes the goals of a literature search, the current state of knowledge in literature searches, and which search methods are currently available. Afterwards, literature reviews from high-quality journals of the past years are examined to analyze which methods are used and whether the search methods used have changed in recent years. It is shown that the methods used have changed and that methods with a higher degree of automation have been used in recent years. Furthermore, the use of the literature search methods depends on the particular search strategy that is being pursued. Based on the findings of the previous steps, seven recommendations are formed, which help researchers improving their literature searches.

Part B discusses five articles that deal with digital transformation. The first article deals with the problem that although there are many ways to analyze the visiting behavior of an organization's website, in practice these are far from being exhausted (Janssen et al. 2019). In a design science research approach a participatory design model is developed. The result is a process model, with which individual web analytics reports are developed with the involvement of the future users. The process model is shown in Figure II.

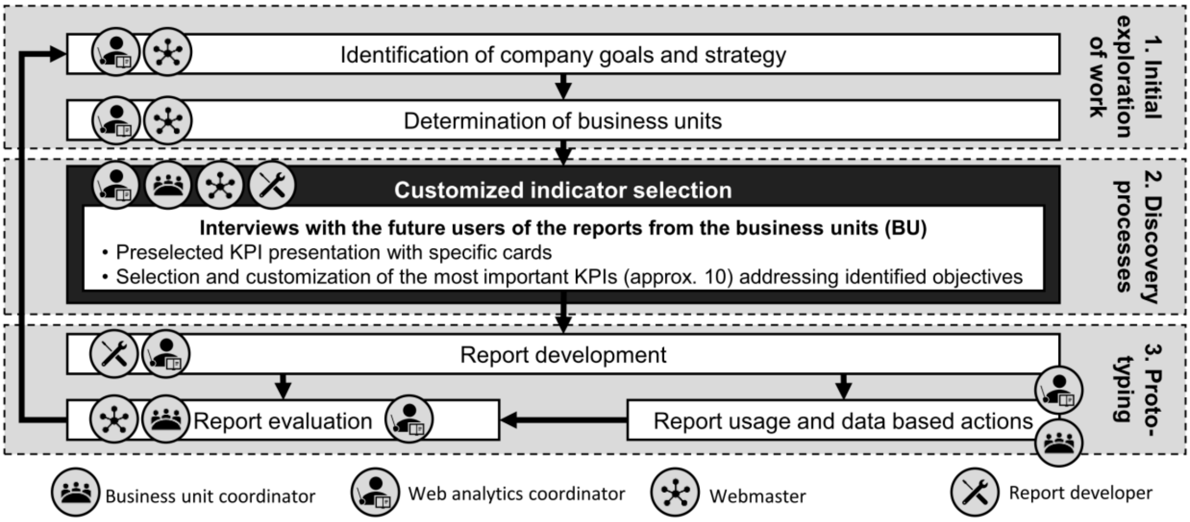

Figure II. The process model for web analytics report development (Janssen et al. 2019, p. 5)

The model shows the relevance of participatory design approaches in the digital transformation, because it can be assumed that the problem with the lower use of web analytics reports can be transferred to other application scenarios of the digital transformation. In the presented example of web analytics, an improved use of the collected analysis data could be achieved by involving the users.

Another article deals with privacy concerns when bring your own device (BYOD) is discussed (Degirmenci et al. 2019). In the article two case studies are conducted to examine the extent to which works councils take data protection concerns into account when evaluating BYOD concepts. In both of the companies studied, data protection is of great importance to the works council and is included in the agreements. In a second step, a structural equation model is used to investigate the relationship between data protection concerns and the use of BYOD. For this purpose, a survey is conducted in Germany, South Korea, and the USA. The investigated structural equation model is shown in Figure III.

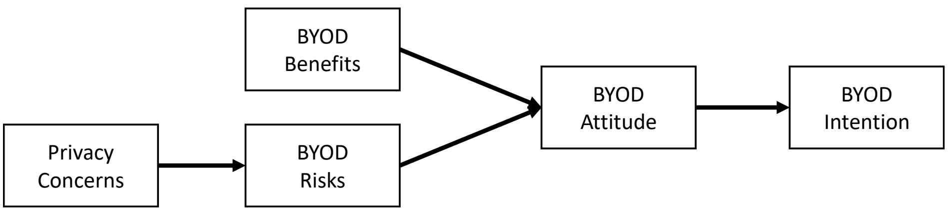

Figure III. The investigated hypotheses (Degirmenci et al. 2019)

For all hypotheses examined, a significant effect can be determined.

The next two articles, which are assigned to the part digital transformation, cover chatbots. Chatbots are a kind of conversational agent and they are discussed as a new form of interaction in very different application scenarios. In the first article, exactly these different application scenarios are examined to structure the different kinds of chatbots (Janssen et al. 2020). A taxonomy is developed according to a process model of Nickerson et al. (2013), which differentiates domain-specific chatbots. The developed taxonomy consists of the three perspectives which are intelligence, interaction, and context. A total of 17 dimensions are assigned to these three perspectives. The taxonomy is based on a data set consisting of 103 different domain-specific chatbots (Janssen et al. 2020). When analyzing the chatbots of the data set, it can be seen that many domain-specific chatbots do not yet exhaust all technical possibilities. In addition to this analysis, a cluster analysis is performed with the data set. Five groups can be identified which represent archetypes for domain-specific chatbots.

Based on this, in a second article a framework is developed, which supports the implementation of chatbots (Janssen et al. 2021). The framework is developed with a design science research approach and is based on 15 expert interviews that are evaluated with grounded theory methods. The expert interviews are used to identify questions that should be asked during the implementation of a chatbot. These questions are structured according to development phases and the four perspectives of the PACT framework by Benyon (2014). Finally, the model is evaluated with a focus group discussion and seven expert interviews.

The last article of the digital transformation part deals with predictive maintenance (PdM) business models (Passlick et al. 2020a). Here, a taxonomy is developed according to the process model by Nickerson et al. (2013), too. In addition to a literature review, the taxonomy is based on a data set containing 113 PdM business models. The dataset was collected at the "Hannover Messe 2018", the "crunchbase" database, and occasionally from lists on the internet. The finished taxonomy consists of seven dimensions, which includes both classical dimensions for the consideration of business models and one dimension that is based on an internet of things architecture model. In a further step, the frequencies of the respective characteristics of the data set are examined. Additionally, a cluster analysis is performed to identify PdM business model archetypes. Six archetypes can be identified which are shown in Table I.

Table I. PdM business model archetypes (Passlick et al. 2020a, p. 11)

	Archetype					
	1	**2**	**3**	**4**	**5**	**6**
Label	*Hardware development*	*Platform provider*	*All-in-one*	*Information manager*	*Consulting*	*Analytics provider*
Key activities	Hardware development	Provision of an application platform	Universal offer	Edge computer development	Consulting	Software development
Value promise	Condition monitoring	Forecasting	All-in-one solution	Condition monitoring	Condition monitoring	Forecasting
Payment model	One-time sales	Hybrid	Hybrid	Hybrid	Project	Time basis
Deployment channel	Physical	Physical + www (cloud)	Physical + www (cloud)	Physical + www (cloud)	Physical	www (cloud)
Customer segment	No industry focus	Manufacturing industry	No industry focus	Manufacturing Industry	No industry focus	No industry focus
Clients	B2B	B2B	B2B	B2B + B2B2B	B2B	B2B
Information layer	Object sensing and information gathering	Application and services	Multiple	Multiple & information delivering	Application and services	Application, services and information handling
Share in sample (113)*	21%	12%	27%	5%	13%	20%
Example company	Rockwell Automation	Test Motors	National Instruments	IXON	Hitachi Consulting	Senseye

It should be noted that there are new business models such as “information manager”, “platform” and “analytics provider”, as well as established business models such as “hardware development”. In addition, there are connecting business models such as “consulting” or “all-in-one” offers (Passlick et al. 2020a). After deducting the archetypes, an autoencoder procedure is applied to map the differences between the business models in a two-dimensional figure. In this way, it can be shown which archetypes are similar to each other and how homogeneous the business models are within an archetype. Figure IV shows the representation of the analyzed data set, with each symbol representing a business model. Business models of an archetype are represented by the same symbol. It is easy to see that e.g. the archetypes analytics provider and platform provider are similar.

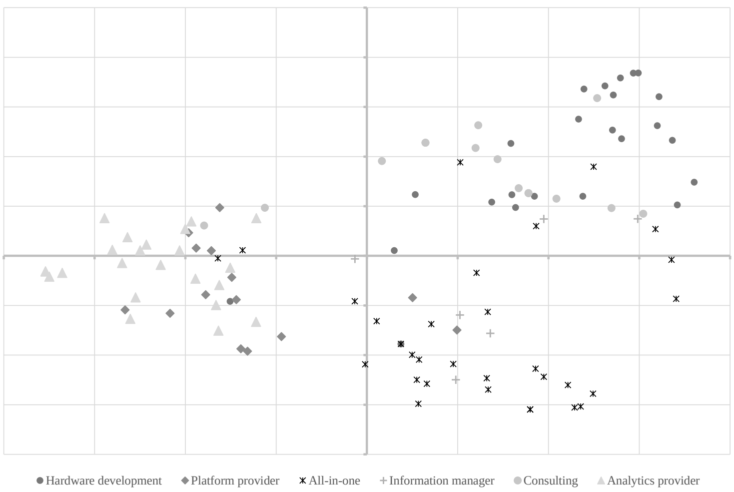

Figure IV. The visualization method with an autoencoder procedure (Passlick et al. 2020a, p. 12)

Part C covers topics of business analytics. The articles can be roughly divided into three streams: Self-service business intelligence (SSBI), operations research in Industry 4.0, and data science. The first article uses a design science research approach to develop an architecture that supports SSBI (Passlick et al. 2017). SSBI describes the ability of employees in a department to create analyses and reports independently of the IT department (Alpar & Schulz 2016). The developed architecture is based on a literature review (Webster & Watson 2002) and semi-structured expert interviews which were evaluated according to Mayring (2002). After completion of the development of the architecture, an applicability check was conducted with a focus group discussion (Morgan 1993). The architecture shows that different user groups exist and their different needs should be addressed with different components. However, components are also needed that promote the collaboration of these user groups.

A further article on SSBI examines which factors increase or decrease the intention of users and potential users to use SSBI (Passlick et al. 2020b). The question is addressed with a structural equation model, which is validated with a survey. It is shown that flexibility, expected time savings, and the importance of data quality lead to a utilitarian value of SSBI, which then increases the expected contribution to information needs. This contribution in turn has a positive influence on the intention to use SSBI. A direct influence of the utilitarian value on the intention to use SSBI was not found. In contrast, the experience with BI applications has a positive influence on the expected contribution to the information needs as well as on the intention to use SSBI. Furthermore, a negative effect of the perceived attention of the company on data quality on the intention to use SSBI was found. Figure V shows the described influences and their levels of significance.

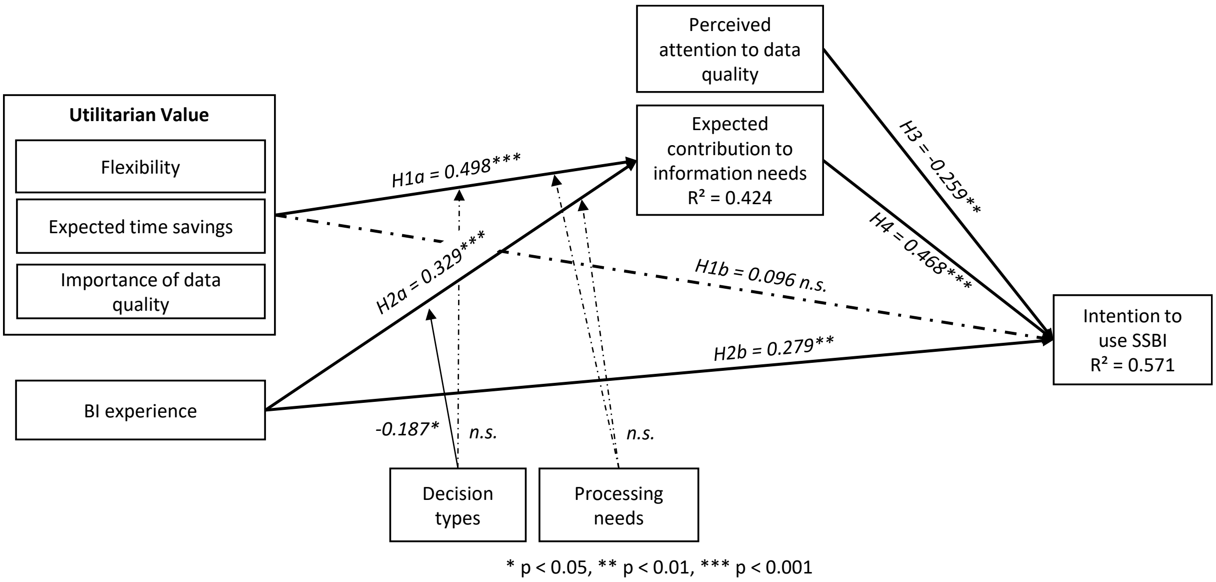

Figure V. Effects on the intention to use SSBI (Passlick et al. 2020b, p. 13)

The third article on SSBI deals with the problem that there is no clear differentiation between different SSBI application scenarios yet (Passlick et al. 2021a). To enable a better differentiation, a taxonomy according to Nickerson et al. (2013) is developed in this research. Based on a literature review, an analysis of SSBI tools, and a case study, the taxonomy development is performed. Afterwards, the taxonomy is evaluated with an illustrative scenario according to Szopinski et al. (2019). The final taxonomy consists of nine dimensions, of which two dimensions were not developed using the analysis of SSBI tools, but based on the literature review and the case study. Within the evaluation, a cluster analysis is performed in which three archetypes are identified. These do not allow conclusions about typical application scenario archetypes in practice, but they show which application scenarios are mainly addressed by the SSBI tool providers.

Two articles deal with operations research models in Industry 4.0, both of which are based on the idea that sensor data can be used to calculate the state of health of a machine. In the models, it is assumed that the state of health can be included in the calculations with a number between 0 and 1. In the first model, the information about the different health states of the machines is then used to calculate how many spare parts should be kept in stock (Dreyer et al. 2018). In addition, the costs of a machine breakdown and the costs for keeping a spare part in stock are also included in the calculation. It is also important to note that the model is based on the assumption that the number of spare parts can be varied at will, which may not be possible in reality, as parts once in stock cannot simply be reduced. However, in new business models that operate within advanced value networks, this would be conceivable.

The second model deals with the question of when maintenance should take place (Olivotti et al. 2018b). It is assumed that there is a set of machines of one type, which should be maintained in groups. The model optimizes how many maintenance groups should be formed, taking into account the expected downtime costs, to find the optimal balance between expected downtime costs and costs for setting up a maintenance event.

Both models have the problem that a large number of possibilities are considered to calculate the correct expected failure costs. As a result, the number of components or machines that can be calculated in one run of the model is limited. Further research is needed here, which could, e.g., by means of a prior grouping of machines or components, enable significantly larger quantities of elements to be optimized.

The last two articles covered in this dissertation can be roughly summarized under the term data science. Data science describes a special form of business analytics, in which more complex statistical, mathematical methods or advanced algorithms are used to analyze data. In the first article, an approach is presented that shows how machine learning algorithms can be combined with human expertise to create robust monitoring systems (Olivotti et al. 2018a). The approach consists of three components, some of which have been prototypically implemented. First an anomaly detection component supervises the sensor data of a machine and detects abnormal data progression. If this occurs, the data is transferred to a monitor component. In this component, a human expert assesses whether the abnormal behavior is really due to a critical wear or other defect and if so, what the cause could be. The result is passed to the classification component, where the data is used to improve the parameters of the anomaly detection component and to improve suggestions that the monitor component makes to the human expert. In this way, the forecast quality can be further improved during operation and the system can be used at the beginning even without extremely large amounts of data.

The second article develops a detailed definition of data science and presents a process model that describes the requirements that exist in the different phases of a data science project (Schulz et al. 2020). The article describes *Data Science as an interdisciplinary field in which, with the help of a scientific, semi-automatic approach, and by applying existing or future analysis methods, knowledge is extracted from partly complex data and made usable under consideration of social effects* (Schulz et al. 2020).

The process in a data science project consists of the phases, project order, data provision, analysis, provision of the analysis model, and usage. The implementation should be carried out according to a scientific procedure. The activities are embedded in the respective domain, which can have a strong influence on the analysis techniques. A large part of the activities is dependent on the organizational and technical infrastructure. Figure VI shows the described elements and their interrelations.

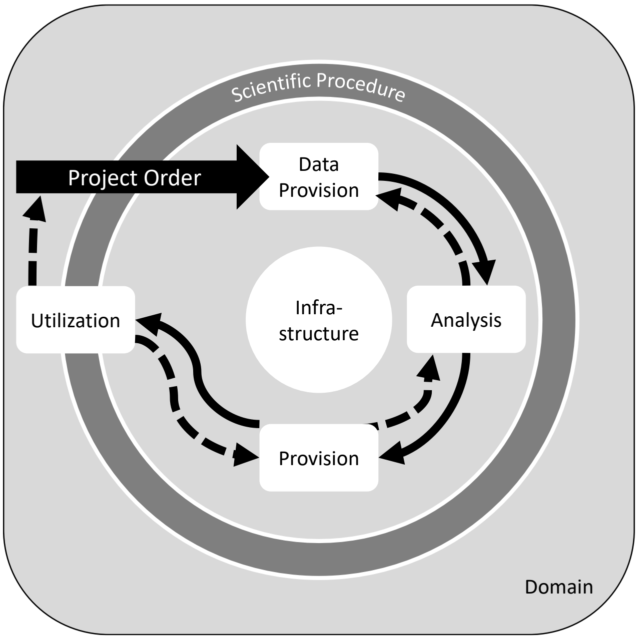

Figure VI. The presented data science process model (Schulz et al. 2020)

The last section of the thesis describes a research agenda for the three major parts of the thesis. For each research area opportunities for further research are presented. These opportunities are distinguished according to the three information systems research traditions. Design oriented research, behavioral research, and economics of information systems are these research traditions. It is shown that there are some connections, not only between the research streams, but also between the major parts of the dissertation. E.g., similar to our research on chatbots, language-based queries of data are also discussed in the context of business analytics. Here, it could be investigated to what extent this new interaction possibility has an impact on a stronger use of business analytics applications.

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List of Abbreviations

BA	Business Analytics
BI	Business Intelligence
BM	Business Model
BUs	Business Units
BYOD	Bring your own device
CRISP-DM	Cross Industry Standard Process for Data Mining
DASC-PM	Data-Science-Process-Model
DT	Digital Transformation
DSR	Design Science Research
ETL	Extract, Transform and Load
IS	Information Systems
ISR	Information Systems Research
IT	Information Technology
KDD	Knowledge Discovery in Databases
KPIs	Key Performance Indicators
OR	Operations Research
PACT	People, Activity, Context, and Technology
PdM	Predictive maintenance
PLS	Partial Least Squares
PSS	Product-Service-Systems
SSBI	Self-Service Business Intelligence
TDSP	Team Data Science Process
WA	Web Analytics

0. Overview of Publications and Task Allocation

Table 1 gives an overview of the publications that constitute this cumulative dissertation. Both published and submitted articles are listed. The table is sorted chronologically, with the most recently submitted articles at the top. In the first column the articles are numbered, starting with the first published article.

In the last submitted article, the different application scenarios of Self-Service Business Intelligence (SSBI) are discussed. To concretize future SSBI research it is necessary to define how SSBI use cases can be differentiated. Through my previous SSBI research the mentioned need for research has become clear to me. Together with my co-authors I created the research design. The data collected within the research was analyzed by me and I also wrote large parts of the initial text. Furthermore, I conducted the case study research. The article was submitted to the "Information Systems and e-Business Management" journal.

Another article deals with the modern possibilities of literature search. It was submitted to "Communications of the Association for Information Systems". The original idea came from me, but was concretized with my co-authors. I was also responsible for our literature review, the summary of the different search methods and the development of the guidelines. I wrote the initial text for all chapters except the analysis of the search methods of current literature reviews.

The article submitted to the "International Journal of Human-Computer Studies" journal in June 2021 is about the introduction of chatbots. The idea came from one of my co-authors. Here, I suggested to structure the framework into the different views of the PACT framework. I also made a proposal for the text of research design chapter.

In October 2020 an article on a predictive maintenance business model taxonomy was published in the "Electronic Markets" journal. The article is based on the bachelor thesis of Lukas Grützner. Together in a team we have further developed the taxonomy and extended the data set. Everyone in the team has analyzed additional business models to enable a cluster analysis. As first author I took care of all chapters. I wrote the initial text for the archetype development as well as discussion and conclusion. I also did the data analysis for the archetype development.

Chatbots were also covered by an article published in April 2020. Here, I had the initial idea to structure existing chatbots in the form of a taxonomy. Together in the team of authors we gathered the data set and assigned the characteristics to each chatbot. I was responsible for analyzing the data and the description of the methodological procedure of the analysis. The literature review and the initial taxonomy was developed by my co-authors while I helped to improve it. The article was published in the "Business & Information Systems Engineering" journal.

A further article, which is available in the "Journal of Decision Systems", deals with factors that may encourage or hinder the use of SSBI. To answer the research question, a structural equation model was developed and validated by a survey. As first author, I was mainly responsible for all parts of the article, except for the calculations of the model, which were done by a co-author. We also discussed the model and the implications of the article as a team.

An approach for the realization of data science projects is described in an article, which was worked on in a group of 22 researchers. The article was released as an open-access publication by the University and State Library of Saxony-Anhalt, among others. In several iterations opinions on different aspects of the model were collected within the working group. I participated in many work phases and at the end I revised parts of the final document.

As a co-author I contributed to an article that describes the challenge of bring your own device regarding privacy concerns. In the article I was responsible for a case study and its embedding in the research design. Furthermore I made suggestions for improvements of the whole article. The article was presented at the "International Conference on Information Systems" and has been published in the corresponding proceedings.

In July 2019, a process model for the development of individual web traffic reports was published at the "Americas Conference on Information Systems". The model is based on a master thesis, which I supervised. As co-author I contributed to the development of the research design and the development of the final model.

At the "International Conference on Exploring Service Science (ESS)", we published an article about the interaction of machine learning algorithms and technical experts. The article was nominated as best paper. Together in a team we developed the presented approach. I wrote the texts for the second chapter and made suggestions for improvements for all chapters.

As a team we also developed a model for optimizing maintenance planning based on condition monitoring data. The final article was published in the proceedings of the "Operations Research Conference 2017". My work focused on the prototypical implementation of the jointly developed model.

An IWI Discussion Paper from February 2018 describes a framework with which planned or conducted research can be clearly presented and evaluated. The framework was developed in equal parts by the team. The first version of the text was written by me, while the evaluation of the model was conducted by all authors. The concept for the discussion chapter was also developed by all authors.

A further operations research model was published in the "OR Proceedings 2016". In this model, we optimize the provision of spare parts on the basis of condition monitoring data. We also developed the optimization model together as a team. I primarily took care of the prototype implementation and the sample calculations presented in the article.

On the basis of my master thesis, a paper was published at the "International Conference on Wirtschaftsinformatik". I was responsible for all parts and wrote the initial text. Co-authors supported in the development of the research design and for writing the discussion chapter.

Table 1. Publications that are part of the dissertation

#	Publication Date	Title	Authors	Outlet	WKWI[a]	JQ3[b]	Section
14	**Submitted** 09/2021	Self-Service Business Intelligence Application Scenarios - A Taxonomy for Differentiation	**Passlick, J.;** Grützner, L.; Schulz, M.; Breitner, M. H.	Information Systems and e-Business Management (ISeB)	B	C	4.4
13	**Submitted** 09/2021	Towards an Improved Literature Search: The Past and Guidelines for the Future	**Passlick, J.;** Werth, O.; Guhr, N.; Breitner, M. H.	Communications of the Association for Information Systems (CAIS)	B	C	2.3
12	**Submitted** 06/2021	A Framework for User-Centered Implementation of Chatbots	Janssen, A.; Rodríguez Cardona, D.; **Passlick, J.;** Breitner, M. H.	International Journal of Human-Computer Studies	B	-	3.5
11	10/2020	Predictive Maintenance as an Internet of Things enabled Business Model: A Taxonomy	**Passlick, J.;** Dreyer, S.; Olivotti, D.; Grützner, L.; Eilers, D.; Breitner, M. H.	Electronic Markets (EM)	A	B	3.6
10	04/2020	Virtual Assistance in Any Context - A Taxonomy of Design Elements for Domain - Specific Chatbots	Janssen, A.; **Passlick, J.;** Rodríguez Cardona, D.; Breitner, M. H.	Business & Information Systems Engineering (BISE)	A	B	3.4
9	03/2020	Encouraging the Use of Self-Service Business Intelligence – An Examination of Employee-Related Influencing Factors	**Passlick, J.;** Guhr, N.; Lebek, B.; Breitner, M. H.	Journal of Decision Systems	B	B	4.3
8	02/2020	DASC-PM v1.0 - Ein Vorgehensmodell für Data-Science-Projekte	Schulz, M.; Neuhaus, U.; Kaufmann, J.; Badura, D.; Kerzel, U.; Welter, F.; Prothmann, M.; Kühnel, S.; **Passlick, J.;** …; Gehrke, N.	Universitäts- und Landesbibliothek Sachsen-Anhalt	-	-	4.8
7	12/2019	Future of Flexible Work in the Digital Age: Bring Your Own Device Challenges of Privacy Protection	Degirmenci, K.; Shim, J. P.; Breitner, M. H.; Nolte, F.; **Passlick, J.**	Proceedings of the International Conference on Information Systems (ICIS 2019), Munich, Germany	A	A	3.3
6	07/2019	Using Web Analytics Data: A Participatory Design Model For Individual Web Traffic Report Development	Janssen, A.; **Passlick, J.;** Breitner, M. H.	Proceedings of the Americas Conference on Information Systems (AMCIS 2019), Cancun, Mexico	B	D	3.2
5	09/2018	Combining Machine Learning and Domain Experience: A Hybrid-Learning Monitor Approach for Industrial Machines *(Best Paper Nominee)*	Olivotti, D.; **Passlick, J.;** Axjonow, A.; Eilers, D.; Breitner, M. H.	Lecture Notes in Computer Science (LNCS)	B	C	4.7
4	05/2018	Maintenance Planning Using Condition Monitoring Data	Olivotti, D.; **Passlick, J.;** Dreyer, S.; Lebek, B.; Breitner, M. H.	Operations Research Proceedings 2017, Berlin, Germany	-	D	4.6

#	Publication Date	Title	Authors	Outlet	WKWI[a]	JQ3[b]	Section
3	02/2018	Assessing Research Projects: A Framework	**Passlick, J.;** Dreyer, S.; Olivotti, D.; Lebek, B.; Breitner, M. H.	IWI Discussion Paper #83, Institut für Wirtschaftsinformatik, Leibniz Universität Hannover	-	-	2.2
2	07/2017	Optimizing Machine Spare Parts Inventory Using Condition Monitoring Data	Dreyer, S.; **Passlick, J.;** Olivotti, D.; Lebek, B.; Breitner, M. H.	Operations Research Proceedings 2016, Hamburg, Germany	-	D	4.5
1	02/2017	A Self-Service Supporting Business Intelligence and Big Data Analytics Architecture	**Passlick, J.;** Lebek, B.; Breitner, M. H.	Proceedings of the International Conference on Wirtschaftsinformatik (WI 2017), St. Gallen, Switzerland	A	C	4.2

[a] Wissenschaftliche Kommission für Wirtschaftsinformatik 2008 WI-Orientierungslisten (WKWI & GI-FB WI 2008)

[b] JOURQUAL3 Verband der Hochschullehrer für Betriebswirtschaft (VHB 2015)

1. Introduction

1.1 Motivation, Problem Definition and Research Questions

The information systems research (ISR) discipline is versatile. This observation is also reflected in this cumulative dissertation, both very different subject areas, as well as different methods are used. One part deals with research methods as such. On the one hand, it deals with the question of how research ideas can be presented in a clear and concise way to provide a quick overview of the respective research idea. Another section deals with the search for literature. Over the years, the amount of literature to be searched has grown steadily, which makes finding the relevant articles a big challenge. The article deals with the question how the use of search methods has changed and what conclusions can be drawn from that for future research. The ideas for both articles were developed during the work on other research projects. Many findings can be applied to many types of ISR, sometimes even to completely different research disciplines.

The other parts of this dissertation deal with digital transformation (DT) and business analytics (BA). A uniform, generally accepted definition of digital transformation does not yet exist (Vial 2019). However, in the existing definitions, DT is seen primarily in the transformation of organizations, but different types of technologies are included in the definitions (Vial 2019). In this dissertation the definition of Bockshecker et al. (2018, p. 9) is used which define DT as "the process of organizational or societal changes driven by innovations and developments of ICT [information and communication technologies]." DT can lead to improvements of any kind of processes, but it can also create challenges that must be taken into account. E.g., with bring your own device (BYOD) initiatives there is the possibility of making work more flexible, but employees may also have concerns about privacy, which prevents them from using BYOD. There is also the possibility for companies to collect even more data about their website visitors, but these data must also be analyzed by the respective departments of the companies to obtain valuable information. Further possibilities arise through the use of chatbots. However, it is a challenge to find the right use cases for such a form of artificial conversational agent. Making the right decisions for the concrete implementation of a chatbot is also a challenge. The DT is also often discussed in relation to changed business models (Vial 2019). New business models such as those that exist in the field of predictive maintenance are interesting. This dissertation takes a closer look at such business models to derive specifics of Industry 4.0 business models (Passlick et al. 2020a).

Often, changes that come with DT have something to do with the analysis of data. Many data analysis processes in companies can be summarized under the term BA. This dissertation examines a trend that has been strongly analyzed in the BA environment in recent years and is called Self-Service Business Intelligence (SSBI). It is about the ability of departments to independently create analyses and reports to meet individual information needs (Alpar & Schulz 2016). In addition, the digital transformation also influences BA in many areas. One example of this are the new possibilities created by the analysis of sensor data. These sensor data have to be analyzed with BA methods to gain insights from the sensor data. In this dissertation two such use cases are treated. First the quantity of spare parts is optimized and next maintenance schedules are adjusted based on the sensor data. Another topic that has emerged in connection with of the DT is data science. Data science refers to advanced analyses that process data using, e.g., complex or machine learning algorithms.

This dissertation deals also with the question of how these complex algorithms can be combined with human expert knowledge, since the implementation of reliable analysis systems that detect anomalies in machines only with machine learning algorithms can be a big challenge. In addition, an article is described in which data science is defined more precisely and a process model is developed according to which data science projects can be carried out in a structured way. Table 2 lists all research questions that are covered in this thesis. The questions are grouped according to the three parts described in section 1.3 and sorted by their occurrence in this thesis.

Table 2. Research questions of the respective articles

Part	Section	Article Title	Research Questions / Objectives
A: Research Methods	2.2	Assessing Research Projects: A Framework	"How does a framework for assessing research ideas look like?"
	2.3	Towards an Improved Literature Search: A Call for Higher Precession (WIP)	"Elaborate the currently available literature search methods, their use, their advantages, and disadvantages, and to derive recommendations for the use of these methods."
B: Digital Transformation	3.3	Future of Flexible Work in the Digital Age: Bring Your Own Device Challenges of Privacy Protection	"How do companies deal with employees' privacy concerns regarding the introduction of BYOD?" "What is the impact of employees' privacy calculus of risks and benefits associated with the use of BYOD mobile devices on their attitude and in turn intention to use their private mobile devices for work?"
	3.2	Using Web Analytics Data: A Participatory Design Model For Individual Web Traffic Report Development	"Development of a [web analytics] process model which improves the adoption of the future users and develops individual web traffic reports."
	3.4	Virtual Assistance in Any Context - A Taxonomy of Design Elements for Domain -Specific Chatbots	"What are conceptually grounded and empirically validated design elements for domain-specific chatbots?" "Which chatbot archetypes can be empirically identified across diverse application domains?"
	3.5	A Framework for User-Centered Implementation of Chatbots	"What aspects need to be considered in chatbot implementation and how can these aspects be structured?"
	3.6	Predictive Maintenance as an Internet of Things enabled Business Model: A Taxonomy	"Which elements of PdM business models are important and which characteristics are interrelated in models that exist on the market?"
C: Business Analytics	4.2	A Self-Service Supporting Business Intelligence and Big Data Analytics Architecture	"How is a self-service supporting BI/big data analytics architecture constructed?"
	4.3	Encouraging the use of self-service business intelligence – an examination of employee-related influencing factors	"What influence do flexibility, expected time savings, BI experience and data quality have on the intention to use SSBI?"
	4.4	Self-Service Business Intelligence Application Scenarios - A Taxonomy for Differentiation	"Which dimensions and characteristics distinguish SSBI application scenarios?"
	4.5	Optimizing Machine Spare Parts Inventory Using Condition Monitoring Data	Development of a model to calculate the optimal amount of spare parts.
	4.6	Maintenance Planning Using Condition Monitoring Data	Creation of a model which calculates the optimal number of maintenance activities for a group of machines.
	4.7	Combining Machine Learning and Domain Experience: A Hybrid-Learning Monitor Approach for Industrial Machines *(Best Paper Nominee)*	Show how experiences of different parties of a product-service-system (PSS) can be combined in a hybrid-learning machine monitoring approach.
	4.8	DASC-PM v1.0 - Ein Vorgehensmodell für Data-Science-Projekte	To create a clearer definition of the term "data science". To create an understanding of the tasks and connections of data science projects.

1.2 Approaches and Methods

According to Abbasi et al. (2016) there are three research traditions in the ISR. These are economics of the IS, behavioral and design science oriented research. None of the research questions were addressed with a research design that comes from the economics of IS tradition. On the other hand, there are a few articles that do behavioral research. However, the majority of the articles in this dissertation follow a design science research (DSR) approach.

In DSR, the goal is to develop an artifact with which a problem can be, e.g., solved or simplified (Hevner et al. 2004). The artifact to be developed can consist, e.g., of software, but also the development of theoretical models is conceivable. In this dissertation there are 11 articles that can be assigned to the DSR tradition. In a few articles this is not explicitly described, but a model, either an operations research (OR) or a theoretical model, is developed. In the other articles, the research design is explicitly described and the details of the respective research design are discussed. A special form of the DSR is the taxonomy development according to Nickerson et al (2013). In three articles of this dissertation, a taxonomy is developed, which corresponds to the artifact of a DSR. Nickerson et al. (2013) have described a structured approach how to develop this special form of artifact. A taxonomy should group different objects of a subject. It consists of dimensions in which are characteristics that describe the objects. The characteristics of a dimension are exclusive, so only one characteristic per dimension can be assigned to each object (Nickerson et al. 2013).

Furthermore, articles in this dissertation are discussed in which behavioral research is conducted. More precisely, there are two articles that verify hypotheses by structural equation modeling. In both research projects the aim is to understand whether certain factors influence the intention to use of a particular IS approach. This kind of research allows a better understanding of human behavior and thus conclusions on how to address the potential users of an IS to promote its use.

Table 3 shows again the research designs used and in which sections they are applied. It should be noted that the details of the respective research designs are again adapted to the respective research. This can be read in the corresponding section or directly in the respective article.

Table 3. Overview of the research designs used in the dissertation

IS Research Tradition	Research Design	Amount	Section(s)
-	Research opinion	1	2.3
Design Science Research	DSR - explicit named	4	2.2; 3.2; 3.5; 4.2
	DSR - implicit named	4	4.5; 4.6; 4.7; 4.8
	Taxonomy development	3	3.4; 3.6; 4.4
Behavioral Research	Structural equation modeling	2	3.3; 4.3

1.3 Structure of the Dissertation

After having already given an overview of the publications that are part of this thesis and have been introduced into the dissertation, three major thematic parts follow. These topic parts arrange the articles thematically. As described, the parts are research methods in ISR, DT, and BA. Each part gives an overview of the articles assigned to it. This includes a description of the research project motivation, the research design used, and a summary of the results, implications, and limitations. Each of the three parts is introduced with a short preface to briefly outline the content of the block. After the three parts follows the description of an agenda for further research for each of the three parts. In this agenda, further research possibilities are discussed in general, as concrete proposals are already made in the respective articles. In a final chapter the findings of the dissertation are summarized.

Figure 1 shows the described research parts and the articles they contain. Additionally, it shows which research streams exist within a part and roughly in which chronological order the articles were created. It is also shown which research design was used in the article. In some cases, there are not only connections between the articles within a research stream, but also between the different research streams. These are findings that are at least in parts included in the following articles. Even the articles within a stream are only partially based on each other. In front of the name of the article is the number of the respective section in which the article is described.

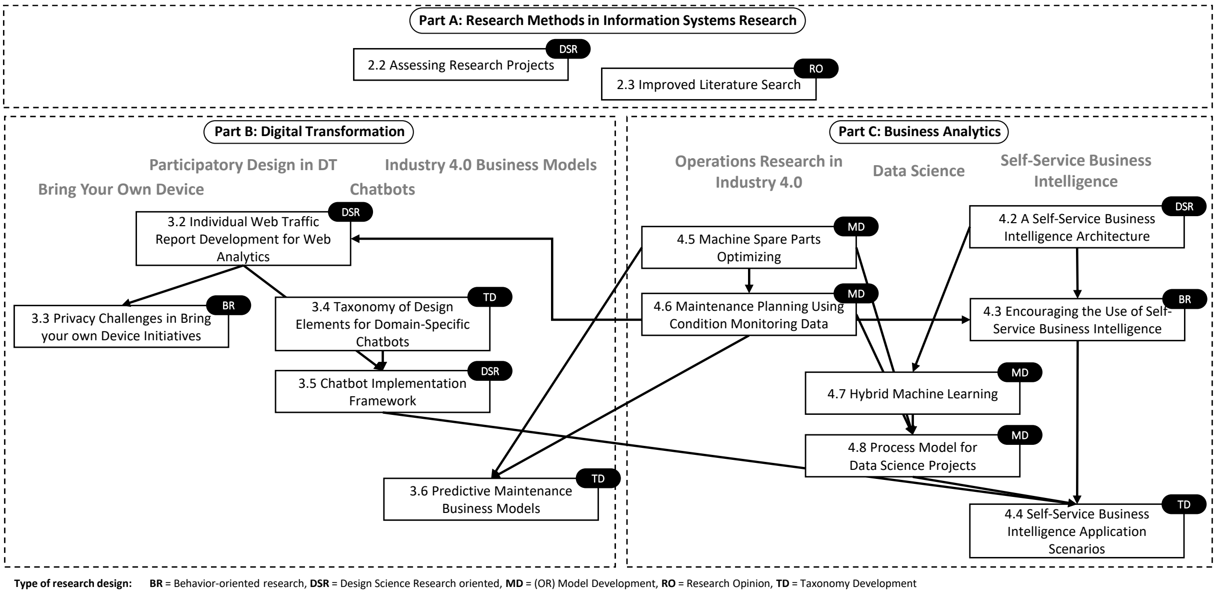

Figure 1. Overview of the parts and articles of this dissertation

2. Part A: Research Methods in Information Systems Research

2.1 A Primer to Research Methods in Information Systems Research

ISR is characterized by its interdisciplinarity and therefore different research methods are used. Roughly speaking, these methods can be differentiated into economics of IS, behavioral and design-oriented approaches. In this dissertation, methods of the last two areas are applied. Regardless of the chosen approach or a deliberate combination of both, a literature review is always the basis for the conducted research. This is the only way to determine what has been researched so far and, if necessary, to base one's own research on it. To conduct a review in a meaningful way, a comprehensive literature search is necessary to find as many relevant articles as possible (Passlick et al. 2021b). Even more fundamental is the general assessment of a research project.

These two topics, the literature search and the general assessment of a research project, are covered in this section of the dissertation. The ideas for both topics have been developed in the course of other research projects. We were faced with the challenge of quickly getting an overview of the ideas for new research projects from students or other doctoral candidates. The aim was to identify problems or inconsistencies in the projects in advance. In a DSR study, a framework is developed, which should enable a simple visualization of research projects (2.2). Another idea for research arose during the literature search on a research project. It has been noticed that many articles decidedly describe the keywords used to search for literature. In contrast, other literature search methods are hardly considered (Passlick et al. 2021b). However, in our practice we have used quite different search methods and achieved good results. This observation is investigated in more detail in the research presented in section 2.3. Figure 2 shows the articles from part A of the dissertation.

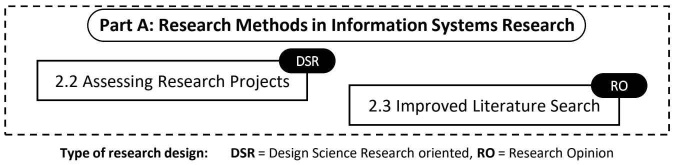

Figure 2. Overview of the articles in Part A

2.2 Assessing Research Projects

2.2.1 Overview

This part discusses the article "Assessing Research Projects: A Framework" which was published as an IWI Discussion Paper (Appendix 1). It was prepared for a discussion at the Doctoral Colloquium of the Universities of Southeast Lower Saxony (DoKoSON).

2.2.2 Motivation and Research Topic

An essential part of working as a scientist is the assessment of scientific projects. Either as an external reviewer for journals or conferences, reviewer of theses or ideas where research is still in its infancy, a researcher has to assess the quality of a scientific paper. Especially as a new researcher this is a major challenge. It is about identifying the essential aspects that make a successful research. In some respects, this is comparable to the assessment of business models. For business models, the established framework known as the “Business Model Canvas” by Osterwalder et al (2010) already exists. This idea has already been partly transferred to the scientific context (Latham 2016; Nagle & Sammon 2016). In all methods, the aim is to visualize the respective ideas in a meaningful way (Passlick et al. 2018). The previous frameworks for the scientific context either have too much focus (Nagle & Sammon 2016) or are more general (Latham 2016). There is also a lack of a kind of risk assessment, which should be carried out by inexperienced researchers in particular. The motivation described above, in conjunction with previous research, results in a research question about what a suitable framework for assessing research looks like.

2.2.3 Developed Framework for the Assessment of Research

The framework we have developed combines the approaches of existing research for the presentation of research projects and extends them by a risk consideration. Roughly it consists of two blocks. In the first block, the problem to be addressed, the resulting objectives, related studies, and the hypotheses and/or the research questions arising from them are to be described. Thus, the first block shows why the respective research is justified.

The second block, on the other hand, focuses on the possible way to answer the given research goal or research question. First, the research design is to be described. Here, for example, it can be mentioned that it is planned to use the DSR paradigm or that it was used. However, combinations of different paradigms can also be presented here. This results in different methods or procedures which have to be carried out due to the research design. The phases or methodical steps are shown in a further box. To the left of the box with the steps, risks are to be listed which could complicate or prevent the conduction of the planned research. For example, in quantitative research it is crucial that a critical mass of empirical data is available to be able to make generalizable statements. It may not be clear at the planning stage of a research project whether this critical mass can be achieved. For example, it can be unclear how many participants can be found for a survey. On the other side, the planned time is shown in another box. The aim here is to show whether the research phases presented are feasible in the planned time. For research that has to be completed by a certain date, for example for scientific conferences, the time planning is also an important aspect. This time planning can then be assessed according to whether the planned times for the respective research phases are realistic. The last box describes the limitations of the research. Here, the points can be mentioned which perhaps deliberately not be dealt with in the respective research to allow a stronger focus. Figure 3 shows a shortened sketch of the developed framework. The original version is optimized for presentation on a Din A4 sheet (Passlick et al. 2018).

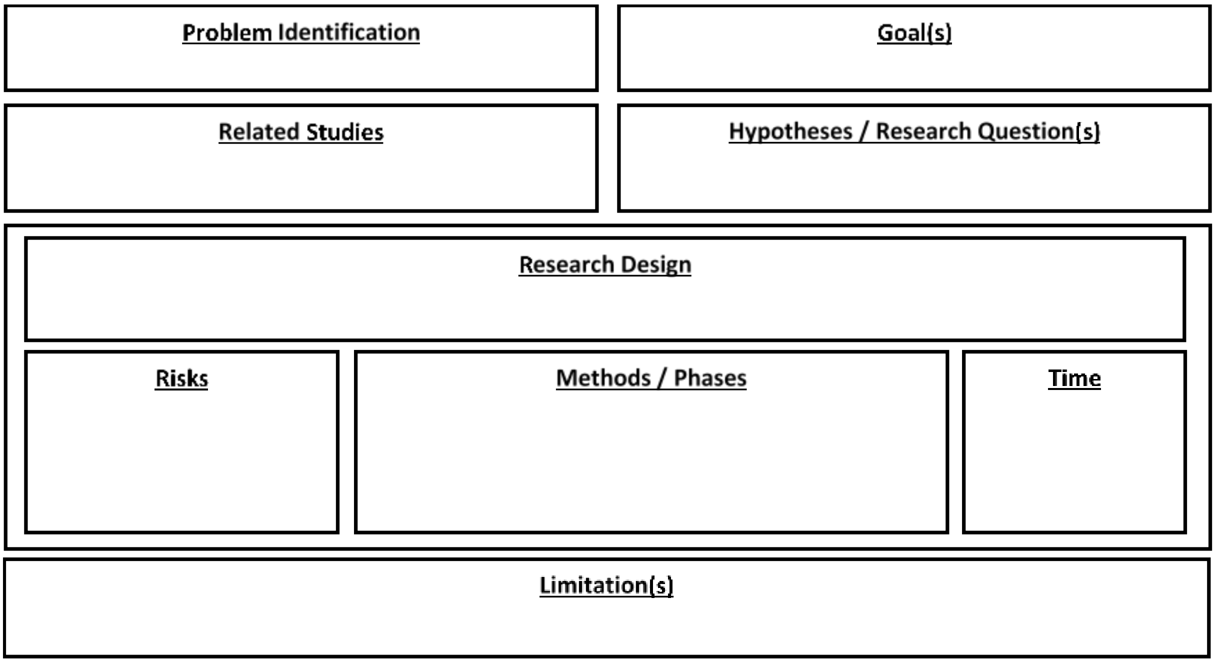

Figure 3. The developed framework for assessing research projects (Passlick et al. 2018, p. 6)

2.2.4 Summary of the Results, Contributions, and Limitations

With the presented framework we show how to present ISR in a clear and concise way. For this purpose, we have combined existing research and extended it by aspects that seemed important to us from our everyday life as researchers. After the publication of the IWI Discussion Paper a discussion with other researchers took place. They also confirmed that such a framework is helpful, but suggested slight adjustments. For us this shows that our framework should be seen as a basis which every researcher can adapt to her or his own requirements. We provide the basis for this and this basis is especially important for inexperienced researchers, as it helps to consider many important aspects when planning a research project. That there is a need for structuring research projects, is also shown by the fact that since the publication of our discussion paper, further articles have been published to support DSR projects. In an article by Herwix and Rosenkranz (2019) a multi perspective framework is described, which presents possible tool support of DSR processes from different perspectives. The project view is an essential part of this framework and the aim is also to reduce complexity.

We have only discussed one application in the ISR environment. It is conceivable that the framework can also be used in other disciplines. However, we have not yet been able to evaluate this transferability. This gap is an opportunity for further research, which will test the framework in other disciplines.

To provide more examples of how to use the framework, the other articles presented in this thesis are summarized with the framework. For this purpose we have made slight modifications, since the framework in the second block primarily deals with project planning aspects that are not relevant for this thesis. Thus, the blocks risk and time are removed. In the other areas, the presentation is identical to the version presented in the discussion paper. While planning of a research project plays an important role in the discussion paper, it is shown here that ex-post research can also be presented with the framework.

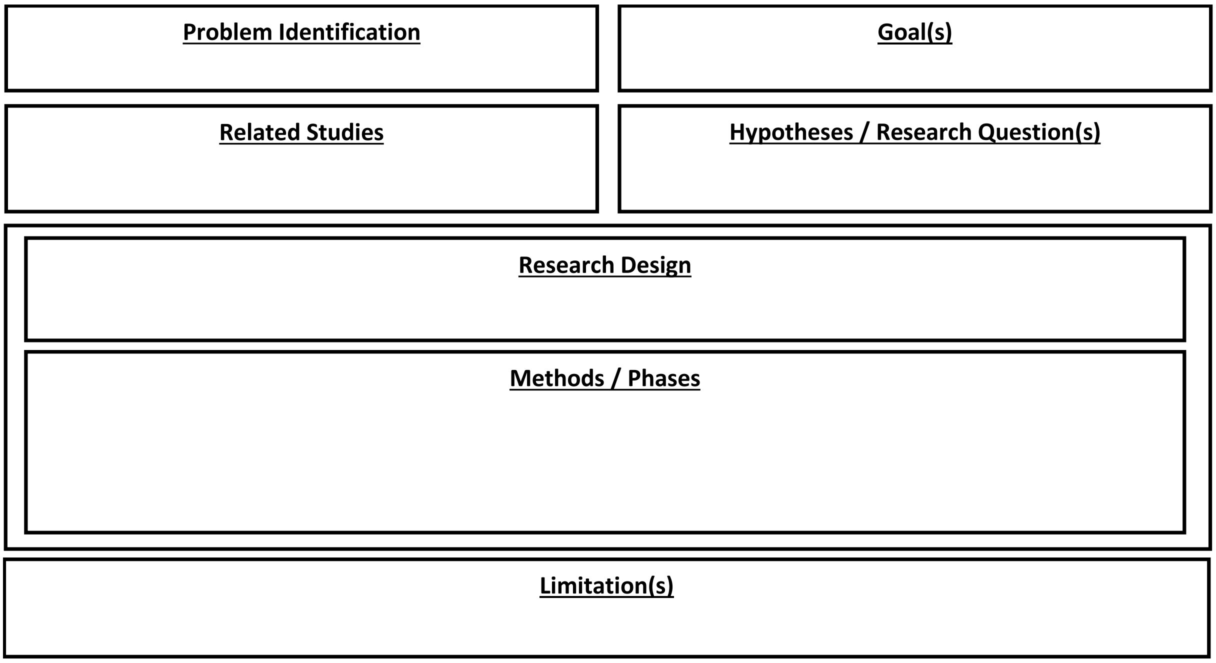

Figure 4. The modified version of the framework

2.3 Improved Literature Search

2.3.1 Overview

This part discusses the article "Towards an Improved Literature Search: The Past and Guidelines for the Future" which was submitted to Communications of the Association for Information Systems (Appendix 2). Table 4 summarizes the article.

Table 4. Overview of the research on improved literature searches

Problem Identification	**Goal(s)**
• Assumption: Currently strong focus on keyword searches • Assumption: Newer search methods are only used sporadically	• Review of the described assumptions • Discussion of the available search methods • Guidelines for improved literature searches
Related Studies	**Hypotheses / Research Objective(s)**
• Webster and Watson (2002) • Vom Brocke et al. (2015) • Boell and Cecez-Kecmanovic (2014) & (2015)	• "Elaborate the currently available literature search methods, their use, their advantages, and disadvantages, and to derive recommendations for the use of these methods."

Research Design and Methods / Phases
• Description of the basic considerations when searching for literature • Analysis of available search methods • Analysis of current literature search practice in IS research • Findings from the analyses in the form of guidelines for improved literature searches
Limitation(s)
• Only consideration of the IS search practice • Only intensive consideration of active search methods • No consideration of when an article is relevant • No measurement of the precision of a search

2.3.2 Motivation and Research Topic

The amount of literature to be searched by researchers is constantly growing. The basis of any research project should be a detailed literature review to be able to work out a research gap in a well-founded way (Baker 2000). An effective method must therefore be used to find as much relevant literature as possible in a limited time. The goal of including all articles relevant to the research project can only be achieved if the search methods have a sufficient precision. The IS community has already started a discussion on how to improve the efficiency of literature searches (Boell & Cecez-Kecmanovic 2015; Watson 2015). In recent years, methods have also been presented that are intended to increase the efficiency of literature searches with new approaches (e.g. Koukal et al. 2014). While the combination of keyword searches with forward and backward searches has already been discussed (Webster & Watson 2002), a combination with newer methods was not yet part of the discussion. This is one of the aims of this research which is to investigate how new literature search methods can be combined with other methods. At the same time, a discussion is to be initiated on what should be important in the future when reviewers evaluate a literature search.

There are three goals in a literature search. The search should be reproducible, comprehensive, and precise (Sturm & Sunyaev 2019). Taking into account the already mentioned discussion in the IS community, it can be assumed that precision has been less in focus so far (Boell & Cecez-Kecmanovic 2015; Watson 2015). However, in the future, precision in the assessment of literature searches must also play a role to cope with the large amount of literature. This research should consider the available search methods from this point of view. Also, the various search strategies described in the article must be considered.

2.3.3 Research Design and Methodology

The research objective is pursued in several steps. First of all, it is described which goals and which search strategies exist for carrying out a literature search. In the next step, the existing search methods are described. The focus is set on active methods. Passive methods, such as alerting services, only provide results if, for example, new search results for a search term exist. However, this event cannot be planned and therefore cannot be used for an active literature search. As a result of the analysis of the available methods for literature search, the advantages and disadvantages of the search methods can be presented. Knowledge of the advantages and disadvantages is the prerequisite for describing a meaningful combination of the different methods in the later course of the project. Furthermore, it is examined how the different search methods have been used so far. For this purpose 235 literature reviews from the period 1999 to 2020 are used to analyze the documentation of the literature searches and the search methods used (Passlick et al. 2021b). Based on the findings from the use of search methods in past literature reviews, the available search methods, and the research on literature search to date, recommendations are developed. Especially the combination of different search methods is recommended to make the best use of the advantages of the respective search methods.

2.3.4 Summary of the Results, Contributions, and Limitations

First of all, the work gives us an overview of different search methods and their advantages and disadvantages. It is shown that the respective search methods can be carried out in different ways. For some methods there are different tools, some of which search for literature with completely different approaches. For example, the tools used to perform a related article search use diverse algorithms to identify similar articles. Also, for the expert consultation there are different approaches. However, the search methods all have the necessary input in common, for example suitable experts or relevant articles.

In a second step, we were able to analyze the previous practice of literature searches. We analyzed how many search methods were combined in the literature reviews, which search methods were used, and how this use has changed over time. From this analysis, we can learn that up to now rather few methods have been used and combined on average. Furthermore, keyword, forward / backward search, and browsing in outlets are the most common methods. The use of the search method related article search was not described at all in the examined data set. Another finding is that the search methods used have changed over time. While browsing in outlets was the most important search method at the beginning of the period under review, the keyword search has become the most frequently used method in recent years. From this observation, a trend towards greater automation in literature searches can be seen.

Based on the findings of the first two steps, seven recommendations are derived to improve future literature searches. These recommendations describe also how, in our view, the search for literature is changing or should change. A search strategy should be defined as a starting point (1.), different search methods should be combined (2.), and automated methods should be used when comprehensiveness and precision are important for the search strategy (3.). In such cases, the search should also be iterative (4.). In addition, it should also be considered to use more automated methods. This should be done to search more precisely and to possibly find articles from other disciplines (5.). Google Scholar can be helpful, but the problems of using it should be taken into account (6.). The documentation of the literature search is still important, because only in this way, at least to some extent, reproducibility can be made possible (7.) (Passlick et al. 2021b).

3. Part B: Digital Transformation

3.1 A Primer to Digital Transformation

One phenomenon that has been a major topic of discussion in recent years, both in the media, politics, and academia, is the digital transformation. New technical possibilities are bringing changes in many areas of everyday life. Bockshecker et al (2018) define the digital transformation as "the process of organizational or societal changes driven by innovations and developments of ICT [information and communication technologies]. DT [digital transformation] includes the ability to adopt technologies rapidly and affects social as well as technical elements of business models, processes, products and the organizational structure" (p. 9). This thematic block of the dissertation deals with these changes.

Problems related to changed working methods are discussed using the example of BYOD (3.3). Using two case studies and a structural equation model, the study examines the extent to which privacy concerns hinder the use of BYOD. In addition to new work opportunities, more data can be analyzed in the course of the digital transformation to support decisions. The fact that technical possibilities alone are not enough to generate company-wide added value is described in section 3.2. An approach is presented, how the new potentials can be better exploited by involving the users. The participatory design model was developed with a DSR approach.

In another article, chatbots are discussed, which enable a completely new customer communication, but also new or different business models. In the chatbot research stream, a taxonomy is first developed that classifies domain-specific chatbots (3.4). In addition, a framework is described that allows the structured development of new chatbots (3.5). This framework is developed in a DSR approach. New business models are examined using the example of predictive maintenance (3.6). Based on new technical possibilities, the individual state of a machine can be determined automatically, which enables new services. Based on the procedure model of Nickerson et al. (2013) a taxonomy is developed, which makes business models comparable. In addition, archetypes are created that show which typical PDM business models exist. The relations of the mentioned articles from part B are shown in Figure 5.

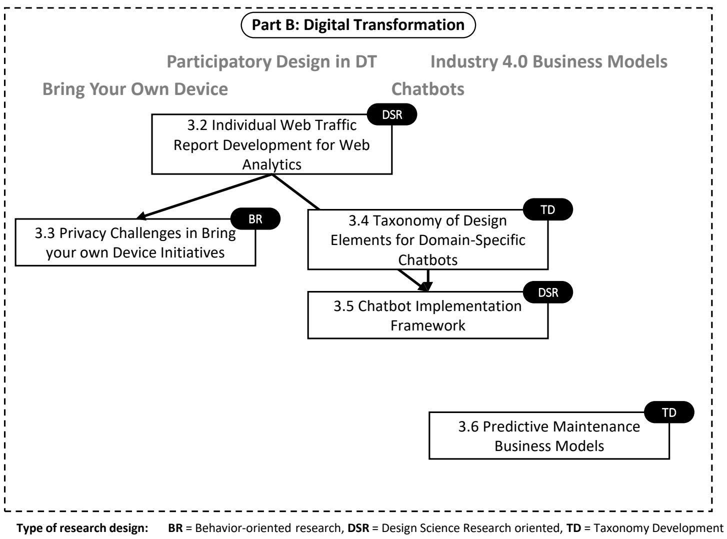

Figure 5. Overview of the articles in part B

3.2 Individual Web Traffic Report Development for Web Analytics

3.2.1 Overview

The section is based on the article “Using Web Analytics Data: A Participatory Design Model For Individual Web Traffic Report Development” and is published in the proceedings of the twenty-fifth Americas conference on information systems (Appendix 3). The research is summarized in Table 5 and is a further development of Antje Janssen's master thesis.

Table 5. Overview of the research on individual web traffic report development

<table>
<tr><td><u>Problem Identification</u>
Many companies collect web analytics data, but do not use it to its fullest extent</td><td><u>Goal(s)</u>
Increased use of web analytics data by the various departments of an organization.</td></tr>
<tr><td><u>Related Studies</u>
Kaushik (2007)
Hausmann et al. (2012)
Studer and Leimstoll (2015)</td><td><u>Hypotheses / Research Objective(s)</u>
“Development of a [web analytics] process model which improves the adoption of the future users and develops individual web traffic reports.”</td></tr>
<tr><td colspan="2"><u>Research Design and Methods / Phases</u>
DSR based on Vaishnavi and Kuechler (2015)
Problem understanding
Open, semi-structured interviews
Literature review (Webster & Watson 2002)
Development of a web analytics development model
Focus group discussion with ten employees of a sample company
Model demonstration
Case study in a sample company of the process model application</td></tr>
<tr><td colspan="2"><u>Limitation(s)</u>
Case study only in one company</td></tr>
</table>

3.2.2 Motivation and Research Topic

Even before digital transformation was discussed, web analytics (WA) was discussed. With the success of the Internet search engine “Google” it became clear how valuable information about the users of a website can be. Many companies have started to collect data about their website users. However, collecting data alone is not enough to create added value for a company. It should be the goal to provide users with the WA data for which they have a value in decision making (Waisberg & Kaushik

2009). The different business units (BUs) of a company usually have very different requirements, which must be taken into account accordingly (Hausmann et al. 2012).

One way of using the data is by calculating key performance indicators (KPIs). They can be used to measure certain activities on the website and derive information accordingly. KPIs should be selected individually, as different departments have different requirements for the information to be derived from the use of the website (Kaushik 2007). A procedure is therefore necessary in which WA KPIs are developed that are adapted to the individual requirements. Previous research has mainly focused on algorithms for evaluating website usage data (Hausmann et al. 2012). How this data is then sensibly distributed within the company and used has been less studied. Studer and Leimstoll (2015) developed a framework that supports the implementation of WA projects. However, an evaluation in practice is missing. The research gap, identified in this research, is the lack of a comprehensive model that includes future users, performs KPI selection, develops reports, and is evaluated within a case study.

3.2.3 Research Design and Methodology

This model was developed in a DSR approach. The approach is mainly based on Vaishnavi and Kuechler (2015). In addition, socio-technical research was included, since the problem under consideration is not a purely technical one, but social factors must also be taken into account (Silver & Markus, 2013). As a first step, the present problem was identified. For this purpose, open, semi-structured interviews were conducted in a sample company. Furthermore, a literature review was conducted, using the guidelines of Webster and Watson (2002). Afterwards the actual development of the process model was carried out. This step was done on the basis of the findings of the problem identification, as well as a focus group discussion, which was conducted in the sample company. The first version of the model was then used in the sample company to create individual WA reports which represents the demonstration of the artifact in a DSR research design. Findings from this case study were integrated into the final model.

3.2.4 Summary of the Results, Contributions, and Limitations

The result of this research is a process model, which develops WA Reports with the involvement of the future users. It is divided into three project phases. The phases are based on the participatory design model of Spinuzzi (2005) and are shown in Figure 6.

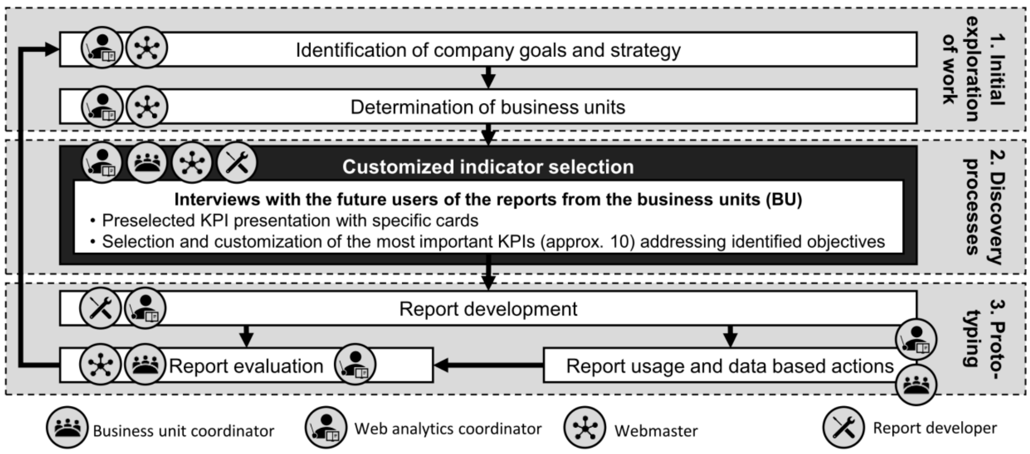

Figure 6. The developed WA process model (Janssen et al. 2019, p. 5)

In the first phase “initial exploration of work” the goals and strategy of the respective company are identified. Then, the various business units (BUs) are determined for which individual WA reports are to be created in the further course of the project. During the second phase “discovery processes” the main part of the work is done. Here, the indicators relevant to the respective business unit are selected. For this purpose, a pre-selection is made within interviews with the future users by using paper cards. Then, the final KPIs are selected and, if necessary, adapted to the individual questions. The third phase “prototyping” includes the technical implementation of the reports. This is followed by the evaluation of the reports and their use. As a result of the report evaluation new findings may occur, which in turn start another iteration. The cycle starts again with a review of the goals of the website. The model also describes the different roles of persons who perform the activities described. These roles will not be discussed further here. For further details see Janssen et al. (2019).

In the case study it was found that the inclusion of the later users also leads to an increased acceptance of the WA reports. Through the individual interviews the users get a better understanding of how WA works and which analysis possibilities exist. It is also important that the users are presented with prepared indicators to reduce complexity (Spinuzzi 2005). Also, it can be confirmed that the BUs have very different requirements for WA reports, since 14 indicators were selected by only one business unit. Thus, this research provides a structured approach to create a broad use of the generated data by the BUs once the technical prerequisites for WA have been created.

The limitation of this work is the fact that only one case study is conducted. However, it is assumed that a transfer to other companies is possible, because other companies have similar WA requirements. Exceptions are probably companies whose main business is conducted via the website or even a web service. Here, WA is even more relevant than for a medium-sized engineering and manufacturing company.

3.3 Privacy Challenges in Bring your own Device Initiatives

3.3.1 Overview

The section is based on the conference paper “Future of Flexible Work in the Digital Age: Bring Your Own Device Challenges of Privacy Protection” and is published in the proceedings of the international conference on information systems (Appendix 4). It was presented at the conference in Munich 2019. Table 6 summarizes the conducted research.

Table 6. Overview of the research on privacy challenges in bring your own device initiatives

Problem Identification	**Goal(s)**
• Privacy concerns may inhibit the BYOD initiatives	• To improve BYOD initiatives regarding user privacy concerns while taking into account cultural differences

<table>
<tr><th><u>Related Studies</u></th><th><u>Hypotheses / Research Question(s)</u></th></tr>
<tr><td>Loose et al. (2013)
Junglas et al. (2019)</td><td>“How do companies deal with employees’ privacy concerns regarding the introduction of BYOD?”
“What is the impact of employees’ privacy calculus of risks and benefits associated with the use of BYOD mobile devices on their attitude and in turn intention to use their private mobile devices for work?“</td></tr>
<tr><th colspan="2"><u>Research Design and Methods / Phases</u></th></tr>
<tr><td colspan="2">Conduction of two case studies
For exploring how work councils deal with privacy concerns in BOYD initiatives
Hypothesis Development
To investigate the BYOD factors that influence employee intention to use BYOD
Conduction of a survey
Test of the hypotheses with structural equation model</td></tr>
<tr><th colspan="2"><u>Limitation(s)</u></th></tr>
<tr><td colspan="2">Comparison of three countries
Self-Selection bias of survey respondents
Generalizability of the case studies</td></tr>
</table>

3.3.2 Motivation and Research Topic

One part of the digital transformation is the possibility to work more independently of a specific location. One component of enabling this independence is the use of private devices for work purposes. This use is called BYOD and describes, for example, the retrieval of e-mails with a private smartphone (Loose et al. 2013). The advantage of this possibility is not only a more flexible workplace, but also more flexible work hours. In addition, higher job satisfaction is assumed (Degirmenci et al. 2019). On the other hand, there are also some challenges in using BYOD. From a company's point of view, there is a risk that no company software is used and thus there is a risk that data protection or data security is compromised (Junglas et al. 2019). Companies therefore install mobile device management software that can monitor the mobile devices to prevent data leakage. However, this device management software may have extensive rights on the end devices with which the employee could be monitored. These rights can lead to concerns on the part of employees to participate in a BYOD initiative. In this research, exactly these concerns are investigated. In two research questions, it is first asked how companies deal with the privacy concerns of employees. In a second question, the influence of the concerns and the advantages of BYOD on the employees' intention to use BYOD is examined.

3.3.3 Research Design and Methodology

To answer the first research question, case studies were conducted in two companies. These studies investigated the extent to which BYOD initiatives have already been implemented in the companies and how the works councils represent the employees with regard to privacy concerns with BYOD. The studies were conducted in a "multinational corporation in the automotive industry with around 250,000 employees" and in a smaller company with around 3,700 employees (Degirmenci et al. 2019, p. 4).

To investigate the second research question, a structural equation model was developed that examines the influence of privacy concerns on the intention to use BYOD. After deriving the hypotheses based on the literature, a survey was conducted to test the hypotheses. The survey was conducted in the United States, Germany, and South Korea. An online survey questionnaire was used, which was distributed via social networks, e-mail, and personal networks. By analyzing different countries, potential cultural differences in privacy concerns can be examined. The survey was analyzed using partial least squares path modeling (Degirmenci et al. 2019).

3.3.4 Summary of the Results, Contributions, and Limitations

In both companies investigated in the case studies, device management software is used to monitor BYOD. Theoretically, private data of employees can be collected with it. In both cases, the works councils have paid special attention to the protection of employee data. This has led to special regulations being agreed upon to ensure data protection. In one company it was agreed with the works council that the data can only be viewed by administrators and that the works council must agree to the collection of the data. It is therefore evident that the presumed privacy concerns also exist among works councils and that works councils also pay great attention to data protection when negotiating works agreements. However, it remains to be seen whether these concerns also exist among employees. For this purpose, a survey was conducted among employees as part of the second research question.

The survey is based on a structural equation model. This model measures the influence of the BYOD attitude on the BYOD intention to use. The BYOD attitude is in turn influenced by the BYOD benefits and risks. It is assumed that privacy concerns have an influence on the BYOD risks. Figure 7 visualizes the constructs and their influence on each other.

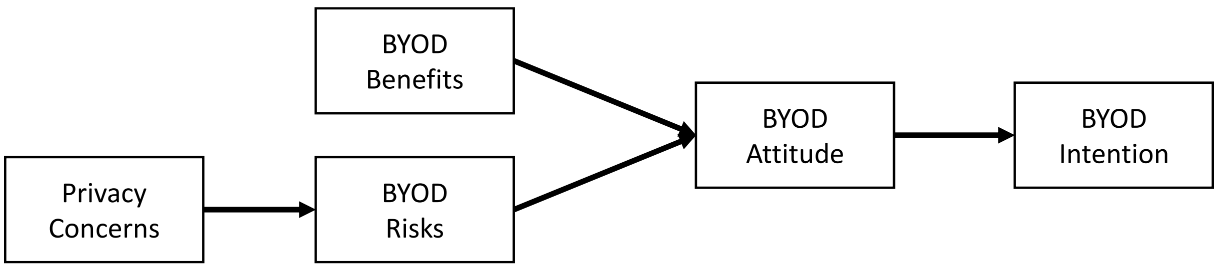

Figure 7. The investigated structural equation model (Degirmenci et al. 2019)

After analysis of the survey all hypotheses can be confirmed. It can be confirmed that privacy concerns also have an impact on BYOD risks among employees. The risks influence the attitude and this influences the intention to use BYOD. Privacy concerns are considered an obstacle to the intention to use BYOD. It can also be noted that the risks in the USA have a stronger influence on attitude than in South Korea. Thus, there are differences between the cultures, but no significant ones regarding the influence of privacy concerns on the BYOD risks. In general, it can be said that agreements between works councils and employers are important because they can help to reduce the privacy concerns of employees. Further research can explore in more detail how organizational culture can help to reduce these concerns. Furthermore, the sensitivity of private data or government initiatives for better privacy could have an influence on the concerns. Further research could also be carried out here.

The study is limited on the one hand by the fact that only three different countries are compared. While this study allows a first impression of cultural differences in terms of privacy concerns, other countries could provide an even more comprehensive view. Furthermore, the results could be biased by the fact that employees are more likely to participate if they like BYOD and therefore have lower privacy concerns. The conclusion that works councils have privacy in mind when discussing BYOD is based only on the two case studies. This small sample may limit generalizability, but both companies are internationally active and it is likely that other internationally active companies are doing similar things. However, this limitation offers potential for further research.

3.4 Taxonomy of Design Elements for Domain-Specific Chatbots

3.4.1 Overview

The article "Virtual Assistance in any Context - A Taxonomy of Design Elements for Domain-Specific Chatbots" is described and discussed in this section. It is published in the "Business & Information Systems Engineering" journal and is part of a special issue on "User Assistance for Intelligent Systems" (Appendix 5). Table 7 summarizes the conducted research.

Table 7. Overview of the research on a domain-specific chatbot taxonomy

Problem Identification	**Goal(s)**
• No holistic view on chatbots • Scientific knowledge restricted to particular aspects	• Development of a taxonomy for domain specific chatbots
Related Studies	**Hypotheses / Research Question(s)**
• Diederich et al. (2019) • Di Prospero et al. (2017)	• "What are conceptually grounded and empirically validated design elements for domain-specific chatbots?" • "Which chatbot archetypes can be empirically identified across diverse application domains?"

Research Design and Methods / Phases
Taxonomy development based on Nickerson et al. (2013) • Literature review • Analysis of domain specific chatbots Taxonomy evaluation (Szopinski et al. 2019) • Focus group discussion Archetype development • Cluster analysis
Limitation(s)
• No consideration of the success of a chatbot • Dataset is only a time consideration due to constant technical development • No testing of the significance of the archetypes in practice

3.4.2 Motivation and Research Topic

A further aspect of the digital transformation is the increased use of conversational agents. This is made possible by advances in artificial intelligence and natural language processing (Nguyen & Sidorova 2018). One form of conversational agents are chatbots (Janssen et al. 2020). The idea of artificial assistants communicating via natural language has existed for some time. However, general assistants such as Cortana, Alexa, Google Assistant, and Siri have given chatbots a new boost in recent years (Janssen et al. 2020). This trend has also increased the interest in domain-specific chatbots (Di Prospero et al. 2017). These are chatbots that have been developed for a specific topic or task and they have not yet been generally investigated in previous research. Either specific use cases or certain aspects, such as technical capabilities, have been investigated.

This research is devoted to this research gap. It is investigated which different dimensions differentiate domain-specific chatbots and which archetypal domain-specific chatbots exist. A taxonomy helps to give an overview of the possibilities and questions that must be considered when discussing chatbots (Diederich et al. 2019; Janssen et al. 2020).

3.4.3 Research Design and Methodology

To find the dimensions, a taxonomy is to be developed with which the various forms of the dimensions can be structured. A structured process model for the development of taxonomies is available from Nickerson et al (2013). In several iterations both theoretical approaches and empirical data are used to develop the taxonomy. In this research, five iterations were carried out. In the first iteration the first dimensions and characteristics were derived on the basis of a literature review. In the further iterations 103 domain-specific chatbots were analyzed. These chatbots were found via botlist.co and chatbots.org. Both databases sort the entries by domain and let the entries be sorted by popularity.

However, both databases were unfortunately changed in the meantime or no longer exist in their former form. Therefore, it is not possible to update or complete the data set via these databases.

After the taxonomy had been developed, an evaluation was carried out. Taking Szopinski et al. (2019) into account, three focus group discussions were conducted. Depending on the discussion, the participants were researcher with knowledge of chatbots, researcher with methodological knowledge of taxonomy development, and practitioners with knowledge of chatbots. The discussions were conducted according to the criteria of comprehensiveness, understandability, wording, and extendibility proposed by Szopinski et al (2019). In the discussions, it was found that the taxonomy is helpful to classify an own chatbot and compare it with others. No new characteristics or dimensions were found, but several dimensions and characteristics were renamed based on the discussions.

Once the development was completed, the final taxonomy was used to determine the domain-specific archetypes that are asked for in research question 2. For this purpose, we first looked at the distribution of the characteristics in the respective dimensions in the data set under investigation. Thus, we can get an idea that certain characteristics are much more strongly represented in the data set. For example, more than two thirds of the examined chatbots were assigned to a rule-based system. In a next step, a cluster analysis was performed. First, the Ward (1963) algorithm was applied to the data set. Unlike partitioning algorithms, this algorithm has the advantage that the desired number of clusters does not have to be specified in advance. The result of the Ward (1963) algorithm can be visualized with a dendrogram. In the dendrogram, the distances between all chatbots are displayed. The distance symbolizes the difference between two chatbots. If the differences are small, the chatbots are connected by a very short way. In the dendrogram, it can be seen that either two or five groups are a useful separation of the data set. This finding can be seen from the fact that a division into three or four groups shows a very similar difference to a division into five groups. For two and five groups, clustering was then performed using the k-means algorithm. The k-means algorithm is a partitioning algorithm that often leads to better results than hierarchical algorithms, which includes the Ward (1963) algorithm, if a reasonable number of clusters is given in advance (Balijepally et al. 2011). For the two and five groups, the respective distribution of the characteristics was then examined. It could be seen that a subdivision into five groups produced a more plausible result. Thus, we assume that five archetypes exist in the data set. Five archetypes could then be formed from these five groups.

3.4.4 Summary of the Results, Contributions, and Limitations

The archetypes found were named goal-oriented daily chatbot, non goal-oriented daily chatbot, utility facilitator chatbot, utility expert chatbot, and relationship-oriented chatbot. Practitioners can use these archetypes to assess to which archetype their chatbot or a planned chatbot belongs and whether it differs strongly from the respective one or not. This makes it easier to decide for or against certain characteristics when constructing the chatbot.

The objective of research question 1 could also be achieved, since a taxonomy was developed that classifies different domain specific chatbots. The taxonomy is composed of 17 dimensions, which were divided into three perspectives. These perspectives are called intelligence, interaction, and context and should increase the clarity. Looking at the examined data set, it is also apparent that many chatbots do not yet make use of all technical possibilities. For example, chatbots often use a communication with fixed answers. However, it would also be possible to implement a text recognition system that can interpret the respective answer from a free text. Further research can be devoted to the question why this is the case and whether more intelligent solutions will be used in the future.

Research has not considered how far the success of a chatbot is influenced by certain characteristics. For this purpose, it first have to be defined when a chatbot is considered successful. These challenges offer potential for further research. The data set examined only represents the situation at the time of the data collection. Also in this case, future research can investigate to what extent the occurrence of the assigned characteristics changes. This research also could not test how relevant the archetypes found are for practice. The value of these archetypes could be demonstrated in practice through further interviews with those responsible for chatbots or case studies.

3.5 Chatbot Implementation Framework

3.5.1 Overview

Here, the manuscript with the title "A Framework for User-Centered Implementation of Chatbots" is discussed. It was submitted to the "International Journal of Human-Computer Studies" journal (Appendix 6). Table 8 summarizes the conducted research.

Table 8. Overview of the research on a chatbot implementation framework

Problem Identification	**Goal(s)**
• Much research on specific and technical aspects for the development of chatbots • Little inclusion of human-centered aspects • Practice misses structure when introducing chatbots in the corporate context (Janssen et al. 2020)	• Support in the implementation of chatbots
Related Studies	**Hypotheses / Research Question(s)**
• Laumer et al. (2019) • Janssen et al. (2020) • Benyon (2014)	• "What aspects need to be considered in chatbot implementation and how can these aspects be structured? "

Research Design and Methods / Phases
• Literature review (Webster & Watson 2002) → Theoretical foundation • Expert interviews with 15 practitioners → Relevance for practice • Deduction of implementation conditions • Framework development using the PACT framework perspectives (Benyon 2014) • Evaluation of the framework using a focus group discussion and seven expert interviews • Application in a case study
Limitation(s)
• Framework depending on the status of the current technologies • No extensive testing through a concrete application in practice

3.5.2 Motivation and Research Topic

Besides the classification of chatbots, there is another important field of research that deals with the development of chatbots. During the work on the research question described in the previous chapter, it became apparent that in practice a structured approach to introducing chatbots is missing. Research has so far dealt with specific aspects of chatbot implementation. Many case studies are available where a chatbot is developed for a specific use case (Laumer et al. 2019). There is still a lack of a generally applicable procedure. However, it is important not only to consider the technical aspects, but also to include the users and their requirements in the implementation (Benyon 2014). Knowing a structured approach to chatbot development is not only helpful for practice, but also for research because it helps to understand which aspects have to be considered during the implementation. This knowledge is the basis for assessing the quality or success of a chatbot, for example. The objective of this research was therefore to develop a structured approach to chatbot implementation, whereby the requirements of the users should be in the foreground.

3.5.3 Research Design and Methodology

With the aim of developing a framework for the implementation of chatbots, the research design is based on the DSR paradigm (Hevner et al. 2004). Specifically, we followed the Hevner (2007) framework. According to this framework, the research design is divided into three cycles. In the design cycle, the artifact is developed. This development is accompanied by the relevance and rigor cycle (Hevner 2007). Within the rigor cycle, we have conducted a literature review taking the guidelines by Webster and Watson (2002) into account. This should provide the scientific foundation for the development of the artifact. To establish a link to the environment, expert interviews with 15 practitioners were conducted within the relevance cycle (Janssen et al. 2021). The analysis of the investigations of the relevance and rigor cycle were done with methods based on grounded theory. The artifact and the chatbot implementation framework respectively was evaluated using seven interviews with participants of a chatbot implementation and a focus group discussion. In a further step, it was applied in a case study.

3.5.4 Summary of the Results, Contributions, and Limitations

The result of this research is a multi-level chatbot implementation framework, which is based on the PACT framework of Benyon (2014). In the PACT Frameworks the perspectives people, activity, context, and technology are considered. A human-computer interaction should be analyzed from these four perspectives to cover all relevant requirements (Benyon 2014). The eight identified stages of the developed framework are named as follows:

- Preliminary Considerations
- Use Case Determination
- Definition of Chatbot Characteristics
- Dialogue tree construction
- Prototype Development
- Acceptance Testing
- Measuring Added Value
- Post-implementation

Within each level, the four perspectives of the PACT framework are again discussed. After analysis of the literature and the expert interviews, 102 questions were formulated, which have to be answered for the implementation of the chatbot (Janssen et al. 2021). Questions were formed because, according to one of the experts, keywords have the disadvantage of anticipating parts of the solution. Each of the developed questions can be assigned to a phase as well as a perspective. This assignment is not always obvious, but the questions could always be assigned to the phase and the perspective to which they fit most. Also, not all questions are necessarily relevant for every implementation project, but the goal was to map all potentially relevant questions.

According to the interviewed experts, decisions in the implementation of chatbots are often influenced by discussions about the platform on which the chatbot will run. This is where the developed framework comes in, as it supports the implementation project independent of a platform. Thereby, the framework represents the current state of chatbot technology. It is conceivable that the questions have to be adapted by new technologies. Although the evaluation with further expert interviews and the focus group discussion already provides indications that the framework offers added value for research and practice, in further research the concrete application in multiple implementation projects could be examined. Furthermore, the framework can be used to investigate which factors are particularly relevant for the success of a chatbot implementation project. Critical success factors can then be derived from this.

3.6 Predictive Maintenance Business Models

3.6.1 Overview

The section is based on the article “Predictive Maintenance as an Internet of Things enabled Business Model: A Taxonomy” and is published on the 19th October 2020 online at the Electronic Markets Journal (Appendix 7). The research is summarized in Table 9.

Table 9. Overview of the research on predictive maintenance business models

Problem Identification	**Goal(s)**
• In an Industry 4.0 context, it is important to understand the business models of partners • Limited research on IoT business models in the manufacturing industry • Predictive maintenance (PdM) is an important Industry 4.0 application scenario for many companies	• Better understanding of the important elements of PdM business models • Investigation of the connections between the business model elements
Related Studies	**Hypotheses / Research Question(s)**
• Müller and Buliga (2019) • Bock and Wiener (2017)	• “Which elements of PdM business models are important and which characteristics are interrelated in models that exist on the market?“
Research Design and Methods / Phases	

• Taxonomy development based on Nickerson et al. (2013)
  o Review of general business models literature
  o Conducting interviews at a trade fair and analysis of websites of PdM providers
• Analysis of the distribution in the examined data set
• Archetype development using cluster analysis
• New visualization method using autoencoders	

Limitation(s)	
• Different definitions of PdM possible • Sample size is limited • Analysis of the market situation only a current snapshot, characteristics could change over time	

3.6.2 Motivation and Research Topic

Enormous potential is seen in the use of the Internet of Things (IoT). The networking of different components enables completely new communication, interaction and analysis possibilities. The term IoT is mainly used for applications in private environments. In the industrial context, the term Industrial Internet of Things (IIoT) is more commonly used. In Industry 4.0 IIoT plays an important role. Both components also have a major influence on business models (Müller & Buliga 2019). However, previous research has mainly dealt with general, digital business models (e.g., Rizk et al. 2018). Research on a concrete IIoT business model could be used to better understand how IIoT business models look like. To this end we take a closer look at services in the field of maintenance. Maintenance activities often represent a big cost factor in the manufacturing industry that should not be neglected. Predictive maintenance (PdM) is a concrete application of IIoT that can reduce those maintenance costs. The aim of PdM is to determine the optimum point in time for the maintenance of a machine. Machines should not be serviced unnecessarily early, but also not too late to avoid damage. For this purpose the condition of a machine is monitored and predicted by using data analytics. Often the data comes from various sensors which are transmitted to an analysis unit via the IIoT.

There is already research that categorizes different types of maintenance (Khazraei & Deuse 2011). However, there is still a lack of research on what business models can look like in which PdM services are offered. This gap should be addressed with this research. It will be asked what PdM business models look like and how the individual components are related to each other.

3.6.3 Research Design and Methodology

For the investigation of PdM business models, a taxonomy is suitable. A taxonomy describes the characteristics of objects and their connections (Gregor 2006). We follow this representation with our research question to categorize the elements of PdM business models. Nickerson et al. (2013) have created a structured approach to taxonomy development, which will be applied in this research.

First of all, various literature on the presentation of general business models was analyzed. Especially the Business Model Canvas by Osterwalder and Pigneur (2010) provided first dimensions for taxonomy. They are the result of our first iteration, which according to Nickerson et al (2013) can be described as conceptual-to-empirical. The further iterations then follow an empirical-to-conceptual approach. For this purpose we used a data set of companies offering PdM. This dataset consists of companies that were interviewed at the Hannover Messe 2018 because they advertised with PdM on the fair website. Additionally, we used the “crunchbase” website. “Crunchbase” is a database that collects various information about startups. We searched for “condition monitoring” and “predictive maintenance” in the short descriptions of the companies. In the end the data set consisted of 113 companies. After analyzing the companies, the taxonomy was further improved in overall five iterations. With the taxonomy completed, we were able to use the already analyzed companies to show the current frequencies of the different characteristics.

While the first goal, the identification of important elements of PdM business models, has been achieved with the completion of the taxonomy, the links between the characteristics need to be analyzed more deeply. For this purpose, we have performed a cluster analysis. Following the taxonomy development of Gimpel et al (2017), we first applied the Ward (1963) algorithm to the data set. Partitioning algorithms are usually more suitable in our case to form the correct groups. However, to use them, it must be known what the correct number of groups is. Hierarchical algorithms, on the other hand, consider the distances of all elements. In our case, a large distance describes a big difference in terms of the business model. The Sokal and Michener (1958) matching coefficient was used as distance measure. There are several ways to determine the most suitable number of clusters. Like other authors (Gimpel et al. 2017), the number of clusters was determined qualitatively in this study. The result of the Ward (1963) algorithm was analyzed in the form of a dendrogram. The dendrogram shows that it would be possible to form two, three or six groups. Between them the differences of the groups are not different enough. When analyzing three groups it is noticeable that the groups are still relatively coarse. Therefore a consideration of only two groups is not necessary. On the other hand, a subdivision into six groups could be useful. A rough consideration of the six groups made clear that these also lead to a plausible subdivisions. The analysis is therefore continued by considering six groups.

Where there is an idea of how many groups the data set can be divided into, partitioning algorithms can be applied. Following Hartmann et al. (2016), we have used two different algorithms to form the groups. The results of both the k-means and the k-medois algorithm were considered. The distributions of the respective characteristics in the individual dimensions were analyzed. The k-medois algorithm provided the more plausible group assignments for this data set. The found archetypes are based on the six groups we formed with the k-medois algorithm.

Methodologically new was the visualization of the analyzed business models and their assigned groups. By using an autoencoder we were able to reduce the seven dimensions of our taxonomy to two, which allows a representation in a two-dimensional diagram. Compared to other methods, i. e. principal component analysis (PCA), an autoencoder is more suitable when there are many non-linear dependencies in the data (Wang et al. 2016). Autoencoders are based on neural networks and aim to first represent the essential characteristics in a compressed form (encoding) (Hinton 2006). In a next step this form can be decoded. In our application, however, we only use the compressed form, which should be two-dimensional, as this can be visualized easily.

3.6.4 Summary of the Results and Limitations

The results of this research are multi-layered. On the one hand, there is the developed taxonomy. It can be seen in Table 10. It consists of seven dimensions, which are the classical dimensions for describing business models (key activities, value promise, payment model, customer segment, clients), but there are also specific dimensions (deployment channel, information layer). The respective characteristics in the dimensions are specifically adapted to the PdM context.

Table 10. The developed taxonomy of PdM business models (Passlick et al. 2020a, p. 6)

Dimensions	**Characteristics**		
Key activities	1) Hardware development	2) Software development	3) Consulting
	4) Edge computer development	5) Provision of a public cloud	6) Hardware retailing
	7) Universal range	8) Provision of an application platform	
Value promise	1) All-in-one solution	2) Condition monitoring	3) Connectivity
	4) Automation	5) Forecasting	6) Data security
	7) Data storage + software development tools		
Payment model	1) One-time sales	2) Time basis	3) Project
	4) Usage basis	5) Hybrid	
Deployment channel	1) Physical	2) www	3) Physical + www (cloud)
	4) www (cloud) + API	5) www (cloud)	6) Physical + www (cloud) + API
Customer segment	1) Manufacturing industry	2) Energy sector	3) No industry focus
	4) High-security areas	5) Manufacturing industry + energy sector	6) Manufacturing industry + logistics/transport industry

Clients	1) B2B	2) B2B + B2B2B	3) B2B + state
Information layer	1) Application and services	2) Information handling	3) Information delivering layer
	4) Object sensing and information gathering layer	5) Multiple	

The seventh dimension is also special because it includes the differentiation of business models through an IoT architecture model. Thus, the business models can also be compared on a technical level, as solutions on all levels of the architecture model are necessary for the complete realization of an IoT use case.

In addition to the taxonomy shown, archetypes were also formed, which represent the groups of typical PdM business models. They are shown in

Table 11. Some of them have already been described in a similar form in previous research, while other archetypes have not yet been represented in this way. For example, our archetypes also show business models that can be described as "born-online" or "born-offline" (Bock & Wiener 2017). The archetype hardware development can be described as "born-offline", while analytics and platform providers as well as information managers are more likely to be seen as "born-online". However, in the use case examined here, there are other archetypes that cannot be easily assigned to one of these categories. The archetypes all-in-one and consulting are separate categories. We conclude that there is also a need for consulting services in Industry 4.0 use cases due to their complexity. It also seems to be interesting for companies if they can obtain the components relevant for the realization of a PdM use case from one source (all-in-one).

Table 11. The archetypes found (Passlick et al. 2020a, p. 11)

	Archetype					
	1	**2**	**3**	**4**	**5**	**6**
Label	*Hardware development*	*Platform provider*	*All-in-one*	*Information manager*	*Consulting*	*Analytics provider*
Key activities	Hardware development	Provision of an application platform	Universal offer	Edge computer development	Consulting	Software development
Value promise	Condition monitoring	Forecasting	All-in-one solution	Condition monitoring	Condition monitoring	Forecasting
Payment model	One-time sales	Hybrid	Hybrid	Hybrid	Project	Time basis
Deployment channel	Physical	Physical + www (cloud)	Physical + www (cloud)	Physical + www (cloud)	Physical	www (cloud)
Customer segment	No industry focus	Manufacturing industry	No industry focus	Manufacturing Industry	No industry focus	No industry focus
Clients	B2B	B2B	B2B	B2B + B2B2B	B2B	B2B
Information layer	Object sensing and information gathering	Application and services	Multiple	Multiple & information delivering	Application and services	Application, services and information handling
Share in sample (113)*	21%	12%	27%	5%	13%	20%
Example company	Rockwell Automation	Test Motors	National Instruments	IXON	Hitachi Consulting	Senseye

*Due to rounding inaccuracy, the sum is not exactly 100%.

Another finding of this research is the new visualization method using an autoencoder. The result is shown in Figure 8. It allows us to visualize how different the business models are within a group and to show the differences between the groups.

The figure shows the similarity of the platform and analytics provider. Also, the major differences between hardware development and analytics provider become apparent. All-in-one providers can be found in all areas which shows that the providers have different focuses despite an all-in-one offering. However, most business models are neither similar to hardware development nor to analytics providers. Many business models of the archetypes consulting and hardware development are also close to each other, but by far not as close as platform and analytics providers.

The following limitations should be taken into account when discussing the results. Statements about the information manager archetype are only conditionally possible, since it is represented by only a few companies in the data set. A larger data set could help here to better define the archetype. The data set in general only represents the state during the survey. Business models change over time, which accordingly leads to a change in the distribution of characteristics in the dimensions. In some cases, new characteristics can also be added. However, it can be assumed that the rough structure of the taxonomy and probably also of the archetypes will remain the same.

It should also be noted that the research carried out is highly dependent on the chosen definition of PdM. For example, if PdM is defined more narrowly and does not include condition monitoring, taxonomies and archetypes change accordingly. For example, hardware development would play a much subordinate role, since hardware components are often necessary to determine the current state of a machine. The predictive part is often not taken over by the hardware developers. A narrow definition of PdM would focus purely on the predictive models and not on the hardware required to provide the data.

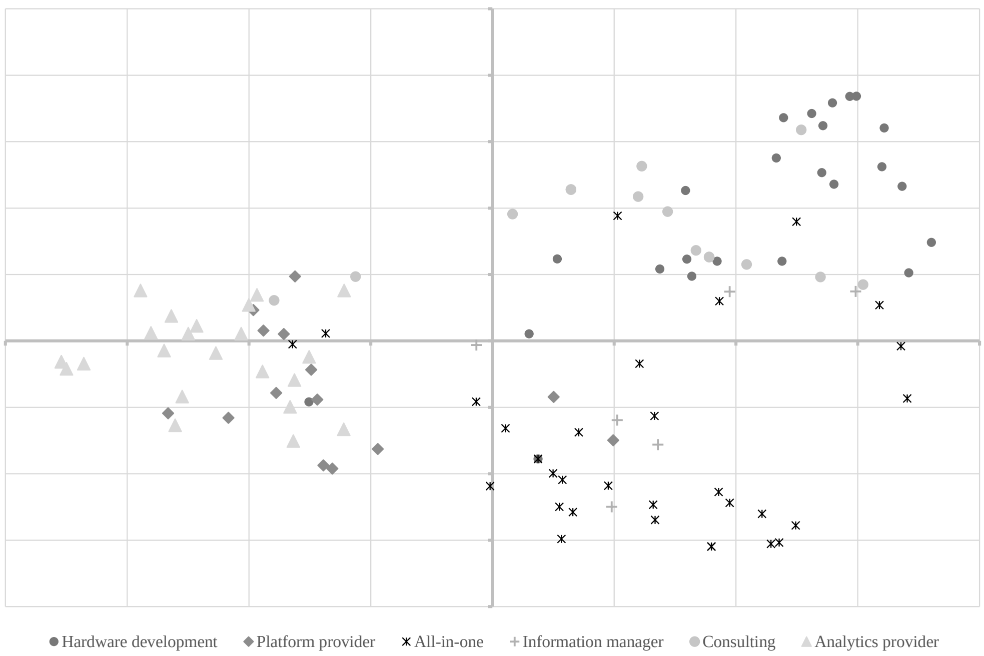

Figure 8. The visualization of the analyzed PdM business models (Passlick et al. 2020a, p. 12)

4. Part C: Business Analytics

4.1 A Primer to Business Analytics

An essential part of the digital transformation is the increased use of data of all kinds (Dremel et al. 2017). From the previous section, the examples of WA report creation and PdM business models show how important the use of data has become. For many years, the use of company data to support decision-making was referred to as Business Intelligence (BI). In recent years, the term Business Analytics (BA) has emerged as an extension of classical BI. BA extends BI by forecasting and a stronger use of statistical and machine learning methods (Chamoni & Gluchowski 2017). This section is dedicated to different aspects of BA.

First, the effects of the new requirements resulting from BA on an analysis architecture are investigated. In addition, another phenomenon is investigated, which has been discussed in recent years. This concerns the ability of departments to independently create analyses or reports. Research on this topic uses the term Self-Service Analytics or SSBI which is also the name of the research stream for this article. Section 4.2 presents in a DSR approach an architecture that meets the new requirements of both BA and SSBI. In a further article on SSBI, it is investigated which factors lead to an intention to use SSBI among users or potential users. In this behavior-oriented research, the significance of various influencing factors is investigated using a structural equation model (section 4.3). Section 4.4 deals with different application scenarios of SSBI found in companies and SSBI tools. According to a process model of Nickerson et al. (2013) a taxonomy is developed, with which the different SSBI application scenarios can be distinguished.

In sections 4.5 and 4.6 two OR models in an Industry 4.0 context are presented in another research stream, which show concrete applications of BA. On the basis of sensor data, optimizations are carried out which provide information on how many spare parts should be kept in stock (4.5) or what a reasonable maintenance plan for a group of machines or components could look like (4.6). Based on my practical experience in a manufacturing company and on the results of the research described in section 4.2, the research presented in section 4.7 was developed. Here, it is assumed that a machine learning model cannot achieve sufficient reliability in certain applications to rely on it alone. Thus, the research will investigate how an approach combining machine learning models with human experts can be used to exploit the strengths of both. This research is part of the research stream data science.

Also part of this research stream is a process model, which is explained in section 4.8. This article structures the execution of data science projects. Data science is considered a new discipline, which combines skills from areas such as mathematics, statistics, computer science, and scientific approaches to enable advanced analysis. These advanced analyses have become possible in recent years due to larger data volumes for machine learning algorithms and new infrastructures. Data science approaches are part of the analyses with which BA extends the classical BI analyses. On the basis of the research findings of the sections 4.5, 4.6, and 4.7, a project group developed a process model to structure data science projects. All these mentioned articles and their connections to each other are shown in Figure 9.

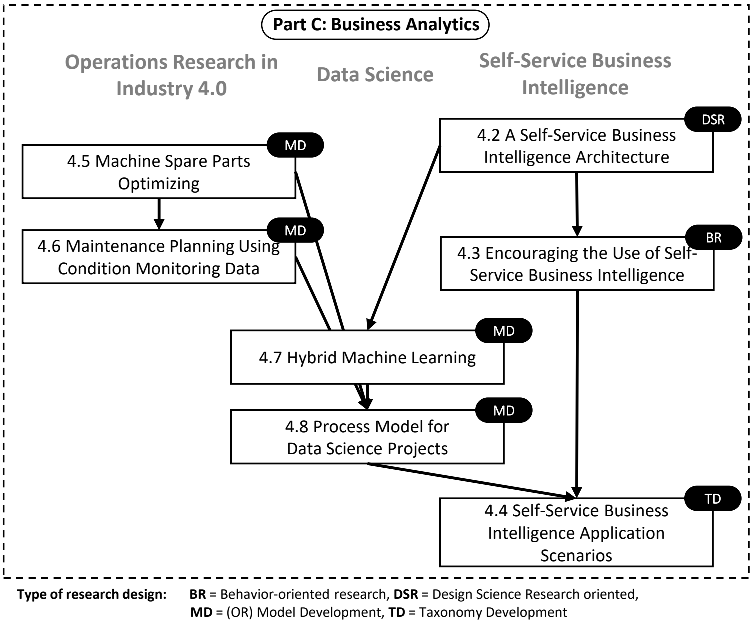

Figure 9. Overview of the articles in Part C

4.2 A Self-Service Business Intelligence Architecture

4.2.1 Overview

The section is based on the article "A Self-Service Supporting Business Intelligence and Big Data Analytics Architecture". The article was published in the proceedings of 13th International Conference on Wirtschaftsinformatik (Appendix 8). In February 2017, the corresponding conference took place in St. Gallen, Switzerland. There, it was discussed in the track "Data Science & Business Analytics". Table 12 gives an overview of the research carried out.

Table 12. Overview of the research on a self-service business intelligence architecture

Problem Identification	**Goal(s)**
• Companies have big amounts of data but often no sufficient technical or organizational infrastructure for time-critical decisions • SSBI is a possible answer to this, but unclear how it affects the BI architecture	• Show how current business analytics architectures have to be adapted to the new requirements regarding SSBI and Big Data analytics
Related Studies	**Hypotheses / Research Question(s)**
• Eckerson (2011) • Watson (2014) • Parenteau et al. (2015) • Phillips-Wren et al. (2015)	• "How is a self-service supporting BI/big data analytics architecture constructed?"

Research Design and Methods / Phases

DSR based on Peffers et al. (2007)

- Problem identification and objectives definition
  - Literature review (Webster and Watson 2002)
  - Requirements analysis -> Conceptual model
- Design & development
  - Semi-structured interviews
  - Qualitative content analysis (Mayring 2002)
- Applicability check
  - Focus group discussions (Morgan 1993)
  - Focus group analysis (Mayring 2002)

Limitation(s)

- Limited amount of interviewees
- No business users involved
- Self-learning knowledge database is presented only theoretically

4.2.2 Motivation and Research Topic

Companies often have large amounts of data at their disposal, which are, however, only used rarely or not comprehensively. This is either because the necessary technical infrastructure is lacking or because no adequate organizational measures have been created to enable data-driven, timely decisions to be made. As already described in the previous section, the use of SSBI software is seen as having enormous potential to accelerate decision-making processes. However, in addition to the choice of suitable software, organizational and infrastructural measures must also be taken to successfully implement SSBI (Clarke et al. 2016). There are very different levels which have to be taken into account. A classical BI process starts with the procurement of raw data, through the transformation of the data into an analysis system (Phillips-Wren et al. 2015). From there the data can be analyzed in different ways (Parenteau et al. 2015). There are different user groups and skills (Eckerson 2011, Watson 2014). All these aspects should be addressed in the architecture, since it is often the interaction of these components that enables successful BI or SSBI systems (Watson 2014). Previous research has already dealt with the respective components, but research that brings these elements together is missing. In this research the interaction of the components can be addressed.

4.2.3 Research Design and Methodology

For the development of the planned architecture, the DSR process model according to Peffers et al. (2007) was used. The model clearly structures the design science process into several phases. In the first phases a structured literature review according to Webster and Watson (2002) was conducted. As a result of the literature review a first conceptual architectural model could be developed. This model was then further refined in the design & development phase by conduction expert interviews. The interviews were evaluated with a qualitative content analysis according to Mayring (2002). With the help of a focus group discussion, the model resulting from the design & development phase was tested for its applicability. The discussion was conducted in consideration of Morgan (1993) and again evaluated with Mayring (2002).

4.2.4 Summary of the Results and Limitations

The result of the research is an architecture model that takes into account the new requirements of Big Data applications and shows how self-service scenarios can be supported by a modern architecture. This includes the consideration of different source systems so that both internal and external data sources can be analyzed. When loading the data, it should be taken into account that, in addition to the classic extract, transform, and load processes (ETL), there is also the possibility of omitting the transform to have data available in its raw form. There are different systems for processing and storing the data to cover all requirements. One system is primarily responsible for data integration and historization. These are the tasks that a classic data warehouse fulfills. Optionally, there can be further components that are necessary for (near) real-time applications. Furthermore, there are systems that are required for Big Data applications. In this context, possibilities must be created in which tests and experiments with analytical methods can be carried out. Regardless of the described infrastructure, it is helpful to introduce a semantic layer. This layer standardizes the access to the data and thus makes the access independent of the system used.

In the presentation layer are three different portals in the presented architecture. These can be understood in connection with the addressed user group and their respective skills. The first form "Dashboards" is used by business users and tends to contain more descriptive analyses. The second is the analytics portal, which is used by business analysts or even power users. Here, more in-depth analyses or diagnoses are created. The last portal is called "data laboratory". This area is used by data scientists who have well IT, statistics, and mathematical skills. They mainly do predictive and prescriptive analysis.

When preparing the analyses or reports, it is important that the exchange between the user groups is encouraged. In the architecture, collaboration rooms are provided for this purpose, which should facilitate communication. A connection to a social company network is also conceivable here, if this is available. In addition, a self-learning knowledge database can also support users. With this database the idea is to analyze how and which analyses and reports are used. For this purpose, the accessed reports and the navigations in them are stored. With advanced analysis methods certain patterns can then be recognized. From the knowledge gained, suggestions can be made to the user as to which analyses and which aspects of the analyses could be of interest to him or her. The self-learning database is seen as a way to promote SSBI. A report and data governance is to be considered on all levels. This regulates aspects such as data security, data protection, but also data quality and metadata management. Figure 10 shows the described architecture model.

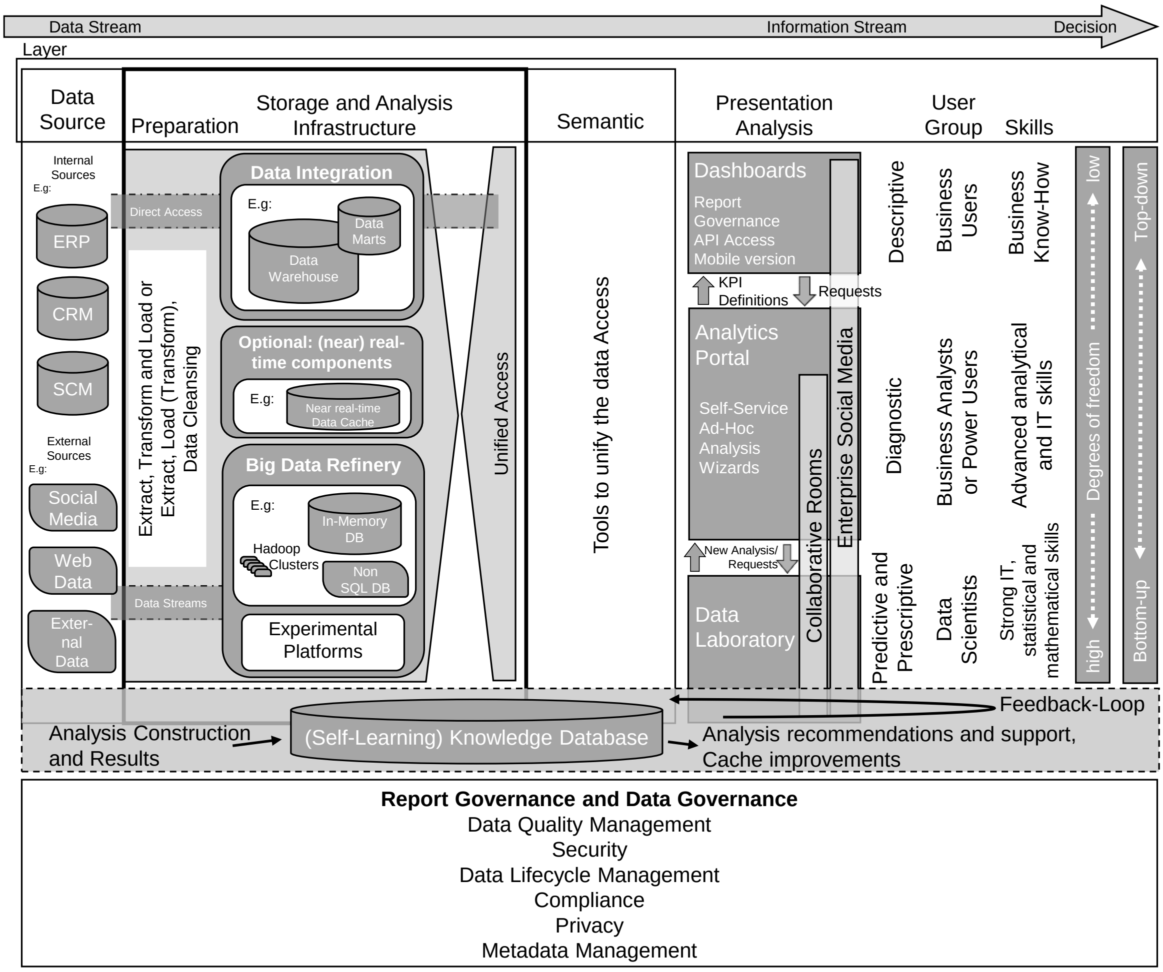

Figure 10. The developed architecture (Passlick et al. 2017, p. 1132)

In addition to the findings resulting from the research presented, it is also important to point out that certain limitations exist. For example, the number of interview partners was limited and no business users were included in the interviews. However, these business users would not have been able to make any statements for large parts of the architecture either, as they do not deal with these questions professionally. Furthermore, the self-learning knowledge database was only considered theoretically in this research. Further research can start here to analyze how valuable the help of the database is for SSBI users.

In a retrospective view, the influence of governance structures on the architecture should also be considered more strongly. The compliance with the different security, data protection and quality guidelines is a big challenge especially in the SSBI environment. Further research shows that this requires own concepts (Clarke et al. 2016). In the next section, we examine, among other things, the influence of quality guidelines on the use of SSBI.

4.3 Encouraging the Use of Self-Service Business Intelligence

4.3.1 Overview

The section is based on the article "Encouraging the Use of Self-Service Business Intelligence – An Examination of Employee-Related Influencing Factors". We published the article in the "Journal of

Decision Systems" (Appendix 9). The journal focuses on research about decision making and decision support. Table 13 summarizes the research conducted.

Table 13. Overview of the research on encouraging the use of self-service business intelligence

Problem Identification	**Goal(s)**
• SSBI is able to provide greater flexibility and faster information delivery • However, the introduction alone does not lead to a use by the business users	• Describe which factors lead to an actual use
Related Studies	**Hypotheses / Research Question(s)**
• Cetto et al. (2015) • Alpar & Schulz (2016) • Schlesinger & Rahman, 2016) • Imhoff and White (2011)	• "What influence do flexibility, expected time savings, BI experience and data quality have on the intention to use SSBI?"
Research Design and Methods / Phases	
• Structural equation model development • Survey development • Conducting the survey • Data analysis	
Limitation(s)	
• Only investigation of the intention to use, not actual usage • Definition of SSBI is vague	

4.3.2 Motivation and Research Topic

The previous section described the technical elements and an architecture that could promote the use of SSBI. However, this is only one side of a successful introduction of SSBI. In addition, a change in culture and behavior is necessary for SSBI to be successful in an organization (Namvar & Cybulski 2014). It is already known from previous SSBI research that "access and use of data" and user uncertainty can be a problem during implementation (Lennerholt et al. 2018; Weiler et al. 2019). On the other hand, time savings and reliability are important factors leading to a renewed intention to use self-service technologies in general (Cetto et al. 2015). According to a survey, too low user skills are the biggest obstacle for the use of SSBI (Imhoff & White 2011). Data quality, control, and governance follow in second place (Imhoff & White 2011). The influences of these aspects on the intention to use SSBI will be analyzed in more detail in this research. The research question asks for the influence of flexibility, expected time savings, BI experience, and data quality to the intention to use of a SSBI environment.

With a better understanding of the influencing factors, recommendations can be derived on how SSBI should be introduced so that it is also adapted to support the daily decision-making. This question is intended to clarify whether certain aspects can be disregarded or what is particularly important.

4.3.3 Research Model and Methodology

Based on the existing literature, the research model was initially derived. It is shown in Figure 11.

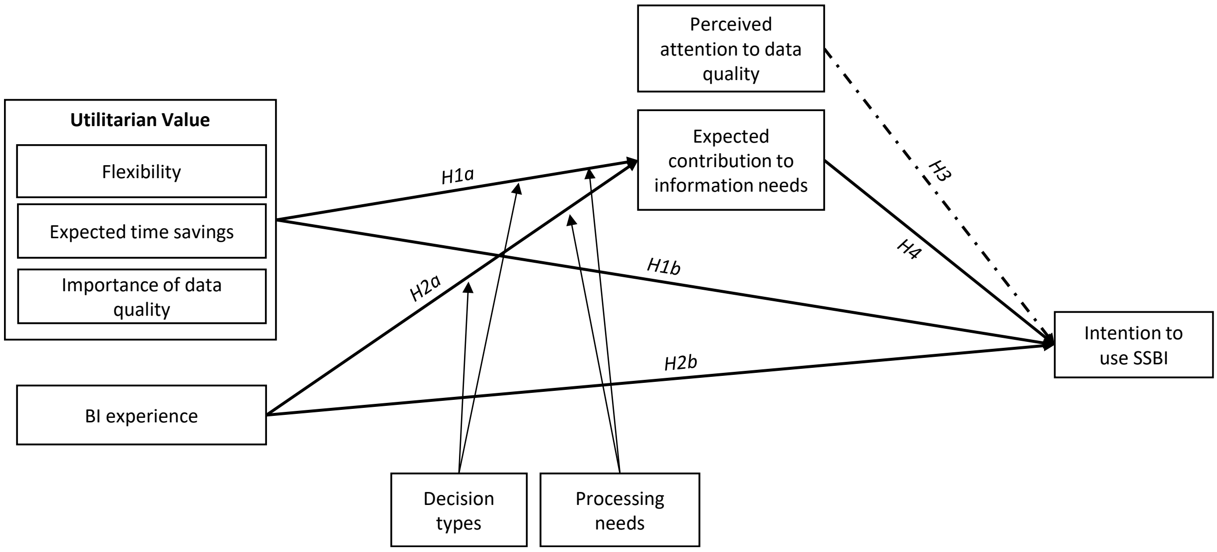

Figure 11. The investigated structural equation model (Passlick et al. 2020b, p. 8)

Following Cetto et al. (2015), we have summarized the three factors flexibility, expected time savings, and the importance of data quality into the second-order construct utilitarian value. We therefore assume that the three factors mentioned are perceived as useful and that this usefulness as a whole promotes both the expected contribution to information needs and the intention to use SSBI (H1a & H1b). Furthermore, we measure the impact of the BI experience on these two elements (H2a & H2b). Additionally, we assume that the perceived attention of the company to data quality has a negative impact on the intention to use SSBI (H3). The expected contribution to information needs also has a positive impact on the intention to use the data (H4) (Passlick et al. 2020b).

As moderating factors, the constructs decision types and processing needs were analyzed. The constructs originate from BI research and give conclusions about whether repetitive or non-recurring decisions are made (decision types), while the construct processing needs asks how granular the data relevant for the decision has to be (Işik et al. 2013). We investigate whether these constructs have an impact on the relationship between BI experience and utilitarian value on the expected contribution to information needs.

The model presented was converted into a survey. The questions used in the survey either originate directly or are based on constructs from previous research. We have randomly selected users or potential users of SSBI as participants for our survey. Since SSBI is still in its infancy in many companies, we decided to include participants who have not used SSBI so far. The decisive criterion was that they use analyses or reports in their organization or create them in some form. We asked about this requirement at the beginning of the survey. The survey could only be continued if this requirement was fulfilled. Participants who have not yet used SSBI are equally relevant for our research question, since we want to investigate factors influencing the intention to use SSBI in general, regardless of whether there is already experience with SSBI. Before the survey started, we showed the survey to four IS researchers and three BI experts to check its comprehensibility and conciseness. The link to the survey was sent via various mailing lists and personal contacts were used for distribution. Additionally, the survey was posted in groups on the social media portals Xing, LinkedIn and Facebook. Participation was possible for six months. At a later point in time, a further survey was conducted to exclude a non-response bias. We compared the surveys with a multi-group analysis, which did not find any significant differences. A total of 196 participants were included in the evaluation of our model. The model was tested using the partial least squares (PLS) method.

4.3.4 Summary of the Results, Limitations, and Further Research

The result of the PLS analysis shows that all the hypotheses presented have significant effects. However, in the investigation of the moderating effects, a significant moderating effect was only found in the connection between BI experience and the expected contribution to information needs. Figure 12 shows the results of the PLS analysis.

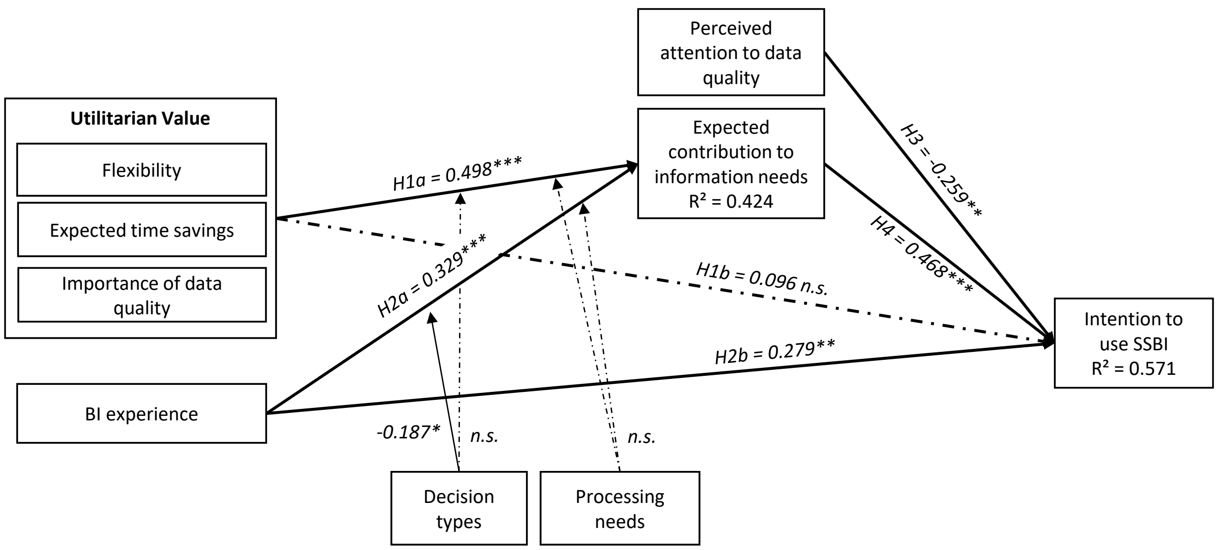

Figure 12. The effects of the investigated connections (Passlick et al. 2020b, p. 13)

It can be confirmed that the factors examined, flexibility, the expected time savings, and the importance of data quality, have an influence on the utilitarian value. This result means that users must be made aware that exactly these characteristics are provided in the respective SSBI environment of the organization. In terms of flexibility and the expected time savings, this is presumably easy to achieve for many users, as they can act independently and thus more efficiently. On the other hand, given the importance of data quality, it is more challenging to convey that SSBI can offer advantages in this respect. Here, the data quality can be increased by IT providing ready-made data models or data modelling assistance. This support should be clearly presented to the users. If a user sees a utilitarian value in SSBI, this has a positive influence on the expected contribution to the information needs as well as the intention to use SSBI.

In addition, the experience with general BI applications has a positive influence on the expected contribution to information needs as well as the intention to use SSBI. SSBI must therefore be promoted rather among inexperienced users, since more experienced users are more likely to use it anyway. The perceived attention of the organization to data quality also has an influence on the intention to use SSBI. However, this influence is negative. If the organization's guidelines are perceived as strict, this can reduce the intention to use SSBI. The expected contribution of SSBI to information needs has a positive influence on the intention to use SSBI. The SSBI usage intention is therefore increased if the user expects that SSBI can support him in satisfying his information needs.

A limitation of this work is that only the intention to use SSBI and not an actual use could be investigated because real statistics are missing. Future research could catch up on this and carry out investigations in companies that already operate SSBI components. These companies have usage statistics of SSBI applications. Such statistics could also be used to investigate whether there is a different influence of SSBI experience in comparison to BI experience.

Another problem is the definition of SSBI. When this research was conducted, SSBI was still relatively broadly defined. As a result, some statements could not be made precisely, since no distinction was made according to the complexity of the SSBI applications. For example, SSBI users who only retrieve data and perform simple navigations in the data are likely to have a higher intention to use SBBI, since maybe no error-prone data modelling is necessary. In contrast, SSBI users might be inhibited in more complex scenarios. The research presented in section 4.4 could be used to differentiate more precisely which SSBI applications are investigated in each case. This differentiation in turn makes more detailed deductions possible.

4.4 Self-Service Business Intelligence Application Scenarios

4.4.1 Overview

The section is based on the article "Self-Service Business Intelligence Application Scenarios - A Taxonomy for Differentiation". It was submitted to the "Information Systems and e-Business Management" Journal (Appendix 10). Table 14 gives an overview of the research carried out.

Table 14. Overview of the research on different forms of Self-Service Business Intelligence

Problem Identification	**Goal(s)**
• SSBI is broad and only roughly defined • Many statements about for example the challenges or benefits of SSBI, can only be made roughly because they are strongly dependent on the respective application scenario	• Better understanding of the range of SSBI applications • Presentation of the dimensions according to which SSBI cases can be differentiated

Related Studies	**Hypotheses / Research Question(s)**
• Alpar and Schulz (2016) • Imhoff and White (2011)	• "Which dimensions and characteristics distinguish SSBI application scenarios?"

Research Design and Methods / Phases
• Taxonomy development based on Nickerson et al. (2013) • Literature review (Webster and Watson 2002) • Analysis of current SSBI software • Case study • Taxonomy evaluation (Szopinski et al. 2019) • "Illustrative scenario" - Cluster analysis of the examined software tools

Limitation(s)
• No quantitative information about how often which SSBI case exists in practice, only the analysis of the amount of tools is possible, but not for how many cases they are used • Difficult differentiation from Data Scientists

4.4.2 Motivation and Research Topic

SSBI is seen as an opportunity to simplify and accelerate decisions and analyses. However, in practice, the question arises in which scenarios or in which business processes an application of SSBI increases the efficiency. It is also important for research to look at SSBI application scenarios in a differentiated way. First approaches were provided by Alpar and Schulz (2016). They differentiate SSBI according to system support and self-reliance. Based on this, they described different levels of SSBI. In addition, different user groups are also discussed, which distinguish SSBI application scenarios (Passlick et al. 2021a; Eckerson 2019). A differentiation with the PACT Framework from Benyon (2014) is also conceivable (Johansson et al. 2015).

It becomes apparent that very different dimensions are conceivable to describe SSBI applications to provide the basis for a better differentiation in research. This problem is to be addressed by this study. It is intended to investigate which dimensions are suitable for differentiating SSBI applications.

4.4.3 Research Design and Methodology

As research approach a taxonomy development process according to Nickerson et al. (2013) is chosen. A taxonomy is suitable to classify and structure objects (Nickerson et al. 2013). This is exactly the aim of this research. Different versions of SSBI applications are to be structured according to certain perspectives. As described in section 3.4.3 the process model by Nickerson et al. (2013) offers a structured procedure for creating a taxonomy. Within the process model we first carried out a literature review according to Webster and Watson (2002). After analyzing the literature, first dimensions were identified, which were then revised in further iterations. Thus, we initially chose a conceptual-to-empirical approach, while the further iterations were empirical-to-conceptual. The empirical iterations were carried out using a self-collected data set. This data set consists of different SSBI tools, which were determined by means of various comparative studies. The 47 tools were analyzed on the basis of the product website, videos, case studies or online interviews.

When comparing the dimensions taken from literature and the data set of the software tools, it becomes clear that not all dimensions relevant for the research question can be found in the data set. E.g. from the literature review it becomes clear that data sensitivity / privacy in SSBI processes is a dimension to be considered. This dimension cannot be observed by analyzing the SSBI tools because it is a criterion independent of the tool. In an SSBI application scenario, either particularly sensitive data are processed or not. For this reason, we conducted an additional case study to collect empirical data for these dimensions as well. We described and analyzed SSBI processes at a medium-sized industrial company. Thereby we identified an additional dimension.

After the analysis of the case study, the development of our taxonomy was completed. For the evaluation of the taxonomy we followed Szopinski et al. (2019). They describe different possibilities to evaluate a taxonomy. We decided to use a quantitative approach with an illustrative scenario. Therefore, all SSBI software tools from the described data set were assigned to the corresponding characteristics. The analysis of the assigned tools shows on the one hand that the taxonomy can differentiate between the different tools, but in addition it gives an overview of the current range of SSBI tools. Furthermore, we performed a cluster analysis with the assigned tools. This allows us to identify archetypes of SSBI tools that currently exist on the market. The cluster analysis was performed equivalent to the research described in section 3.4 and 3.6. Further details can be found in the manuscript in the appendix.

4.4.4 Summary of the Results and Limitations

The result of this research is the successful answering of the research question that asks for the dimensions and characteristics that differentiate SSBI application scenarios. The taxonomy developed for this purpose consists of nine dimensions, of which two dimensions could not be evaluated by the analysis of the SSBI tools because the dimensions do not directly affect the tools. These are the dimensions "data sensitivity/privacy aspects" and "data reliability and completeness". The conducted case study has shown that if these dimensions have a high weight in the respective scenario, they can complicate the implementation of the SSBI case. Thus, these dimensions are important for a differentiated consideration of SSBI application scenarios. The other dimensions are "user roles", "user skills", "BI analytics activities", "requirements for data management", "collaboration in development", "access type", and "nature of the analysis". With the developed taxonomy it is now possible to look at SSBI application scenarios more differentiated in research and practice. Investigations can especially address whether a certain aspect is differently pronounced depending on the application scenario.

Furthermore, the analysis of the SSBI tools showed that, e.g., the collaboration between users of BI or BA applications, as also described in section 4.2, is not yet strongly considered. It is also noticeable that about half of the tools are specialized in the creation of ad-hoc analysis. This focus is also evident in the archetypes found. One of the three deduced archetypes describes tools that can be used for simple ad-hoc analysis. As a further archetype, all-round tools were identified, which can also be applied for advanced analysis. The third archetype consists of tools that are only used by the user role "producer". This archetype refers to tools that are mainly used for data preparation and where the presentation of the data may be done in another tool. However, this archetype is by far the least common in the data set under investigation. The conducted analysis has shown that the developed taxonomy can be used to differentiate the examined tools and it was shown which application scenarios are primarily addressed by the providers of SSBI tools.

As a limitation of this research, it must be considered that despite the now better differentiability of SSBI application scenarios, there may still be difficulties in differentiating SSBI from data science. The transitions are fluent and a clear demarcation can be difficult. In section 4.8, a possible definition of Data Science is discussed in more detail. In addition, it must be noted that the analysis of the SSBI tools only allows conclusions about which application scenarios are seen by the tool providers. This does not allow strict conclusions about which SSBI application scenarios exist mainly in practice. With a survey, this research gap could be analyzed in further research. Also, the range of SSBI tools will change over time. Further research can analyze changes and maybe draw conclusions about a changed usage of SSBI.

4.5 Machine Spare Parts Optimizing

4.5.1 Overview

The article "Optimizing Machine Spare Parts Inventory Using Condition Monitoring Data" is described in this section. It was presented on the OR2016 - International Conference on Operations Research in Hamburg and is published in the respective proceedings (Appendix 11). Table 15 visualizes the conducted research for developing the decision support systems.

Table 15. Overview of the research on machine spare parts optimization

Problem Identification	**Goal(s)**
• Storage of unnecessarily many spare parts is expensive • Keeping too few spare parts in stock can lead to unnecessarily long machine downtimes	• Finding the right quantity of spare parts that should be kept in stock
Related Studies	**Hypotheses / Research Objective(s)**
• Chang et al. (2005)	• Development of a model to calculate the optimal amount of spare parts
Research Design and Methods / Phases	
• Literature review • Model development • Prototype development and experiments	

Limitation(s)

- No consideration of the path from sensor data to a probability of default of a machine
- Quantity of parts to be considered limited

4.5.2 Motivation and Research Topic

With the use of sensor data, new or more precise applications are possible. The research presented in this section shows an example of this. In this research an optimization model is described, which optimizes the amount of spare parts in stock. It is assumed that the current failure probability of a machine can be calculated from the sensor data. Taking into account the individual failure probability, the question can then be asked how many spare parts should be kept in stock for the respective machine type or component. This involves weighing up the costs of keeping spare parts in stock and long machine downtimes because not enough spare parts have been kept in stock. The model is made possible by a new service model that allows the spare parts stocked to be adjusted in each period. Normally, this would not be possible and the model would also have to take into account that the amount of spare parts cannot be reduced (Chang et al. 2005). Therefore, it is assumed that the spare parts are not purchased in advance, but a fee is paid for the provision of each spare part in stock in each period.

4.5.3 The Developed Optimization Model

The model requires as inputs the amount of machines considered. For these machines, the individual failure probabilities must be given, as well as the costs in case of a failure, if no spare parts are available. In addition, the cost rate to be paid for keeping a spare part in stock must be specified. This rate remains constant and is independent of the amount of spare parts in stock. Once the input parameters are passed, a developed algorithm determines all possible combinations of faultless and defective components. Then, the relevant probabilities for the respective combinations are calculated. Based on this, the costs for the different scenarios can be computed. Thereby all possible scenarios are calculated. These scenarios range from not having a spare part in stock to having one spare part per component or machine under consideration. The scenario in which the total costs from the provision fee and the expected costs of a failure are the lowest is shown as optimal. This means that the quantity of spare parts to be kept in stock is known by the respective scenario. Figure 13 shows the representation of the result in a prototype implemented in Excel. The calculated values are based on random input parameters.

	A	B	C	D	E	F
1						
2		die geringsten erw. Gesamtkosten betragen		**63.53 €**		
3			und werden erreicht bei	3	Komponenten im Lager.	
4						
5	Teile im Lager	Kosten für Vorhaltung	erw. Ausfallkosten	Gesamtkosten		
6	0	0.00 €	657.50 €	657.50 €		
7	1	20.00 €	207.33 €	227.33 €		
8	2	40.00 €	37.95 €	77.95 €		
9	3	60.00 €	3.53 €	63.53 €		
10	4	80.00 €	0.19 €	80.19 €		
11	5	100.00 €	0.01 €	100.01 €		
12	6	120.00 €	0.00 €	120.00 €		
13						

Figure 13. Result of the optimization model for six components in an Excel prototype

4.5.4 Summary of the Results, Contributions, and Limitations

The primary goal of this research is the development of the optimization model. It optimizes the amount of spare parts on stock based on the individual condition of each machine or component under consideration. This individual probability is one of the main challenges in solving the optimization problem. Due to them, the different constellations have to be calculated and these increase exponentially depending on the amount of machines or components considered (2^c). Thus, the amount of machines or components that can be considered is limited, because all constellations have to be loaded into the computer's memory. Depending on software and hardware, it may not be possible to compute more than 20 machines or components. In further research, an approach can be investigated in which machines or components with similar failure probabilities and costs are grouped together. The model would then optimize the groups and thus enable a consideration of significantly more machines or components.

A further limitation is that this research has not considered the way in which the failure probability of the respective machines or components is determined. This is a problem of its own and very much dependent on the respective machines or components. Depending on the machine, different sensors can be used and different wear models can be used as a basis.

In addition to the development of the model, first experiments with the model were also conducted. It could be seen that the amount of spare parts held in stock is not strongly dependent on the provision fee. The optimal quantity did not change much, even if the provision fee is changed significantly (Dreyer et al. 2017). Of course, these findings also depend strongly on individual parameters of the machines or components, but it can be assumed that a breakdown is more problematic for machine operators than keeping one spare part too many.

4.6 Maintenance Planning Using Condition Monitoring Data

4.6.1 Overview

The paper "Maintenance Planning Using Condition Monitoring Data" is described in this section. It was presented on the OR2017 - International Conference on Operations Research in Berlin and is published in the respective proceedings (Appendix 12). Table 16 summarizes the conducted research.

Table 16. Overview of the research on maintenance planning

Problem Identification	**Goal(s)**
• Finding the optimal maintenance times for a groups of machines is difficult	• Finding the optimal maintenance times for a groups of machines
Related Studies	**Hypotheses / Research Objective(s)**
• Wildeman et al. (1997)	• Creation of a model which calculates the optimal number of maintenance activities for a group of machines
Research Design and Methods / Phases	
• Literature review • Model development • Prototype development and experiments	
Limitation(s)	
• No consideration of the path from sensor data to a probability of default of a machine • No consideration of the deviation from the optimal maintenance time of a machine • Quantity of parts to be considered limited	

4.6.2 Motivation and Research Topic

This research is also about the right time for maintenance activities. However, here the problem is considered that several machines are to be maintained and if maintenance is to be performed, then as many machines as possible at the same time. This grouping of machines should help to minimize the setup and fixed costs of maintenance (Wildeman et al. 1997). It is assumed that again sensor data are available, which allow to determine a machine condition, from which again a probability for a failure can be calculated. In the model, it is considered whether a machine might be assigned to a group with an unnecessarily early maintenance date, or whether the risk of a failure is accepted because it is assigned to a later maintenance date. The model should calculate the optimal number of groups in which maintenance is performed. The model should also determine which machine is assigned to which maintenance group.

4.6.3 The Developed Optimization Model

The model is similar to the one presented in section 4.5. After entering the parameters, an algorithm is used to create all group combinations. Then, the parameters of the groups are calculated, the machines are sorted according to the optimal maintenance time, and the optimization model is run through. The maintenance plan can be derived from the optimal case constellation. To perform the optimization, the inputs required are the number of machines, the number of time periods considered, the costs of setting up a maintenance, and the individual data per machine. The necessary data per machine are the maintenance costs, the breakdown costs, and the failure probabilities for all considered periods. In this model, there are 2^{m-1} different combination possibilities depending on the considered machines (Olivotti et al. 2018b). In comparison to the model described in section 4.5, the question if maintenance should be done must be answered in addition to the consideration of when it should be performed. In the spare part optimization model, the question of how many parts are kept, i.e. whether maintenance is performed or the expected value of a failure is lower, is considered.

4.6.4 Summary of the Results, Contributions, and Limitations

In this research a model was developed which calculates the optimal maintenance strategy based on the failure probabilities of machines. This involves weighing up the expected costs of downtime and maintenance costs. Additionally, it is determined in how many groups the maintenance is performed. With the model a first approach is created to use sensor data from different machines to reduce maintenance costs.

As described in section 4.5, the problem remains that the number of machines that can be optimized is limited. Again, a grouping of machines could be a remedy. In addition, this model also assumes that the failure probabilities of the machines are present. How the probabilities can be determined based on sensor data is not considered. To simplify the complex calculation, the influence of a deviation from the optimal maintenance time of a machine is currently not calculated. Every machine has an optimal maintenance time. Deviations from this time can be made if maintenance is planned at a different time due to other machines. The effect that machines are then possibly serviced too early is currently not taken into account. This aspect offers potential for further research. Research can also be done on, for example, how a production plan can be included in the model (Olivotti et al. 2018b).

4.7 Hybrid Machine Learning

4.7.1 Overview

The section is based on the article "Combining Machine Learning and Domain Experience: A Hybrid-Learning Monitor Approach for Industrial Machines" and is published in the proceedings of the international conference on exploring service science (Appendix 13). At the conference the article was nominated for the best paper award. Table 17 summarizes the conducted research.

Table 17. Overview of the research on hybrid machine learning

Problem Identification	**Goal(s)**
• Reliable machine monitoring is important for cost reduction and breakdown avoidance • Machines are complex and individual, therefore a specific domain knowledge is necessary for effective monitoring	• Combination of domain knowledge and machine learning for monitoring industrial machines

Related Studies	Hypotheses / Research Objective(s)
• McArthur et al. (2004)	• Show how experiences of different parties of a product-service-system (PSS) can be combined in a hybrid-learning machine monitoring approach
Research Design and Methods / Phases	
• Exploring the research background • Development of a hybrid-learning machine monitoring approach • Partial application to a real case	
Limitation(s)	
• So far no complete application on a real case • No clarification of who owns which data	

4.7.2 Motivation and Research Topic

Monitoring of industrial machines is an important component to avoid unexpected failure as described in previous sections, but also to avoid unnecessary early maintenance. Maintenance can be a significant cost factor. Machine learning is a technique that allows the generation of much more precise information about the condition of a machine. However, it is challenging task because industrial machines can be very different and therefore the creation of robust machine learning models is difficult. Human expert knowledge could be part of the solution, as it can be used to complement the machine learning models. Additionally, it should be taken into account that machines are increasingly used in product-service-systems (PSS). This can mean, for example, that a machine is no longer bought, but only a service, for example a certain availability is purchased. These new ways of working lead to a stronger interaction of users and manufacturers of machines. This cooperation must also be taken into consideration for models that combine machine learning models with the expert knowledge of users or operators of machines.

McArthur et al (2004) describe a condition monitoring model, which does not yet consider the use in a PSS. This gap shall be closed with this research and an approach combining expert knowledge and machine learning models should be presented. This approach is embedded in a PSS, so the different roles within the system have to be considered.

4.7.3 Research Design and Methodology

After analyzing the current literature, an approach was developed on the basis of the findings, which represents a possible solution for the research objective. In a next step, the first part of the approach was implemented on a special demonstrator. Using a machine learning model, the point in time at which sensor values deviate from a normal course was identified.

4.7.4 Summary of the Results, Contributions, and Limitations

The core of the research is the developed approach to combine machine learning and expert knowledge in one PSS. The approach consists of three main components. First, an anomaly must be detected. The detection is done using a machine learning model, for example a long short-term memory (LSTM) network. If a deviation from the normal course is detected, it is processed by the monitor component. This component may then send the data to the third component, the classifier. Figure 14 shows the approach. In the following we will go into more detail about the individual components.

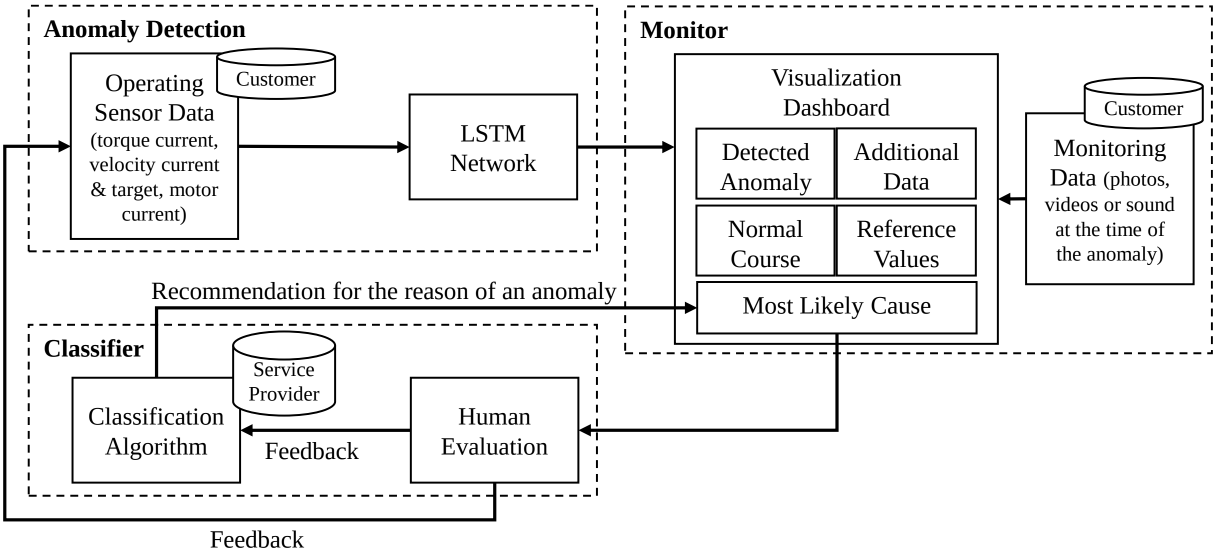

Figure 14. The developed hybrid-learning machine monitoring approach (Olivotti et al. 2018a, p. 4)

We assume that a machine can record a wide variety of data during operation. These data are with the customer who uses the machine. With a machine learning model anomalies shall be detected on the basis of this sensor data. In case of an anomaly, the monitor component takes over. Here the sensor data is processed and analyzed by an expert. This data can be enriched for example by photos, sound recordings or videos. The monitor component also suggests a presumed cause of the anomaly. The expert who carries out the analysis of the data can come from different parties of the PSS, depending on the application. It can be an employee of the service provider, the machine manufacturer, but also the user of the machine. The expert then makes a decision as to what he considers to be the cause of the anomaly or that it is not an anomaly at all. Once the human expert has made his assessment, the result is passed on to the classification algorithm. This algorithm is responsible for proposing a cause in the monitor component. With the feedback data, the algorithm that makes the suggestion can be improved. Additionally, the result is transferred to the Anomaly Detection component. Again, the feedback is used to improve the algorithm and correct wrong classifications. The data of the classification algorithm is in the hands of the service provider, since the service provider can collect and aggregate the data of several customers. With many classification algorithms, larger data volumes also lead to better classification results.

The presented approach combines the strengths of machine learning models and human experts. Experts are only involved if the sensor values show an abnormal course. Especially when a machine is newly introduced, the presented approach is helpful, because the monitor component initially does not require a large amount of data. In the course of time, the model is then trained so that it can always better suggest a possible cause. It is assumed that it can be difficult to provide large amounts of data, especially for rare errors. Without these large amounts of data, the machine learning algorithms tend to work less well and therefore require the knowledge of human experts.

As a limitation of the work, it is to be seen that it has currently only been tested partially in practice. The anomaly detection component was implemented exemplarily in an industrial company. In further research the other parts should be supplemented to evaluate the model in its entirety. Furthermore, the question of who owns which data must be clarified. This question is of enormous importance in the presented approach, because the accuracy of the machine learning models benefits from the fact that they can be trained with large amounts of data. These large amounts of data are available when sensor data can be used anonymously by several machine users to train the models.

4.8 Process Model for Data Science Projects

4.8.1 Overview

The whitepaper "DASC-PM v1.0 Ein Vorgehensmodell für Data-Science-Projekte" is summarized in this section. It is freely accessible on the Internet and is the result of a virtual working group that spent several weeks discussing the development of a process model for data science projects (Appendix 14). Table 18 describes the conducted research.

Table 18. Overview of the research on a process model for data science projects

Problem Identification	**Goal(s)**
• Different understanding of the term "data science" • No clearer requirements for data science projects	• To obtain a clearer understanding of the term "Data Science"
Related Studies	**Hypotheses / Research Objective(s)**
• Fayyad et al. (1996) • Wirth and Hipp (2000)	• To create a clearer definition of the term "data science" • To create an understanding of the tasks and connections of data science projects
Research Design and Methods / Phases	
The individual chapters of the paper were discussed successively within the working group	

Limitation(s)

- No detailed description of the selection process of data science analysis methods

4.8.2 Motivation and Research Topic

The topic of data science is increasingly being discussed in theory and practice. However, especially in practice, very different understandings and definitions of the term can be found (Schulz et al. 2020). It is difficult to distinguish between the terms data mining and operations research (Schulz et al. 2020). There are already widespread process models for data mining which are the knowledge discovery in databases (KDD) process and the cross industry standard process for data mining (CRISP-DM). This research will develop a specific data science definition and describe a corresponding process model, taking into account previous definitions and related process models. For this purpose, the requirements for a data science process model must first be discussed. From the requirements, key areas can be derived, from which specific tasks result. The overall result is the data science process model, which is to be developed with this research.

4.8.3 Research Design and Methodology

The research was conducted within a group of 22 researchers. The individual aspects of the process model were worked on in ten work packages. The structuring of the work packages emerged in the course of the project. For each work package, a questionnaire was sent to all participants, who were then able to answer voluntarily. Fixed deadlines were always given for the work packages to ensure continuous progress. Most questions were answered qualitatively and were read and summarized by Daniel Badura, Uwe Neuhaus and Michael Schulz. After the consolidation, the results of the work package could be viewed by all participants and comments could be made.

4.8.4 Summary of the Results, Contributions, and Limitations

As a first result, a definition of Data Science could be developed within the working group. This definition is translated here from German and states that

> *Data Science is an interdisciplinary field in which, with the help of a scientific, semi-automatic approach, and by applying existing or future analysis methods, knowledge is extracted from partly complex data and made usable under consideration of social effects.* (Schulz et al. 2020)

The essential components of Data Science are thus interdisciplinarity, scientificity, semi-automation, the consideration of different analysis methods, knowledge extraction, data complexity, utilization, and the consideration of social effects. After the definition of data science, three process models are discussed that have a relation to data science. In addition to the KDD and the CRISP-DM process already mentioned, there is the Team Data Science Process (TDSP), which was published by Microsoft (2017). From the comparison of the three processes, seven key areas of data science are derived which must be considered for a process model. These are scientific procedure, data, analysis procedures, provision, utilization, domain and infrastructure (Schulz et al. 2020). Figure 15 shows the relationship between these key areas.

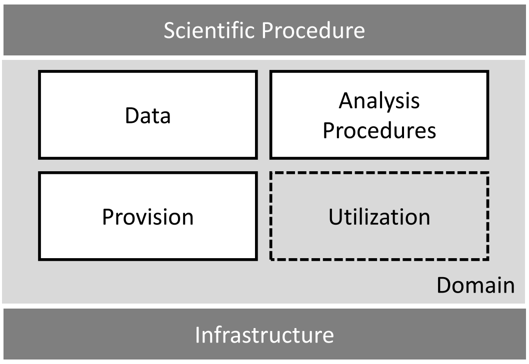

Figure 15. The relationships of the identified data science key areas (Schulz et al. 2020)

It is shown that the core is the data, the analysis procedures, and the provision of the analysis models. These key areas are followed by the actual use of the models, which is not yet described in any data science or data mining model (Schulz et al. 2020). These areas are framed by the respective domain, which has a significant influence on the key areas mentioned. Throughout the entire Data Science project, it is also assumed that a scientific procedure is taken into account. The infrastructure also plays a role, as it is the basis for data handling, analysis, provision and use.

Furthermore, it is worked out what is meant by the role of the data scientist and which other roles can be found in a data science project. However, the final Data Science process model (DASC-PM) is mainly based on the described key areas and their relationships. The model is visualized in Figure 16.

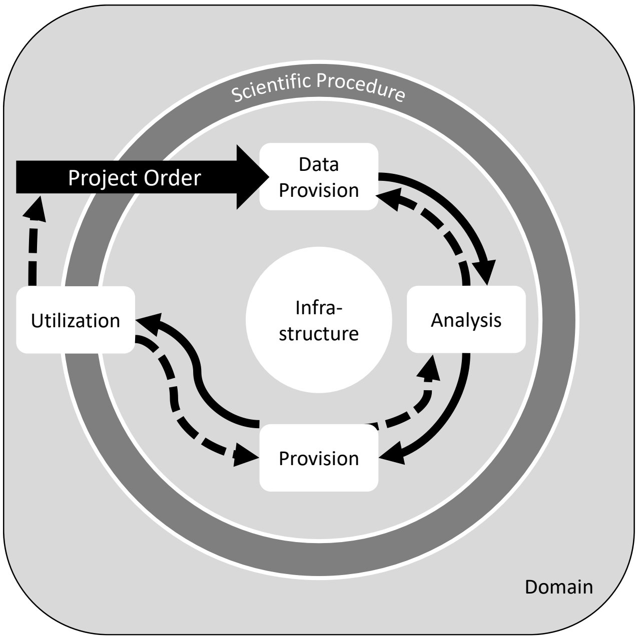

Figure 16. The developed data science process model (Schulz et al. 2020)

The project is initiated by an order. The entire procedure in the project is embedded in the respective domain. The following steps are to be processed according to scientific procedures. This means a structured approach but also depends on the domain and the project conditions. The next step is to provide the data. This step includes many tasks, since not only the acquisition of data, but also the processing and management are covered. This step can be by far the most time-consuming. Afterwards the data is analyzed. Either existing procedures are selected and applied or new procedures are developed. The analysis of the data is followed by the provision of the results. Depending on the project, elaborate procedures may have to be applied to visualize the results. It is also conceivable that new visualization methods have to be developed for the respective application. An example of this was shown in section 3.6, where several dimensions of PdM business models were reduced to two dimensions to be able to visualize the differences between the analyzed business models. The project is concluded by the actual use of the Data Science model. The utilization is only partly part of the project as the actual development is finished. This step involves checking whether the model is being used as planned to make changes if necessary. If it is determined that changes to the previous process step are necessary, it is possible to go back to a previous step. In the middle of DASC-PM, the infrastructure is located, because it is the basis for the respective process steps.

The individual process steps are described in much more detail in Schulz et al (2020). However, this level of detail would go beyond the scope here. What has not been described in more detail so far, is the choice of a suitable analysis method. This aspect should be dealt with in a future update of the model and represents a limitation of the model in the current version.

5. An Agenda for Further Research

5.1 A Primer

In this section, possibilities for further research are described. Roughly all described research streams of the discussed articles are gone through. The research opportunities are differentiated according to the different IS research traditions and do not claim to be exhaustive, but are only meant to provide an indication of what further questions exist. In addition, it is shown which relations exist between the different topics covered in this dissertation.

5.2 Research Methods in ISR

In Part A of this dissertation, two articles were presented that deal with research methods in ISR. In addition, a new method of visualization was presented within the research on a PdM BM taxonomy (section 3.6), which allows a two-dimensional representation of the investigated business models. In the research on the assessment of research projects, there is the possibility to analyze in more depth in which constellations assessment frameworks can lead to quality improvements and time savings. E.g., it could be investigated to what extent the usefulness depends on the IS research tradition for which the assessment is performed. However, perhaps other factors are also conceivable, which are crucial for a successful use. These factors could also be investigated in DSR-oriented research.

In the research stream of literature search, research could be done on the reasons for the documentation of a literature search and the choice of search methods. Findings from such research could be used to develop more targeted guidelines and thus improve literature searches in the long term. Through the research presented in this dissertation, it has also become clear that after deciding on the combination of different literature search methods, the respective choice of suitable tools can also be a challenge. In further research, it could be analyzed according to which criteria a literature search tool should be chosen, this can be done using a DSR oriented approach.

A new visualization method for cluster analyses was presented in section 3.6. In this context, there are further research possibilities with regard to how the new technique improves the evaluation of clustering and how it could also be used in cluster formation. In the research on a PdM BM taxonomy, the new visualization method was able to provide significant added value in the evaluation of the cluster results. To what extent these results are transferable can be tested with further research. Table 19 shows the mentioned possibilities of further research.

Table 19. Research opportunities for research methods in ISR

Research Stream	Behavior Research	DSR	Economics of IS
Assessing Research Projects	Tests in which constellations assessment frameworks for research projects lead to quality improvements and time savings	Development of success factors for the application of assessment frameworks in research	-
Literature Search	Investigation of the reasons for the type of documentation and choice of search methods in ISR	Development of a framework that supports the selection of tools for literature search	-

Research Stream	Behavior Research	DSR	Economics of IS
Visualization of Cluster Analysis	-	Examination in how far the new visualization technology can represent an improvement during evaluation but also already during formation of clusters	-

5.3 Digital Transformation

In this dissertation, BYOD was discussed in the context of digital transformation. There are still opportunities for further research that investigate in detail cultural differences in the use of BYOD. The research presented in this dissertation provided initial approaches for this (Degirmenci et al. 2019; Weeger et al. 2020). It is also open to what extent labor markets can benefit from the greater spatial and temporal independence made possible by BYOD.

Using WA as an example, the project also investigated how participatory design can be applied to make meaningful use of the increasingly diverse possibilities of digitization by the various departments of an organization. Further research can be done on how the use of digital self-services changes when the services are developed using participatory design. First research on this topic already exists (e.g., Mahamuni et al. 2016). However, this research could be further generalized. Another research possibility is to develop participatory design models that support the creation of SSBI concepts (Johansson et al. 2015).

The further research opportunities with regard to chatbots are considered here with a focus on an application in the BA environment. For instance, a behavioral research approach could be used to investigate how chatbots change the use of BA applications. In a DSR oriented approach, success factors that exist for the use of chatbots in BA applications could be identified. Independent of BA applications, it could also be investigated to what extent chatbots influence business models (Damnjanovic 2019).

Research on Industry 4.0 BMs could consist of investigating further concrete Industry 4.0 BMs to identify possible differences. The question can also be addressed of the extent to which providers of old business models are being displaced or whether they are adapting to Industry 4.0 offerings (Ibarra et al. 2018). In particular, the transition paths of business models offer opportunities for further research (Weking et al. 2020). Table 20 shows the described opportunities for further research in a bundled form.

Table 20. Research opportunities for the digital transformation

Research Stream	Behavior Research	DSR	Economics of IS
BYOD	Detailed exploration of the cultural differences in the use of BYOD	-	Investigation of different labor markets on the change by a stronger spatial and above all temporal independence by BYOD

Research Stream	Behavior Research	DSR	Economics of IS
Participatory Design in DT	Examination of a use of digital self-services created through participatory design	Application of participatory design models in the development of SSBI concepts	-
Chatbots	Influence of chatbots when using BA applications	Value adding factors when using chatbots in the BA environment	Influence of chatbots on BM
Industry 4.0 Business Models	-	Investigation of further industry 4.0 business models to show differences to PdM	Investigation in how far industry 4.0 BM displace old BM

5.4 Business Analytics

Three major research streams were covered in the Business Analytics part of this thesis. These are SSBI, Operations Research Models in Industry 4.0, and Data Science. In the area of SSBI, the research presented here can be used as a basis for further research on how SSBI can create value in companies. The articles of this dissertation have shown how architectures should be adapted, what is important for users of SSBI, and how application scenarios can be differentiated. These findings are the basis for a differentiated consideration of the question when SSBI is value-creating. For example, a precise definition of the considered SSBI application scenarios is necessary to analyze the factors that are crucial for value contribution. This can then also result in guidelines that support companies in choosing the right governance structures for the respective scenario. The dissertation has shown that these governance structures have a significant impact on the use of SSBI (Clarke et al. 2016; Passlick et al. 2020b). Potential is also offered by an examination of concrete SBBI application scenarios to analyze reasons for use from a company perspective. The examination could be conducted with case studies. Also, a general look at the value contribution of SSBI to organizations offers potential for further research. First works already exist in the big data environment (Günther et al. 2017). It is to be examined to what extent these results can be transferred to SSBI.

In the research stream OR in Industry 4.0 is the research opportunity on a process model for the choice of a suitable procedure for the calculation of failure probabilities. Both models presented in this dissertation share the assumption that a failure probability can be calculated based on sensor data. How this is done is not part of that research. There is the opportunity to shed light on this problem, even if the challenge is that very individual procedures are needed depending on the respective machine. Also, the challenge in both models is that any constellation of a breakdown must be taken into account for an accurate calculation of the expected failure costs. Further research could be devoted to approximation methods that can calculate the expected failure costs without processing all possible constellations. E.g., a meaningful grouping of machines could reduce the time and effort required for calculation.

In the data science stream there are opportunities for further research in all IS traditions. In the tradition of behavioral research it can be analyzed when and how hybrid intelligence can be used successfully. The development of selection processes for the choice of appropriate analysis methods in data science projects is a research opportunity in the DSR tradition. Such research would be a further detailing of the process model presented in section 4.8. Also, research that works out how data science citizen and data scientists work together, is an opportunity. Within the economics of IS tradition, research can be done on changes in business models caused by more data-driven decisions. Table 21 summarizes the described research opportunities of the BA part.

Table 21. Research opportunities for business analytics topics

Research Stream	**Behavior Research**	**DSR**	**Economics of IS**
SSBI	Further research of concrete SSBI application scenarios in companies and the reasons for its use	Development of guidelines for appropriate governance structures Development of guidelines to identify value-adding SSBI application scenarios	Value of SSBI for organizations
OR in Industry 4.0	-	Process model(s) for choosing a procedure, which can calculate the respective failure probabilities Approaches for processing individual default probabilities to avoid the need to consider all possible default constellations	-
Data Science	Investigation when and how hybrid intelligence is successfully used in companies	Development of concrete selection processes for the selection of suitable analysis methods in data science projects Improved coordination of the roles of the Data Science Citizens and Data Scientists	Change of business models through more data-driven decisions

6. Conclusions

This cumulative dissertation dealt with various topics of ISR. The respective articles were discussed in three blocks. These blocks are research methods in ISR, the digital transformation, and business analytics. Several research methods were used to investigate the respective problem. This included various forms of DSRs, but also behavioral research with quantitative analyses was conducted. The findings are briefly summarized below.

Part A first discusses an article that allows to present ideas for research projects in a compact way. The framework connects ideas from different previous works and can be used independently from the research design. For all further articles of this dissertation the framework is used to give a short overview of the respective research at the beginning of a section. The second article deals with literature searches. The challenge to search for literature has become greater in recent years and is expected to become even more difficult. This article aims to address this problem and to provide approaches on how to search for literature more precisely to find literature relevant for the respective research despite the large amount of literature. First, the currently available search methods are described. In a further step, literature reviews from renowned outlets are reviewed to analyze which search methods are used. The result is that the search methods used have changed over time and a trend towards more automated search methods can be identified. Based on these findings, seven recommendations are developed, which result from the findings of the previous analyses and are intended to stimulate a discussion on how to further improve literature searches. The combination of different search methods is an important aspects of these improved searches. Here, the aim is to combine the methods in such a way that the advantages of the respective search method are used meaningfully.

Part B discusses articles dealing with digital transformation in the broadest sense. For example, an article on the creation of WA reports shows how a participatory design approach can be used to create reports in such a way that the available data is used sensibly by multiple departments of an organization. This research addresses a problem that is also found in other areas of digital transformation, namely that just because functions or data are available, they are not necessarily used. With the involvement of employees, significantly better utilization can be expected. In another article, structural equation modeling is used to investigate the influence of privacy concerns on the use of BYOD. It is shown that privacy concerns have a negative impact on the use of BYOD. This is the result of a multicultural survey among employees. Work councils, who were examined in two case studies, also deal with privacy and influence BYOD concepts accordingly.

Two other articles deal with chatbots. This form of conversational agents offers new possibilities for the interaction with customers. In the first article, a taxonomy is developed which classifies domain specific chatbots and thus shows which forms currently exist. The second article describes a structured approach for implementing chatbots. Both articles help practitioners to consider the relevant application scenarios for chatbots as well as the most important aspects in the implementation. Research also benefits from the structuring of chatbots and from the knowledge of the difficulties during planning and implementing. The last article of Part B uses a taxonomy to describe different business models of predictive maintenance and shows their archetypes. Using a concrete business model, it is shown that not only purely digital business models exist in Industry 4.0. In addition, a new visualization method is used to show the differences of the grouped business models.

Part C deals with articles on business analytics. Three articles are dedicated to the topic SSBI. In a first article an architecture is developed with a DSR research design, which presents different components and their interaction to support SSBI application scenarios. It is important to keep in mind that there are different user groups and that they have to be supported with different components. Another article uses a structural equation model to investigate which factors influence the use of SSBI. Among other things, the article emphasizes the importance of governance structures to ensure sufficient data quality on the one hand, but also not to unnecessarily hinder SSBI users in their analyses. The third article then describes the dimensions and characteristics that are necessary to distinguish between SSBI application scenarios. In addition to the developed taxonomy, SSBI tool archetypes are examined, which allow conclusions about which SSBI application scenarios are addressed by the providers of the SSBI tools.

Two articles describe OR models that solve problems in Industry 4.0. In the first article, the amount of spare parts in stock is optimized based on sensor data. The second article deals with whether and when machines of a certain type are serviced. Again, the sensor data and the associated failure probability are the starting point for the model. Two articles of the dissertation deal with the topic data science. An approach for hybrid machine learning is described in the first article. Three components are used to automatically detect an abnormal behavior of a machine, which is then presented to a human expert. This human expert will then assess whether the detection was correct and what kind of failure it was. Besides the theoretical approach, the prototypical implementation of the first component is described. The second article describes a process model for the implementation of data science projects. This article was developed in a working group and combines diverse views on the topic. It offers a definition of data science and describes the different requirements for a data science project.

The last section discusses research possibilities that exist in each part of this dissertation. For this purpose, the related articles were summarized into research streams and exemplary research possibilities were discussed for each stream. The different IS research traditions are also discussed and research possibilities are subdivided into the traditions.

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Appendix

The following table shows the articles of this dissertation sorted by their occurrence. The appendix contains the articles in the same order. Pages for articles that have been published contain the respective link to the publication. Unpublished articles are attached.

#	Title	Section
1	Assessing Research Projects: A Framework	2.2
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3	Using Web Analytics Data: A Participatory Design Model For Individual Web Traffic Report Development	3.2
4	Future of Flexible Work in the Digital Age: Bring Your Own Device Challenges of Privacy Protection	3.3
5	A Self-Service Supporting Business Intelligence and Big Data Analytics Architecture	4.2
6	Virtual Assistance in Any Context - A Taxonomy of Design Elements for Domain -Specific Chatbots	3.4
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13	Combining Machine Learning and Domain Experience: A Hybrid-Learning Monitor Approach for Industrial Machines *(Best Paper Nominee)*	4.7
14	DASC-PM v1.0 - Ein Vorgehensmodell für Data-Science-Projekte	4.8

Appendix 1 - Assessing Research Projects: A Framework

Outlet: IWI Discussion Paper #83, Institut für Wirtschaftsinformatik, Leibniz Universität Hannover

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The article follows on the next pages.

IWI Discussion Paper Series
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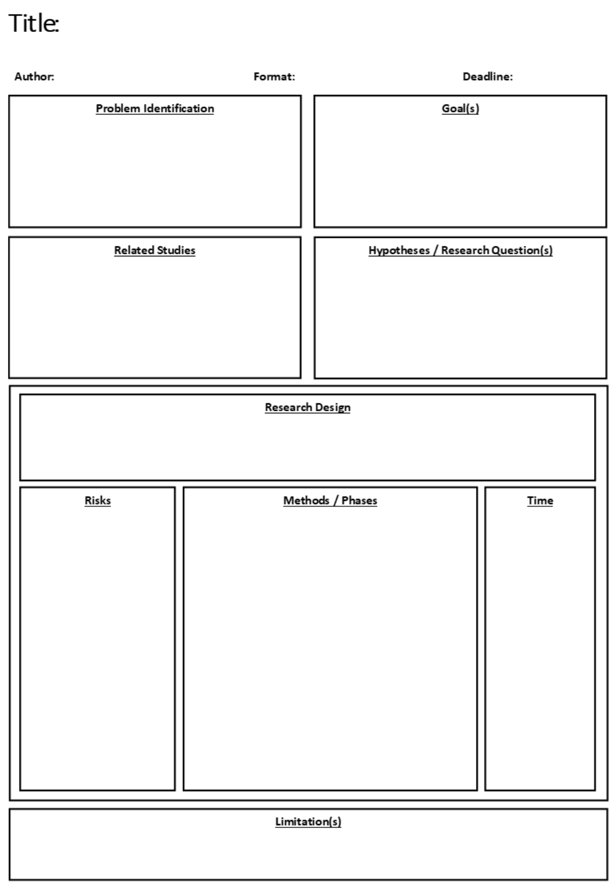
Assessing Research Projects: A Framework

Jens Passlick[2], Sonja Dreyer[2], Daniel Olivotti[2], Benedikt Lebek[3] and Michael H. Breitner[4]



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1 Introduction

In the day-to-day life of researchers, they are constantly faced with new research opportunities. At a first glance it is not always clear whether an idea can be put into real-world research. A researcher has to select the most suitable ideas for his personal research. A suitable tool is required that helps to decide whether a research idea has the potential to contribute to close a research gap and to academic and/or practical knowledge. Challenges and possible problems have to be uncovered in an early stage, ideally before starting the research. Additionally, further aspects have to be considered, such as hypotheses, goals and potential methods. Not only the assessment of own ideas but also of those from other researchers requires a compressed overview. A short summary of the rough research idea should enable an early assessment whether the research approach is promising. This is similar to the situation of company founders or investors who have to identify the best ideas from many business opportunities.

The “Business Model Canvas” by Osterwalder et al. (2010) is often used for evaluating business models. The works of Latham (2016) as well as Nagle and Sammon (2016) have already shown that it is also possible to develop a canvas for research. As Nagle and Sammon (2016) have already described, such a framework is similar to “Design Thinking” and “Visual Thinking” (Ware 2010) methods as they visualize ideas and enable collaboration on them. Nagle and Sammon (2016) focus on the application of a research canvas in the design science environment. On the other hand, Latham's research canvas aims to be universally valid. He divides his canvas into the parts foundation and method. When applying the research canvas to assess ideas for own ideas and publications, we have missed aspects in both models. We think that an examination of the problems and risks that can arise in a research project should be part of a framework for assessing research ideas. The rough research design should also emerge from the framework. This leads us to the research question of this paper:

RQ: How does a framework for assessing research ideas look like?

We developed our framework in different steps. We analysed existing literature and frameworks in the field of research idea evaluation. Based on this, in combination with our own experiences of important aspects, we designed a first prototype of a framework. We and further participants tested this prototype. Through tests and focus group discussions the prototype was improved and led to the final framework.

The paper is organized as follows: Chapter 2 presents existing literature concerning frameworks for evaluating and assessing research approaches. It is followed by the development of an own framework. The results are discussed in the fourth chapter. The paper closes with conclusions in chapter 5.

2 Related Literature

To get a comprehensive overview of existing literature dealing with frameworks for assessing research ideas, a systematic literature review was conducted. In order to ensure a structured search process, the following three search terms were predefined:

- "Evaluating research"
- "Presenting research"
- "Research canvas"

As representative for an academic database in the field of information systems, we chose "AISeL". This database includes peer-reviewed papers from different high ranked journals and conference proceedings. "Google Scholar" was used to include research from all research disciplines. In this way, potential articles that are not assigned to the information systems research can also be found. As already explained, the aim of this paper is to develop a framework that is useful in practice for researchers. Google Scholar also helps here, because it includes also non-academic publications such as whitepapers and book chapters.

The objective of research is to contribute to academic and/or practical knowledge (Hassan et al. 2013). To reach this, gaps that are promising for future research have to be identified (Müller-Bloch and Kranz 2015). Important publications in the research field should be identified as well as definitions of key terms should be determined. Based on this, research questions can be formulated and the objective of research can be clarified (Wang et al. 2010). To be able to do this in a structured way, a framework is helpful. Fulfilling this purpose, two different frameworks are identified from literature, Latham (2016) and Nagle and Sammon (2016).

Latham (2016) developed a framework called "Research Cancas", to design and structure research ideas. The framework aims at general applicability and comes from an application in the social sciences. The Research Canvas is divided into two big blocks: Foundation and methodology. The foundation consists of the areas: Problem, purpose, research question/hypotheses and the conceptual framework. The methodology block consists of a literature review, an overview of how research questions should be "approached", the data collection, the data analysis and the last block in which conclusions are to be drawn. Further, Latham shows interdependencies and connections of the individual areas of the model. The framework aims to show a research process from the problem formulation to the problem solution. This is only a suggestion and the research process can include several iterations or jump over some steps.

A framework by Nagle and Sammon (2016) is called "Design Research Canvas" and focuses on design research approaches. This means that quantitative research, for example, cannot be mapped optimally. The aim is to support the connection between practitioners and researchers as described by Hevner et al. (2004). The model itself is even developed in a design research process. The framework is devided into four different aspects which are "problem", "impact", "design & build" and "evaluation". The

practical and scientific aspects of each aspect is examined. So, there is a concentration on the cooperation between practitioners and researchers. Two of the five considered aspects deal with the impact of research. On the one hand it is viewed on the research idea from a practical perspective. It is intended that the practical impact should be evaluated. On the other hand, the academic impact has to be determined, coming from a researcher's perspective. Continuing the two different perspectives, three further aspects are considered in the framework, namely problem, design and build as well as evaluation. Nagle and Sammon emphasize that iterations are very important in design research. That is why they recommend to adapt the framework in each iteration of the research approach development process.
In order to be able to assess research ideas, the problems and risks that can arise in carrying out research play a major role for us. Not only the possible impact should be considered but also potential risks. The presented frameworks from Latham (2016) as well as from Nagle and Sammon (2016) do not consider this at all or only secondary. Therefore, we developed a framework to assess research ideas that does also focus on potential limitations, the planned time for each phase of the research and the risks in the different phases.

3 The Developed Framework

The framework that we developed to assess research ideas consists of six main blocks. The first four blocks help to locate the research idea in its context. The last block consists of in total five sub-blocks. In this, it is focused on the research design and approach. Our framework is based on the work by Latham (2016) in the first blocks. The first one has the heading "problem identification". In this part the research problem should be specified. This can be both a practical or an academic problem. Afterwards, two different processing sequences are conceivable. One possibility is to first define the goal of the research based on the problem. This refers to a description of a goal regardless of existing research. It leads to the box "related articles" which is based on the block "literature review" by Latham (2016). Here, first papers can be mentioned that serve as a foundation or follow a similar idea. The mentioned literature may also show that only a certain aspect of the goal has not yet been researched. Based on the review of the existing literature, the hypotheses and/or the research questions of the planned research can be described. This also represents the research gap and completes the first part of our framework. It is also conceivable to describe similar studies directly after defining the problem. Coming from existing literature in the research field, goals and research questions/hypotheses arise. Which way is more suitable for the resepective idea has to be determined individually.
The second part of the framework describes the research design. First of all, there is space to mention the basis of the research design (e.g. Design Science Research). The block also contains the sub-blocks "risks", "phases/methods" and the time required for the conduction of the research. The phases/methods block lists the scientific

methods which should be used in the presented research. For example, “literature review”, “expert interviews” or “survey” is entered here. The block "risks" shows which problems might arise with each method or in each phase. For example, a risk could be that not enough participants are found for a survey. The scheduled time for each phase/method is entered in the block "time". It can be checked whether the planned time is sufficient for the execution of the respective method/research phase.
The framework is arranged in such a way that both the risks and the expected duration can be assigned to the different phases. The separation into single phases in the research design block is adapted from the framework presented by Nagle and Sammon (2016). However, we enrich it through the risks, the planned time and the limitations of the respective research. The limitations will then describe what cannot be treated in the described research project. By presenting the risks and the planned time in one line with the individual phases of the research, it is possible to see more quickly where problems might occur and whether the time is sufficient or not.
Figure 1 shows the final framework.

4 Discussion

The framework proved to be very helpful in the first tests when using the framework for bachelor and master theses of students. Additionally, focus group discussions with testers of the developed framework led to further findings. In the first version, the framework had even more boxes which caused confusion among some students, as the delimitation of the boxes were much more difficult. It was also important for the students to know if and how they have to follow a certain order when completing the form. As supervisors of the work, we found that it is important for us to quickly identify which research design and methods should be used, also in order to assess the risks of the application.
We find it very helpful to divide the framework into two parts. This is similar to the design by Latham (2016). However, the two parts have very different focuses. Latham (2016) assumes a fixed sequence of research, which can be described as follows: Literature review, overall approach, data collection, data analysis and finally drawing conclusions. We do not consider this structure to be flexible enough. In addition, we believe it is important that the risks are also taken into account at every stage of research. For each method it should be checked whether it can lead to valid results or whether it could be problematic. Compared to Nagle and Sammon (2016), we have detached from a particular information systems research design. With the developed framework, behavioural as well as design-oriented research can be presented. The appendix contains two examples of filled out frameworks. They show how it can be used. So far, no statements can be made about the transferability of the framework from information systems research to other research disciplines such as the social sciences. We have only tested the framework in the information systems research environment. But this might be an interesting starting point for further research.

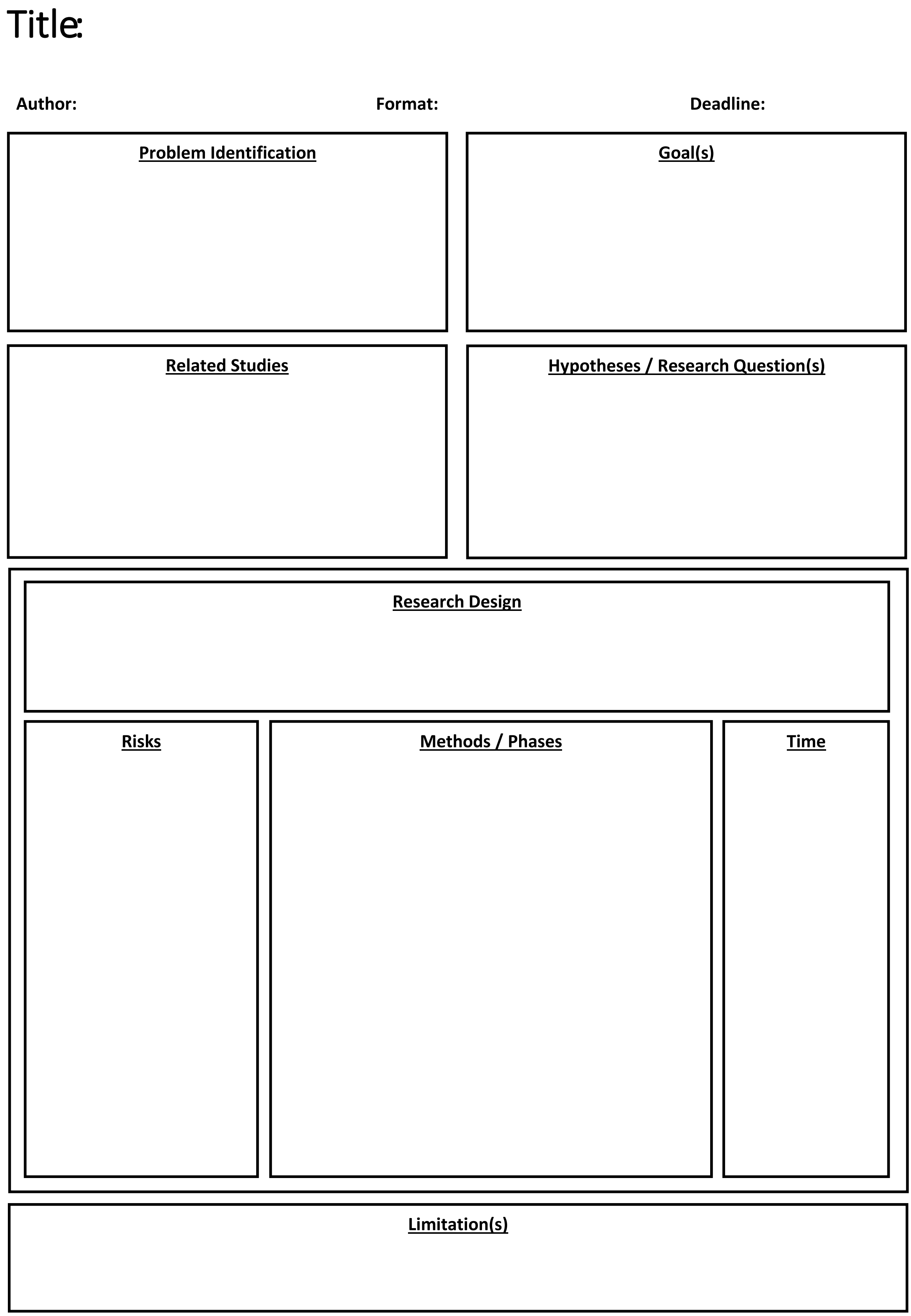

Figure 1. The developed research assessment framework

5 Conclusions

The first approaches to the evaluation of research ideas by Latham (2016) and Nagle and Sammon (2016) are already a good basis for a framework. However, we have seen room for improvement in the analysis of risks and the presentation of the research design. Our developed framework is divided into two parts. The first part describes the basis of the research. The second part is devoted to research design, limitations, the planned time, individual methods and their risks in the elaboration. During the development phase, the first tests with bachelor and master theses of students have already been incorporated into the structure of the framework. It has been shown that it is important for the students that the individual areas of the framework can be easily delimited. The maturity of the model is to be further enhanced by additional tests with students and doctoral students.

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Appendix

Examples of filled out frameworks

A quantitative study

Research Assessment Framework

Title: Individual Factors for using SSBI

Author: **Format:** **Deadline:**

Problem Identification

- Data Quality because of Shadow BI
- Introduction of SSBI Software does not necessarily lead to an active use of SSBI tools

Goal(s)

- To understand what leads to the use of SSBI

Related Studies

- Işik et al. (2013)
- Hou (2014)
- Bani-Hani et al. (2017b)
- Daradkeh and Moh'd Al-Dwairi (2017)

Hypotheses / Research Question(s)

- How do individual factors influence the intention to use SSBI and the expected success of SSBI applications?

Research Design

- Quantitative research
- Structural equation modeling

Risks

- Constructs which are not validated enough
- Not enough participants

Methods / Phases	Time
Literature review	30 days
Model & hypotheses development	10 days
Survey development	5 days
Conducting the survey	90 days
Analysis of the survey	30 days
Writing	20 days

Limitation(s)

- Only the individual factors that influence SSBI are considered
- Limitations of quantitative research

Title: Literature Review in the Field of Smart Services

Author: **Format:** **Deadline:**

Problem Identification

- No structured overview of existing smart service literature
- No existing research agenda available

Goal(s)

- Comprehensive overview of current state of research in the field of smart services
- Identification of research gaps

Related Studies

- Allmendinger and Lombreglia (2005)

Hypotheses / Research Question(s)

- Which topics in the field of smart services in the academic literature are focused on which lifecycle phases?
- Which important research gaps are promising for further research?

Research Design

- Structured literature review according to Webster and Watson (2002)

Risks

- No interesting analysis results
- Identification of an existing research agenda

Methods / Phases	Time
Literature search	25 days
Analysis and categorization of literature	50 days
Identification of research gaps	10 days
Writing	25 days

Limitation(s)

- Use of predefined search terms
- Limited to eight databases

IWI Discussion Paper Series/Diskussionsbeiträge

ISSN 1612-3646

Michael H. Breitner, *Rufus Philip Isaacs and the Early Years of Differential Games*, 36 S., #1, 22. Januar 2003.

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Appendix 2 - Towards an Improved Literature Search: The Past and Guidelines for the Future

Outlet: Communications of the Association for Information Systems (CAIS)

Abstract

Finding most of the relevant literature is necessary to justify relevance and need of research. Due to a permanently growing number of scientific articles, a successful literature search is demanding and time-consuming, especially for novice researchers. Often a literature search is ineffective, i.e., important papers are missing, the search is imprecise, or too much time is spent. We conduct a literature review to discuss advantages and disadvantages of today's literature search methods. Further, we analyze the current literature search practice by examining methodological trends within the Information Systems (IS) research domain in the timeframe 1999-2020. We synthesize the findings from the initial literature review and the analysis of the search practice into seven recommendations to assist researchers in future literature searches. The possibilities of more automated search methods, such as a related article search, are presented and discussed.

Keywords: Literature Search, Review Types, Research Methodology, Search Methods, Improved Literature Search, Search Tools

The article has been submitted and follows on the next pages.

Towards an Improved Literature Search: The Past and Guidelines for the Future

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Third Author’s Department and University or Other Affiliation

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Fourth Author’s Department and University or Other Affiliation

Abstract:

Finding most of the relevant literature is necessary to justify relevance and need of research. Due to a permanently growing number of scientific articles, a successful literature search is demanding and time-consuming, especially for novice researchers. Often a literature search is ineffective, i.e., important papers are missing, the search is imprecise, or too much time is spent. We conduct a literature review to discuss advantages and disadvantages of today’s literature search methods. Further, we analyze the current literature search practice by examining methodological trends within the Information Systems (IS) research domain in the timeframe 1999-2020. We synthesize the findings from the initial literature review and the analysis of the search practice into seven recommendations to assist researchers in future literature searches. The possibilities of more automated search methods, such as a related article search, are presented and discussed.

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1 Introduction

Finding relevant and current literature, as a basis of research, is one of the most important tasks at the beginning of every research project aiming to contribute to existing knowledge (Baker, 2000). A critical review of current literature in a specific research area influences both actual research, as research depends on the identified research gaps and needs, and later the communication of the conducted research. The scientific community must be convinced that the described research has brought new insights. The challenge of covering the current state of research is becoming increasingly demanding as literature searches are more complex because progressively more research is being published and more information is available (Hilbert & López, 2011; vom Brocke et al., 2015; Larsen et al. 2019; Sturm & Sunyaev, 2019). An effective literature search process facilitates the consumption and generation of knowledge, these are qualities that researchers must consider foremost in the research process. In addition, "the quality of literature reviews is particularly determined by the literature search process" (vom Brocke et al., 2009, p. 1). Another challenge is that "there is no one-size-fits-all approach" for a literature search (vom Brocke et al., 2015, p. 209).

To cope with the high amount of literature there is already a discussion about how to improve the efficiency of literature searches (Boell & Cecez-Kecmanovic, 2015a; Watson, 2015). Watson states that the "the academy in general has ignored changes in technology and failed to exploit opportunities to advance the efficiency of scholarship" (Watson, 2015, p. 186). In recent years, further promising opportunities for improved literature searches have arisen in the field of artificial intelligence in its broadest sense (Polonioli, 2020). Papers have been published, in which tools recommend similar articles based on semantic indexing (Koukal et al., 2014), based on citation analysis (Xu et al., 2017; Larsen et al. 2019), or help by unifying the "access to multiple literature databases" (Sturm & Sunyaev, 2017, p. 7). However, it is unclear how all these possibilities can be used or combined meaningfully. In addition, a well-documented keyword search seems to be a decisive criterion for assessing the transparency of a literature search. It appears essential for the reproducibility of the search to specify these keywords to be able to check them for plausibility. Other search methods could be neglected for this reason. With this paper we want to shed light on what distinguishes literature search methods and how to use them. We pursue the research objective:

Research objective (RO): Elaborate the currently available literature search methods, their use, their advantages, and disadvantages, and to derive recommendations for the use of these methods.

The next section describes the theoretical background of literature search and considerations when searching. Based on Paré et al. (2015) we derive possible stratagems of a literature search. We then discuss common search methods, tools, and techniques. The advantages and disadvantages of the respective search methods are summarized to determine how they complement each other. The current practice of literature search is analyzed in the fourth section. Here, the researchers' side is represented by a set of literature reviews in which we analyze how the literature search was conducted and described. More precisely, we analyze how current and previous literature searches have been conducted to demonstrate how common methods used have changed. We then bring together the findings from the review of current search methods and the analysis of current practice with seven recommendations for literature searches. Limitations of our research are presented and suggestions for further research are made. Our paper ends with conclusions.

2 Foundations and Research Approach

2.1 Different Literature Searches and their Goals

To lay the foundation for our research, it must be elaborated which role the literature search has in research that should have a high impact. We agree with Baker (2000) that a well-founded literature search is the basis of all research. Only an extensive literature search, makes it possible to describe the current state of research allowing the identification of a research gap. The defined research gap is the essential justification of a research project. In addition, previous research has shown that if the literature search is properly documented, the citations of the research is significant higher (Wagner et al., 2016). Although this has only been explicitly investigated for literature reviews so far, it underlines the traceability of the literature search for research in general. The assumption is that when a literature search is documented, conclusions about its completeness and rigor are possible which in turn could indicate the overall quality of the methodological approach (Wagner et al., 2016).

In addition to providing basic justification for a research project, a literature review can be a research method in itself. Paré et al. (2015) describe a taxonomy that organizes the different forms of literature reviews. They also assigned at least one characteristic search strategy to each review type. The assigned four search strategies are shown in the following table. It can be seen that the search strategy must be derived from the research objectives. The requirements of a literature search depend on the goal of a literature review.

Table 1. Literature Review Goals and Search Strategies based on Paré et al. (2015)

Search strategy	**Our description of the search goal**	**Overarching goal of the literature review**	**Theoretical review types**
Comprehensive	Finding all relevant literature of a certain topic	Summarization of prior knowledge	Scoping review
		Data aggregation or integration	Meta-analysis, qualitative systematic review, umbrella review
		Explanation building	Theoretical review
Iterative and purposive	Searching for specific aspects, for example, finding specific models that explain certain circumstances	Explanation building	Realist review
Selective	Search in specific outlets or selection of specific papers	Summarization of prior knowledge	Narrative review
		Critical assessment of extant literature	Critical review
Representative	Examination of a set of papers intended to be a representative sample of all research on the aspect in question	Critical assessment of extant literature	Critical review
		Summarization of prior knowledge	Descriptive review

The various challenges of a literature search have already been mentioned, for example, difficulty to plan a search, databases with different coverage and functionality (vom Brocke et al., 2015). Also the requirements for a literature search have already been described by Sturm and Sunyaev (2019). Literature searches need a high level of comprehensiveness, precision, and reproducibility (Sturm & Sunyaev, 2019). Precision in this context means that a large amount of the search results are also considered relevant for the research project. In particular, the need for precision has continued to gain in relevance over the past years and is likely to continue to grow in importance (vom Brocke et al., 2015). The larger amounts of literature to be searched also require search methods that have a high precision, which means that they do not complicate the analysis of the results by many irrelevant items (Sturm & Sunyaev, 2019). In addition, it must be noted that “comprehensiveness usually does not equal completeness” (Sturm & Sunyaev, 2019, p. 97). We think that especially the amount of available literature to be reviewed is such a big challenge that an improved practice in literature search must be discussed. In addition to the choice of the most suitable search techniques, various considerations must be made during a search. With regard to the big amount of literature, it is a matter of balancing coverage and feasibility (vom Brocke et al., 2015). Figure 1 visualizes the three mentioned goals for a literature search. Depending on the search strategy, the goals may need to be weighted differently. While comprehensiveness tends to take a secondary role for the “selective” and “representative” search strategies, it is of particular relevance for the “comprehensive” strategy. Complicating the goal comprehensiveness is the fact that resources for searching are limited. Precision will therefore have to play a more important role. There is only a limited number of researchers and they can only search for a limited time. Here, the best possible compromise has to be found.

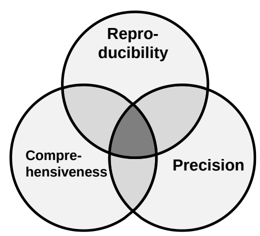


Figure 1. Goals of a Literature Search based on Sturm and Sunyaev (2019)

In the academic discussion, it has already been mentioned that the described goals for a literature search partly conflict with each other (Boell & Cecez-Kecmanovic, 2015a). Boell and Cecez-Kecmanovic (2015a) state that systematic literature reviews focus on the reproducibility of the search. This aim is at the expense of the precision of the search (Boell & Cecez-Kecmanovic, 2015a). We see this especially in the keyword search. This search method is well reproducible, because one can easily specify which search strings were used, but many search results have to be looked through where much is irrelevant. In this context, iterative approaches are discussed to be more precise and at the same time contribute to the completeness of a search (Boell & Cecez-Kecmanovic, 2014). In contrast, it is questionable whether they are equally well reproducible. For this reason first efforts to change this goal to repeatability exist (Cram, 2019).

2.2 Research Approach and Methods

To identify which search methods are currently available, we conducted a literature review as a first step. According to the Paré et al. (2015) definition, this form of review can be called a narrative review. The search terms used were “literature search,” “related search,” “keyword search,” and “literature review.” We examined various databases, including Google Scholar, AISel, and EBSCOhost. Most of the papers were found with a forward / backward search and the use of a related article search function. This process was helpful for identifying literature both within and outside of IS research. Particularly in the field of medical research (e.g., Bethard & Jurafsky, 2010; Booth et al., 2016) and systems engineering (e.g., Wohlin, 2014; Kitchenham et al., 2016), valuable contributions have been made to the presented research objective. The publication lists of certain authors were analyzed to identify further suitable papers (e.g., Beel, Boell, Cecez-Kecmanovic, or Polonioli). After analyzing the literature found, it could be described which search methods are available. From this, the advantages and disadvantages of the respective methods could then be derived in a further step. After showing which literature search methods exist theoretically, it must be clarified whether and how they are used in practice. Thus, conclusions can be drawn about how the search methods are combined and how newer search methods could fit into these strategies. For this purpose, we conducted another literature review, which can be classified as a meta-analysis according to the Paré et al. (2015) classification.

To provide a state-of-the-art indication of the search practices used, we analyze literature review articles more in detail. We collected the search practices used with a two-step procedure. Paré et al. (2015) constructed a theoretical typology of review types from literature reviews in journals. Equipped with an outlet of 138 literature reviews in the timeframe 1998-2013, we looked for descriptions and further information regarding the literature search practices used. To update these practices and provide a long-term, more recent view, we extend the methodology of Paré et al. (2015) to the timeframe of the years 2014-2020 by browsing in outlets. Therefore, we searched the five IS journals Information & Management, Information Systems Research, Journal of the Association for Information Systems, Journal of Management Information Systems, and Management Information Systems Quarterly (MISQ). We looked for papers "whose overarching goal was to summarize or synthesize the extant literature on a given topic or methodology without collecting or analyzing any primary data" manually (Paré et al. 2015, p. 190). This process led to an additional 97 reviews. To construct comparable 2-year time spans for our analysis, we dropped one review in 1998, resulting in a total of 235 literature reviews from 1999-2020 in the mentioned IS journals. Not all researchers define their methodologies for their literature search in the main article in detail. Therefore, we also downloaded and searched for used literature search methods within the supplementary material or appendices where this information was available (e.g., Chen et al., 2010). The papers mentioned are examined for the type of literature review and the search methods used. From this, statements can then be derived as to how literature is and has been currently and previously searched for.

The findings from the studies of available literature search methods and literature search practices can then be used to derive recommendations and guidelines for literature searches. Figure 2 summarizes the procedure described.

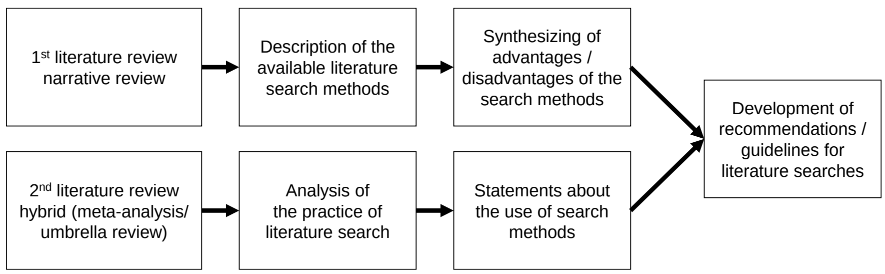


Figure 2. Research Steps

3 Available Search Methods

In the following, we present the identified methods, possible tools, and techniques for using the literature search methods in alphabetical order. We also address the advantages and disadvantages of the respective methods. The boundaries between the methods and their respective techniques are fluid. We distinguish the methods mainly according to the required input and the degree of automation.

The **analysis of secondary literature** is useful to provide a brief overview of a topic or a subject area. In contrast to secondary literature, all papers "that are specifically focused on the target topic" are called primary literature (Bandara et al., 2015, p. 164). Thus, secondary literature includes all studies that provide an overview of a topic or a subject area. An example of secondary literature might include a literature review on a specific research topic. Then, the literature review can provide the initial papers for an introduction to the topic. Other sources can include encyclopedias, handbooks, edited books, or editorials of special issues (vom Brocke et al., 2009; Boell & Cecez-Kecmanovic, 2014). We also see calls for papers as a possible source for literature. Bandara et al. (2015) suggest NVivo as a supporting tool. With a "keyword in context" search, searches within a document can be supported (Bandara et al., 2015, p. 164). This approach is a methodology that does not require much effort, but the results are likely also limited. However, secondary literature can provide familiarity with a topic, providing both a good overview as well as an introduction to a topic (Baker, 2000; vom Brocke et al., 2009; Boell & Cecez-Kecmanovic, 2014). The decisive factor for the value of the method is how close the content of the overview is to the research question. Since an overview is given, the contribution to individual research questions may often be limited.

Browsing in outlets means that certain journals or conference proceedings are defined and then their complete tables of contents are screened for suitable papers. This approach can also be called manual search or hand searching (Booth et al., 2016). This step is taken without the definition or input of any keywords (Rowe, 2014). Thus, there is no automation here. However, this method can always be used, although it is time consuming.

Expert consultation includes all methods for which a corresponding expert must be identified and used for literature extraction. We differentiate this approach in consulting these experts on literature recommendations actively, whereas screening of the publication lists of the experts. One way to perform an expert consultation is to look for authors who have already published papers about aspects of the research question. The experts can also be asked for material that has not yet been published (Petticrew & Roberts, 2006; Booth et al., 2016). Templier and Paré (2015) report that it is also possible to use ListServs such as the one from the AISWorld to ask the community for unpublished and working papers that could counteract a publication bias. A publication bias results from the fact that usually, only significant results are published. Thus, a literature search without asking for unpublished material does not provide a comprehensive picture of current research, which is especially necessary for aggregating reviews (Templier & Paré, 2015). A disadvantage of the expert consultation in general is that it can lead to biased results, since more papers of a specific author may be included and thus a particular viewpoint may be analyzed and prioritized. In addition, if experts were asked for recommendations, the search is not easily reproducible, which can be the goal of a literature search (Rowe, 2014; vom Brocke et al., 2015). It is also uncertain whether an expert contacted will cooperate willingly. However, meaningful results can be expected, as the results have already been edited by the experts to some extent (Booth et al., 2016). Another advantage can be the avoidance of a publication bias as described above (Templier & Paré, 2015). In contrast, simple screening of publication lists is often reproducible and quickly performed, but only publications by the respective author can be found. Whereas with a recommendation, other authors can also be found.

Forward / backward search describes a search based on citations. The search starts with one or more papers (input papers). Either papers that have quoted the input papers (forward) or papers quoted in the input paper (backward) are analyzed. In other sources, the method is also called citation searching, snowballing, or citation analysis (e.g., Boell & Cecez-Kecmanovic, 2014; Wohlin, 2014; Booth et al., 2016). Wohlin (2014) uses "snowballing" as an umbrella term, while Boell and Cecez-Kecmanovic (2014) use the term to specifically indicate a backward search. One of the first publications describing this concept is that of Webster and Watson (2002), who recommend conducting a forward / backward search after a keyword search or browsing in outlets. Boell and Cecez-Kecmanovic (2014) note that no more recent literature can be identified in a backward search further back than the date of the input paper. The forward search has the problem of not being able to quickly identify the context of a citation. A paper can be cited for a variety of reasons (Nicolaisen, 2007). For an analysis of frequently cited papers, a large number of papers must be evaluated accordingly (Boell & Cecez-Kecmanovic, 2014). However, no tools are necessary to perform a backward search. Nevertheless some tools supporting a backward search exist, for example, CiteSpace (Bandara et al., 2015) or PaperVis (Chou & Yang, 2011). Several sources report how efficiently (the relationship between found relevant literature and amount of screened literature) the authors searched for literature with a forward / backward search (Greenhalgh & Peacock, 2005; Athukorala et al., 2013; Wohlin, 2014). A disadvantage is that identifying suitable input papers can be difficult. Furthermore, there is the risk that only certain clusters of papers are identified, since only papers are found that have a direct or indirect connection to the input paper (Wohlin, 2014). A connection between papers through citations does not always have to exist.

By the term **keyword search**, we mean all methods in which keywords are needed to search for papers. After the development and evaluation of keywords the search can be carried out in different types of databases. In the following, we distinguish between publisher databases (e.g., SpringerLink, IEEEXplore or AISeL) and meta-databases (e.g., Web of Science, Scopus or Google Scholar). For our research objective, this distinction is sufficient, as a more detailed differentiation between the databases can be found in Sturm and Sunyaev (2017). A keyword search starts with the selection of databases for the search to be performed and the definition of keywords (Schoormann et al., 2018). The context and the aim of the research have a strong influence on the choice of sources (Bandara et al., 2015). When selecting the databases, no database currently exists in which all IS journals are available (Boell & Cecez-Kecmanovic, 2014). In contrast to the literature databases, meta-databases combine several different literature databases. For multi-disciplinary coverage, meta-databases can be used (Boell & Cecez-Kecmanovic, 2014). However, this process can also lead to a large number of results that overlap with truly important papers (Booth et al., 2016). For this reason, a combination of different databases and meta-databases is recommended (Samadzadeh et al., 2014). The use of Google Scholar has been debated in this context by several authors (e.g., Bandara et al., 2015; Kuhrmann et al., 2017). They recommend a search in accepted databases followed by a “backup search” in meta-databases (Kuhrmann et al., 2017). This context demonstrates how decisive the choice of databases can be for the success of a keyword search. After selecting the databases, the keywords for using the search engine must be defined. The classical method for this is to derive the words from the research goal or the research question and then, several techniques for refining these keywords exist. One possibility is the use of a thesaurus to create a list of different expressions that mean the same thing (Booth et al., 2016). In many search engines, the identified keywords can then be linked using different operators. The work by Boell and Cecez-Kecmanovic (2014, p. 279) describes how ‘or,’ ‘and,’ ‘not,’ and others can be used meaningfully, so that the keywords become a search string. The search engines can use different syntaxes when interpreting the search strings. However, the tool LitSonar can then help to adapt the developed string to the specific requirements of the respective search engines (Sturm & Sunyaev, 2017). Thus, the tool can support the requested use of different databases. Additional strategies include successive fractions, building blocks, and pearl-growing (Boell & Cecez-Kecmanovic, 2014). These strategies are techniques with which the search string can be iteratively improved. The definition of keywords can be supported by tools such as NVivo or TAGME, described by Bandara et al. (2015) and Marrone and Hammerle (2016). The tools help identify meaningful keywords.

In summary, the hurdles associated with performing a keyword search are rather low because, in general, it is possible to define keywords. However, there are also considerable weaknesses associated with a keyword search. Boell and Cecez-Kecmanovic (2015b) illustrate this challenge with the example of the Technology Acceptance Model (TAM). If “Technology Acceptance Model” or “TAM” is searched, Davis' decisive paper from 1989 is not found, as the term does not appear anywhere in the paper (Boell & Cecez-Kecmanovic, 2015b, p. 165). Another problem is that a keyword search is limited by the use of acronyms and plurals with the same meaning for a specific topic (Marrone and Hammerle, 2016). This difficulty especially arises in the IS domain because of the highly dynamic nature of IS research with respect to new technologies and the rapid evolvement of “buzzwords” for different topics which is particularly challenging for novice researchers (vom Brocke et al., 2015, p. 210).

Methods comprising **related article search** are methods that automatically display related articles only on the basis of input papers. Within this method, different approaches to finding similar articles occur. One approach is presented by Bethard and Jurafsky (2010). They use factors such as author impact, author citation habits, topical similarity, citation count, publication age and citing terms to determine similarity. Building on this method, Xu et al. (2017) present an extended approach that places a greater emphasis on when an paper was cited and by whom and when the paper was not quoted. More extensive is “the automated detection of implicit theory technique” by Larsen et al. (2019, p. 887). Here, a basket of papers is formed by analyzing a citation network. From this, papers are evaluated for their relevance by experts and thus a machine learning model is trained. With the trained model, further papers can then be found automatically. Another approach to determining similarity is the use of latent semantic indexing. An exemplary implementation is shown in the paper by Koukal et al. (2014) with the tool TSISQ. The semantic structures of papers are used to calculate a similarity. The following approaches also show that the boundaries between the methods are fluid. Approaches such as RefSeer use a bibliography and its citations (Huang et al., 2014), similar to Rec4LRW (Raamkumar et al., 2015), to make recommendations. The presented tools are only examples of possible variants of a related article search. In a literature review, Beel et al. (2016) show further tools that enable a related article search (they name this “recommender systems”). We deliberately omitted tools that are not standalone tools or that make suggestions based on historical data as they are not immediately usable in a meaningful way. In addition to the scientifically discussed approaches, Google Scholar also offers a “related article” function. The procedure used in this function remains unknown; however, this function has the advantage of directly accessing the Google database. In other procedures (e.g., Koukal et al., 2014), such databases must first be set up. This requirement is also a major disadvantage of the method. Another disadvantage, similar to the forward / backward search, is the need to identify suitable input papers. In general, an advantage of the method is that related article search is a highly automated method of literature search and thus a rapid search method. In addition, some forms of the related article search allow to find papers from other disciplines that may not be found using the other search methods. Some forms of the related article search are not dependent on citation networks, specific keywords, or experts, allowing circumvention of these limitations.

The best use of this method has not yet been conclusively determined. We roughly divided the related article search into the groups “semantic indexing”, “citation network analysis” and “unknown”. This refers to the procedure used to identify similar papers. Further groups and finer subdivisions are certainly conceivable here, precisely because this area is currently developing. The groups here are intended to provide a first insight into the different forms and characteristics of related article searches.

Other methods are all methods that do not match the ones described above, including passive search methods, in which users can find information about suitable papers without actively searching for them. For example, the researcher may know about a certain paper through experience (Greenhalgh & Peacock, 2005) or his/her own knowledge. Other examples are alerting services (e.g., from Google Scholar about new search results for defined keywords) or emails from reference management software (e.g., Mendeley). Another example is Docear, which uses mind maps created by the user to recommend further papers (Beel et al., 2013). These methods are listed here to show that other ways to discover literature in addition to the active methods exist. The results from passive search methods cannot be planned because they appear more or less randomly (Boell & Cecez-Kecmanovic, 2014). In conclusion, advantages and disadvantages exist for all methods. Table 1 summarizes the main aspects of each method, sorted alphabetically.

Table 2. Comparison of Literature Search Methods and their Characteristics

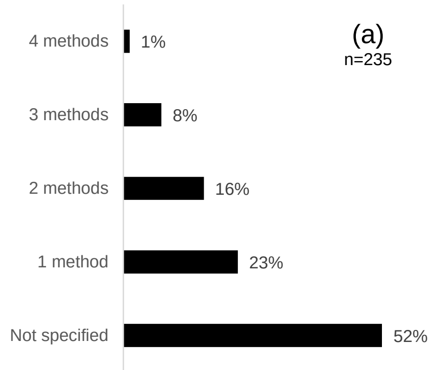
Search method		Input	Level of automation	Examples for techniques/tools	Advantages (+) Disadvantages (-)
Analysis of secondary literature	Searching in encyclopedias, handbooks, call for papers, or editorials of special issues	relevant literature	low	*NVivo*	(+) good entry and overview (-) usually not deep enough or extensive
	Searching in literature reviews or edited books	relevant literature	low	*NVivo*	(+) good entry and overview (-) often not existing for the respective question
Browsing in outlets	Screening the table of contents of selected journals	selected journal(s)	no automation	not available	(+) always possible (-) time consuming
Expert consul-tation	Screening publication lists of experts	names of experts	no automation	*Researchgate*, personal websites	(+) relatively efficient (+) reproducible (-) limited to the defined authors
	Ask experts for recommendation or unpublished material	names of experts	no automation	email	(+) unpublished material (-) not easily reproducible (-) subjective viewpoint (-) dependent on the cooperation of the experts consulted
Forward / backward search	Forward search	relevant paper(s)	medium	*Google Scholar* 'cited by', *Web of Science*	(+) efficient (-) finding suitable input (-) clustered papers
	Backward search	relevant paper(s)	no automation	*CiteSpace*, *PaperVis*	(+) efficient (-) clustered papers (-) only research that goes back in time can be found
Keyword search	Publisher database	search string and databases	low	thesaurus, *LitSonar*	(+) small barrier (-) weakness of keywords
	Meta database	search string and databases	medium	thesaurus, *LitSonar*	(+) small barrier (+) multiple publisher (-) weakness of keywords (-) possibly overwhelming result lists
Related article search	Semantic indexing	relevant text	high	*TSISQ*	(+) high automation (+) independent of citation network (+) find papers from other disciplines (-) depending on tool database with fulltexts necessary
	Citation network analysis	relevant paper(s)	high	*RefSeer*	(+) high automation (-) depending on how comprehensive the citation network is
	Unknown	relevant paper(s)	high	*Google Scholar* 'related articles'	(+) high automation (+) maybe other disciplines (-) possibly not transparent
Other methods	Multiple	various	dependent	alerting services, *Docear*, own knowledge	dependent

The tools and techniques presented are not considered complete but are intended to indicate how many variations of a search method are possible because the boundaries between the described methods are fluid in certain instances. Our overview also shows that no method is perfect, but a combination of several methods can counteract the weaknesses of a particular method.

4 Practice of Literature Search in IS Research

Part of our research objective is to analyze how the use of literature search methods has changed over time. First, we looked for the number of combined methods in our total of 235 literature reviews (see Figure 3a). More than the half (52%) of the found reviews do not specify their literature search process at all. In these review papers and their attached appendices (where available), the exact methodology of finding relevant literature is unknown to the readers. The remaining 48% of the identified literature reviews used one or up to four methods for their literature search. One method was used by 23% of our investigated papers (e.g., DeLone & McLean, 2003). Only 16% of papers used two methods and 8% used three methods for their literature search (e.g., Melville et al., 2004; Bélanger & Crossler, 2011). Four methods were used by 1% of the examined papers (e.g., Kohli & Devaraj, 2003). Figure 3a shows that the number of papers lowers, with more combined methods. To be more precise, in the literature review papers, authors tend to use and report fewer methodologies in the same paper.

In Figure 3b, we provide a more detailed view of the methods used, which include one or more search practices. Consequently, we analyzed 48% (n=113) of our total outlet of 235 review papers, where a description of the methods used was available. Based on the theoretical background presented before, we found that the most dominant method in searching for literature is the keyword search, accounting for 68% of the total number of papers. Another frequently used procedure (42%) is the forward / backward search. A total of 40% of the papers conducted browsing in pre-defined outlet of academic journals and/or conference proceedings (e.g., Legris et al., 2003) which we call browsing in outlets. Other research teams (14%) reported that they analyzed secondary literature (e.g., Hwang & Thorn, 1999). Only 7% of the studies contacted experts about a specific topic and further literature though listservs such as AISWorld (e.g., Montazemi & Qahri-Saremi 2015) or by speaking to them directly regarding unpublished work (e.g., Sabherwal & Jeyaraj 2015). Most trivial, some authors received relevant literature from their own knowledge (2%) because of their experience of work in the specific research field (e.g., Elliot, 2011). Figure 3a and 3b give us a first overview of the amount and type of the used search methods.



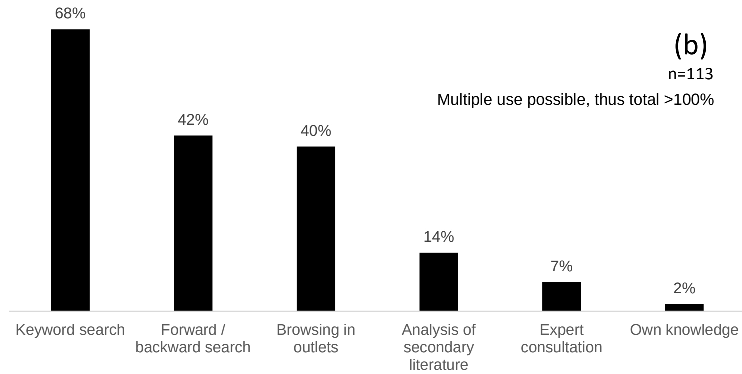


Figure 3a. Number of Combined Methods

Figure 3b. Distribution of Methods Used for all Papers that Specified at Least One Method

Looked into used search methods and taken in mind the search strategy of the literature review presented in Section 2, we can make some observations (see Figure 4). If the chosen search strategy of a literature review paper is representative, browsing in outlets seems to be the dominant search method (50%), while keyword search was used as the second often methodology (30%). In contrast, selective review papers tend to use keyword search as the most common methodology (42%) and browsing in outlets takes the second often search methods (39%). If literature reviews are hybrid in nature, a more distributed usage of search methods can be observed. We found here, that keyword search (39%) and forward / backward search (29%) was mostly used. Hybrid (6%) and comprehensive (5%) literature reviews tend to use expert consultation as an additional search method. In addition, comprehensive review use the biggest bunch of methodology, for example, identifying literature by own knowledge (2%). Also, they analyze secondary literature most often (10%) compared to other literature review types.

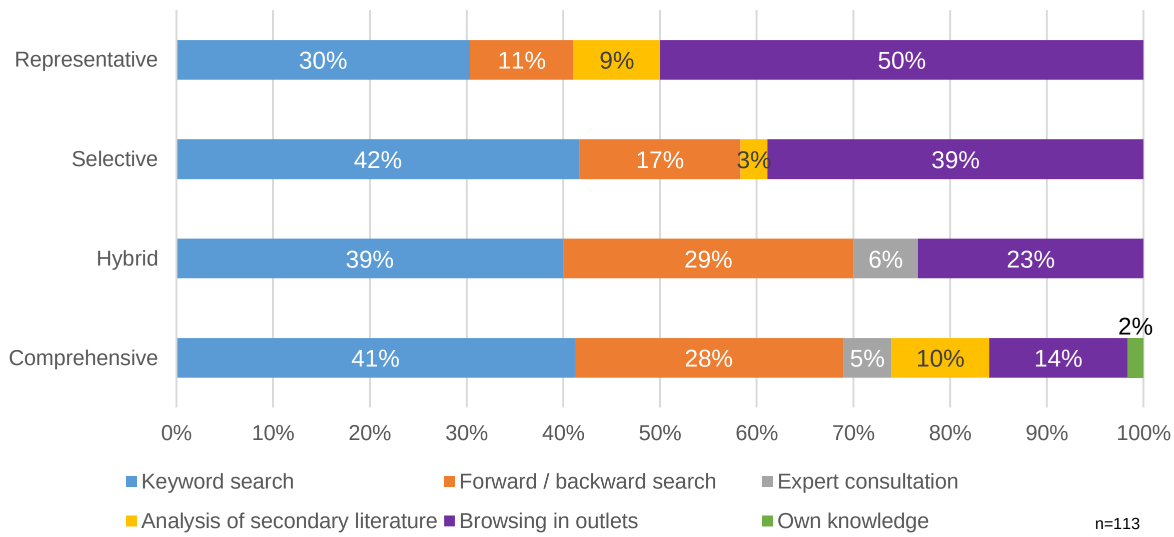


Figure 4. Used Search Methods in each Search Strategy

However, to learn how to use the search methods in the future, it might be helpful to consider the temporal change. Figure 5a provides an overview of the development and trends of the literature search methods used in our analyzed time spans. To make the different numbers of papers in the 2-year time spans more comparable, we used relative percentages of the number of papers in every time span. The percentage distribution of the respective methods is shown for each time span. For example, in the first period (1999-2000), 20% of the papers in the period used a keyword searched.

We identified an increase of the usage of keyword search from20% in 1999-2000 to a peak of 100% in 2009-2010 and 90 % in 2019-2020. The browsing in outlets method was used fewer from 1999-2000 (80%) to 2013-2014 (15%). However, the usage raised until 2017-2018 (75%) and lowers in the last time span (32%) Except until 2004 and in 2017-2018, authors of literature reviews used keywords in electronic databases more extensively than browsing in whole journals or complete conferences proceedings (outlets). Forward / backward search (Webster & Watson, 2002; Wohlin, 2014; Wohlin, 2016) becomes more popular and was used by researchers more frequently over time (from 20% in 1999-2002 to 80% in 2009-2010). However, except a short raise in 2015-2016 (60%), the usage of this methodology was around 40 % in the last years. Analysis of secondary literature lowers from 40% in the first time span until 2006 to 0%. It raises up to 25% in the time span from 2007 to 2008. In the last 10 years, it was used from 20% (2009-2010) to 0% (2019-2020). Expert consultation was used by none of the observed review papers in the first time span and raises up to 22% in 2001-2002 and lowers to a minimum of 0% in, for example, 2019-2020. Own knowledge was used most few with a maximum of 15% in 2013-2014.

Figure 5b visualizes shares of search strategies over time, which show also the percentage distribution of the respective strategy. Except from the first time span in 1999-2000, comprehensive search strategies were identified as the most common. For the other three strategies, the occurrence varies. Representative search strategies were most common in 1999-2000 (60%). Hybrid reviews occur in 2003-2004 most often with 43%. Since 2015 until 2020, all search strategies were identified, dominated by comprehensive ones.

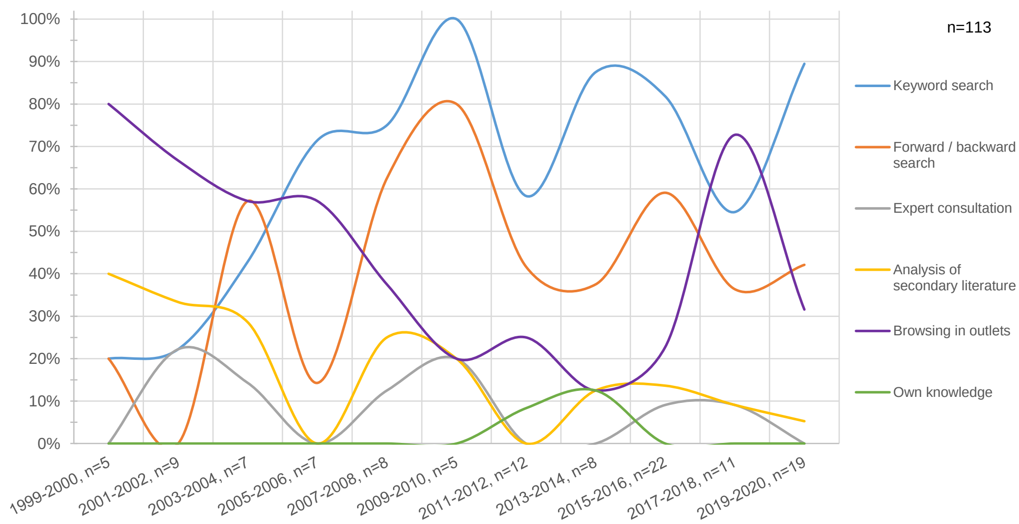


Figure 5a. Percentages of Search Methods Used over Time

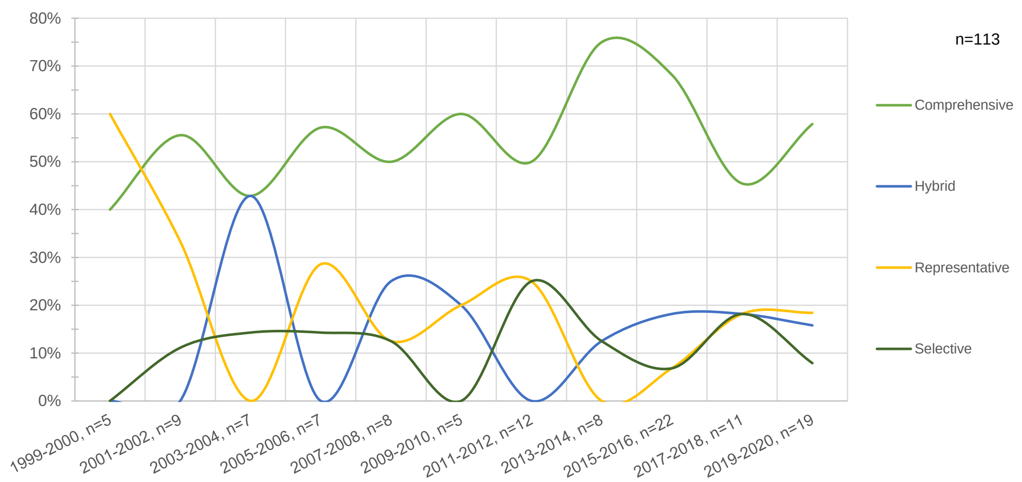


Figure 5b. Shares of Search Strategies over Time

The deliverables of this section can be summarized in five statements. First, Figure 3a shows that authors are likely to report the usage of few methodologies and combinations of methodologies to find literature for their review papers. Similar to Templier and Paré (2017), our analysis of the literature search practice shows that the documentation of the search processes leaves room for improvement. With regards to the authors who specify a search method, 25% of the papers combine several methods (more than one method). The others only use one search technique. Second, our examination of literature search practices indicates that the number of different approaches in the last 18 years in conducting literature reviews is limited (Figure 3a). It seems that well-known methods to find relevant literature such as keyword search or forward / backward search, have been most preferred by researchers in the case of literature reviews over the last 12 years since 2008 (Figure 5a). This could also have been triggered by works such as those by Webster and Watson (2002). In their publication in 2002, the concept of a forward / backward search is recommended and articulated about how to write a literature review. Third, we found a change in the usage of methodologies (Figure 5a) for literature searches in our 2-year time spans from 1999-2020. We conclude that this trend shows an inclusion of new technical possibilities for literature search practice. With the help of electronic databases, researchers are able to conduct (exploratory) keyword searches in order to find additional keywords and/or relevant literature more effectively instead of reading every abstract or title of a journal or proceeding, which can be time consuming (Bandara et al., 2015). Figure 5a shows an increase in forward / backward search as well as keyword search from the year 2008 onwards. In comparison, the browsing in outlets search method decreased until 2011. Fourth, we found a connection of the search methods used to the search strategy, if a review is comprehensive in its nature, keyword searches and forward / backward searches are dominant (Figure 5a and 5b). This connection probably also explains the massive increase in browsing in outlets in the 2017-2018 frame, where there are significantly fewer papers in the sample that follow the search strategy comprehensive. In the other strategies, browsing in outlets appears to be more important. Fifth, the full potential of the available methods is not used yet, because methods such as the related article search are not documented in the sample. However, the finding that there is a trend towards the use of methods with bigger technical support indicate that new methods could be included in the literature search in the future. In the following we describe how the different methods can be combined and according to which criteria the selection can be made. We will also describe the new possibility of using a related article search.

5 Discussion, Literature Search Recommendations, and Further Research

In section two we have shown which basic considerations have to be made when conducting a literature search. In the third section we described which search methods are available, which variations exist and what the respective advantages and disadvantages are. Section four then analyzes how literature has been and is being searched.

First, it must be determined which of the four presented search strategies will be pursued or whether a hybrid approach will be chosen. From this decision derives in the first instance, which of the three search goals (reproducibility, comprehensiveness, precision) should be primarily pursued or whether they are equally targeted. This decision then in turn influences the choice and combination of the available search methods. The search strategy comprehensive will probably be the biggest challenge in the future, as it could become almost impossible to find all relevant literature due to the ever increasing amount of literature. In this context, precession is also becoming increasingly important. In the following, we describe in particular how these goals can be better pursued in the future.

Recommendations

1. **Before starting the search, be clear about the search strategy to be followed.**

Figure 4 clearly shows that the choice of search methods is strongly dependent on the respective search method. Depending on the search strategy, certain search methods may be excluded or the advantages and disadvantages of a method have a completely different weight. If the search strategy is unclear, unnecessary steps may be taken and a literature search is already time-consuming. Additionally, an understanding of the strategy is important to structure the search and organize the process (vom Brocke et al. 2015).

2. **Combine different methods to take advantage of the respective search methods and to avoid their disadvantages.**

Depending on the search strategy, the goal of a literature search should be to combine the different search methods to use their advantages and avoid the disadvantages (Okoli, 2015). For example, it makes only sense to use the time-consuming browsing in outlets method if suitable keywords have not yet been identified or it is mandatory due to the search strategy. This is also in line with our findings from the analysis of the literature search practices, which show that the use of browsing in outlets has declined over the last years. The analysis of the research practices also shows that the use of several combined search methods is becoming increasingly important. To combine the search methods, researchers must have sufficient methodological competence to apply the methods in the best possible way. Our recommendations differ from the concept presented by Zhang et al. (2011) of using a 'quasi-gold basket' of papers. They use browsing in outlets to identify a base of papers, the 'quasi-gold standard.' With this approach, the results of an automated search can then be better evaluated. This strategy leads to a more "systematic, evidence-based, and rigorous approach" (Zhang et al., 2011, p. 636). However, the approach is time-consuming and we think that with today's possibilities, browsing in outlets should be avoided if possible (Okoli, 2015). This preference is illustrated in a quotation by vom Brocke et al. (2009) based on a quote in an paper by Webster and Watson in 2002 (p. xvi): "Many reviewers conducted a journal search instead of a database search, though there is no justification for searching by journal instead of searching by topic" (vom Brocke et al., 2009, p. 6).

Nevertheless, the analysis in section four showed that there is significantly more potential in this area. Only 52% of the papers examined, that provide information on the search method used, apply more than one search method. Of course, this is not as important for papers that do not have a comprehensive search goal, yet the percentage could be higher.

3. **If comprehensiveness and precision are important, involve more automated methods in your search process.**

As we have already discussed, the use of highly automated search methods has advantages, for example, the related article search, because relevant papers can be found in certain constellations with little effort (Larsen et al., 2019). One can also find papers from related research areas that might otherwise not have been found because they use different terms or are written by young researchers. The practice of literature searches examined has shown that there is a trend towards a greater use of automated methods. This is shown by the circumstance that the use of browsing in outlets has decreased in favor of keyword searches.

However, automated methods have disadvantages, which can be avoided by supplementing them with further search methods.

Again, the analysis in section four shows that the potential of the related article search method has not yet been fully exploited. We have not identified any paper that describes the use of such a method. We can only assume why this is the case. One possibility could be that the methods and their applications are not yet well-known enough. Another possibility could be that they are not yet accepted by reviewers due to their more difficult reproducibility. If the latter is the case, we would like to plead with this paper that also a related article search will be necessary in the future and in other search methods the reproducibility cannot always be guaranteed 100%.

4. **If comprehensiveness and precision are important, search processes should be iterative, as this is the only way to search in a targeted and thus precise way.**

We perceive the concept of an iterative literature search as the most flexible and promising concept for achieving efficiency leading to the goal of high precision. This is due to the fact that the individual process steps can be carried out better in each iteration until saturation. In the process, researchers' obtain an ever better feeling for the most suitable keywords or significant experts (Boell & Cecez-Kecmanovic, 2014; Schultze, 2015). Thus, we do not see any sequential process for future literature searches, especially for searches where the goal is to "understand or explain" something (Paré et al., 2016, p. 500). Exceptions are search strategies such as representative or selective where the focus is on repeatability or where the search method is directly dictated by the research question. For example, if publications from a particular outlet are to be examined. An iterative literature search has the advantage that it can use the information from papers that were already identified as relevant, which is not the case in a strictly conducted sequential process. We think that an iterative approach is generally more suitable for efficiently searching for literature, today.

5. **Consider using more automated search methods to achieve greater precision, but also to easily find possibly relevant articles from other disciplines.**

We contribute to the discussion about a higher efficiency or a higher precision in literature search initiated by Boell and Cecez-Kecmanovic (2015a; 2015b) and Templier and Paré (2017). We think that for a literature search for systematic literature reviews, the methodology should open up to emerging search methods such as the relevant article search to achieve a higher precision (Larsen et al., 2019). We have described various forms of a related article search that could be used for this purpose. Using these methods can often be quick and easy, but the results can be different from the other search methods. For example, relevant articles may be found more quickly that would require multiple iterations using other search methods. However, in some constellations, the precession may be worse than with the “conventional” methods (Koukal et al. 2014). Thus, the method is suitable in a combination with other methods, such as the keyword search.

In addition, the related article search has the potential to find papers from completely different disciplines. It can therefore enable a view beyond the "edge of one's nose". Many methods may only find papers that come from a citation network (forward / backward search), belong to a certain group of experts (expert consultation), or are found under certain technical terms (keyword search). However, there may also be the same relevant questions from other disciplines, which are discussed by completely different authors under different terms. In such constellations, these papers could then be found by related article search methods.

6. Google Scholar can be helpful, but keep the problems of using it in mind.

When looking at the tools discussed, Google Scholar stands out because it allows keyword, forward, related article search, and, in parts, expert consultation. Nevertheless, researchers discuss controversially whether usage should be recommended. Bandara et al. (2015) discuss the advantages of Google Scholar being easy to use and connecting and finding many sources, but that this black box tool is not especially transparent in terms of the way it works and which sources are included. Kuhrmann et al. (2017) also warn against the use of Google Scholar, as the results are influenced by personal preferences as well as trends, making the results difficult to repeat. However, Google Scholar covers many sources and disciplines. Google Scholar is a search engine, database, and several tools in one and can therefore provide an efficiency advantage. We think that every researcher has to make the individual decision regarding the use of Google Scholar. In addition, Google Scholar’s ranking of search results is also a factor well known in many meta-search engines (Athukorala et al., 2013). Here, the criteria according to which the results are sorted are not always clear. Beel and Gipp (2009) have already tried to investigate the functionality of the Google Scholar sorting algorithms, but these algorithms can change at any time. However, this factor has a strong influence on the further progress of the search, especially in an iterative process.

7. **Although precision is becoming increasingly important, documentation of the search and thus reproducibility should not be forgotten.**

Documentations are a challenge, since the ISR community has not yet satisfactorily discussed how search documentations should be done when using new search methods. We found that if a keyword search is used, the keywords and the databases used are normally described. However, for other methods, for example, forward / backward search, it is often not precisely documented how the forward / backward search was carried out. Thus, the search is not reproducible. This problem can become even more acute with a related article search, as it is sometimes not known how the determination of similar articles works. Wohlin (2014) provides first approaches how a documentation for a forward / backward search can be done. However, its documentation depths is probably too detailed, which raises the question of how detailed a search must be documented. This is a discussion for which further research is necessary, too.

As a first approach we propose that a documentation must include search methods, date of execution, search sources, search tools, and search techniques used. Furthermore, contacted authors, sets of search results and how each result of a search was classified should be described (Templier & Paré, 2015; Booth et al., 2016). Thus, documentation is still time-consuming, but possible. Nevertheless, it must be noted that perfect reproducibility often cannot be achieved (Cram, 2019). Too many factors influence the course of the search. We think that precision and completeness will be the most challenging goals in the future. Like Cram (2019), we argue for the goal of repeatability rather than reproducibility.

Limitations and Further Research

In the case of our examination of literature search practices, we only analyzed literature reviews in IS research. As our findings indicate, the documentation of search practices in literature reviews in IS research leaves room for improvement. Even in these types of papers, the description of the methodology and search practices is not satisfying which offers potential for further research. This finding is consistent with the work of Templier and Paré (2017). The literature search process and the adequate documentation of this process ought to receive more attention from IS researchers. A deeper revelation on the type and scope of the documentation is fruitful enhancing the effectiveness and efficiency of current literature searches and subsequent literature search processes of future researchers. With this documentations of literature searches, researches would be able to compare search processes in depth and could construct highly detailed best-practices in the IS research field. We have limited ourselves to active search methods when discussing the recommendations. Further research should consider how passive methods such as alerting services, for example, automatically inform the researcher about new search results (Athukorala et al., 2013).

In this paper, the evaluation process of the papers found through the literature search is deliberately not discussed because the extraction of literature is already a major challenge. We also think that this challenge will tend to increase. The evaluation of the identified papers in terms of their relevance is a further challenge requiring other tools (Bandara et al., 2015) and is independent of the acquisition of the papers, thus it is independent of the respective search method. We refer to the paper by Watson and Webster (2020), which provides new approaches in this respect. Another problem is the difficulty to make statements about the efficiency of the discussed search methods. The application of the related article search is still relatively unexplored. With this paper we want to show a first approach how the related article search can be integrated into a search process. We also give first differentiation criteria for the choice of a sub-form of a related article search. For example, the technique is dependent on the research question and the respective decision on the relevance of the screened paper.

Making general statements about the precession or efficiency of a search method is impossible. As Wohlin (2014) describes, measuring efficiency is difficult because the effort involved in a search can be defined differently. Should the time spent or the screened papers be used as an indicator for efficiency? Time spent is a subjective measure, and if the effort required for the screened papers is compared, the question arises as to how complex it is to actually go through the reference list of a paper (Wohlin, 2014). However, some authors (Greenhalgh & Peacock, 2005; Athukorala et al., 2013; Wohlin, 2014) report that they have achieved a high level of effectiveness with a forward / backward search, as many papers have been identified with this method. Nevertheless, a combination with other methods is important (Hinde & Spackman, 2015). However, we have discussed in which constellations a search method tends to be more precise than others.

6 Conclusions

Although recent research has noted different literature search strategies and methods, IS research does not properly consider the roles of different literature search methods. We address the research objective:

“Elaborate the currently available literature search methods, their use, their advantages, and disadvantages”. First, the different literature search strategies and the objectives of literature searches were described. A literature review was conducted to analyze the currently available literature search methods. We have divided the methods into different groups and subgroups. For each method advantages and disadvantages were discussed and supporting tools were described. We examined literature reviews published in renowned outlets in which search methods were named. Currently, a relatively large number of papers still rely on just one search method. Over time more papers used automated search methods, for example, keyword search often replaced manual browsing in outlets (manual search). Currently, a relatively large number of papers still rely on just one search method. We then synthesized these findings into seven recommendations that can assist in future literature searches. Further research is needed in the area of more automated search methods, such as the related article search, to make these method more common. In the analyzed sample of literature reviews, not a single paper has made use of it so far. Today’s literature searches must change to address the rapidly increasing abundance of literature. A literature search must be comprehensive and repeatable, but also the search precision will be more important in the future.

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Appendix 3 - Using Web Analytics Data: A Participatory Design Model For Individual Web Traffic Report Development

Outlet: Proceedings of the Americas Conference on Information Systems (AMCIS 2019), Cancun, Mexico

Abstract

Web Analytics (WA) tools offer an increasing amount of analysis options. This amount of possible data overwhelm business users who are not familiar with WA and therefore the potential of WA is not fully exploited. We address this demand of individual information needs with the development of an indicator selection process. By using participatory design methods future users from different business units are involved in order to adopt WA into their workspace through building individual WA reports. The developed iterative model consists of five main steps. After the presentation of the developed model, we demonstrate the applicability in a case study at an industrial company. The case study shows a greater adoption by the different users, as the dashboards are individually tailored to them.

Link: https://aisel.aisnet.org/amcis2019/adoption_diffusion_IT/adoption_diffusion_IT/21/

Keywords: Web Analytics Key Performance Indicators, Web Traffic Report Development, Participatory Design, Individual Technology Adoption

Appendix 4 - Future of Flexible Work in the Digital Age: Bring Your Own Device Challenges of Privacy Protection

Outlet: Proceedings of the International Conference on Information Systems (ICIS 2019), Munich, Germany

Abstract

The future of work is getting increasingly flexible due to the rising expectations of employees away from traditional 9-to-5 office work towards flexible work hours, which drives employees to use their mobile devices for work. This ever-growing phenomenon of Bring Your Own Device (BYOD) creates security risks for companies, which leads to an implementation of mobile device management (MDM) solutions to secure and monitor employees' mobile devices. We present insights from two multinational case companies, where works councils have expressed their concerns for privacy intrusion into employees' lives through BYOD. To examine whether employees share works councils' concerns, we conducted a survey with 542 employees from three countries: United States, Germany, and South Korea. Results of a structural equation modeling show that American employees place greater emphasis on BYOD risks associated with privacy concerns compared to employees from Germany and South Korea.

Link: https://aisel.aisnet.org/icis2019/mobile_iot/mobile_iot/2/

Keywords: Bring Your Own Device (BYOD), IT consumerization, IT-enabled work arrangements, mobile devices, policies and regulations for digital work, privacy

Appendix 5 - Virtual Assistance in any Context - A Taxonomy of Design Elements for Domain-Specific Chatbots

Outlet: Business & Information Systems Engineering

Abstract

Several domain-specific assistants in the form of chatbots have conquered many commercial and private areas. However, there is still a limited level of systematic knowledge of the distinctive characteristics of design elements for chatbots to facilitate development, adoption, implementation, and further research. To close this gap, the paper outlines a taxonomy of design elements for chatbots with 17 dimensions organized into the perspectives intelligence, interaction and context. The conceptually grounded design elements of the taxonomy are used to analyze 103 chatbots from 23 different application domains. Through a clustering-based approach, five chatbot archetypes that currently exist for domain-specific chatbots are identified. The developed taxonomy provides a structure to differentiate and categorize domain-specific chatbots according to archetypal qualities that guide practitioners when taking design decisions. Moreover, the taxonomy serves academics as a foundation for conducting further research on chatbot design while integrating scientific and practical knowledge.

DOI Link: https://doi.org/10.1007/s12599-020-00644-1

Keywords: Chatbot taxonomy, Design elements, Domain-specific chatbots, Human computer interaction

Appendix 6 - A Framework for User-Centered Implementation of Chatbots

Outlet: International Journal of Human-Computer Studies (Submitted)

Abstract

The implementation of chatbots is discussed in many companies and organizations for a powerful enablement of automated processes. They are also capable of enabling completely new processes. Previous studies mainly focused on specific aspects of chatbot implementations. We discuss the introduction of chatbots with a strong focus on (potential) users. Using qualitative content analysis we conduct semi-structured interviews with chatbot developers and responsible experts for chatbot introductions to understand implementation processes. Based on this knowledge and reviewing human computer interaction (HCI) and chatbot literature, we develop an implementation framework that supports successful introduction of chatbots. This framework contains 102 questions to be answered during each phase of an implementation considering the people, activity, context, and technology (PACT) framework. Our adapted PACT framework is evaluated using a three-step evaluation and application process. The framework can be seen as a bridge between science and practice, where both sides benefit from the extensive list.

Keywords: PACT Framework, Chatbot Implementation Framework, Human Computer Interaction, Human-Centered Design

The article has been submitted and follows on the next pages.

A Framework for User-Centered Implementation of Chatbots

ABSTRACT

The implementation of chatbots is discussed in many companies and organizations for a powerful enablement of automated processes. They are also capable of enabling completely new processes. Previous studies mainly focused on specific aspects of chatbot implementations. We discuss the introduction of chatbots with a strong focus on (potential) users. Using qualitative content analysis we conduct semi-structured interviews with chatbot developers and responsible experts for chatbot introductions to understand implementation processes. Based on this knowledge and reviewing human computer interaction (HCI) and chatbot literature, we develop an implementation framework that supports successful introduction of chatbots. This framework contains 102 questions to be answered during each phase of an implementation considering the people, activity, context, and technology (PACT) framework. Our adapted PACT framework is evaluated using a three-step evaluation and application process. The framework can be seen as a bridge between science and practice, where both sides benefit from the extensive list.

KEYWORDS

PACT Framework, Chatbot Implementation Framework, Human Computer Interaction, Human-Centered Design

1 Introduction

Chatbots have been around since the 1960s, but strong developments in artificial intelligence (AI), machine learning (ML), and natural language processing (NLP) have made completely new forms of chatbots possible (Seeger et al. 2018). Chatbots, also known in academic research as a form of conversational agents (Bittner et al. 2019; Diederich et al. 2019a; Gnewuch et al. 2017), can be found in various application fields, such as business and private use (Seeger et al. 2018). When developing a chatbot, many decisions must be made. These decisions provide interesting questions, especially for research (Diederich et al. 2019a; Meyer von Wolff et al. 2019a). In a rapidly changing and increasingly digitized world, where people are constantly confronted with new technological changes, a key success factor within the design, implementation as well as evaluation phasis is to gain a deep understanding of how people interact with the technology being developed (Adam et al. 2021). Previous research has focused primarily on specific aspects of chatbot implementation. For example, design techniques have been discussed or specific prototypes have been developed through case studies (Laumer et al. 2019; Seeger et al. 2018). Creating comprehensive user-centered knowledge about chatbot development has been scarcely addressed. Zierau et al. (2020) emphasize as a result of their comprehensive literature review that the task context and user characteristics have hardly been studied in chatbot research so far, although they have an impact on HCI interaction just as the system characteristics and the task do (Zierau et al. 2020; Li and Zhang, 2005). From human computer interaction (HCI) research, we know the importance of including human-centered aspects in the development of artifacts (Benyon 2005; Adam et al. 2021). There can be concerns among users toward a new technical solution, which makes adequate requirements engineering important to develop a chatbot that works for various user groups and contexts (Laumer et al. 2019. Therefore, not only technical factors but also (potential) users, their activities, and the respective context must be considered during implementation (Benyon 2014; Adam et al. 2021). Several authors have already described the need for further research on chatbot development, design aspects, and requirements for the introduction of chatbots (Diederich et al. 2019b; Meyer von Wolff et al. 2019a; Zierau et al. 2020).

We elucidate these other factors in the development of chatbots. Well-founded knowledge on each aspect of the development of chatbots is crucial for practitioners. In addition, this is important knowledge for research as it is the basis for measuring chatbots' success. Understanding the application and environment of chatbots is a first step toward understanding the success or failure of a particular chatbot. This insight motivates the objective of our article, which we address with our research question:

RQ: What aspects need to be considered in chatbot implementation and how can these aspects be structured?

Within the interior mode, we apply HCI design science research to address the (technical) implementation of chatbots with a user-centered lens (Adam et al. 2021). We first conduct a literature review on the implementation of chatbots. We then conduct 15 semi-structured interviews with practitioners who have already implemented chatbots. We analyze these interviews qualitatively to gain an understanding of how chatbot development works. We use our results and findings to describe the most relevant aspects of chatbot implementation. Further, we develop an implementation framework containing 102 questions and classify them to the four PACT elements of Benyon et al. (2005; 2014). The framework, questions and the PACT allocation are evaluated through interviews, a focus group discussion, and a case study. Our results are discussed, implications and limitations of the research are highlighted. Our paper ends with conclusions and an outlook for further research.

2 Related Literature

Chatbots (Meyer von Wolff et al. 2019a; Rodríguez Cardona et al. 2019; Jain et al. 2018), also known in the scientific literature under the term of "conversational agents" , are interactive application systems that are able to conduct a conversation about a specific topic with a human while using NLP and ML techniques (Janssen et al. 2020; Diederich et al. 2019a; Følstad et al. 2019a; Meyer von Wolff et al. 2019b). Chatbots are used in countless private and commercial areas, each of which has widely varying requirements related to the capabilities and tasks of a chatbot that need to be considered in chatbot design (Følstad et al. 2019a).

Previous research has mainly concentrated on developing chatbots based on specific scenarios as a basis for deriving design or architecture frameworks to enhance chatbot development processes (e.g., Di Prospero et al. 2017; Feine et al. 2020a) or, human-chatbot dialogue patterns (e.g., Ma and Ho 2018). Other researchers have concentrated on the technical aspects of the human-chatbot interaction while focusing on the personality processing of cognitive agents (e.g., Di Prospero et al. 2017) or the integration of social characteristics (e.g., Chaves and Gerosa 2020) and anthropomorphic characteristics (e.g., Diederich et al. 2020; Seeger et al. 2021). However, Liu et al. (2017) noticed that the mass of possible techniques can overwhelm chatbot design novices when selecting an appropriate technique. Therefore, researchers have identified design features or developed design principles to facilitate the selection process of design techniques, for instance, in enterprise chatbots (e.g, Diederich et al. 2020; Feine et al. 2020b), customer service chatbots (e.g., Gnewuch et al. 2017), education chatbots (Sjöström et al. 2019; Bahja et al. 2020), facilitator chatbots (e.g., Tavanapour and Bittner 2018), collaborative chatbots (e.g., Bittner et al. 2019), open-domain chatbots (e.g., Janssen et al. 2021), energy feedback chatbots (e.g., Gnewuch et al. 2018), and B2B chatbots (e.g., Gnewuch et al. 2019; Janssen et al. 2020a). Notwithstanding the foregoing, after analyzing 107 scientific papers related to chatbot design elements in the IS and HCI fields, Zierau et al. (2020) determined that the task context and user characteristics have been little studied in chatbot research so far, although these components have a fundamental impact on HCI interaction (Zierau et al. 2020; Li and Zhang, 2005). This indicates that while much research has been conducted on technical specifications of chatbots and their designs, scientific knowledge on context- and user-centered requirements engineering in the chatbot environment is still limited. Nevertheless, it is only possible to select appropriate chatbot design techniques if it is known for what should be developed (e.g., business problem), which is why the determination of the preliminary considerations for chatbot deployment (e.g., organizational development expertise) are crucial (Schuetzler et al. 2021). Thereby, recent studies such as Bahja et al. (2020) and Schuetzler et al. (2021) provide frameworks to support the deployment of chatbots. Schuetzler et al. (2021) derive three guiding questions (i.e., "should we build a chatbot?", "what technology should we use?", and "how humanlike should the chatbot be?") (Schuetzler et al., 2021, p. 3) based on their own experiences in chatbot research and development. With the first question, whether a chatbot is a suitable technology for the business problem, the article distinguishes from other literature, which predominantly sees the chatbot technology as set. However, Schuetzler et al. (2021) address chatbot deployment from an organizational perspective and, only the framework of Bahja et al. (2020) incorporate user-centered factors in the specific context of the deployment of educational chatbots.

Nonetheless, a holistic chatbot implementation framework that puts the user at the center of its focus is still missing.

As chatbots are seen as appropriate examples of HCI artefacts (Adam et al. 2021), HCI implementation models might be interesting as an abstract guidance for developing chatbots. In the field of HCI, diverse user-centered design frameworks and methods with different degrees of user involvement have been employed to understand the technical and social aspects of the design situation and inform the development of HCI artifacts using collaborative design approaches with users as active design partners (e.g., participatory design) or informing design approaches with users as reactive informers (Scaife 1997; Wallisch et al. 2019; Salinas et al. 2020). These include, for example, the "DIN EN ISO 9241-210:2011-01: Human-centered design for interactive systems" which presents a framework how to develop an interactive system, and the PACT framework by Benyon et al. (2005; 2014) which presents four elements (i.e., people, activities, context and technology) that should be considered within human-centered design.

Since, chatbots differ from other interactive systems in their degree of interaction and intelligence (Maedche et al. 2019), and the interaction between a chatbot and a user is formed not only by the characteristics of the user, but also of the system, the task and context (Zierau et al. 2020), the PACT framework has been found more suitable to cover all the fundamental aspects of user-centered HCI design in the context of chatbots (Seeger et al. 2021).

3 Research Design and Methodology

3.1 Design Science Research Orientation

Our research aims to determine the user-centered aspects that should be considered when developing and implementing a chatbot. We regard this framework as a human-centered HCI artifact in the context of computational design science research (Rai 2017). In HCI, a distinction is made between the three DSR modes. While exterior mode focuses on observational analysis of human-computer interactions and user behavior, and gestalt mode investigates a balance between IT system and human behavior through a combination of technical and observational studies, in this study we focus on interior mode, which is technical studies of IT system design with a focus on human-computer interfaces (Adam et al. 2021). Following Hevner (2007) and vom Brocke et al. (2020), we structured our research project into three research cycles. The cycles and research procedure are illustrated in Figure 1.

The relevance cycle connects our design to the environment of our research (vom Brocke et al. 2020). From previous research, problems are known to exist in practice when implementing chatbots in corporate environments. To collect further practical insights and to understand the implementation processes, we conducted expert interviews with 15 practitioners. The interviewees have different roles in development projects and, thus, different perspectives on the challenges and crucial aspects. The findings should be integrated into our implementation framework development and build a bridge to the practical problems encountered. Further, we conducted a literature review based on the guidelines of Webster and Watson (2002) so that our research is based on current knowledge. We regard the PACT framework by Benyon (2014) as a suitable basis for a chatbot implementation framework. The PACT framework provides a structure for examining interaction design from different angles and puts the user at the center of its focus. The connection of the findings of the relevance and rigor cycle forms our design cycle. In the further course of our research, the framework will be evaluated with further expert interviews and a focus group discussion. All analyses of expert interviews and focus group discussion will be conducted using qualitative content analysis (Mayring 2015). With the suggestion of vom Brocke et al. (2020) to show the applicability in practice, the framework is applied in a suitable environment by developing a chatbot for a car dealership. In the following section, we describe qualitative content analysis and other research methods used in detail.

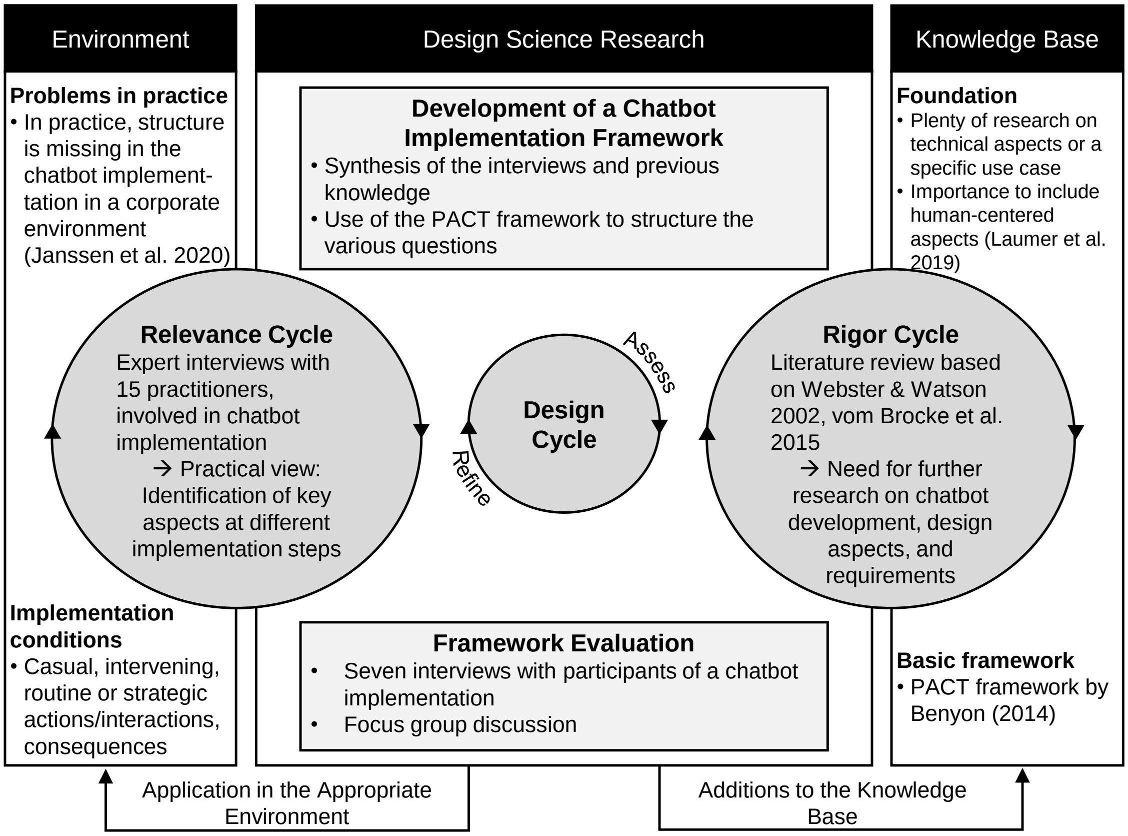

Figure 1: Research design based on Hevner (2007) and vom Brocke et al. (2020).

3.2 Data Collection Procedure

3.2.1 Literature Search

We conducted a literature review using the search string *(chatbot* OR "conversational agent*" OR chatterbot* OR "dialog system*" OR talkbot*) AND (implementation OR development OR design OR prototype OR framework)* to perform an efficient and comprehensive literature search (Webster and Watson 2002; vom Brocke et al. 2015; Watson and Webster 2020). We included the databases AISeL, EBSCO, ScienceDirect, IEEE Xplore, ACM, Wiley Online Library, Web of Science, and TIB Online Contents as they commonly include ISR and HCI literature; therefore, we partially adapted our search phrase to the syntactic specifications of these databases. By scanning for the search string words within article titles, we initially found 446 articles within the nine selected databases, which were minimized to 385 articles after removing duplicates. In the next step, the articles were read and examined for their content value for the literature review. Articles that provide a guide to chatbot implementation or describe chatbot implementation were considered as relevant. This article selection was used to perform a backward and forward search based on Webster and Watson (2002), utilizing Google Scholar, followed by an author and similarity search of the most relevant papers before. 51 relevant articles were identified finally, which will be used in developing the chatbot implementation framework.

3.2.2 Expert Interviews

To incorporate practical experience into the development of a user-centered chatbot implementation model, in-depth semi-structured expert interviews were conducted with 15 experts. To collect qualitative information about the approach followed by different types of companies to undertake a chatbot implementation process, a guideline for semi-structured interviews was first developed. This offers the advantage that a predetermined spectrum of questions is asked, but the sequence is flexible. The guideline questions were designed as open-ended. When creating the questionnaire, the wording of the interview questions was adapted such that a discussion between the expert and interviewer was created (Bogner and Menz 2009). In addition, main questions were created and assigned to these sub-questions (Bogner and Menz 2009). This allows a main question to be asked first and enables the interviewee to answer it freely, while the sub-questions can be inserted if necessary.

The selection of the experts was conducted by a sampling process in which they were contacted via e-mail and through career-oriented social networking sites. The participants are IT executives from chatbot development firms, heads of IT departments, and IT project managers from German companies that have already implemented a chatbot or are still in the implementation stage, as announced in press releases. The sizes of the companies and numbers of employees vary from fewer than 1,000 employees (n = 5) and up to ones with 650,000 employees (n = 10). Depending on the availability of the interviewed experts, qualitative interviews were conducted either face-to-face (n = 4) or via telephone (n = 11). Interview lengths varied from approximately 25:38 minutes and 44:36 minutes. All interviews were conducted in German. Quotations from them have been translated accordingly. An overview of the interviewed experts is provided in Table 1.

The interviews were conducted in two iterations. In iteration 1, experts 1 to 8 were interviewed about their previous experiences with the introduction of chatbots. Based on the literature review and the results of the first interviews, a prototype of the PACT implementation model was developed. In the second iteration, experts 9 to 15 were interviewed with the slightly adapted questions from the guide to extend the PACT chatbot implementation model. The second half of interviews dealt with evaluation of the implementation model. At the beginning of each interview, this research was briefly presented and its related terms were clarified. This was followed by a presentation of the experts, who shared their experiences from chatbot introduction by answering the questions according to the previously developed interview guide. We conducted in-depth semi-structured expert interviews with (i) IT directors, product owners, and IT project managers responsible for planning or monitoring the implementation of a chatbot within companies headquartered in Germany as well as (ii) IT executives from chatbot development firms in Germany responsible for or directly involved in the development process of a chatbot, such as design engineering and prototyping, outside the companies carrying out the implementation.

Table 1: Expert Descriptions.

Expert	*Position*	*Industry sector*	*Number of employees*
Exp1	IT director	Insurance provider	12,000
Exp2	Product owner	Automation industry	4,000
Exp3	IT project manager	Automotive industry	650,000
Exp4	Chatbot developer	Chatbot developing startup/IT consultancy	5
Exp5	IT project manager	Banking industry	50,000
Exp6	Chatbot developer	Chatbot developing firm/IT consultancy	350,000
Exp7	IT project manager	Media industry	16,000
Exp8	Product owner	Financial consultancy	2,000
Exp9	Product owner	Transportation industry	135,000
Exp10	Product manager	Transportation industry	9,600
Exp11	Head of sales / Business development	Chatbot developing firm/IT consultancy	26
Exp12	Consultant	Chatbot developing firm/IT consultancy	160
Exp13	Product owner / consultant	Healthcare industry	4
Exp14	Chief marketing officer	Telecommunications industry	65
Exp15	Product manager	Healthcare industry	1,400
Exp16	IT project manager	Automation industry	4,000
Exp17	Digital analytics consultant	Automation industry	4,000
Exp18	Business driver/Innovation project manager	Automation industry	4,000
Exp19	IT consultant	Automation industry	4,000

All interviews were recorded with the consent of the interviewees, transcribed verbatim, and subsequently codified using the software MAXQDA for qualitative data analysis.

3.3 Data Analysis

As described by Mayring (2015), qualitative content analysis is a systematic evaluation method used by researchers to generate a conceptual understanding from the analysis of the content of text components embedded in data material derived from, for example, narrative or semi-structure interviews. The target of this qualitative analysis method is segmenting the text components of the primary data into analysis units (i.e., coding, context and evaluation units) as well as the allocation of these analysis units into categories (Mayring 2015). The coding units are the smallest text components that may be evaluated and classified under a category. A context unit represents the largest possible text component of the primary material that can be subsumed under a category. Finally, the unit of analysis determines which components have to be analyzed (Mayring 2015). The category formation can be done in an inductive or deductive manner. In a deductive category formation, categories are defined in advance based on theoretical considerations, while in an inductive category formation the categories are derived directly from the analyzed data material in order to capture the relevant statements as close as possible to the source material (Mayring 2015).

3.3.1 Procedure

The systematic process used to analyze the primary data obtained through the semi-structured expert interviews can be divided into three feedback loops or stages in which the data material is assigned to categories. To gain an initial understanding and perspective of the content of the data material, the first stage (neutral category development) consists of an inductive analysis of the collected primary data by means of extraction through open coding of an initial set of 54 coding units related to more than 1000 segment quotes of the verbatim interview transcripts (Myers 2020). The open coding units are induced by words used by the interviewees and therefore reflect the substantive nature of the interviewees' statements (e.g., response speed, standard features, limits to technology, human-like performance). Subsequently, to increase the level of abstraction, in the second stage, the previously identified codes were sub-grouped into 18 second-order inductive categories (context units), e.g., environmental context conditions, organizational context conditions, strategical causal conditions, operational causal conditions, positive effects, and negative outcomes (Myers 2020). Afterwards, to reduce the data material to its essential content and achieve a deeper insight into the pattern regularities of the primary data, in the third stage, the sub-categories identified through inductive category formation were subsumed into the five main deductive categories (evaluation units) of: (i) context conditions, (ii) causal conditions, (iii) intervening conditions (e.g., variables limiting the causal conditions), (iv) routine or strategic actions and/or interactions, and (v) consequences (Corbin and Strauss 2015). Within the text analysis the deductively developed categories are assigned to the text passages. After performing the aforementioned category formation stages, the code list was extended to include a total of 77 codes. With the help of this category system we have determined when a text passage can be assigned to each category. Table 2 provides an illustrative overview of the category formation. A detailed representation of the categories formed in each stage is provided in Appendix A1.

In Section 4, we describe the data-driven insights obtained through the qualitative content analysis of the experts' statements and subsequently synthesize the results into a user-centered framework to implement chatbots from a user's perspective contingent on the strategic actions and interactions identified in the second stage of the analysis and secondary data derived from existing scientific literature related to chatbot design, development, and implementation.

Table 2: Illustrative Category System Formation Procedure.

Exemplary Interview Statements	*Stage 1: Coding units*	*State 2: Context units (Subcategories)*	*Stage 3: Evaluation units (Main categories)*
"(…) There must be no delays in providing the information. The response must not take too long[1]. The speed must be approximately the same as the human speed, which should be seen as the lower limit[2]. Under no circumstances should it be slower[2]. The chatbot should be able to use the amount of information necessary to make qualitative judgements. It must be a stable channel and must not suddenly break off[3]. These are the same requirements I would have for a human being. A person must be competent, understand as quickly as possible what the customer wants, make adequate suggestions, be able to react to these suggestions, be able to provide the necessary information on them or find the knowledge from databases very quickly and not break off[4] (…)"	1) Response speed 2) Standard features 3) Limits to technology 4) Human-like performance	Technology-related intervening conditions	Intervening conditions

4 Model Evaluation and Application

4.1 Expert Interviews

According to the DSR procedure of Hevner (2007) and vom Brocke et al. (2020), a central step is to evaluate the artefact. This was done in a three-step evaluation process: seven expert interviews, a focus group discussion and case study application. A first evaluation of the developed PACT framework was conducted using an interview guide (see Appendix A2). This evaluation took place in the second half of the interviews with experts 9 to 15. First, a representative extract of the model was sent to the experts (see Appendix A3). The experts' first impressions of the model were positive. Experts 11 and 15 described the model as *"comprehensible,"* expert 14 as *"relatively consistent and constant [looking],"* and expert 12 said *"There are thought-provoking impulses in it, which one must definitely be taken along away."* Suggestions for improvement were also mentioned in the interview evaluation, which were subsequently implemented. With regard to the development of the first prototype, the experts pointed out that it is important to rely primarily on a minimum solution and not to waste too much time on a design that will not be accepted at the end. Instead, an iterative approach should be adopted, i.e., gather results after the first "go-live" and modify the chatbot accordingly (Exp11, Exp13, Exp14). According to expert 14, this is more of a cycle, a *"permanent build-measure-learn-build-measure-learn-build-measure-learn model,"* where you can *"jump back in [the] four [steps]."* Expert 11 agreed with this and said that *"the measurement of added value, [...] is a permanent cycle"* and that "the dialogue tree construction, [...] alternates with prototype, sharpening dialogs, testing, prototype, sharpening dialogs. This always goes in this [a] loop until you get to the point where you say, this is what we have minimal."

A further area that several experts believe should be included in the model is "the legal aspect. Not so relevant for many companies, but for us [it] may have become an issue in the meantime due to DSGVO and Co [...]" (Exp15) and thus the resulting questions "Which data can we use? What do we learn about the user?" (Exp12). Based on the EU-DSGVO, it is possible "to obtain a large amount of data but not to be allowed to do so." (Exp12). This aspect was added subsequently. From the discussions, it can be concluded that there are some issues that are relevant for one company or use case but not important for other chatbot implementations.

4.2 Focus Group Discussion

After an initial evaluation using expert interviews, the revised model was discussed in a focus group discussion by following the requirements of Rosemann and Vessey (2008). One difference to the interviews is that the participants had the entire and already expanded model available for evaluation and could take more time to familiarize themselves with the model. As Rosemann and Vessey (2008) demand that participants should be appropriate to the subject area and the research object, the focus group discussion was conducted with five participants from an industrial company who already have experience with the implementation of chatbots. One participant (Exp2) already took part in the first round of the expert interviews. The participants can be divided into experts with chatbot implementation experience (Exp2, Exp16 and Exp17) and IT consultants (Exp18 and Exp19) with experience in the introduction of other IT tools. Because the chatbot implementation model to be evaluated is especially aimed at people who want to introduce a chatbot for the first time, these two experts can check how well the model helps to start with chatbots and chatbot implementations. The duration of the focus group discussion was 90 minutes. Four participants took part in the discussion on site, while one was connected via Skype. The focus group discussion began with a presentation of the implementation model and delivery of the model printed on a sheet of paper (see Appendix A3) and a worksheet containing a focus group questionnaire (see Appendix A4)to familiarize the participants with the research object (Rosemann and Vessey 2008). Each participant was asked, as a first step, to answer questions on an individual basis regarding the division into eight steps, and the listing of relevant questions within these steps. The participants were further asked what type of possible application areas the model can be used in and how to apply the guide to individual chatbot implementation. The focus was placed on the comprehensibility, logic, and completeness of the steps. The analysis of the focus group discussion was performed by summarizing all data available in the form of field notes and a tape recording (Rosemann and Vessey 2008). One of the recurrent discussion points concerned steps I to IV. These steps were initially not understandable to all participants. After the first considerations (step I "Preliminary Considerations"), the step II "Use Case" was determined. However, the question of what is counted for the use case determination and what for the determination of the "Chatbot Characteristics" in step III was raised. Expert 16 specified that the "Use Case" should answer the question: *"What do I want to achieve with the chatbot?"* He would define the "Characteristics" more precisely: *"What should the chatbot have and what not?"* (Exp16). Step 4 would then, according to all experts, focus more on the technical implementation of a dialogue tree. Overall, the participants agreed that the first four steps should not be combined but considered separately. Furthermore, expert 2 believed that a loop in steps II, III, and IV would represent the real sequence of these steps. This loop was based on the participants' own experience that the attempt to construct a dialogue tree showed that what was planned as an area of application and was further elaborated in the third step could not be converted into a dialogue (Exp2). From this, it follows that after the fourth step, it may be necessary to go back to the third step and see how the properties of the chatbot in the application area can be changed in such a way that the chatbot can later be realized in dialogue construction. If no profitable change can be found within the application area, the application area itself will be reconsidered (step II) (Exp2). From the expert's point of view, it follows that development is not conducted sequentially from step I to prototype development but that it may be necessary to go back one or two steps from step IV. With regard to the application possibilities and the added value of the model, the experts assumed that the basic structure can make a positive contribution to chatbot introduction by helping as a guideline.

4.3 Case Study Application

According to vom Brocke et al. (2020), a DSR artefact should be applied into an appropriate environment. To test the applicability of the framework in practice, a single case study was conducted. In this case study, a chatbot prototype was developed for a car dealership. A chatbot developer was introduced to the framework so that one could undertake the development in a structured way. In doing so, the user experience was focused during the development. The chatbot should support the customers in ordering and searching for products.

So far, the first six steps of the framework have been completed. After a productive use of the chatbot, the added value was determined and the post implementation phase could be run through.
At the beginning, preliminary considerations took place regarding the opportunities and future prospects that exist for the chatbot in the car dealership. The second implementation step dealt with the definition of the use case, which should generate added value for the employees and customers of the dealership. Customers who either want to sell or buy a new car are to be supported. Since the car dealership for which the chatbot was to be developed already conducted some marketing campaigns using Facebook Messenger, this channel was chosen as a platform for the chatbot. Based on this, the important properties and characteristics of the chatbot were determined in a third step. These properties and characteristics form the basis for the possible conversation paths to be constructed. Here, for example, the decision is made to develop the chatbot in German, since analyses on Facebook show that almost all visitors of the fan page come from Germany. It is further decided to provide the user with answer buttons for the communication, since this allows the conversation to proceed in fixed frames and fewer problems with comprehension can occur. In a fifth step, the actual development of the prototype took place.
The acceptance of the prototype was analyzed with a survey among 20 selected users. The feedback from the users was predominantly positive. The managing director of the car dealership was also satisfied with the result and sees the greatest potential in supporting customers with the search for a car. Further development of the chatbot is to be carried out primarily to increase customer satisfaction. The chatbot developer also found the use of the framework useful in that it structured the design and development of the chatbot and prioritized the user experience.

5 Results and Analysis

5.1 Chatbot Implementation Conditions

The qualitative content analysis of the collected primary data from the expert interviews led to the identification of context conditions, causal conditions, intervening conditions, routine or strategic actions and/or interactions, and consequences, along with a set of aspects presented as bullet points in Figure 2, whose interactionism must be considered when developing a chatbot.
Context conditions: To describe the conditions under which the chatbot implementation process takes place at different levels of analysis, this category has been divided into two sub-contexts: (*i*) environmental and (*ii*) organizational. This differentiation is important given that it offers a direct indication of the rationale behind the chatbot implementation depending on the power that the company has to influence the context conditions at each level of abstraction. In line with this, at the environmental level, within which companies have no power to control the context conditions, the interviewed experts not only identified potential opportunities related to the diffusion of new and readily available technologies across industries (Schuelke-Leech 2018) but also emphasized the strong competitive pressure that comes with this rapid technological diffusion. For example, an IT director of an insurance company stated that *"it is true that if there is no specific application case, then the implementation can easily become a mistake. However, if we wait until our customers say that they (…) want to get a chatbot to provide them assistance, then it could be too late for us. By this, I mean that our competitors could be faster than us to integrate the technology,"* which suggests that the implementation of chatbots in organizations could be conjectured to be the result of mimetic isomorphism (Kee 2017; Zorn et al. 2011). Conversely, in the organizational sub-context, there are aspects that shape the strategy to respond to environmental context conditions, such as managerial support, budget, and expert knowledge constraints. Accordingly, the analyzed qualitative data indicate that at the organizational level, the decision to implement chatbots is part of an ongoing strategic process of digital transformation. Specifically, the organizational context condition implicit in the digital transformation path followed by two-thirds of the companies in our sample closely resembles the digital customer engagement strategy delineated by Sebastian et al. (2017 pp. 199), which focuses on creating "a seamless omnichannel experience that makes it easy for customers to order, inquire, pay, and receive support in a consistent way from any channel at any time" (Sebastian et al. 2017). While it is true that the aforementioned environmental and organizational context conditions do not directly act as drivers (i.e., causal conditions) of the chatbot implementation, in the information systems (IS) literature related to diffusion and technology acceptance research, comparable

factors, such as the internal and external characteristics of the organization and the leader characteristics (including his or her attitude toward the adoption of a new technology), have been identified as adoption predictors (Hameed et al. 2012; de Vries et al. 2018), used as a theoretical foundation for the theory of innovation diffusion in organizations by Rogers (2003).

Causal conditions: The incorporation of innovations in the form of chatbots in the business strategy of the analyzed companies, regardless of the type of industry and company size, has three primary purposes, which act as causal conditions: (i) the leverage of new technologies to gain advantages over their competitors, (ii) the digitalization of the customer interface to enhance the internal or external customer experience, and (iii) the automation of repetitive operational processes to improve internal efficiency and reduce operative costs.

Intervening conditions: The intervening conditions illustrate the aspects that enable or limit the drivers behind a chatbot implementation. From the experience and perspective of the interviewees, these principally include aspects such as the inherent limits of the technology and its interplay with the technical expectations of the internal and external customers, as well as overall user acceptance, inter alia (see Appendix A1). Furthermore, the experts highlighted the importance of intervening conditions, such as the stakeholder support level, which they believe should properly be ensured during the entire implementation process. Based on the information provided in the interviews, we were able to identify seven key stakeholders that should be involved besides the implementation team throughout the chatbot implementation process: (i) top-level managers, (ii) legal departments (or external consulting firms on information technology law), (iii) IT security experts (intern or outsourced, depending on the level of available expert knowledge within the company), (iv) works council, (v) corporate communications department, (vi) process owner (and technical experts) of the specific application case, and (vi) employees whose activities are planned to be digitalized by means of the chatbot.

Routine or strategic actions and/or interactions: Based on the statements of the interviewees, the strategic actions and interactions performed throughout a chatbot implementation process can be grouped in eight sequential implementation steps, which we have identified as: (I) preliminary considerations (i.e., identification of redundant processes along with potential information, computing, communication, and/or connectivity technologies that can help to optimize them), (II) use case determination (i.e., detection of potential use cases within the organization, identification of project stakeholders and development of a stakeholder engagement plan), (III) definition of the chatbot characteristics (i.e., determination of the intelligence, interaction, and technical features of the chatbot), (IV) dialogue tree construction (i.e., process mapping and digitalization of relevant technical documents), (V) prototype development (i.e., development of a proof of concept and further enhancement of the dialogue tree through training and testing), (VI) acceptance testing (i.e., in-house and target group-specific acceptance testing), (VII) performance measurement (i.e., determination and monitoring of key performance indicators), and (VIII) post-implementation (i.e., chatbot revision).

Consequences: Most of the experts interviewed indicated a high level of manager support (i.e., direct endorsement from the board of directors); half of them identified (i) the presence of strong budget constraints and (ii) internal resistance (in most of the cases coming from the work council) as the main challenges to accomplish successful chatbot implementation. According to the experts, of particular importance are (i) the involvement of stakeholders responsible for ensuring compliance with labor, privacy, and data protection laws because the extent to which a chatbot can be integrated as a socially acceptable alternative is a key determining factor for the success of chatbot implementation at the organizational level and (ii) the acceptance of the end-user. With regard to this last point, one of the interviewees (IT project manager) mentioned that the most valuable lesson learned, after experiencing a failed implementation attempt, is the following: *"(…) we learned that we cannot just pick a use case and build a chatbot; it is fundamental to consider what the user wants from the very outset and then build the appropriate use case for it (…)."* This technology-push dynamic between companies and users was acknowledged by both of the interviewees belonging to chatbot developing/ IT consultancy firms, as demonstrated by the following statement: *"Often in the case of large companies, we receive an order to develop a chatbot, but the companies did not really understand or properly ask the customer. Finally, we end up developing a chatbot that the customers do not even need (…)."*

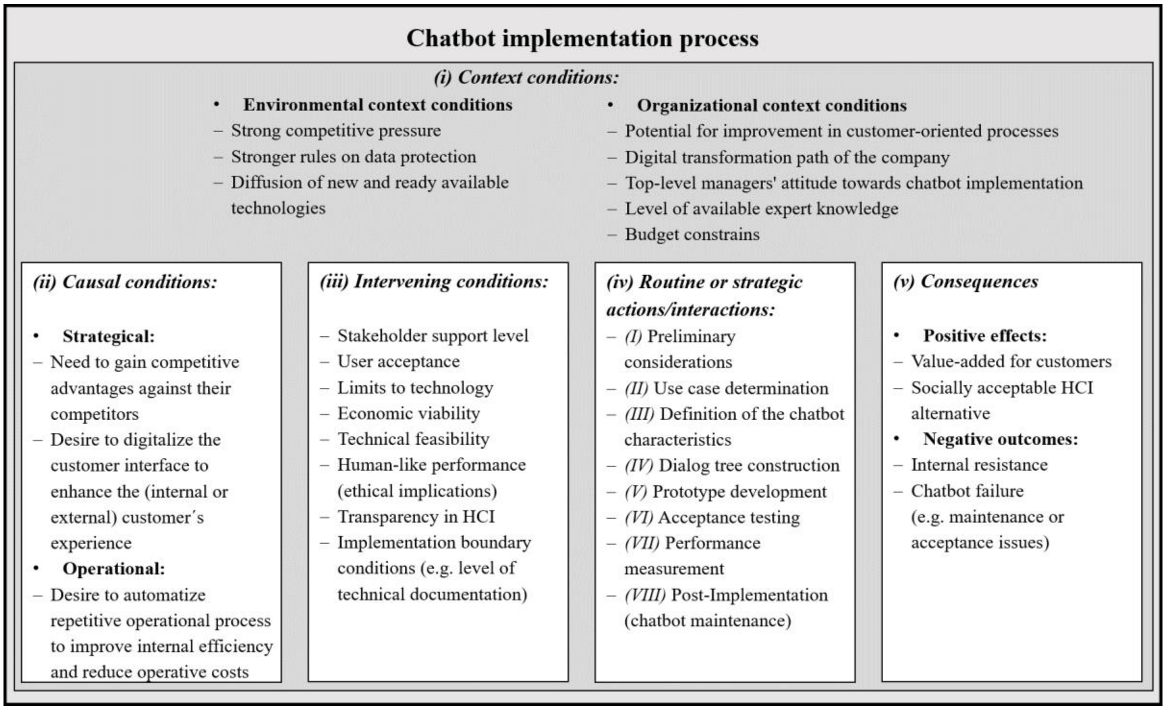

Figure 2: Chatbot Implementation Process Conditions.

5.2 PACT-adapted Chatbot Implementation Framework

Various conditions influence the introduction of chatbots. What unites them all is that the success of the chatbot implementation is measured in terms of how well the developed chatbot is accepted by its users. According to Benyon et al. (2005), "People use technologies to undertake activities in contexts." This quote represents the dependencies of the four elements of people, activities, context, and technology, forming interactive systems design into a complex entity. To develop interactive technologies, it is essential to comprehend the diversity of these four elements (Benyon 2005). PACT is an evaluation framework that assists organizations in capturing the requirements for designing interactive systems while focusing on people (Benyon 2005; Liao et al. 2019; Sarbazhosseini et al. 2019). These four PACT elements will be adapted to chatbot implementation using our results. By adapting this framework, we can understand why people intend to use a system, the related activities they want to perform with the system, the context, and the activities taking place, and we get an overview of the functions of the technology (Adamu 2019). We extended the PACT framework by assigning the four PACT elements to each of the eight sequential implementation steps, which are the result of the statements of the interviewees about the strategic actions and interactions performed throughout a chatbot implementation process described in Section 4.1. Table 3 shows an excerpt of step-related relevant PACT questions for the introduction of chatbots. The full list can be found in Appendix, A5. In the following, the four elements of the PACT framework will be outlined from the perspective of chatbot implementation to show which relevant user-related questions should be considered during the implementation.

People: People differ physically in terms of appearance, weight, and height, but also in personality, preferences, and cognitive abilities, as well as on a psychological level, uttered in their needs, abilities, and mental models (Benyon 2005; 2014). This in turn implies a design for groups that are most heterogeneous. For this purpose, we identified 24 questions along with the chatbot development, which should be considered from the "People" element point of view to be able to better classify the future users of a chatbot. Therefore, the target group should be identified (IIP1) as well as which of them should be addressed (IIP2). To comprehend the "people" element, it is helpful to identify the goals, needs, and motivations that lead to the use of the technology (Benyon 2014; Johansson et al. 2015). This is the aim of question (IIIP3), which considers the motivation of the user to utilize the services of the chatbot. This motivation also shows the extent to which users are motivated by themselves to use the chatbot (IIIP4) (Nguyen and Sidorova 2018). Personality and cognitive abilities are also expressed in language usage and vocabulary, which is why question (IVP1) aims to capture users' language. The language habits of users should be considered in the development because language is a medium to express the apparent chatbot personality suitable for the application domain (Jain et al. 2018).

Activity: To learn more about the activities and related purpose and target of the chatbot, we formulated 26 questions. The analysis of the activity element involves finding out the intended task the chatbot is used for, what is expressed in it, what type of objectives the users attempt to meet through using the chatbot (IIIA3), and what answers these users expect (IVA3). The limits of context-specific chatbots are often given both technically and financially (Jain et al. 2018). To prevent a gap in user expectations, a chatbot must be familiar with all possible plot strands (Tavanapour and Bittner 2018; Gwenuch et al. 2017). To prevent misunderstandings and frustration, the chatbot should be proactive in asking smart questions to minimize the search space (Jain et al. 2018). By leading the dialogue, it is possible to avoid deviating to other topics that the chatbot does not know, which can lead to frustration (Tavanapour and Bittner 2018).

Context: Activities are always embedded in a context representing the natural environment (i.e., where the user is located), indicating that these elements should be considered together (Benyon 2005). The 24 context-related questions examine the context and environment in which chatbot activity occurs. Taking the context into account allows us to offer the correct solution depending on the situation and to minimize the mismatch between a chatbot's real context and the users' perception of the chatbot's context (IIIC2) (Jain et al. 2018). Context in the chatbot field specifies in which domain (e.g., daily life, work support, e-learning) the chatbot serves specific business tasks or functions (IIC2) (Diederich et al. 2019a; Knote et al. 2018); it should be used for internal or external purposes (IIC3) (Meyer von Wolff et al. 2019b). This determines how users prefer to communicate (e.g., text/speech/video) and what their preferred language is (IIIC1) (Exp4). In addition to personality habits, as described in the People section above, the context in which the dialogue takes place also has an influence on language habits. For example, a chatbot for customer support in an insurance company ideally uses much more formal language than an e-commerce chatbot selling tracking equipment even if the same person is being addressed (Gnewuch et al. 2017). The answers should be appropriate, depending on the context of the user and how much time they have. If the user does not have much time and must reach their goal quickly, the answers should be as short as possible (Gnewuch et al. 2017). This also relates to the consideration of which platforms the target group is active on and which communication technologies they use (IIC1) (Sjöström et al. 2019). Consequently, communication technology or a chatbot should be provided within the application ecosystem of the target group (Sjöström et al. 2019).

Technology: The term technology refers to all hardware and software components in interactive systems design that ideally work together to carry out the user's activities (Johansson et al. 2015). The purpose of technology is to support different people who carry out different activities in different contexts (Benyon 2005). There are 28 technology questions, which start with the question of which communication technology the chatbot users use in their surroundings (IIT2). The technology element also incorporates questions from other elements, such as whether the chatbot understands the user's request correctly (IIIA1), (IIIC2), (IVC1), (IVA3), and (IVT2) (Bittner et al. 2019; Knote et al. 2018). A chatbot is only able to answer a message satisfactorily, independent of the message formulation, if it is able to understand a message and to analyze the content correctly (Gnewuch et al. 2017). Depending on the application, advanced NLP may be required to ensure natural communication (Gnewuch et al. 2017; Nguyen and Sidorova 2018).

As described in Section 4.1, the qualitative content analysis of the conducted interviews identified eight sequential implementation steps that should be performed within chatbot development. In the following sections, we describe these eight steps from different perspectives of the PACT framework which are listed in Table 3:

Table 3: Excerpt from Guiding Questions for PACT Chatbot Implementation

Steps		***P**eople*	***A**ctivity*	***C**ontext*	***T**echnology*
(I)	*Preliminary considerations*	**(IP1)** What are the business processes in which the (internal or external) users' desire (need) to receive more (better) support to improve the customer/user value perception? (Exp5), (Exp11), (Exp13), (Exp15)	**(IA1)** What are the most repetitive/ monotonous activities from a user viewpoint? (Exp5, Exp6), (Exp12)	**(IC2)** In which task fields can a chatbot add value to the company? (Exp11), (Exp12), (Exp14), (Exp15)	**(IT1)** Taking into account the value proposition of the organization, is a chatbot the appropriate technology to improve the customer/user value perception (e.g., by overcoming previously identified difficulties/problems)? (Exp6), (Exp11), (Exp13), (Exp14), (Exp15)
(II)	*Use case determination*	**(IIP1)** Who are the end-users? (i.e., target group) (Exp2, Exp6), (Exp12), (Exp15)	**(IIA2)** What is the users' desired outcome? (Exp4), (Exp11)	**(IIC2)** What is the application domain? (Exp13) (Diederich et al. 2019a; Knote et al. 2018)	**(IIT1)** How is the data situation? (i.e., quality of the process/technical documentation) (Exp4, Exp6) (Exp13)
(III)	*Definition of chatbot characteristics*	**(IIIP2)** Self-evolution: What features should the chatbot have to produce the users' desired outcome? (Exp11) (Knote et al. 2018)	**(IIIA6)** What should the chatbot be able to do? What should the chatbot be unable to do for now? (core function) (Exp11), (Exp15)	**(IIIC2)** What type of context-awareness is needed by the chatbot? (Exp15)	**(IIIT3)** Which interfaces to further knowledge bases are required to provide the information requested by the users? (Exp11), (Exp13), (Exp14) (Knote et al. 2018; Di Prospero et al. 2017)
(IV)	*Dialogue tree construction*	**(IVP2)** What type of characteristics should the chatbot's response have from the user perspective? (e.g., long/short answers) (Exp14) (Tavanapour and Bittner 2018; Feine et al. 2019)	**(IVA4)** Are there previous dialogue trees that can be used as a base? (Exp6)	**(IVC4)** How should the chatbot react if it is asked something out of context? (i.e., marriage proposal) (Exp12)	**(IVT1)** Which data are usable? (Exp6), (Exp11), (Exp12), (Exp14), (Exp15)
			(V) Prototype development		
(VI)	*Acceptance testing*	**(VIP1) A**re the expectations of the end-users fulfilled in the test phase? (Exp3), (Exp11), (Exp14)	**(VIA2)** Which questions can the chatbot not answer yet? (Exp11), (Exp15)	**(IVC1)** Does the chatbot match the intended context use and user's perceptions? (Exp15) (Jain et al. 2018)	**(VIT1)** From an NLP perspective, does the chatbot interact as the users expected? (Exp11), (Exp14) (Bittner et al. 2019; Knote et al. 2018)
(VII)	*Measuring added value*	**(VIIP1)** What are the usage criteria for the users in the end?/What perceived value does the chatbot have to the user? (Exp6), (Exp11), (Exp15)	**(VIIA3)** How often is the conversation surrendered to a human? (Exp9)	**(VIIC1)** Does the chatbot accomplish its primary task? (Exp13), (Exp14) (Jain et al. 2018)	**(VIIT2)** Does the chatbot do what it is supposed to do? (Exp12), (Exp13) (Jain et al. 2018)
(VIII)	*Post-implemen-tation*	**(VIIIP1)** Do we still reach the target group with the chatbot? (Exp15)	**(VIIIA1)** Does the chatbot still represent the activity requested by the user? (Exp15) (Jain et al. 2018)	**(VIIIC1)** Does the context in which the chatbot is used still fit the chatbot? (Exp1), (Exp13)	**(VIIIT1)** How can the answer given by a human to a question that the chatbot cannot solve be built into the chatbot? (Exp4), (Exp11), (Exp13), (Exp14)

5.3 PACT-adapted Guiding Steps

5.3.1 I Preliminary Considerations

The first step in the process of implementing a chatbot to digitally redesign or integrate internal or external business processes (BP) (IP2) is to identify specific BP activities (IA1), (IA2) within an area or business context with potential for optimization from a service-oriented perspective (IC1); this allows an innovation agenda containing the general problems experienced by the organization to be set (Kee 2017). This primary step of the chatbot implementation process is intricately connected with the digital business strategy (DBS) defined at the organization level; therefore, the deployment decisions must be aligned with it. A DBS is a merger of IT and business strategies that delimits the goal-oriented approach in which new digital technologies are to be enforced according to the core value proposition of the organization (Bharadwaj et al.

2013). Ross et al. (2016) found that depending on the organization's strategic approach, they overall conceptualize their DBS either in the form of a "digital customer engagement" or "digitized solutions" strategy. The strategic goal of the "digital customer engagement" perspective focuses on building customer loyalty and trust through reengineering of the customer experience through integration of seamless digital interactions, omnichannel capabilities, and customer-centered digital platforms, while the "digitized solutions" perspective is centered on the digital servitization of products and the reformulation of the value proposition of products and services through data and customer analytics (Ross et al. 2016; Sebastian et al. 2017). Although Sebastian et al. (2017) found evidence that suggests that a certain degree of synergy exists between both strategies, the specific relevance of the potentially applicable information, computing, communication, and/or connectivity technologies will primarily depend on their utility to contribute to generating added value by enabling the proper fulfillment of the DBS chosen by the organization (IT1) (Kane et al. 2015; Ross et al. 2016; Brown and Brown 2019). Consequently, the organizational adoption of a new technology should only be made when a technology constitutes a suitable solution to some of the identified issues of the organization's innovation agenda (Kee 2017).

Chatbot technology, depending on the case-specific system design and application domains, can contribute at the organizational level to accomplishing a DBS oriented toward both a digital customer experience (e.g., by improving the organization-to-customer communication through digital channels) and customer-centered operationalization (e.g., by gathering user data during dialogue interactions, which can be utilized for product or service customization) (Zumstein and Hundertmark 2018) (IT1), (IC2).

The preliminary identification of regulatory, ethical, and security issues related to a potential chatbot implementation (IT2) is also of major strategic importance because a higher level of user acceptance can also be achieved through the enforcement of standards and regulations that ensure the safety of users (e.g., data security and privacy) and increase user trust in the chatbot (Nili et al. 2019; Rodríguez Cardona et al. 2019; Laumer et al. 2019). Other strategic factors to be considered are both the level of chatbot-human integration, i.e., the level of workload that is intended to be shifted to the chatbot (Castro et al. 2018; Nili et al. 2019) (IC3), and the need for trained personnel to provide assistance with complex requests beyond chatbot capabilities (Nili et al. 2019) (IC4) as well as skilled IT personnel to train the chatbot (Følstad and Brandtzæg 2017).

5.3.2 II Use Case Determination

As indicated by Brandtzaeg and Følstad (2018 p. 2), "we are currently witnessing a rush of businesses and organizations vying to be the first to deploy chatbots in their particular service domain. In this early phase of chatbot deployment, chatbot initiatives too often aim for poor use-cases, ignoring user needs and user experiences." On these grounds, the second step of the chatbot implementation process concentrates on the identification of the personal characteristics of the target users, such as their demographic segmentation (IIP1), (IIP2), technological preferences and habits (IIP3), (IIC5), (IIT2), extrinsic motivations for chatbot use (IIP4), and key value perception factors (IIP5), (IIP6). The aforementioned factors are crucial to the practical success of chatbot implementation and should, therefore, be kept in the foreground during the selection of a chatbot use case (De Vries et al. 2018). Results from various empirical studies (e.g., Brandtzaeg and Følstad 2017; Zamora 2017; Brandtzaeg and Følstad 2018; Følstad and Skjuve 2019b; Følstad and Brandtzaeg 2020) have shown that most people use chatbots on the basis of motivational factors in the form of gratifications or social and psychological needs. Based on the "uses and gratifications theory" as a baseline for research, Brandtzaeg and Følstad (2017) identified productivity (i.e., ease, speed, convenience, and information) as the main motivational factor underlying chatbot use, followed by other factors, such as entertainment, social interaction, and curiosity, (IIA2). Similarly, subsequent studies have not only reasserted the overriding importance of productivity as a motivational factor for use but have also identified "effectiveness and efficiency" as the most important productivity aspects from a user's perspective (Brandtzaeg and Følstad 2018; Følstad and Skjuve 2019b). The former shows a preference for task-oriented chatbots (Følstad and Brandtzaeg 2020).

A wide range of tasks in diverse application domains can be performed or supported by chatbots (Følstad et al. 2019a). The term application domain embodies "the primary application purpose for which the chatbot has been designed" (Janssen et al. 2020 p. 8). A recent systematic analysis of 103 real-world chatbots identified e-customer service, e-commerce, e-learning, finance, daily life, and work and career support as the six prevailing chatbot application domains (IIC2) (Janssen et al. 2020). From a user-centered perspective, diverse scientific studies, such as those by Zamora (2017), Brandtzaeg and Følstad (2017), Piccolo et al. (2018), Rodríguez Cardona et al. (2019), and Følstad and Skjuve (2019a), offer insights into the debate over what are the most appropriate tasks to be assigned to a chatbot. Through an analysis of 131 user-centered scientific publications on chatbot design an evaluation published between 1975 and 2018, Piccolo et al. (2018) identified that the accumulated scientific knowledge over time suggests that chatbots are not only considered by users to be mostly appropriate for the execution of simple, non-risk-related tasks, such as rapid provisioning of information and assistance, but also can be useful for handling topics that are personal or embarrassing to ask a human agent about. Similarly, Zamora (2017) indicates that "common tasks, such as information seeking or other administrative needs, are objective and can be fulfilled by a chatbot. Some chatbots are also designed to attempt to build relationships between human and AI" (Zamora, 2017, p. 254). In view of the foregoing, customer service is one of the most widespread use cases for chatbots, particularly with regard to simple text-based chatbots using simple pattern-matching techniques (Laumer et al. 2019; Janssen et al. 2020). In addition to information retrieval and customer support use cases, Laumer et al. (2019) identified through a user survey a total of seven categories (smart home control, goods and services shopping, car and navigation, music and entertainment, work and office, and others, such as support for the elderly) and 33 sub-categories of chatbot use cases that users perceive to be of particular utility, especially for speech-based chatbots using more advanced NLP techniques.

In addition to chatbot use cases for external application, the implementation of chatbot use cases within the enterprise context can lead to productivity and efficiency gains as the chatbot can help automate work and organizational processes (Nawaz and Gomes 2019) and digitalize work environments (Frommert et al. 2018) (IIC3). However, the scientific literature on chatbot use in enterprise contexts is still in its early stages (Stöckli et al. 2019). Most chatbot research at the organizational and industrial levels has tended to focus on business use and acceptance of chatbots for customer engagement (e.g., Johannsen et al. 2018; Castro et al. 2018; Nuruzzaman and Hussain 2018; Rodríguez Cardona et al. 2019). In this area, the utilization of hybrid (chatbot-human) interaction design has been found to be particularly advisable in complex use cases associated with risks (e.g., financial, psychological, and privacy) to address current gaps in user acceptance with regard to chatbot technology due to trust and privacy issues (IIA4) (Piccolo et al. 2018; Rodríguez Cardona et al. 2019).However, regardless of the selected chatbot use case, five organizational capabilities have been identified by Tarafdar et al. (2019) as decisive for the implementation of AI-based innovations: i) data science competence (i.e., the possession of big data and extensive data analytics capabilities) (IIA4), (IIC4), ii) business domain proficiency (i.e., comprehensive business process know-how), iii) enterprise architecture expertise (i.e., competence to execute technology-driven transformations), iv) an operational IT backbone (i.e., adequate levels of existing operational technology, high-quality data, and IT staff), and v) digital inquisitiveness (i.e., ability to question and improve the outcomes of AI algorithms). Based on a strategic assessment of the level of development of the aforementioned organizational capabilities, the implementing organization should consider whether in-house chatbot development (IIT6) or outsourced chatbot development would be more appropriate (IIT7).

5.3.3 III Definition of Chatbot Characteristics

The next step after defining a suitable use case is to determine the set of chatbot characteristics needed to ensure that the end-user can achieve their desired outcome (IIIP2). As mentioned by Janssen et al. (2020), the design decisions related to the characteristics to be integrated in the chatbot (e.g., socio-emotional skills, personality, and anthropomorphic features) must be aligned to domain application, characteristics and preferences of the end users, and platform (e.g., social media, website, app, collaboration tools) where the chatbot is expected to be utilized. The extensive body of literature on chatbot design provides diverse classification structures of design elements (e.g., Knote et al. 2018; Braun and Matthes 2019; Janssen et al. 2020) and chatbot development frameworks (e.g., Wei et al. 2018; Jain et al. 2018; Power et al. 2019; Suta et al. 2020) that provide potential implementers of chatbots with archetypal patterns to support chatbot deployment. Knote et al. (2018) classified chatbots on the basis of the functionality principles of self-evolution, anthropomorphism, multimodality, context-awareness, platform integration, and extensibility. According to the former classification, chatbots can employ self-learning, simple reflex, model-based, goal-based, or utility-based self-evolution mechanisms to achieve a specific task (IIIP2). The empirical taxonomy of Janssen et al. (2020, p. 7) defines the above-mentioned mechanisms of intelligence as "the underlying cognitive system design delimiting the technical principles under which a chatbot communicates, processes information, and/or selects an action or response" and provides a detailed description of their architecture in the supplementary material of the article. The information used by the chatbot to retrieve the response can come from structured, semi-structured, or unstructured data sources (IIIT3) (Suta et al. 2020).

Similarly, to increase chatbot user interaction and engagement, the scientific literature provides theoretical context and practical procedures for the decision of the adoption of interactive design features, such as anthropomorphic elements by which a chatbot is able to simulate unique human and mental abilities, such as consciousness, intentionality, and emotions (Seeger et al. 2018; Knote et al. 2018; Virkar et al. 2019; Muresan and Pohl 2019; Feine et al. 2019). For instance, Feine et al. (2019) provided a configuration system of 48 social cues for chatbots (e.g., degree of human-likeness, small talk behavior, gender, age, clothing, ethnicity, interaction order), 18 influencing factors, and 192 possible user reactions toward them (IIIC4) to guide the decision-making process of chatbot developers in relation to the incorporation of certain anthropomorphic characteristics according to a specific context of interaction.

Alternatively, other studies, such as that by Rietz et al. (2019), provide additional insights into the impact of anthropomorphic and functional chatbot design features on the user acceptance of chatbots in enterprise collaboration contexts. According to Janssen et al. (2020, p. 8), the chatbot collaboration goal "determines whether or not the chatbot helps the user to accomplish a common goal or task" (IIIA3), (IIIA4). As a rule, the dialogue design of the locus of control to perform a common goal or task can be internal (chatbot driven) of external (user driven) (Knote et al. 2018; Følstad et al. 2019a) (IIIA1). Depending on their application purpose and interaction design (i.e., user or chatbot-driven locus of control and long or short length interactions), Følstad et al. (2019a) proposed a typology of four forms of chatbots: i) chatbots for customer support, ii) content curation chatbots, iii) personal assistant chatbots, and iv) chatbots for coaching (IIIA3). According to this typology, the locus of control of customer support and personal assistant chatbots is commonly user-driven, while in the case of content curation and coaching chatbots, the locus of control is mostly chatbot-driven (IIIA2). From a technological point of view, the design of a chatbot-driven dialogue is more complex than a user-driven dialogue (Følstad et al. 2019a).

However, it is important to consider that the platform selected for chatbot deployment (e.g., Chatfuel, ManyChat, Microsoft Bot Builder SDK, Dialogflow, IBM Watson Conversation) and the delivery channel platform (e.g., Facebook Messenger, Skype, Telegram, Slack, Microsoft Teams, Amazon Alexa, Cortana, Google Assistant) will delimit the characteristics of the chatbot architectural elements and ultimately the feasible set of chatbot functionalities (Sousa et al. 2019; Kostelník et al. 2019; Suta et al. 2020). Kostelník et al. (2019) distinguish between two types of chatbot platforms: one-purpose only chatbot platforms (also referred to as What You See Is What You Get "WYSIWYG" platforms or high-level chatbot platforms) and all-purpose chatbot platforms. The first type (e.g., Chatfuel, ManyChat) is broadly a cloud computing platform that applies keyword matching, pre-trained datasets, and pre-defined templates to deploy chatbots, while the second type (e.g., Dialogflow, IBM Watson Conversation, Microsoft Bot Builder SDK) is an AI platform that enables users to integrate additional capabilities (e.g., image recognition, NLP analysis) through the integration of application programing interfaces (APIs) and the use of pre-built client libraries in multiple programing languages, such as Python and JavaScript (Kostelník et al. 2019). Based on their characteristics, one-purpose only chatbot platforms are the most appropriate solution for use cases on a limited budget or with implementation teams with limited technical skills. Conversely, all-purpose chatbot platforms are appropriate for complex use cases that require a higher level of NLP maturity, API options, and additional chatbot capabilities (IIIT5). Meanwhile, with regard to the features provided by different delivery channel platforms, Suta et al. (2020) identified the features (i.e., text messages, carousels, buttons, quick reply, web view, group chatbot, list, audio, video, GIF, image, and document/file) provided by the messaging platforms of Facebook, Skype, Slack, Telegram, Microsoft Teams, and Viber. The results of their research show that

Facebook, Telegram, and Skype are the messaging platforms that enable integration of all the analyzed features into the chatbot architecture to a larger extent. According to the results of the exploration of Jain et al. (2018), chatbot users prefer to interact with a user interface (UI) that provides speech recognition (IIIT4), a summary of the main functionalities of the chatbot, a horizontal scrolling carousel to view lists of options, and auto-suggestion buttons (IIIT6).

5.3.4 IV Dialogue Tree Construction

In step IV, dialogue trees are constructed. Dialogue training data can be applied to train an adaptive dialogue flow (Tavanapour and Bittner 2018). Ideally, conversations from the company context (e.g., emails or human-to-human chats) (IVA4) or dialogues from the industry sector are used to adopt phrases (IVP2) and (IVP4) and to build up a suitable vocabulary (IVA3). In addition, publicly accessible training dialogue datasets containing a collection of example conversations labeled with the corresponding entities and intents can also be utilized (Tavanapour and Bittner 2018). Therefore, it should be considered whether sufficient data is available and usable (IVT1) or should be purchased (IVT3). These external data can also be especially helpful when answering questions that do not fit the actual context of the chatbot, such as reacting to a marriage proposal or telling a favorite joke (IVC3). These data must be classified (IVT2). The natural speech understanding unit constitutes the main element for understanding user input to the conversational system, classifying the user's intention and extracting the intended and desired settings of that intention (Bashir et al. 2018). Many techniques have been used for text classification in recent years, such as convolutional neural networks (CNN) (Bashir et al. 2018). Bashir et al. (2018) worked with neural networks that use numerical values to classify texts. Zschech et al. (2020) conducted a comprehensive technical investigation and evaluation of multiple word processing and classification process pipelines to create a system design artifact for selecting data mining methods for text-based intelligent assistance systems. Loisel et al. (2009) described a procedure of data collection and processing to create a dialogue system by recording real conversations and analyzing the obtained text bodies of the dialogues by dividing them into sub-dialogues directly related to a task. Girol et al. (2008) used a classification procedure for user input that considered the complete course of the dialogue to select the system response. A language understanding module within a dialogue system consists of an intent classifier, which is responsible to classify the user's intentions to guide the chatbot to the appropriate answer, and an entity extractor, which extracts the main tags from commands by assigning a label to each word in the sentence to identify its role (Bashir et al. 2018). It should always be questioned whether different formulations of the classification lead to the same result (IVA5) and to what extent the chatbot must be trained to answer various questions (IVT4).

Typically, the conversation starts with a greeting, which can be initiated by the chatbot or the user, e.g., by saying "Hello." However, the way this opening should be designed depends on the application area and target group, which is why the user perspective should be considered here (IVC2) (Feine et al. 2019). To enable the user to assess what the chatbot can be used for, the chatbot introduces itself (e.g., name) before describing the task and process (Tavanapour and Bittner 2018). Attention should also be paid to checking whether the chatbot communicates and advertises its functionalities to the user (Jain et al. 2018) because functionalities of a chatbot that the user is not aware have no added value. The dialogue ends with the chatbot saying, e.g., "Goodbye" (Tavanapour and Bittner 2018). As described in the previous steps, the focus should always remain on the user, which is why the language specifications and wording that the user communicates to the chatbot with (IVP1) as well as what type of language specifications (IVP2) or visualizations (IVP4) that the chatbots should use should be considered.

5.3.5 V Prototype Development

In this step, the prototype is developed based on the decisions made in the previous steps. As mentioned in step III, chatbot engineers can use a variety of deployment platforms (e.g., DialogFlow, ManyChat, Rasa.ai) to design, program, and host a chatbot (Diederich et al. 2019b; Tavanapour and Bittner 2018; Feine et al. 2019). Which of these existing platforms is suitable for prototyping a specific chatbot depends on various factors and requirements, such as the context, supported language, preferred hosting, and pricing model (Diederich et al. 2019b). If the chatbot is primarily based on rules that perform a simple pattern matching, e.g., ChatbotsBuilder could be used (Diederich et al. 2019b; Feine et al. 2019). If the chatbot should improve over time in a self-learning way while communicating with the user, the provider Twyla could be used (Diederich et al. 2019b). Platforms also differ in the way chatbots are built by developers. There are platforms in which chatbots are programed by writing code (e.g., wit.ai); other providers allow the modeling of user conversations using flowcharts (e.g., ManyChat and IBM Watson Assistant). In addition, the necessity of a preconfigured interface or an API, allowing the chatbot to access existing applications or web services during a conversation, such as a CRM system or a database, determines which chatbot platform provider is the most suitable (Diederich et al. 2019b; Meyer von Wolff et al. 2019a). A distinction can be made between different types of prototypes. Usually, functional chatbots are built in this step, which will be evaluated in the next steps. However, some researchers have reported the development of a WoO (Wizard of Oz) as the first prototype (Sjöström et al. 2019; Bittner and Shoury 2019; Tavanapour and Bittner 2018). In this case, a chatbot interface is merely developed so that a respondent is assumed to communicate with an interactive system, although the reactions of the system are in reality generated by a human (Bittner and Shoury 2019).

5.3.6 VI Acceptance Testing

Acceptance testing includes evaluation and assessment by considering future users. Thus, it is suitable to invite, e.g., between five (Feine et al. 2019), and fifteen (Jain et al. 2018; Krisnawati et al. 2018) and forty (Hobert 2019), test users who will be asked to have a dialogue with the chatbot. The limited number of participants should be encouraged to provide qualified feedback to evaluate the chatbot in terms of acceptance and satisfaction (Ghose and Barua 2013; Krisnawati et al. 2018). This acceptance testing can be divided into two phases: an exploratory analysis and a task scenario analysis. In the exploratory phase, the test users should be asked to start a dialogue with the chatbot. Hereby, the participants should state their first general impression and overall opinion concerning the prototype (Hobert 2019). Based on the first impressions, questions (VIAI) and (VIA2) can be answered. After introducing the test users to the context and purpose of the chatbot, it is helpful to provide test users with a task scenario by defining concrete targets or achievements that the test users should find complete using a chatbot-user conversation (Krisnawati et al. 2018; Hobert 2019). This helps find out which phrases and formulations users enter to achieve a certain goal and if the chatbot can already answer the sentences in a satisfactory way (VIA2). These phrases and synonyms should then be used as training data so that the chatbot can respond more flexibly to utterances and questions from users (Tavanapour and Bittner 2018).

To answer question (VIP1), it helps to give each test user a list of topics, based on which each user asks the chatbot a limited number of questions. The answers from the chatbot are then classified by the test user into "satisfactory" and "unsatisfactory", representing how appropriate and accurate the chatbot responses are to the query asked by the user (Ghose and Barua 2013). If a large number of test users exist, a quantitative questionnaire can be used to test functional aspects, such as usefulness and form aspects, such as ease of use, by applying a 5-point Likert scale (Davis et al. 1989; Hobert 2019). Jain et al. (2018) observed that users blamed themselves when chatbots did not perform their expected task or did not behave as expected, which was attributed to Norman's theory of "human error." To prevent frustration and a negative impression, this should be circumvented.

First, it should be verified whether the user's expectations of the chatbot are fulfilled (VIP1). This is a fundamental question that depends on whether users see an added value in the consultation and whether they will decide to use the chatbot again in the future. Ideally, a chatbot should have an apparent and consistent personality appropriate to its field of application, which may be expressed, for instance, in initial small talk ("Good morning, how are you?"), in appreciative farewells ("have a great day") or humorous replies (Jain et al. 2018). However, the perception of a chatbot's personality is highly dependent on the application area of the chatbot, which is why it should be asked in this step whether the user perceives the chatbot as a serious conversational partner (VIP2). In addition, the average character length can be analyzed to determine how users communicate and how long the responses of the chatbot should be (Jain et al. 2018). Finally, it should be verified whether the user's expectations of the chatbot are fulfilled (VIA1). This is a fundamental question that depends on whether users see an added value in the consultation and whether they will decide to use the chatbot again in the future. Based on the valuable feedback of the participants within the acceptance testing, the prototype should be revised before conducting a further acceptance test (Hobert 2019).

5.3.7 VII Measuring Added Value

After a chatbot has been implemented and released, chatbot performance should be measured by tracking human–chatbot interactions (Przegalinska et al. 2019). To assess whether a chatbot is successful, evaluation metrics should be applied to quantify system performance (Krisnawati et al. 2018; Przegalinska et al. 2019). In the scientific community trust in a chatbot is mainly related to the users' perception of the knowledge and expertise of this chatbot (e.g., Przegalinska et al. 2019). From a user perspective, the target of the chatbot is to maximize user satisfaction (Krisnawati et al. 2018). To measure user satisfaction, user tests can be conducted, as described in step VI (acceptance testing). In addition, this can be determined by performance measurement using metrics such as conversation length (VIIA1), customer retention, or lead generation (VIIT1) (Przegalinska et al. 2019). From an information gathering perspective, the effectiveness of the system is evaluated by measuring, for example, the precision (VIIA2), recall (VIIA1), and F-score (Krisnawati et al. 2018). The quantitative evaluation of system performance can be done by dialogue-based metrics, such as the average conversation duration (VIIA1) (Jain et al. 2018). The number of turns is defined as the number of messages exchanged between the user and the chatbot within a dialogue (Jain et al. 2018). To determine how profound the responses to the inquiry are (VIIA2) and how effectively the chatbot engages with the user, the average number of turns necessary for each concept to be understood by the chatbot (Krisnawati et al. 2018; Jain et al. 2018). Further indicators include word error rate (WER), sentence error rate (SER), and task completion rate (TCR) (Glass et al. 2000; Krisnawati et al. 2018; Jain et al. 2018). Monitoring real-time human-chatbot conversations has the advantage of obtaining valuable insights about the context (VIIC1) when communicating with the chatbot, such as why they visited the website and what they were looking for. This in turn can give impulses to update the chatbot but also to revise further marketing and sales processes and channels according to altered user needs.

5.3.8 VIII Post-implementation

The last step refers to the phase after the go-live. Therefore, constantly checking whether the chatbot fulfills the functionalities and abilities expected by the user (VIIIA1) is crucial. The expected functionalities can change constantly because users expect positively experienced functionalities from other chatbot environments and application fields in this chatbot. Therefore, regularly checking whether the chatbot is still suitable for the context in which the users use it (VIIC1) and whether it can help with users' questions is essential. If not, it should be considered how the dialogues, expertise, and answers of service employees to questions of customers might be transferred to the chatbot in the future (VIIT1). For upcoming technologies, trends, and innovations (e.g., in AI), customer data processing should also be considered.

In addition to technologies, regulations and legislation on data protection have evolved over the years. One such example is the General Data Protection Regulation (GDPR), which addresses the export of personal data outside the European Union (EU). To provide the user with the most personalized experience possible, many chatbots rely on the collection and processing of personal information, such as customer number or name. While this can be partially circumvented by login mechanisms on websites, it is a challenge when using non-customer data in chatbot dialogues offered, e.g., on public insurance sites (Koetter et al. 2019). The EUGDPR also applies to chatbot applications, so the regulations must be fully complied with as soon as personal data are collected and processed (Nuseibeh 2018). In this context, it is crucial to communicate clear guidelines and agreements on data storage and use at the very beginning of the conversation and to obtain the consent of the chatbot users (Nuseibeh 2018). Chatbot services should be capable of demonstrating that there are appropriate technical and administrative measures that protect against data breaches in the form of user data or conversation protocols (Nuseibeh 2018). As described in step I (preliminary considerations), the purpose of the chatbot is ideally directly related to the DBS. Because an organization's strategic approach can change over time (Kee 2017), the purpose of the chatbot should be regularly aligned with the DBS and adapted to the new DBS if necessary (VIIIC2).

6 Implications, Recommendations, Limitations, and Further Research

We pursued a design science research-oriented HCI approach and developed a user-centered framework that helps to implement chatbots through a set of 102 guiding questions. We focus on the interior mode of an IT system design (Adam et al. 2021) and present a framework on how future technical artifacts in the form of chatbots can be developed considering the characteristics of the intended end-user, activities, context and technology. Our findings in Section 4.1 show that the strong competitive pressure that comes with the rapid diffusion of technological innovations is causing a strong isomorphic pressure at the environmental level. This indicates that companies are often pressed to mimic their peers and enforce the adoption of technologies, such as chatbots, by compelling their operational processes and (internal and external) users to fit the technology. The former technology-push dynamic represents an important economic and strategic risk for companies attempting to gain a competitive advantage through the rapid integration of new technologies. However, our research has contributed to identify, inter alia, a set of enabling and constraining factors in the form of intervening conditions, such as end-user involvement to enhance acceptance, which can be managed at the organizational level by using, for example, in the case of user acceptance, a user-centered approach like the PACT-adapted implementation framework proposed.

Based on the literature review and expert interviews, our developed PACT-adapted chatbot implementation framework contains guidelines along the identified eight steps. These questions were sorted into the four elements of People, Activity, Context, and Technology developed by Benyon (2005; 2014). The developed PACT-adapted framework for chatbot implementation and the detailed explanations of each step serve as a notional structure for practitioners to introduce a chatbot in a structured and user-centered manner regardless of their level of technical knowledge. The connection between the four PACT elements and their data-driven questions (Table 2) shows how many mutually dependent factors must be considered during a chatbot implementation process to mitigate the risk of implementation failure.

With explicitly focusing on the four user-centered PACT elements, including the context of the chatbot and the user (people) we close this gap in chatbot research which was named by Zierau et al. (2020). According to Zierau et al. (2020), the interaction between a chatbot and a user is formed by the characteristics of the system, the user, the task and context but concluded that task context as well as user characteristics were hardly considered in previous literature, except as being a control variable, in which they see major research gaps that have a great impact on both chatbot design and user behavior (Zierau et al. 2020).

Not all presented questions are necessarily relevant for every chatbot development project and involved stakeholders. Rather, the purpose is to provide an overview of all potentially important questions to maintain an overview throughout the entire process. The framework can be seen as a bridge between science and practice, where both sides benefit from the extensive list. For practice, we see our contribution in the fact that we offer project stakeholders a certain independence with our guiding questions so that they can really focus on the future user instead of looking at what the chatbot platform provider or chatbot developing service provider offers. For research, it reveals many issues that are highly relevant in practice but have rarely been considered in academia. Even though most of the steps are mentioned by both researchers in literature and practitioners in interviews, it is noticeable that step 1 "Preliminary considerations" in particular is almost exclusively addressed by the practitioners. While the chatbot literature is more concerned with the development of a chatbot, e.g., (IIIA4), (Ghose and Barua, 2013) or specific design aspects of chatbots e.g., (IIIP2), (Virkar et al., 2019), the practitioners emphasize the need to take a step back and consider where a chatbot actually makes sense, e.g., (IA3, IT1). This highlights the need to first question whether a chatbot is the appropriate communication tool before starting with the development. A chatbot, no matter how well designed, is superfluous if the use case does not fit because the user does not use it (Schuetzler et al. 2021). With the questions in step 1, we therefore provide a basis for researchers taking another glance at the preliminary considerations to find clues for future research, e.g., comparation of different communication tools with chatbots. Furthermore, the interviews have shown that practitioners are often very focused on their own use cases and their environment. Here the summarized results of literature and practice within our framework give the possibility to make decisions based on scientific studies and to draw attention to design considerations, which otherwise would not have been considered at all. In addition, by providing the sources, it gives starting points for practice to read deeper into individual topics. From a research point of view, the use case determination is more descriptive, which has not been in the research focus so far.

Chatbots are seen as an ideal example of an HCI artefact (Adam et al. 2021) as the success of the technology lies directly in the interaction with the user but also differ decisively from other HCI systems in their interaction and intelligence capabilities (Maedche et al. 2019; Zierau et a. 2020). By conducting a literature review, it became clear that a general, user-centered chatbot implementation model, which lists the entire decision-making process independent of the field of application, does not yet exist in the scientific literature, while practically oriented introduction models are available in the field of HCI. One example is DIN EN ISO 9241-210:2011-01: Human-centered design for interactive systems, which aims to develop highly usable systems and products applying the provided framework for human-centered design. Although the basic characteristics and steps of this model are very close to those of our developed model (e.g., "understand and specify the context of use" and "produce design solutions to meet user requirements" (DIN EN ISO 9241-210:2011-01)), our developed model differs from other models developed in the field of HCI in that it was especially designed for chatbots. This can be observed, for example, in step IV (dialogue tree construction), which is not relevant for other interactive systems as well as within individual questions (e.g., IIIC2; VIA2; VIT1). In addition, although the steps are intended to provide structure and orientation, the added value lies in the listing of questions within the steps.

Our limitations give rise to diverse open research directions (RD), which can be addressed by HCI and IS researchers in the future. To identify the relevant questions, we conducted an extensive literature review and interviewed 19 experts. When interviewing the experts, we reached a saturation point. Even though the goal was to get insights from as many deployment areas as possible, questions may be missing due to our focus on introduction of chatbots with a holistic perspective. Future research could also focus on individual ones of the eight stages identified in this work (RD1). The collection gives future researchers the opportunity to identify thematic areas that receive broad attention in practice but are rarely addressed in research (RD2). Another example is the post-implementation step. Through the interviews, we learned that post-implementation is just as essential as the implementation steps for long-term success of a chatbot. This is crucial to ensure that chatbots evolve according to the needs of their users. Nevertheless, the scientific literature often focuses on chatbot introduction, and post-implementation phases are rarely considered. Our research makes a first contribution to this, which can be expanded in the future. The results of the interviews reflect the subjective opinions of the interviewees and therefore may be self-biased. To generalize the individual experiences of the interviewees, we consolidated the results with scientific literature. Future research could focus on weighting of the individual steps as well as the specific questions within each step, which could be represented by color coding (RD3). This would make the weighting of the individual steps more visible and assessable for research and practice. We have assigned the identified questions to the four PACT elements according to Benyon (2005; 2014). Even if these questions have different perspectives, as described in Section 5.2, it may be possible that certain questions can also be assigned to one of the other elements or other steps. For the sake of clarity, we have decided to assign the questions to the element that fits best, which we then had confirmed in the evaluation.

Although we have applied a three-stage evaluation process, we can only partially generalize about the success of using the framework within chatbot development in practice. Therefore, it would be useful in the future for different chatbot development teams to apply this framework to analyze their practical application as it was done within the applicability check (see Section 4.3) (RD4). In this context, discovering and evaluating additional methods is necessary, such as workshops, exercises, questionnaires, or experiments, which could be used to apply the framework in organizational settings (RD5). Our questions also provide a basis for the future development of critical success factors (Williams and Ramaprasad 1996). Further research could focus on the question of how crucial the presented questions are for the success of an implementation (RD6). Here, certain platforms for the realization of a chatbot can make an adjustment necessary for part of the questions; for example, the choice of platform can determine the possible communication channels. To develop the PACT framework, we interviewed different stakeholders, such as chatbot developers, IT project managers, and product owners, who had already been involved in a chatbot implementation process. It became apparent that the participants had different perspectives depending on their area of responsibility. Further research can systematically examine the role of these stakeholders at the different steps of the process and broaden our questions by specifically considering each stakeholder (RD7). This would allow us to formulate further stakeholder-related questions to obtain a holistic view of the implementation. The chatbot environment has evolved dramatically through developments in areas such as NLP and AI, and it will continue to evolve at least as rapidly in the future. Hence, the framework should be regularly reviewed and updated (RD8).

7 Conclusions

To fill the research gap of missing knowledge on the requirements and implementation of chatbots, we conducted a qualitative content analysis to identify aspects which require consideration developing a chatbot. Fifteen experts in this field, who had already been involved in chatbot implementations, shared their expertise in semi-structured interviews, which were enriched with scientific literature. The analysis of the interviews led to the identification of five categories, six sub-categories, and diverse aspects whose interactionism should be considered during the design and implementation of chatbots and for further theory development in research. The findings from our research provide a comprehensive understanding of how the successful introduction of chatbots can take place.

Contributing to the knowledge on chatbot implementation, we further developed the user-centered PACT framework by Benyon (2005; 2014). Our framework contains 102 questions for the development of a user-centered chatbot implementation using the results of our qualitative content analysis as well as our literature review. We evaluated this framework in a three-step evaluation process by conducting interviews as well as a focus group discussion. Our results help practitioners to keep track of the relevant issues throughout the chatbot implementation process and academic researchers by gathering design knowledge as a basis for further research. The questions developed in the PACT framework have a user-centered focus, but various stakeholders are involved in the implementation process, as identified in Section 4.1.

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A APPENDICES

A.1 CATEGORY FORMATION PROCEDURE

Stage 1: Coding units	***State 2: Context units (Subcategories)***	***Stage 3: Evaluation units (Main categories)***
1. Competitive pressure 2. Data protection regulations 3. Diffusion of new technologies	1. Environmental context conditions	1. Context conditions
4. Available expert knowledge 5. Budget constraints 6. Customer-oriented improvements 7. Top-level manager's attitude	2. Organizational context conditions	
8. Business competition 9. Digital transformation process 10. Potential benefits 11. Technology acceptance	3. Strategical causal conditions	2. Causal conditions
12. Suitable application areas 13. Use case driven design	4. Operational causal conditions	
14. Intern chatbot user 15. Stakeholder support level 16. Target group 17. User acceptance	5. People-related intervening conditions	3. Intervening conditions
18. Deciding factors 19. Economic viability 20. Technical feasibility	6. Activity-related intervening conditions	
21. Ethical implications 22. Legal aspects	7. Context-related intervening conditions	
23. Cost 24. Economic viability 25. Human-like performance 26. Implementation boundary conditions (e.g., level of technical documentation) 27. Implementation time 28. Limits of technology 29. Pace of technology change 30. Prototype tools 31. Response speed 32. Standard features 33. Transparency in HCI	8. Technology-related intervening conditions	
34. Employee/user participation 35. HCI expert support 36. IT security 37. Pace of technology change	9. Pre-implementation preparation	4. Routine or strategic actions/interactions
38. Business case (cost-benefit analysis)	10. Use case determination	

39. Definition of application context 40. Stakeholders 41. Chatbot characteristics 42. Hybrid model 43. Platform determination 44. Dialogue tree 45. Flowchart generation 46. Practical/performance test (proof of concept) 47. Group-specific acceptance test 48. In-house testing 49. Measuring added value (KPIs) 50. Chatbot maintenance	11. Definition of chatbot characteristics 12. Dialogue tree construction 13. Prototype development 14. Acceptance testing 15. Performance measurement 16. Post-implementation	
51. Customer value added 52. Socially acceptable alternative 53. Chatbot failure 54. Internal resistance	17. Positive effects 18. Negative outcomes	5. Consequences

A.2 INTERVIEW GUIDE

Entrance questions

- Presentation of yourself (age, profession, industrial sector, number of employees)
- How long have you been dealing with chatbots?
- What is your role (job title and responsibilities) in the chatbot implementation?
- What was your last chatbot implementation project? What type of chatbot is it? (name, purpose, target group, type of development, platform)
- Are your customers more likely to have a use case first by wanting a chatbot as a solution or did you want to install a chatbot as a new communication technology in your company and then searched for a use case?

Key questions:

- What do you think is the first question before implementing a chatbot?
- How do the requirements analysis and definition of a chatbot work?
    - To what extent does the target group play a role? How are future users involved?
    - How do you define the tasks and purpose of the chatbot?
    - To what extent do you consider the environment in which chatbot will be used?
    - How are the technical functionalities determined? Are there any choices? Are the target group and content determined first or are the definitions of the functions considered in isolation?
    - In which order are the different aspects in the decision-making process considered?
    - Which areas are also considered?
    - Which challenges arise?
- How do you proceed after the requirements analysis and definition?
    - Is there a previously defined procedure?
- How do you measure the success of the chatbot?
    - Which key performance indicators (KPIs) do you use?
- When do you think the introduction phase is finished?
    - In your opinion, what are the three biggest challenges for the introduction of a chatbot?

Evaluation:

- How do you evaluate the designed chatbot introduction model?
- How do you evaluate the outline of 8 steps?
- Are you missing steps or should something be summarized?
- What is your opinion about the formulation of questions instead of key points?
- How well can a guideline be applied to the introduction of individual chatbots?
- Are there other areas that should be covered in addition?

A.3 MODEL EXCERPT

Steps	***People***	***Activity***	***Context***	***Technology***
I **Preliminary considerations**	**(IP2)** What type of communication technologies do the users use on a regular basis?	**(IA1)** What are the most repetitive/monotonous activities from a user viewpoint?	**(IC1)** In which area or business context do users present more (special) difficulties/problems? (e.g., customer service context)	
II **Use case determination**	**(IIP3)** Which target group segments perceive added value in the potential use of a chatbot?	**(IIA4)** Does the activity require historical user information to be accomplished?		**(IIT3)** What type of platform integration is needed?
III **Definition of chatbot characteristics**				**(IIIT4)** How should the user interface (UI) look from the user's viewpoint?
IV **Dialogue tree construction**	**(IVA4)** Are there previous dialogues threes that can be used as a base?			**(IVT1)** Which data are usable?
		V Prototype development		
VI **Acceptance testing**		**(VIA1)** What questions do users have?		
VII **Measuring added value**			**(VIIC1)** Does the context in which the chatbot is used still fit the chatbot?	**(VIIT1)** How often is the chatbot used as an offer?
VIII **Post-implementation**			**(VIIIC1)** Does the context in which the chatbot is used still fit the chatbot?	

A.4 FOCUS GROUP QUESTIONNAIRE

How do you assess the division into 8 steps?

Are there any steps missing?
Should steps be deleted?
Should steps be combined?

Are all relevant questions listed?

Are relevant questions missing?
Should questions be left out?
Can questions be summarized?

Are the questions correctly classified?

Old position		New position	
Step	Element	Step	Element

What are the possible application areas?

How can the guide be applied to individual chatbot implementation?

Do you prefer the formulation of questions or key points?

☐ Questions ☐ Key points

Other issues and opportunities for improvement

A.5 A Framework for User-Centered Implementation of Chatbots

Steps		*People*	*Activity*	*Context*	*Technology*
(I)	*Preliminary Considerations*	**(IP1)** What are the business processes in which the (internal or external) users' desire (need) to receive more (better) support to improve the customer/user value perception? (Exp5), (Exp11), (Exp13), (Exp15) **(IP2)** What type of communication technologies do the users use on a regular basis? (Exp13), (Exp14)	**(IA1)** What are the most repetitive/ monotonous activities from a user viewpoint? (Exp5, Exp6), (Exp12) **(IA2)** What are the characteristics of the previously identified activities? (Exp4), (Exp14) **(IA3)** What type of activities should be handled by a human employee to achieve the best outcome for the user? (Exp12)	**(IC1)** In which area or business context do users present more (special) difficulties/problems? (e.g., customer service context) (Exp4), (Exp11), (Exp13), (Exp15) **(IC2)** In which task fields can a chatbot add value to the company? (Exp11), (Exp12), (Exp14), (Exp15) **(IC3)** In which cases can a chatbot relieve employees? (Exp12) **(IC4)** Do employees need to be trained in handling chatbots? (Exp10)	**(IT1)** Taking into account the value proposition of the organization, is a chatbot the appropriate technology to improve the customer/user value perception (e.g., by overcoming previously identified difficulties/problems)? (Exp6), (Exp11), (Exp13), (Exp14), (Exp15) **(IT2)** Which technology concerns should be considered (i.e., regulations and ethical and security issues)?
(II)	*Use case determination*	**(IIP1)** Who are the end-users? (i.e., target group) (Exp2, Exp6), (Exp12), (Exp15) **(IIP2)** How is the target group segmented? (Exp6), (Exp11), (Exp15) **(IIP3)** What type of communication technologies do the target group use on a regular basis? (Exp13), (Exp14) **(IIP4)** What would be the end-users' main extrinsic motivation for using a chatbot? (Brandtzaeg and Følstad, 2018) **(IIP5)** Which target group segments perceive added value in the potential use of a chatbot? (Exp6), (Exp11), (Exp15) **(IIP6)** What availability does the target group look for? (i.e., 24 – 7 service chatbot) (Exp12)	**(IIA1)** What are the collaborative requirements of the activity to be digitalized? (Exp11) **(IIA2)** What is the users' desired outcome? (Exp4), (Exp11) **(IIA3)** Do the users need (desire) to receive additional human support to accomplish their activity? (Handover) (Exp14), (Exp15) **(IIA4)** Does the activity require historical user information to be accomplished? (Exp4), (Exp12) (Følstad et al. 2019a)	**(IIC1)** On which communication platforms is the target group active? (Exp7), (Exp11), (Exp13), (Exp15) (Sjöström et al. 2019) **(IIC2)** What is the application domain? (Exp13) (Diederich et al. 2019a; Knote et al. 2018) **(IIC3)** Is the chatbot intended for an internal or external context use? (Exp13) (Meyer von Wolff et al. 2019b) **(IIC4)** Is customer data necessary to optimally support the user? (i.e., login, 2-factor authentication) (Exp11), (Exp12), (Exp15) **(IIC5)** Which device does the target group use? (i.e., Smartphone or tablet?) (Exp11), (Exp15) **(IIC6)** Should the method of communication (i.e., e-mail, web interface) also attract potential customers? (Exp12), (Exp15) **(IIC7)** Where are possible or existing touch points with customers? (Exp13), (Exp14)	**(IIT1)** How is the data situation? (i.e., quality of the process/technical documentation) (Exp4, Exp6) (Exp13) **(IIT2)** Through which communication channels have users been reached so far? (Exp6), (Exp11) **(IIT3)** What type of platform integration is needed? (Exp13), (Exp15) (Diederich et al. 2019b) **(IIT4)** How does a typical chatbot interface look like in the application domain? (Exp6), (Exp14) **(IIT5)** Which server fulfils the requirements? (Cloud or on-premises?) (Exp9), (Exp15) **(IIT6)** In-house development or Outsourcing? (Exp9) **(IIT7)** Which provider fulfils the technical requirements? (Exp15)

(III)	*Definition of chatbot characteristics*	**(IIIP1)** How many users can be reached through the chatbot? (Exp11) **(IIIP2)** Self-evolution: What features should the chatbot have to produce the users' desired outcome? (Exp11) (Knote et al. 2018) **(IIIP3)** To what degree is the behaviour of using the chatbot self-motivated? (Exp14) (Nguyen and Sidorova 2018) **(IIIP4)** Does the user need a tutorial on how to use the chatbot? (Exp14) **(IIP5)** How can a chatbot measure user satisfaction? (Exp10), (Exp13) **(IIP6)** Is the user experience improved by integrating gimmicks? (Exp11)	**(IIIA1)** How do the users formulate their requests? (Exp6), (Exp13), (Exp14) **(IIIA2)** Is a chatbot-driven or user-driven dialogue preferred? (Exp14) (Følstad et al. 2019a) **(IIIA3)** What type of objectives do the users attempt to meet by using the chatbot? (Exp14), (Exp10) (Tavanapour and Bittner 2018; Følstad et al. 2019a) **(IIIA4)** Is the intent to use the chatbot more goal-oriented or non-goal-oriented? (Bittner et al. 2019; Jain et al. 2018; Janssen et al. 2020) **(IIIA5)** How did a typical conversation between a customer and an employee look like before the chatbot? (Exp14) **(IIIA6)** What should the chatbot be able to do? What should the chatbot be unable to do for now? (core function) (Exp11), (Exp15) **(IIIA7)** What activities are measurable after implementation? (Exp10), (Exp13)	**(IIIC1)** In what way (text/speech/video) do users wish to communicate? (Exp4), (Exp14) **(IIIC2)** What type of context-awareness is needed by the chatbot? (Exp15) **(IIIC3)** How should the chatbot react if it cannot respond? (Exp14) **(IIIC4)** Is the emotional context explicitly of the users handled properly? (i.e., stressed or frustrated users) (Exp9)	**(IIIT1)** Are there already chat interfaces in the company that can be adapted or should the company start from scratch? (Exp6), (Exp13) **(IIIT2)** To what extent is it desired for the chatbot to present human-like features? (e.g., avatar, personality) (Exp12) (Knote et al. 2018) **(IIIT3)** Which interfaces to further knowledge bases are required to provide the information requested by the users? (Exp11), (Exp13), (Exp14) (Knote et al. 2018; Di Prospero et al. 2017) **(IIIT4)** How should the UI look from a user viewpoint? (Exp14) **(IIIT5)** Are the users' desired chatbot features within the approved company budget? (Exp4), (Exp6), (Exp11), (Exp13), (Exp15) **(IIIT6)** Is the chatbot expected to have good speech recognition/ NLU? (Exp11) **(IIIT7)** Does the chatbot need an interface for pictures? (Exp12) **(IIIT8)** Are licenses/ permissions for access required? (Exp13) **(IIIT9)** Are there any data protection restrictions? (Exp9), (Exp10), (Exp11), (Exp12), (Exp14), (Exp15) **(IIIT10)** Does the chatbot need artificial intelligence? (Exp12), (Exp15)

(IV)	*Dialogue tree construction*	**(IVP1)** In which language specifications do the users wish to communicate with? (Exp11) (Tavanapour and Bittner 2018) **(IVP2)** What type of characteristics should the chatbot's response have from the user perspective? (e.g., long/short answers) (Exp14) (Tavanapour and Bittner 2018; Feine et al. 2019) **(IVP3)** Does my target group use multiple languages? Should the chatbot work with translating tools? (Exp10), (Exp11), (Exp13) **(IVP4)** Do answers include emojis, visualizations, and/or text? (Exp12), (Exp14) **(IVP5)** Will it be a B2B or B2C chatbot (technical or colloquial)? (Exp13)	**(IVA1)** Do the users prefer to use a pre-configured selection menu or would they prefer to formulate their own questions/requests? (Exp4), (Exp14), (Exp15) **(IVA2)** What do sample texts look like? (Exp12) **(IVA3)** What answers do users expect? (Exp6), (Exp14) **(IVA4)** Are there previous dialogue trees that can be used as a base? (Exp6) **(IVA5)** Do multiple formulations lead to the same result? (Exp13)	**(IVC1)** Does the chatbot match the intended context use and user's perceptions? (Exp15) (Jain et al. 2018) **(IVC2)** How should the conversation start from the user's perspective for it to sound more human-like? **(IVC3)** What chatbot personality traits do the users expect? (Exp11) (Jain et al. 2018) **(IVC4)** How should the chatbot react if it is not asked anything something out of context? (i.e., marriage proposal) (Exp12)	**(IVT1)** Which data are usable? (Exp6), (Exp11), (Exp12), (Exp14), (Exp15) **(IVT2)** Do these data still need to be strongly classified? (Exp6), (Exp11), (Exp14) **(IVT3)** Is there enough data or should data be purchased? (Exp13), (Exp15) **(IVT4)** How much training does a chatbot need to obtain enough data without overloading? (Exp15)
(VI)	*Acceptance Testing*	**(VIP1) A**re the expectations of the end-users fulfilled in the test phase? (Exp3), (Exp11), (Exp14) **(VIP2)** Does the user perceive the chatbot as a serious communicator? (Exp11)	**(VIA1)** What questions do users have? (Exp5), (Exp12) **(VIA2)** Which questions can the chatbot not answer yet? (Exp11), (Exp15)		**(VIT1)** From an NLP perspective, does the chatbot interact as the users expected? (Exp11), (Exp14) (Bittner et al. 2019; Knote et al. 2018)
(VII)	*Measuring Added Value*	**(VIIP1)** What are the usage criteria for the users in the end?/What perceived value does the chatbot have to the user? (Exp6), (Exp11), (Exp15) **(VIIP2)** How often do the users leave the chatbot or stop writing and why? (Exp6), (Exp11), (Exp13)	**(VIIA1)** What is the average duration of a chat? (Exp3), (Exp13) **(VIIA2)** How profound is the response to the inquiry? (Exp4), (Exp15) **(VIIA3)** How often is the conversation surrendered to a human? (Exp9)	**(VIIC1)** Does the chatbot accomplish its primary task? (Exp13), (Exp14) (Jain et al. 2018)	**(VIIT1)** How often is the chatbot used as an offer? (Exp6), (Exp11), (Exp12), (Exp13), (Exp15) **(VIIT2)** Does the chatbot do what it is supposed to do? (Exp12), (Exp13) (Jain et al. 2018)
(VIII)	*Post-implementation*	**(VIIIP1)** Do we still reach the target group with the chatbot? (Exp15)	**(VIIIA1)** Does the chatbot still represent the activity requested by the user? (Exp15) (Jain et al. 2018) **(VIIIA2)** Are there any conversational flows that led to a failure because the flow was not modelled? (Exp12) (Jain et al. 2018)	**(VIIIC1)** Does the context in which the chatbot is used still fit the chatbot? (Exp1), (Exp13) **(VIIIC2)** Does the chatbot fit the company? (Exp11) **(VIIIC3)** Is the chatbot affected by legal changes? (Exp12)	**(VIIIT1)** How can the answer given by a human to a question that the chatbot cannot solve be built into the chatbot? (Exp4), (Exp11), (Exp13), (Exp14) **(VIIIT2)** What newfound technologies can be included? (Updates) (Exp12)

Appendix 7 - Predictive Maintenance as an Internet of Things enabled Business Model: A Taxonomy

Outlet: Electronic Markets

Abstract

Predictive maintenance (PdM) is an important application of the Internet of Things (IoT) discussed in many companies, especially in the manufacturing industry. PdM uses data, usually sensor data, to optimize maintenance activities. We develop a taxonomy to classify PdM business models that enables a comparison and analysis of such models. We use our taxonomy to classify the business models of 113 companies. Based on this classification, we identify six archetypes using cluster analysis and discuss the results. The "hardware development", "analytics provider", and "all-in-one" archetypes are the most frequently represented in the study sample. For cluster analysis, we use a visualization technique that involves an autoencoder. The results of our analysis will help practitioners assess their own business models and those of other companies. Business models can be better differentiated by considering the different levels of IoT architecture, which is also an important implication for further research.

DOI Link: http://dx.doi.org/10.1007/s12525-020-00440-5

Keywords: Taxonomy, Predictive Maintenance, Business Models, IoT

Appendix 8 - A Self-Service Supporting Business Intelligence and Big Data Analytics Architecture

Outlet: Proceedings of 13th International Conference on Wirtschaftsinformatik, St. Gallen, Switzerland

Abstract

Self-service Business Intelligence (SSBI) is an emerging topic for many companies. Casual users should be enabled to independently build their own analyses and reports. This accelerates and simplifies the decision-making processes. Although recent studies began to discuss parts of a self-service environment, none of these present a comprehensive architecture. Following a design science research approach, this study proposes a new self-service oriented BI architecture in order to address this gap. Starting from an in-depth literature review, an initial model was developed and improved by qualitative data analysis from interviews with 18 BI and IT specialists form companies across different industries. The proposed architecture model demonstrates the interaction between introduced self-service elements with each other and with traditional BI components. For example, we look at the integration of collaboration rooms and a self-learning knowledge database that aims to be a source for a report recommender.

Link: https://aisel.aisnet.org/wi2017/track12/paper/5/

Keywords: Business Intelligence, Big Data, Architecture, Self-Service, Analytics

Appendix 9 - Encouraging the Use of Self-Service Business Intelligence – An Examination of Employee-Related Influencing Factors

Outlet: Journal of Decision Systems

Abstract

This study examines which factors influence the use of self-service business intelligence (SSBI) applications. To analyse the interdependencies, we develop a structural equation model (SEM) and test it by surveying potential users of SSBI across different sectors. The SEM shows that the intention to use is significantly influenced by the expected contribution of SSBI to information needs, which is significantly influenced by business intelligence (BI) experience, SSBI flexibility, SSBI expected time savings and the importance of data quality. The perceived attention of a company to data quality has a significant negative influence on the intention to use. These results imply that the mere introduction of SSBI is not sufficient for successful use. Training on how to use SSBI and how SSBI can change individual ways of working are important components. A well-designed concept for ensuring data quality also promotes the intention to use. In addition, we found that the utilitarian value is independent of the decision environment.

DOI Link: https://doi.org/10.1080/12460125.2020.1739884

Keywords: Self-service business intelligence; intention to use, structural equation modelling, contribution to information needs

Appendix 10 - Self-Service Business Intelligence Application Scenarios - A Taxonomy for Differentiation

Outlet: Information Systems and e-Business Management (Submitted)

Abstract

Self-Service Business Intelligence (SSBI) empowers non-IT users to independently create reports and analyses. SSBI methods and processes are discussed in an increasing number of application scenarios. However, previous research on SSBI makes only a limited distinction between these scenarios. There is a wide range from simply retrieving data to the application of complex algorithms and analysis methods. It is not clear which dimensions are suitable for differentiating SSBI application scenarios. In this article we develop a taxonomy to better differentiate SSBI applications. We analyze the literature, SSBI tools and conduct a case study in a company. In addition, we perform a cluster analysis based on the analyzed SSBI tools. Finally we deduce three archetypes, which describe typical SSBI tools. These archetypes show which application scenarios are mostly addressed by the SSBI tool providers. We conclude with limitations and a further research agenda.

Keywords: Self-Service, Business Intelligence, Data Analytics, Taxonomy, Software Archetypes

The article has been submitted and follows on the next pages.

Self-Service Business Intelligence Application Scenarios
A Taxonomy for Differentiation

1. Introduction

The goal of modern companies is to make more decisions based on facts and figures instead of subjective decisions. This development leads to higher demands on a business intelligence (BI) environment, which should provide the necessary information for decision-making. However, an easy and flexible access to the data is a major problem in conventional BI architectures, as classical BI structures are often too rigid and slow (Imhoff & White 2011). Changes to reports and the creation of new analyses must be carried out to a high degree by the IT department. Enabling business departments to carry out reports and analyses on their own can be a possible solution to this problem. The qualification of the business departments to create their reports and analyses by themselves, is often summarized under the term self-service business intelligence (SSBI). In recent years, software manufacturers have tried to offer increasingly simple and above all target group-oriented SSBI tools.

Alpar and Schulz (2016, p.151) describe the goal of SSBI as to "... empower casual users to perform custom analytics and to derive actionable information from large amounts of multifaceted data without having to involve BI specialists. Power users, on the other hand, can accomplish their tasks with SSBI more easily and quickly than before." Various aspects of an SSBI approach have already been discussed. Different perspectives, user roles, experiences, and self-service levels were investigated in SSBI research (Michalczyk et al. 2020). Especially the diverse self-service levels show how different SSBI application scenarios can be (Alpar & Schulz 2016). Alpar and Schulz (2016) distinguish these levels only by two dimensions which are self-reliance and system support. In further publications other dimensions are addressed that differentiate self-service levels. E.g., the mentioned user roles or the experiences of the users. The necessary data management, which varies in complexity, can strongly differentiate the SSBI application scenarios (Imhoff & White 2011). A more detailed understanding of the self-service levels is important to conduct more targeted research on SSBI. E.g., developers of SSBI applications need to know exactly for which SSBI level they create applications to adapt them in the best possible way (Johansson et al. 2015). The value of SSBI for a company is also extremely dependent on the realized SSBI application scenarios. Previous research does not necessarily consider this stronger differentiation, which is made possible by the more target group-oriented SSBI tools. To enable a detailed description of these application scenarios, we follow our research question (RQ):

Which dimensions and characteristics distinguish SSBI application scenarios?

Based on these dimensions and characteristics, various SSBI applications can be better described and investigated. First, we discuss the existing literature dealing with SSBI levels. Then we develop our taxonomy in an iterative procedure following Nickerson et al. (2013). For this purpose, we use not only our findings from previous publications, but also our analysis of SSBI tools and a case study. Afterwards, we deduce our final taxonomy. We continue to investigate which SSBI applications are currently supported by SSBI tools on the market. Using our taxonomy, we classify these tools and perform a cluster analysis. With the clusters found, archetypes can be formed which allow conclusions to be drawn about which SSBI application scenarios are increasingly addressed by the SSBI tool providers. Finally, we discuss our results and findings, their implications, recommendations, limitations, and provide further research opportunities.

2. Knowledge about SSBI Dimensions

Research has dealt with different aspects of SSBI. Imhoff and White (2011) have conducted a survey to identify the challenges and opportunities from a practical perspective. These can be summarized in the areas ease of use of the software, access to data, data management, and easy deployment (Imhoff & White, 2011). Johansson et al. (2015) differentiate SSBI from traditional BI using the PACT framework. The PACT framework comprises the dimensions People, Activity, Context, and Technology (Benyon 2014). An often quoted article by Alpar and Schulz (2016) gives a first overview of what SSBI is. Alpar and Schulz (2016) describe levels of SSBI.

They differentiate these levels by the dimensions “system support” and “self-reliance” (Alpar & Schulz 2016). Figure 1 shows the levels addressed and the dimensions by which they are differentiated.

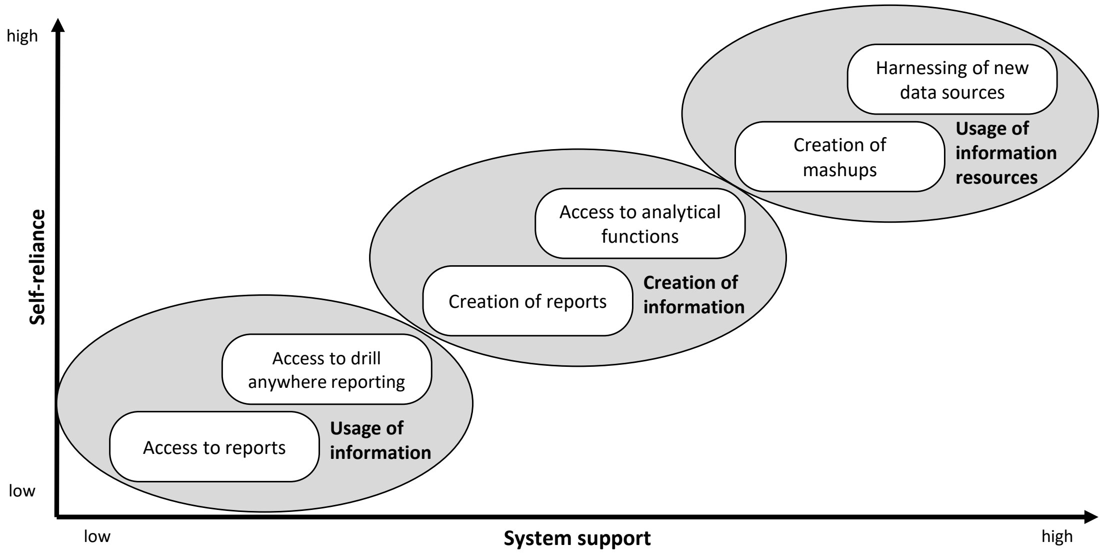

Figure 1. Differentiation of SSBI levels according to Alpar and Schulz (2016, p. 152)

The three levels can be easily differentiated by using the two dimensions. The question remains whether further dimensions are necessary to differentiate SSBI applications in other considerations. Ogushi and Schulz (2016) use a literature analysis to identify the dimensions technology, data, presentation, and social features. Bani-Hani et al (2019) analyze business employees' independence and the value that is co-created. Similar to Alpar and Schulz (2016), they identify three constellations of SSBI that create value. These constellations differ according to how independently the business users work from the IT department. But the identified steps are cut slightly differently. They differentiate according to whether the business users are responsible for interpretation (level C), additionally also analysis and visualization (level B), or also for data preparation and gathering (level A) (Bani-Hani et al. 2019). Based on a literature analysis, Lennerholt and van Laere (2019) analyze the challenges of introducing SSBI. They identify the access and use of data as well as data quality as upper groups for the challenges of introducing SSBI (Lennerholt & van Laere 2019). Thus, completely different dimensions for differentiation are identified than those identified by Alpar and Schulz (2016). Michalczyk et al. (2020) analyze the SSBI research conducted to date. They categorize the literature according to self-service levels. For this purpose they use the levels identified by Alpar and Schulz (2016). They also use the dimensions perspective, user role, and experience for differentiation. So here too, other dimensions are used. The importance that SSBI efforts should address various user types is evident in various works by Eckerson (2012, 2014, 2019). These user types are put into relation with different analytical tools.

For a maturity model by Halper (2017), other SSBI dimensions are again described. They are named organization, data management, infrastructure, analytics, and governance (Halper 2017). However, the model does not classify individual SSBI application scenarios, but describes the maturity of the entire organization with regard to SSBI. E.g., the extent to which an SSBI culture prevails in the company is not directly relevant to our objectives.

It can be seen that SSBI has already been discussed from different angles. Various dimensions were worked out, which highlight the different requirements for an SSBI environment, depending on the application. However, a clear approach on how to differentiate these application scenarios has not yet been developed. The work of Alpar and Schulz (2016) provides first insights, but a comparison with other SSBI literature shows that only two dimensions are not sufficient to adequately differentiate the application scenarios. Further, increasing numbers of companies are also addressing the topic and discussing the use of SSBI for different areas (Gartner 2018). We address this research gap and needs with our research.

3. Taxonomy Development

3.1 Research Design and Methodology

“A fundamental problem in many disciplines is the classification of objects of interest into taxonomies” (Nickerson et al. 2013, p. 336). Classification systems like taxonomies, often also referred to as typologies, help to structure and organize knowledge. Taxonomies uncover and classify objects based on common characteristics and explain their correlation to each other, which allows researchers to understand and analyze complex fields (Glass and Vessey 1995; Varshney et al. 2015; Nickerson et al. 2013; Miller & Roth 1994). In our case the goal is to create more structure in the wide range of SSBI application scenarios. A taxonomy development is therefore suitable to create a better differentiation of the SSBI application scenarios.

The design of our taxonomy is based on Nickerson's et al. (2013) methodology for taxonomy development, as this methodology provides a structured and scientifically sound process for the development of taxonomies. Their methodology is an iterative process based on existing theoretical foundations (conceptualization) and empirical evidence (empiricism). The obtained dimensions consist of mutually exclusive and collectively exhaustive characteristics. “Mutually exclusive” means that no object has two characteristics in one dimension and "collectively exhaustive" means that each object has at least one characteristic in each dimension (Nickerson's et al. 2013). These two attributes of the taxonomy ensure in combination that each object has exactly one single characteristic in each individual dimension.

Starting with the analysis of scientific literature on SSBI elements, the dimensions of the taxonomy are derived conceptually. Following this, related characteristics are identified by empirically examining SSBI tools as well as conducting a case study. Figure 2 gives an overview of these steps. In the next sections we describe in more detail the steps we carried out. After each iteration step multiple ending conditions are checked. If the ending conditions do not completely apply, a further iteration step is necessary. The ending conditions applied in this process were taken from Nickerson et al. (2013) (see Appendix 10.1).

In accordance with Nickerson et al. (2013), we base our meta-characteristic on the purpose of the taxonomy in line with our RQ. Therefore, we define our meta characteristic as follows: definition of SSBI dimensions that help to differentiate SSBI application scenarios. We specify that the demands of data scientists are only seen as SSBI, if they can be realized within analysis applications (Bani-Hani et al. 2019; Eckerson 2019). If the analyses are implemented completely in a programming language, e.g. in Python or R, this is an IT implementation for us and thus no longer an SSBI scenario. However, the partial use of programming language in analysis applications can represent an SSBI scenario. According to this definition, the work of a "Citizen Data Scientist" belongs to SSBI applications (Mullarkey et al. 2019).

The development of a taxonomy is derived from the artifact development of design science research (Hevner et al. 2004; Nickerson et al. 2013). Within design science research, evaluation and/or demonstration is an essential part of the research process. For the evaluation of taxonomies there is a framework by Szopinski et al. (2019). In this framework they show different ways in which a taxonomy can be evaluated. We follow this framework and evaluate our taxonomy with an "illustrative scenario" in section 5 (Szopinski et al. 2019, p. 13).

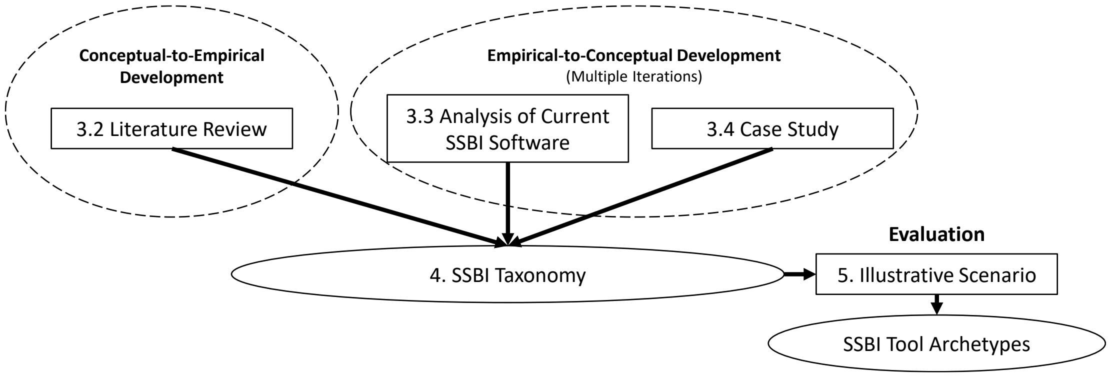

Figure 2. Performed steps for the taxonomy development

3.2 Literature Review

We conducted a literature review of SSBI elements and identified 54 relevant papers. To identify the relevant literature, we followed the guidelines by Webster and Watson (2002) and vom Brocke et al. (2015). We used the search string "Self-Service Business Intelligence" OR "Self-Service Analytics" OR "Self-Service Business Analytics" in the search engines ScienceDirect, AiSeL, and Google Scholar. In addition, we conducted a forward and backward search (Webster & Watson, 2002). For particularly relevant papers we also used the related article function of Google Scholar to find further papers. These articles are Alpar & Schulz (2016), Bani-Hani et al. (2017, 2019), Burke et al. (2016), Eckerson (2009, 2012, 2014, 2019), Halper (2017), Imhoff & White (2011), and Lennerholt et al. (2018). In addition, we searched the publication lists of the authors Bani-Hani and Eckerson for further relevant articles.

Based on the SSBI architecture by Passlick et al. (2017), which shows the relationships between new self-service elements and traditional BI components, we used the following five topics, “data modelling”, “data presentation and analysis”, “user”, “data governance”, and “architecture elements”, to classify the identified literature. “Data modelling” describes tools, components and techniques that are necessary to transform the data so that they can be analyzed in the next steps. The “data presentation and analysis” topic then focuses on exactly these further analyses. Here, tools and techniques are described that display and visualize data. The topic “user” describes the user groups that can be found in an SSBI environment. Under “data governance” guidelines are summarized which have to be adhered to, e.g. with regard to data quality or data protection. Under “architecture elements” we summarize components that can support SSBI technically or organizationally.

We found 11 articles for the topic “data modelling”, 48 articles for “data presentation and analysis”, 40 articles for “user”, 30 articles for “data governance” and 20 articles for the topic “architecture elements”.

Table 1. Occurrence of perspectives on SSBI in the literature

	Data modelling	**Data presentation and analysis**	**User**	**Data governance**	**Architecture elements**
Abelló et al. (2013)	x	x		x	x
Alpar, P. & Schulz, M. (2016)		x	x	x	
Bani-Hani et al. (2017)		x	x		x
Bani-Hani et al. (2018a)		x	x		x
Bani-Hani et al. (2018b)		x	x		x
Bani-Hani et al. (2019)		x	x		
Berthold et al. (2010)		x	x	x	x
Böhringer et al (2009)		x		x	x
Burke et al. (2016)		x	x		x
Burnay et al. (2014)			x		
Clarke et al. (2016)			x		
Convertino, G. & Echenique, A. (2017)			x		
Corral et al. (2015)		x		x	
Daradkeh (2019)		x	x		
De Mauro et al. (2018)			x		
Eckerson, W. (2009)		x	x	x	
Eckerson, W. (2011)	x	x	x		x
Eckerson, W. (2012)		x	x	x	
Eckerson, W. (2014)			x		
Eckerson, W. (2019)		x	x		x
Goeken et al. (2014)		x	x		
Halper (2017)	x	x		x	x

	Data modelling	Data presentation and analysis	User	Data governance	Architecture elements
Horvath et al.(2014)		x			x
Howson, C. (2015)	x	x		x	
Imhoff, C. & White, C. (2011)	x	x	x	x	
Johannessen, T.V. & Fuglseth, A.M. (2016)	x		x	x	
Johansson et al. (2015)		x	x		
Kobielus et al. (2009)		x	x		
Kosambia, S. (2008)				x	
Kretzer, M. et al. (2015a)		x			
Kretzer, M. et al. (2015b)		x		x	
Lennerholt, C. & van Laere. J. (2019)	x		x	x	
Lennerholt. et al. (2018)		x	x	x	
Li, Y. et al. (2017)		x	x		
Liu et al. (2012)		x		x	x
Mayer et al. (2014)		x			x
Meyers, C. (2014)		x	x	x	
Michalczyk et al. (2020)	x		x	x	
Morton et al. (2014)	x	x	x	x	
Naish, A. G. (2013)				x	
Ogushi, Y. & Schulz, M. (2016)		x			x
Passlick, J. et al. (2017)		x	x	x	x
Pickering, C. & Gupta, M. (2015)		x	x	x	
Poonnawat, W. & Lehmann, P. (2014)		x	x		
Savinov, A. (2014)	x	x	x	x	
Schlesinger, P. A. & Rahman, N. (2016)		x	x		x
Schuff et al. (2018)				x	
Smuts et al. (2015)		x	x		
Spahn et al. (2008)		x			x
Stodder, D. (2015)		x	x	x	
Stone, M.D. & Woodcock, N.D. (2014)		x	x	x	
Sulaiman et al. (2013)		x	x		x
Tona & Carlsson (2013)					x
Vance et al. (2015)				x	
Varga et al. (2014)		x		x	
Weber, M. (2013)		x	x	x	
Weiler et al. (2019)		x	x		
Yu et al. (2013)		x	x		
Zaghloul et al. (2013)	x	x		x	
Zilli, D. (2014)		x			
Zorrilla, M. & García-Saiz, D. (2013)		x			x
Total	**11**	**48**	**40**	**30**	**20**

Based on the review of the literature mentioned in Table 1, we have formed the first dimensions that classify SSBI applications. According to the process model by Nickerson et al. (2013), this is our first iteration. This first iteration follows the conceptual-to-empirical approach of the process model. Possible dimensions which are not in accordance with the meta characteristics are dropped. We split the "user" perspective into the two dimensions *userskill* (Imhoff and White 2011; Eckerson 2014) and *userrole* (Eckerson 2011; Alpar et al. 2016), renamed "Data modelling" and "Data presentation and analysis" into *requirements for data management* (Lennerholt & van Laere 2019; Johannessen & Fuglseth 2016; Abelló et al. 2013) and *BI analytics activities* (Alpar & Schulz 2016). In addition, we converted *"data governance"* into *data sensitivity / privacy aspects* (Lennerholt et al. 2018; Lennerholt & van Laere 2019). We further add the dimensions *collaboration in development* (Böhringer et al. 2009), *access type* (Tona & Carlsson 2013), and *nature of the analysis* (Eckerson 2019). This led to a preliminary taxonomy with a total of eight dimensions. A description of the dimensions follows in section 4 and the definitions of the various dimensions are given in Appendix 10.2. Multiple ending conditions were not met due to the purely conceptual-to-empirical approach taken so far, as shown in Appendix 10.1.

3.3 Analysis of SSBI Tools

After performing the first iteration, in which we performed a conceptual-to-empirical development, we conduct an empirical-to-conceptual approach. For this purpose, we analyze SSBI tools. To identify possible tools we used Gartner's Magic Quadrant Report (2019), the "BI Products List" of the website "BI-Survey.com", the google search engine, as well as our own knowledge in this field. We found 49 software products labelled as SSBI tools. After identifying these tools, we checked the website of each tool to verify that the tools can actually be used to perform SSBI in accordance with our definition. Two tools were dropped because they were not providing tools to support SSBI. This led to the final sample size of 47 SSBI tools which can be found in Appendix 10.3. The companies developing the tools range from medium-sized companies, e.g., Phocas, to large corporations, e.g., Microsoft. To analyze the 47 tools, the websites of the respective companies (websites, online interviews, and videos), product sheets, case studies and whitepapers were examined. Based on this examination of SSBI tools, we conducted the next iteration steps of Nickerson's et al. (2013) process model. The next iterations follow the empirical-to-conceptual approach of the process model.

In the second iteration a sample of 10 randomly selected SSBI tools is examined, from which suitable characteristics for the dimensions, obtained in the first iteration, can be derived. Very similar characteristics, but with different names, have been grouped together as a single characteristic, e.g., creation of reports, creation of dashboards, data visualization and presentation to the characteristic *Report creation and visualization.* The ending conditions of the taxonomy were not reached due to the newly identified characteristics which indicate a significant change.

For the third iteration we analyze another random sample of 10 remaining SSBI tools and added further characteristics, e.g., *All-rounder* in the nature of the analysis dimension and *natural language chat* in the access type dimension. The four dimension's *BI analytics activities, requirements for data management, collaboration in development* and *access type* are transformed into hierarchical layers, because the characteristics in the corresponding dimension build-up on each other. This means that the characteristic of a higher level also includes the lower levels. The taxonomy changed significantly due to the newly identified characteristics and the changed dimensions. Therefore, the ending conditions of the taxonomy were not reached.

In the fourth iteration we examined a larger random sample of 15 remaining SSBI tools, to confirm if the dimensions and characteristics of the first three iterations are stable enough, i.e. whether there are sufficient numbers available and whether they have been chosen reasonably. We added some more characteristics, e.g., *None* in BI analytics activities and remodeled the hierarchical structure of the dimension *Requirement for data management*. The reason for the remodeling was the change of the hierarchical position of the characteristic *Data cleansing and enhancing* from second lowest to highest position. This was done because the process of eliminating inconsistencies and errors in the data can only be done after the completion of the extract, transform and load (ETL) process. Due to minor additions and changes the final conditions of the taxonomy were not reached.

Finally, we analyze the remaining 12 SSBI tools in the fifth iteration. During this iteration no dimensions or characteristics were added or changed. Thus, the subjective and objective end conditions of the development process are considered as fulfilled.

3.4 Case Study

The development of the taxonomy, mainly based on the analysis of SSBI tools, is formally completed. But, certain important SSBI aspects are difficult to analyze with the empirical data. E.g., data governance is still discussed in the literature as an important element of SSBI. Whether SSBI application scenarios can be differentiated by means of data governance is still unclear. The different aspects of data governance are very difficult or even impossible to determine. Therefore, our developed taxonomy is not yet complete as important SSBI aspects are not covered. For this reason we have additionally conducted a case study. Here, it can be seen whether different SSBI applications exist depending on, e.g., the data governance. In this case study we investigated which SSBI application scenarios are available or planned. Therefore, we recorded which SSBI tool is used, why and how it is used.

The company under investigation is active in the field of engineering and manufacturing and has its headquarters in Germany. With approximately 4000 employees worldwide, it is considered a medium-sized company. In the context of this study, we have only examined BI tools that have SSBI components.

The company's BI architecture is based on a core data warehouse (DW), which mainly processes data from the Enterprise Resource Planning (ERP) system. For access to the DW data, there are different, predefined queries for different departments. The DW data is often processed with Excel. There is a web front-end for this purpose, in which the data can be filtered, torn up and downloaded in the desired form. In addition, there is a plug-in for Excel, which allows direct access to the queries. This plug-in is increasingly used by financial analysts, since some of them are very well trained in Excel and can work efficiently with it. Furthermore, the users feel a sufficient freedom in these scenarios to quickly create ad hoc analyses.

To further simplify the access to the data and enable a more efficient interaction, selected applications are created in another tool by the IT department. The results are web-based dashboards with partly very extensive functions, which are provided for different business areas. For the sales department there is some kind of data mart, which is supplied with data from the core DW. This Data Mart is realized with a completely different tool. Here, the data modelling is done by the IT department while the dashboards are created by selected power users in the sales department.

New is the requirement of different departments to introduce an additional tool for SSBI application scenarios. From the point of view of the departments, the existing tools are partly too inflexible (web-based applications), there are no up-to-date visualizations (Excel), and the tools do not offer interfaces for complex algorithms (sales reporting). Microsoft Power BI is discussed here as a possible all-round SSBI tool that can meet the mentioned requirements. However, during the concrete examination of the tool, it becomes clear that other challenges arise. E.g., when using the tool in the cloud, the role and authorization management implemented in the core DW is bypassed. This is because the data is accessed with a technical user. Permissions can also be bypassed using Excel worksheets, but the extent is different. For particularly sensitive data, the download to Excel is prohibited. This shows that SSBI application scenarios can also be differentiated depending on the sensitivity of the data. While less critical data can be analyzed group-wide with any tool without major difficulties, the access to sensitive data is restricted. With sensitive data, it must be ensured in the SSBI analysis process that only those persons who are authorized, have access. Under certain circumstances this can lead to the fact that a certain SSBI tool cannot be used.

Another question that arises when discussing Microsoft Power BI is how to ensure that correct information is displayed in the applications. This is a general problem of SSBI. Data provided by IT are usually extensively tested and thus their correctness can be assumed. When using queries of the core DW, the sales DW, and the web-based dashboards, the information is reliable as the modelling is carried out by IT. When using Power BI, data reliability depends on the application scenario. It is possible that the data modeling is performed to a high degree by the business department and that data quality is not necessarily guaranteed. How likely the data quality is, depends largely on the complexity of the modeling, possible transformations, and the completeness of the data. Thus, there is a further dimension in the consideration of data reliability with which SSBI application scenarios can be distinguished.

In our case study, further dimensions can be identified in addition to the already known dimensions for differentiating SSBI application scenarios. Depending on the data to be analyzed and its sources, it makes a difference how sensitive the data is and how important the reliability and completeness of the data is. Accordingly we have added these two dimensions to our taxonomy.

4. SSBI Application Scenario Taxonomy

After a literature review and the analysis of SSBI tools, we have developed a taxonomy for SSBI application scenarios using the development process according to Nickerson et al. (2013). This is supplemented by a case study, which led to further dimensions in consideration of the literature. However, these dimensions cannot be derived from the analyzed tools, because they differentiate SSBI application scenarios independently of the software. The final taxonomy is shown in Table 2.

The first dimension distinguishes the SSBI application scenarios according to user types, which have different tasks in the SSBI process (Eckerson 2011; Alpar et al. 2016). This is followed by the next dimension, which distinguishes the users according to their skills. Skills include statistics, coding, data management, visualization and discovery, and reporting skills (Cosic et al. 2012). The next dimension differentiates analytical activities (Alpar & Schulz 2016). In self-service data-preparation tools there is no analytical activity, which is the first characteristic. On the other hand, there may be application scenarios where very extensive analytical activities are performed. E.g., this can be the application of more complex analyses using clustering algorithms or regressions. Such extensive analysis activities represent the highest level of activity in this dimension. This third dimension is hierarchical, which means that the last characteristic also contains the previous characteristics. E.g., *report creation and visualization* also contains *having access and using reports*. In the fourth dimension the requirements for data management in the SSBI case are distinguished (Cosic et al. 2012). Here it is possible that there is already a finished data model that can be used directly (first characteristic), but also that very extensive adjustments are necessary.

The next dimension addresses the importance of collaboration between users in the development of SSBI applications. SSBI can support this with comment or rating functions of dashboards, e.g., Alpar et al. (2015). How the final SSBI application is accessed, is addressed in the sixth dimension. If a finished application is to be used by mobile devices, e.g., this must also be taken into account during the development process. This additional requirement can then also increase the complexity further. However, the complexity also depends on the tools used. The next dimension describes what actually drives the respective SSBI analysis or report (Schulz et al. 2015). It may be to answer an ad-hoc question or to develop a regular report. It is also conceivable that experiments are to be conducted with a data set to check whether relevant information can be found in it. The characteristic *all-rounder* describes application scenarios where several of the other characteristics apply.

As described, the last two dimensions are not based on the analyzed SSBI tools, but on literature and case studies. The dimension *Data sensitivity / Privacy aspects* asks how important it is in the application scenario to clearly define who has access to the data. E.g., the sensitivity of personal data is very high and therefore has a great influence on the complexity and the choice of tools for the implementation. The last dimension differentiates how important the completeness and reliability of the data is for the application scenario. If SSBI applications support decisions that have a high relevance, reliability must be ensured to a particular extent. While in other application scenarios slight deviations are not a problem.

Table 2 shows the dimensions described and all characteristics identified. The definition of dimensions and characteristics is given in Appendix 10.2. In addition, the dimensions in which the characteristics are hierarchically structured are marked. In the last column, the sources of the respective dimensions are named.

Table 2. Final taxonomy of SSBI dimensions

<table>
<tr><th>Dimension</th><th colspan="6">Characteristic</th><th>Hierarchy</th><th>Source</th></tr>
<tr><td>User roles</td><td>Information consumer</td><td colspan="3">Information producer (power user)</td><td colspan="2">Information collaborator</td><td>No</td><td>L, C</td></tr>
<tr><td>User skills</td><td>Basic</td><td colspan="3">Standard</td><td colspan="2">Advanced</td><td>No</td><td>L, C, T</td></tr>
<tr><td>BI analytics activities</td><td>None</td><td colspan="2">Having access and using reports</td><td>Report creation and data visualization</td><td colspan="2">Applying advanced analytics</td><td>Yes</td><td>L, C, T</td></tr>
<tr><td>Requirements for data management</td><td>Only small changes</td><td colspan="2">Integration and modeling of existing data sources</td><td>Integration of new data sources</td><td colspan="2">Data cleansing and enhancing</td><td>Yes</td><td>L, T</td></tr>
<tr><td rowspan="2">Collaboration in development</td><td colspan="2" rowspan="2">No software supported collaboration</td><td colspan="2" rowspan="2">Individualization of other people's reports</td><td colspan="2">Comments</td><td rowspan="2">Yes</td><td rowspan="2">L, S</td></tr>
<tr><td colspan="2">Ratings</td></tr>
<tr><td>Access type</td><td>Desktop</td><td colspan="2">Big Display</td><td>Mobile</td><td colspan="2">Natural language</td><td>Yes</td><td>L*, C*, T*</td></tr>
<tr><td>Nature of the analysis</td><td>Standard/ scheduled</td><td colspan="2">Ad-hoc</td><td>Experimental</td><td colspan="2">All-rounder</td><td>No</td><td>L*, T*, C</td></tr>
<tr><td colspan="9">Dimensions not based on the analyzed data set</td></tr>
<tr><td>Data sensitivity/Privacy aspects</td><td>Non sensitive</td><td colspan="2">Slightly sensitive</td><td>Moderately sensitive</td><td>Moderately high sensitive</td><td>Highly sensitive</td><td>No</td><td>L, C</td></tr>
<tr><td>Data reliability and completeness</td><td>Low</td><td colspan="3">Medium</td><td colspan="2">High</td><td>No</td><td>C</td></tr>
</table>

*Based on L= Literature, C=Case study, T=SSBI tool analysis, * = partly*

5. Evaluation

5.1 Analysis of the Examined Data Set

As described, we evaluate the developed taxonomy taking the framework by Szopinski et al. (2019) into account. For this purpose we have chosen a quantitative approach and "illustrative scenario" as a method. We assign all examined SSBI tools to the found characteristics and make a cluster analysis based on this. This answers the "how?" and "what?" questions of the Szopinski et al. (2019) framework. The "who?" is answered by the fact that we, as authors, conduct the evaluation. We have experience with the domain and the method, have an academic background, and have also been involved in taxonomy development.

The assignment of the SSBI tools to the respective characteristics of our taxonomy was made by one author. Approximately 10% of the tool was analyzed by a second author to ensure that there is a consistent understanding of the definitions. In dimensions where the assignment of the SSBI tools to the characteristics was not obvious, assignment criteria for the tools were developed. These criteria can be found in Appendix 10.2. Figure 3 shows the frequency of the assigned characteristics in the respective dimensions.

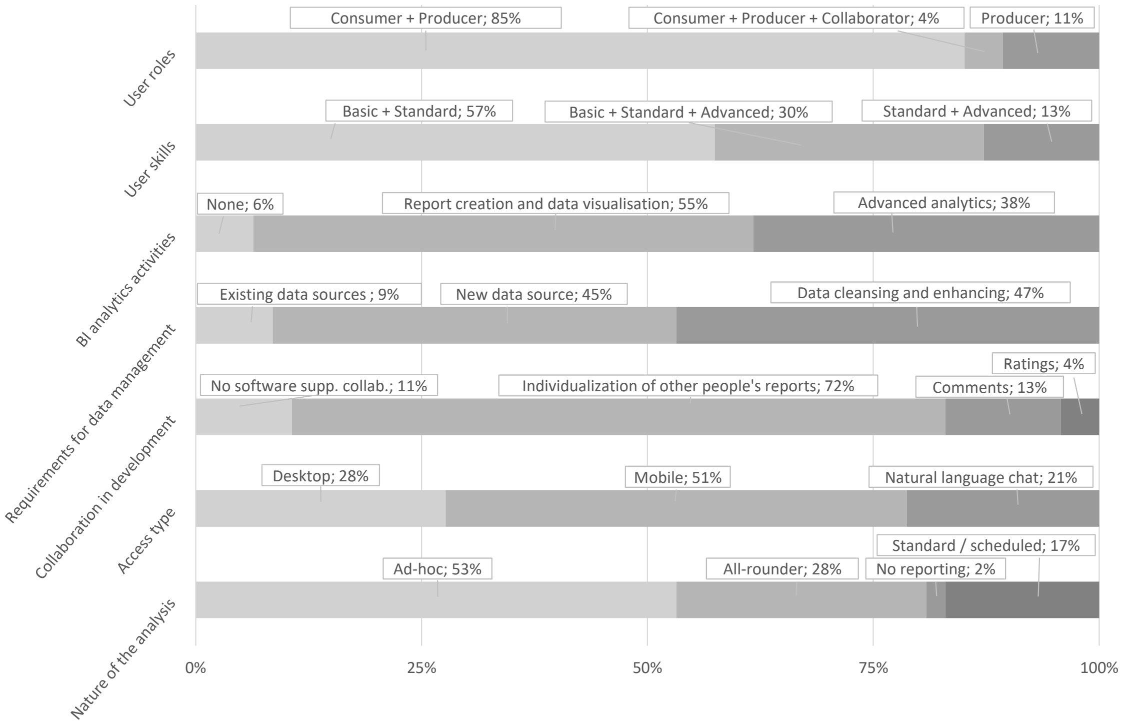

Figure 3. *Frequency distribution of the characteristics of the analyzed tools*

In the user roles dimension, it is apparent that the vast majority of SSBI tools address both *information consumers* and *information producers*. The *information collaborator* type is not addressed by any tool as the sole characteristic. 11% of the tools only focus on *information producer*. *Basic + standard* is covered by more than half of the SSBI tools in the user skills dimension. 30% of the tools additionally serve the *advanced* skill. Few tools (13%) do not address the lowest skills (*basic*). In the dimension BI analytics activities about half of the tools are designed for *report creation and data visualization*. 38% of the tools offer additional *advanced analytics* capabilities. At least the *integration of existing data sources* is supported by all SSBI tools in the dimension requirements for data management. But about 90% also support further activities. We have identified full support also for *data cleansing and enhancing* in 47% of the tools.

Only about 11% of the tools do not support collaboration in development at all. The majority (72%) supports the *individualization of other people's reports*. A small percentage (together approx. 17%) also offers comment or rating functions. Most tools support access via mobile devices (51%). Approximately 21% even enable *natural language chat*, while 28% only offer information access via *desktop*. In the last dimension investigated, nature of the analysis, the *ad-hoc* characteristic dominates with 53%, while 28% of the tools try to act as *all-rounders*. Significantly fewer (17%) tools address standard reporting and 2% of the tools do not have a reporting function because they have their focus in data preparation.

5.2 Cluster Analysis

The described assignment of the examined SSBI tools to the characteristics of our taxonomy is the basis for our cluster analysis. With this cluster analysis we identified typical SSBI tools which are offered on the market. These typical forms are also known as archetypes. The analysis shows that the developed taxonomy can differentiate the tools well. In addition, we get an insight of which SSBI application scenarios are seen by the SSBI tool vendors, because they orientate their tools to these application scenarios.

To perform the cluster analysis, we first applied a Ward (1963) algorithm to the collected data set. The Ward (1963) algorithm has the advantage of being a hierarchical partitioning algorithm. In contrast to the k-means algorithm, there is no need to specify an amount of clusters to be formed in advance. On the other hand, the clusters formed by k-means are often better. For this reason, a combination of hierarchical and non-hierarchical algorithms is recommended (Balijepally et al. 2011). For using the Ward (1963) algorithm, we use the Sokal and Michener (1958) matching coefficient to calculate the distances. After execution, the result can be visualized in a dendrogram. This dendrogram is shown in figure 4. It shows the SSBI tools that we have analyzed.

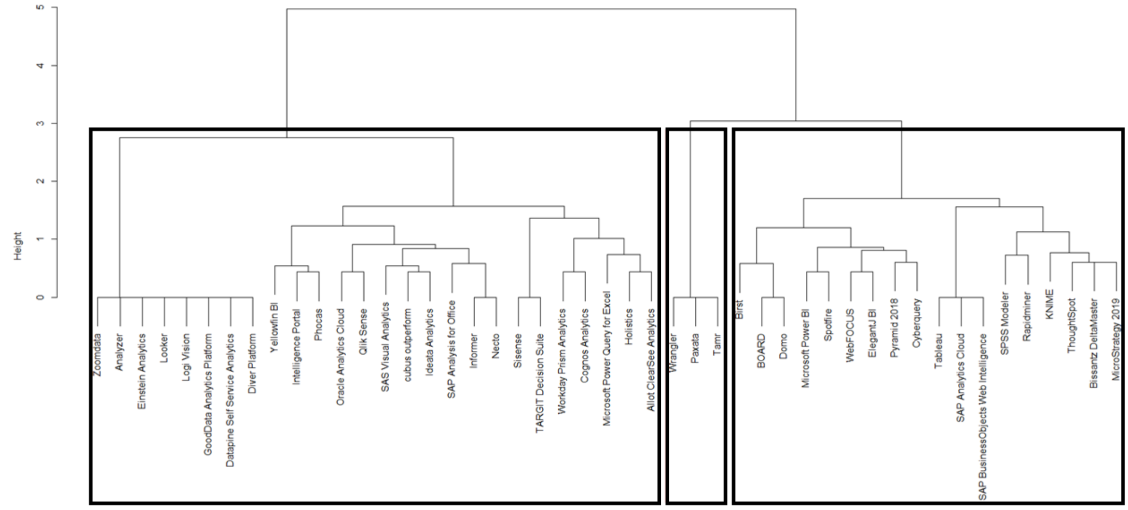

Figure 4. *Clustering with the Ward (1963) algorithm visualized by a dendrogram*

All tools are connected by different branches. If the connection is long here, this also stands for great differences in the assigned characteristics. The height of the branching gives an impression of how many and how strongly different groups are in the data set. At a height of about 3 we see three groups. This could be a suitable cluster number. These three groups are also marked by thicker boxes. However, four clusters would also be conceivable because the junction is at a similar height. The fourth branch is at a height of about 2.8, so we continue with three and four as a possible cluster amount. Two groups would also be conceivable, but should three or four groups already lead to plausible results, these three or four groups are preferable, since the archetypes are then more differentiated. The data set in this constellation is too small for more than four groups. Although there are several measures that can calculate the optimal number of clusters, several studies have shown that the measures come to such different results that a qualitative assessment is more appropriate for our study (Gimpel et al. 2018; Janssen et al. 2020). To this end, we have analyzed the distribution of the characteristics in a separation into three and four groups in more detail. If the study was divided into four groups, no plausible groups could be identified. No clear differences can be identified between two of the four groups. We came to the conclusion that a division into three groups provides plausible results. The distribution with a separation into three groups is shown in Table 3.

Table 3. Distribution of characteristics in the respective archetypes

	Label	All-rounder with advanced analytics	Simple ad-hoc application scenarios	Tools used by information producers
	n	18	23	6
	Group	A	B	C
User roles	Consumer + Producer	94%	100%	
	Consumer + Producer + Collaborator	6%		17%
	Producer			83%
User skills	Basic + Standard	33%	91%	
	Basic + Standard + Advanced	67%	4%	17%
	Standard + Advanced		4%	83%
BI analytics activities	None			50%
	Applying advanced analytics	78%	4%	50%
	Report creation and data visualization	22%	96%	
Requirements for data management	Existing data sources	6%	13%	
	New data sources	17%	78%	
	Data cleansing and enhancing	78%	9%	100%
Collaboration in development	Comments	11%	9%	33%
	Individualization of other people's reports	83%	78%	17%
	No software supported collaboration		9%	50%
	Ratings	6%	4%	
Access type	Desktop	6%	26%	100%
	Mobile	56%	61%	
	Natural language chat	39%	13%	
Nature of the analysis	Ad-hoc	28%	87%	
	All-rounder	67%		17%
	No reporting			17%
	Standard / scheduled	6%	13%	67%

Note: Due to rounding inaccuracies, the sum of a column in a dimension is not always exactly 100%.

We have given each group a label that reflects its essential characteristics. The groups or archetypes we call *all-rounder with advanced analytics* (A), *simple ad-hoc application scenarios* (B), *tools used by information producers* (C). In the *all-rounder with advanced analytics* archetype, all user skills are usually covered by the analyzed SSBI tools. Any analytics and data management activities are typically possible. Most tools support the individualization of other people's reports. Often, mobile BI applications can be realized, but many tools of this archetype already have a natural language chat. All kinds of analyses are supported.

In the archetype *simple ad-hoc application scenarios* the basic + standard user skill is supported. In rare application scenarios other skills are also supported. No advanced analytics functions are offered and also the data management is limited to the integration of new data sources. The individualization of other people's reports is supported as a form of collaboration and the analyses can usually be accessed via mobile devices. The tools of this archetype very often focus on ad-hoc analyses.

The user role information producer is the focus of the archetype *tools used by information producers*. Standard + advanced is often addressed as a user skill. The skill basic is therefore rarely used. Either no analysis activities or advanced analytics are enabled. Most tools support data management with data cleansing and enhancing. Collaboration is often not supported. Access to all tools is only possible via desktop. Above all, the standard reporting is addressed in this archetype. Table 4 summarizes the archetypes found.

Table 4. Found SSBI tool types

	A	B	C
Label	**All-rounder tools also for advanced analytics**	**Tools for simple ad-hoc application scenarios**	**Tools used by information producers (power users)**
User roles	Consumer + Producer	Consumer + Producer	Producer
User skills	Basic + Standard + Advanced	Basic + Standard	Standard + Advanced
BI analytics activities	Applying advanced analytics	Report creation and data visualization	None + advanced analytics
Requirements for data management	Data cleansing and enhancing	Integration of new data sources	Data cleansing and enhancing
Collaboration in development	Individualization of other people’s reports	Individualization of other people’s reports	Primary no software supported collaboration
Access type	Primary mobile, also natural language chat	Mobile	Desktop
Nature of the analysis	All-rounder	Ad-hoc	Primary standard /scheduled
Share in sample (47)	38%	49%	13%
Example tool	SAP Analytics Cloud	GoodData Analytics Platform	Paxata

6. Discussion, Implications, and Recommendations

Based on our literature review, our analysis of SSBI tools, and our case study, we developed a taxonomy that describes different application scenarios of SSBI. This taxonomy gives a detailed answer to our RQ which asks for the dimensions and characteristics which distinguish SSBI applications. The taxonomy provides nine relevant dimensions to differentiate SSBI application scenarios and is evaluated according to Szopinski et al. (2019) with an illustrative scenario.

With the found dimensions we extend an initial differentiation which consists of the two dimensions "self-reliance" and "system support" (Alpar & Schulz 2016). E.g., the developed taxonomy concretizes the dimension "self-reliance". The dimensions user skill, BI analytics activities, and requirement for data management can be seen as a further detailing of "self-reliance" which has implications for both practice and research.

Further research can now better differentiate which application scenario of SSBI is being treated when investigating SSBI aspects. Under certain circumstances, e.g., certain user skills or analytics activities may not be relevant for a research project. This research focus can now be better differentiated. It can also be better described and analyzed whether certain characteristics have a stronger or weaker influence. E.g., experience with BI applications can be even more relevant if the requirements for data management are high, since many things have to be taken into account when performing complex data manipulations. Further research must take this differences into account to meet significantly better tailored SSBI tools. Our research paves the ground for a differentiated view on SBBI. Our literature review in Section 3.2 shows that there has been no increase in publications on SSBI in recent years. This is astonishing, since SSBI tools from a few years ago are only partly comparable with today's tools.

Practice benefits from our taxonomy, because it can better differentiate SSBI application scenarios. To analyze in which application scenarios processes can be improved with SSBI, the SSBI application scenarios must be described exactly. The choice of a suitable SSBI tool is then also simplified by the taxonomy. Since SSBI tools have very different focuses, there is no tool that fits for all SSBI application scenarios.

In addition to the taxonomy knowledge, there are implications that result from the analysis of the data set. We can get an impression of which properties are currently addressed by SSBI software providers. E.g., SSBI tools usually offer functions for both information consumers and producers. However, a small percentage (11%) only addresses information producers who use the tools to process data to prepare it for a presentation or to use it with other tools. More complex forms of collaboration such as comments and ratings are not yet widespread (17%). 28% of the SSBI tools do not yet support mobile access to data, while 21% even support a natural language chat. It is also remarkable that about half (53%) of the SSBI tools focus on ad-hoc analyses. This shows that many vendors see SSBI for the creation of ad-hoc analyses, mainly.

The fact that ad-hoc analyses play an important role in the analyzed SSBI tools is also evident in the archetypes found. In the archetype B, tools for simple ad-hoc application scenarios, mainly ad-hoc application scenarios are addressed which are rather simple with regard to the analytics activities. In the differentiation of Alpar and Schulz (2016) the nature of the analysis is not discussed in the levels of SSBI. But, the high frequency of the characteristics shows that SSBI application scenarios must be differentiated according to a number of dimensions which we provide. The levels found by Alpar and Schulz (2016) can also be found in our taxonomy, but our archetypes show that the SSBI application scenarios can also be differentiated quite differently.

Considering SSBI tools, it must be kept in mind that they only indirectly provide conclusions about the SSBI forms that exist in organizations. As mentioned, our taxonomy contains two dimensions that we could not analyze with the SSBI tools. In addition, the dimension requirements for data management shows that not all characteristics can be observed in the tools, but the literature and partly also the case study report its existence. This is due to the fact that SSBI application scenarios can only be indirectly deduced from the advertised functions of SSBI tools. E.g., in practice, there are also SSBI application scenarios where only slight changes have to be made to data or data models, but this is not mentioned by any software provider, as this is not a functionality to be advertised.

7. Limitations and Further Research

Certain limitations need to be taken into account, which also offer the opportunity for further research. The differentiation of SSBI users, data scientists, and citizen data scientist is not always strictly possible. This problem is also evident in the definition of advanced algorithms. These algorithms can be realized to a certain extent as a self-service, e.g., if a citizen data scientist uses a k-means algorithm. However, there are also advanced algorithms that are so complex that these probably can no longer be considered as a self-service. E.g., the use of artificial neural networks or machine learning can be so complex in terms of their architecture, data management, interpretation, etc. that it cannot be called a self-service. In such scenarios, advanced knowledge is required in constructing the models, but especially in correctly interpreting them. Further research must provide a stronger distinction here.

It must be taken into account that characteristics of SSBI tools analyzed do not provide any quantitative information about which SSBI application scenarios are increasingly found in practice in organizations. We counter this limitation with our case study. However, the case study does not allow a broad generalization, as the analysis of the tools does. We can draw conclusions about practice only indirectly from the combination of the findings from literature, case study, and analyzed tools. E.g., SSBI seems to be used a lot for ad-hoc analyses. This is due to the fact that many tools address this and previous research has also identified flexibility and time savings as major advantages of SSBI (Passlick et al. 2020). For ad-hoc analyses both high flexibility and fast execution are important characteristics.

Findings from the analysis of the SSBI tools only offer temporary insights. In further research, the analysis must be repeated to identify changes. The focus of SSBI tool providers will change over time. In contrast, our taxonomy is more time-independent, since the dimensions found are not purely based on the analyzed tools. Nevertheless, further research must check whether additional characteristics might be added or whether certain elements might become unnecessary.

8. Conclusions

Awareness and understanding of SSBI have changed. While in the beginning limited and simple SSBI application scenarios were realized, the goal is now to implement almost all conceivable analyses with SSBI up to applications for citizen data scientist. We show dimensions that must be considered when investigating and discussing SSBI application scenarios. Our dimensions include users, their skills, analysis activities, necessary data management, intensity of collaboration, how finished reports can be accessed, type of analysis, how sensitive the data is, and how important the reliability and completeness of the data is. Furthermore, we present the different characteristics that exist in each dimension. Based on literature, an analysis of SSBI tools, and a case study in a company, our taxonomy was developed. This approach allowed us to look at SSBI application scenarios from different perspectives. The developed taxonomy helps both research and practice, since the examination of SSBI scenarios is now possible in a more differentiated way. Thus, it can be described and analyzed that opportunities and challenges of SSBI applications can be quite different depending on the scenario.

In addition to the taxonomy, our cluster analysis also identified archetypes of SSBI tools. All-round tools, which are also suitable for advanced analyses, tools for simple ad-hoc analyses, and tools especially for the user group information producer were found in the data set. Our archetypes confirm that the developers of SSBI tools also address different SSBI application scenarios. These archetypes show that when discussing SSBI, it is necessary to differentiate which application scenario is dealt with.

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6 Appendix

6.1 Summary of fulfilled ending conditions per iteration based on Nickerson et al. (2013)

Iteration					Ending conditions
1. con.*	**2. emp.***	**3. emp.***	**4. emp.***	**5. emp.***	
	•	•	•	•	Concise
			•	•	Robust
				•	Comprehensive
•	•	•	•	•	Extendible
		•	•	•	Explanatory
				•	All objects or a representative sample of objects have been examined
•	•	•	•	•	No object was merged with a similar object or split into multiple objects in the last iteration
	•	•	•	•	At least one object is classified under every characteristics of every dimension
				•	No new dimensions or characteristics were added in the last iteration
			•	•	No dimensions or characteristics were merged or split in the last iteration
•	•	•	•	•	Every dimension is unique and not repeated (i.e., there is no dimension duplication)
		•	•	•	Every characteristic is unique within its dimension (i.e., there is no characteristic duplication within a dimension)
	•	•	•	•	Each cell (combination of characteristics) is unique and is not repeated (i.e., there is no cell duplication)

**con. = conceptual; emp. = empirical*

6.2 Definition of the found characteristics

Characteristic	Definition	Criteria for the assignment of the software
	User roles This Dimension describes the division of SSBI business user types into distinctive categories based on their their specific work task (Eckerson 2011; Alpar et al. 2016).	
Information Consumer (casual)	Casual BI Users who gather information to increase personal knowledge and make business decisions. Allowed to access data but don’t have time or the needed skills for analyzing Data in a higher structured manner. (Imhoff and White 2011; Eckerson 2014)	The most basic user with very limited skills. Allocated to every software as long as the focus of the software is not on high complicated tasks such as advanced analysis or data preparation.
Information Producer (power)	Power BI Users who gather information to increase personal knowledge and help to make tactical and strategic business decisions, who have time and the necessary skills for analyzing data and creating their own solutions. (Imhoff and White 2011; Eckerson 2014)	Each of the analyzed software tools address information producers. Therefore, the characteristic is assigned it to each software tool. However, the case study shows that there are also SSBI application scenarios without information producers, namely when the IT provides an application in which information can be consumed.
Information Collaborator	They are specific subject matter experts and have the necessary skills to improve Data and Reports. They also rate existing Reports and give constructive criticism. (Imhoff and White 2011)	Allocated to the software if it has a strong emphasis on BI development collaboration and the possibility to write Comments on Reports.
	User skills This Dimension describes the different technical skills and knowledge levels of business users. These skills include statistics, coding, data management, visualization and discovery and reporting technologies (Cosic et al. 2012). The more complex the SSBI task and the accompanied SSBI tool, the higher the required computer and analytical skills of business users need to be (Spahn et al. 2008; Eckerson 2014).	
Basic	Users have low analytical, mathematical and IT skills and don’t take part in implementation, architectural focus, or design oriented tasks. Their capabilities include “established views of data, routine queries, and regularly produced reports” (Imhoff and White 2011). (Eckerson 2014)	Allocated to the software if it has a very simple and manageable user interface and the software is mainly designed for simple applications such as drill down in reports.
Standard	Users have moderate mathematical and analytical skills, but low IT Skills (Eckerson 2014. “They are able to do ad hoc analysis as well as create and publish reports” (Imhoff and White 2011).	Allocated to the software if it has a simple user interface and the software is designed for uncomplicated creation (e.g. drag and drop) or editing of dashboard, reports, etc.
Advanced	Users have high analytical and mathematical skills, as well as moderate IT skills. They can include structured and unstructured Data in their self-created statistical analytics and reports, as well as predictive modeling and Data Mining (Imhoff and White 2011; Eckerson 2014). Data Scientists may also be covered if they do not fully implement the analysis in a programming language (Bani-Hani et al. 2019; Eckerson 2019).	Allocated to the software if it can be used for highly advanced analyses (e.g. k-means) and/or for complex data preparation/data processing. The analyses can be created or edited by coding.

Characteristic	Definition	Criteria for the assignment of the software
BI analytics activities (based on Alpar and Schulz 2016) - **Hierarchical structure** BI analytics activities describes how SSBI users use the data to be analyzed (Cosic et al. 2012). The dimension has a hierarchical structure. This means that the next level also contains the previous one. The dimension has a hierarchical structure which means that the following characteristic contains all underlying or previous characteristics.		
None	No BI analytic activities. Complete focus on data preparation can be a reason for it.	Allocated to the software if the theoretically possible applications of the software matched the characteristics definition.
Having access and using reports	Analyzing data by using reports.	Allocated to the software if the theoretically possible applications of the software matched the characteristics definition.
Report creation and data visualization	Creating new reports or accessing already existing reports, as well as visualizing and presentation of Data.	Allocated to the software if the theoretically possible applications of the software matched the characteristics definition.
Applying advanced analytics	Analyzing Data using advanced algorithms such as k-means or similar.	Allocated to the software if the theoretically possible applications of the software matched the characteristics definition.
Requirements for data management - Hierarchical structure This dimension describes the different demands of the respective SSBI application scenarios with regard to data management. It is about the necessity to link different data sources, to connect new data sources, and to manipulate or cleanse the data (Cosic et al. 2012). The dimension has a hierarchical structure which means that the following characteristic contains all underlying or previous characteristics.		
Only small changes	No complex data management necessary.	Allocated to the software if the theoretically possible applications of the software matched the characteristics definition.
Integration and modeling of existing data sources	Combination of different data sources. The creation of a new data model is necessary for this combination of data sources.	Allocated to the software if the theoretically possible applications of the software matched the characteristics definition.
Integration of new data sources	Adding new data source to existing or new reports. E.g. creation of complete ETL processes.	Allocated to the software if the theoretically possible applications of the software matched the characteristics definition
Data cleansing and enhancing	Process of eliminating inconsistencies and errors in huge amount of data, and solving the object identity problem (Galhardas et al. 1999). This can include the adaption of data types or a combination and/or a separation of data fields.	Allocated to the software if the theoretically possible applications of the software matched the characteristics definition

Characteristic	Definition	Criteria for the assignment of the software
Collaboration in development - Hierarchical structure Distinguishes how strongly the cooperation of BI users is supported in a tool. This includes sharing and reusing of reports as well as social software features like rating or comments (Alpar et al. 2015). The dimension has a hierarchical structure which means that the following characteristic contains all underlying or previous characteristics.		
No software supported collaboration	No collaboration.	Allocated to the software if the theoretically possible applications of the software matched the characteristics definition
Individualization of other people's reports	Possibility to use, adapt and further develop the reports of others (Alpar et al. 2015).	Allocated to the software if the theoretically possible applications of the software matched the characteristics definition
Comments	Adding expert/domain knowledge through comments (Imhoff and White 2011; Alpar et al. 2015).	Allocated to the software if the theoretically possible applications of the software matched the characteristics definition
Ratings	Improving data or reports of other users by rating figures or reports (Imhoff and White 2011).	Allocated to the software if the theoretically possible applications of the software matched the characteristics definition
Access type - Hierarchical structure Describes how the reports can be accessed. Mobile devices require techniques for smaller displays and touch-capable control. Access via text interfaces is also conceivable (Power 2013; Tona & Carlsson 2013). The dimension has a hierarchical structure which means that the following characteristic contains all underlying or previous characteristics.		
Desktop	Access via a device like a notebook or desktop computer.	Allocated to the software if the technical capabilities of the software matched the characteristics definition
Big Display (with touch)	Access via a device like a tablet or a big monitor (with or without touch control) in a conference room.	Not found in the analyzed sample.
Mobile	Access via a device like a smartphone. (Tona and Carlsson 2013)	Allocated to the software if the technical capabilities of the software matched the characteristics definition
Natural language	Access via a natural voice controlled device or a natural language chat. The device does not necessarily has a screen (Stedman 2017). The chat can include a chatbot.	Allocated to the software if the technical capabilities of the software matched the characteristics definition
Nature of the analysis Describes what the main focus of the report / analysis is. Application scenarios can contain elements of all characteristics, but one characteristic is in the foreground (Schulz et al. 2015).		
No reporting	Tool includes process steps of an SSBI analysis process, but has no component for reporting. E.g., it has no output of the data in the form of a dashboard or charts.	E.g., for tools that support the processing of data or the creation of an ETL process, but require an additional frontend for reporting.

Characteristic	Definition	Criteria for the assignment of the software
Standard / scheduled	Reports are required several times in a similar form. Therefore, a high degree of automation for updating the data should be aimed at. The information is relevant at regular intervals (Schulz et al. 2015).	Allocated to the software if reports can be completely automatically generated, update timer can be used, etc. The high degree of automation is an outstanding characteristic of the software.
Ad-hoc	A one-time analysis is to be carried out. For this reason, the automation of data loading processes can be neglected. Initially, the focus is on a single use (Schulz et al. 2015).	Allocated to the software if reports, dashboards, etc. must be created or edited manually and are not automatically updated. Or if it's the dominant application scenario.
All-rounder	Includes one-time analysis as well as a high degree of automated report creation. Combination of the characteristics Standart/scheduled and Ad-hoc.	Allocated to the software if both of the previously mentioned characteristics are fulfilled, but neither of them is highlighted.
Data sensitivity / Privacy aspects Describes the "degree to which problems would arise if the contents of data files were known to others" (Zviran & Haga 1999, p.167). The degree is divided into five gradations.		
Non sensitive	No problems would arise if the data would be made public. There is "nothing to hide" (Zviran & Haga 1999, p.167	Not analyzed.
Slightly sensitive	Minor problems would arise if the data would be made public.	Not analyzed.
Moderately sensitive	A few problems would arise if the data would be made public. It would be "mildly embarrassing" personally or for the organization (Zviran & Haga 1999, p.184).	Not analyzed.
Moderately high sensitive	Problems would arise if the data would be made public.	Not analyzed.
Highly sensitive	Major problems would arise if the data would be made public. It would be "embarrassing personally or to the organization" (Zviran & Haga 1999, p.184).	Not analyzed.
Data reliability and completeness "Data reliability refers to the accuracy and completeness of computer-processed data, given the uses they are intended for" (Government Accountability Office, Applied Research and Methods: Assessing the Reliability of Computer-Processed Data (GAO-09-680G) (July 1, 2009). Whereas "Data completeness refers to the degree to which all data necessary for current and future business activities (e.g., decision making) are available in the firm's data repository" (Kwon et al. 2014 p. 389).		
Low	The selected data is not complete and/or reliable enough to solve the problem. Certain data is missing and/or needs to be adjusted first.	Not analyzed.
Medium	The selected data are almost complete and reliable for solving the problem, but some data still need to be added or adjusted.	Not analyzed.
High	The selected data is complete and reliable and allows to correctly solve the problem.	Not analyzed.

6.3 List of analyzed SSBI Tools

Tool name	Company	Website
Allot ClearSee Analytics	Allot Works	http://www.allotworks.com/ClearSee-Analytics.asp
Analyzer	Strategy Companion	http://strategycompanion.com/
Birst	Birst Inc.	https://www.birst.com/
Bissantz DeltaMaster	Bissantz	https://www.bissantz.com
BOARD	BOARD International	https://www.board.com/de
Cognos Analytics	IBM	https://www.ibm.com/de-de/products/cognos-analytics
cubus outperform	cubus	www.cubus.eu
Cyberquery	Cyberscience	www.cyberscience.com
Datapine Self Service Analytics	Datapine	https://www.datapine.com/de/self-service-analytics
Diver Platform	Dimensional Insight	www.dimins.com/
Domo	Domo	www.domo.com
Einstein Analytics	Salesforce	https://www.salesforce.com/de/products/einstein-analytics/overview/
ElegantJ BI	ElegantJ BI	https://www.elegantjbi.com/smarten/self-serve-data-preparation.html
GoodData Analytics Platform	GoodData	https://www.gooddata.com/
Holistics	Holistics	https://www.holistics.io/product/data-reporting/
Ideata Analytics	Ideata Analytics	https://www.ideata-analytics.com/big-data-analytics/
Informer	Entrinsik	https://entrinsik.com/informer/
Intelligence Portal	MarketLogic	https://www.marketlogicsoftware.com/intelligence-portal/
KNIME	KNIME	https://www.knime.com/
Logi Vision	Logi Analytics	https://www.logianalytics.com/
Looker	Looker	www.looker.com
Microsoft Power BI	Microsoft	https://powerbi.microsoft.com
Microsoft Power Query for Excel	Microsoft	https://www.microsoft.com/de-DE/download/details.aspx?id=39379
MicroStrategy 2019	MicroStrategy	https://www.microstrategy.com/us
Necto	Panorama	https://www.panorama.com/necto/
Oracle Analytics Cloud	Oracle	https://www.oracle.com/de/solutions/business-analytics/analytics-cloud.html#products
Paxata	Paxata	https://www.paxata.com/product/self-service-data-prep/
Phocas	Phocas	www.phocassoftware.com
Pyramid 2018	Pyramid Analytics	https://www.pyramidanalytics.com/
Qlik Sense	Qlik	www.qlik.com
Rapidminer	Rapidminer	https://rapidminer.com/
SAP Analytics Cloud	SAP	https://www.sap.com/germany/products/cloud-analytics.html
SAP Business Objects Analysis	SAP	https://help.sap.com/viewer/product/SAP_BUSINESSOBJECTS_ANALYSIS_OFFICE/2.8.3.0/en-US
SAP BusinessObjects Web Intelligence	SAP	https://www.sap.com/germany/products/bi-platform.html
SAS Visual Analytics	SAS	https://www.sas.com/de_de/software/visual-analytics.html
Sisense	Sisense	https://www.sisense.com/

Tool name	Company	Website
Spotfire	TIBCO Software	https://www.tibco.com/
SPSS Modeler	IBM	https://www.ibm.com/de-de/products/spss-modeler/details
Tableau	Tableau	https://www.tableau.com/
Tamr	Tamr	https://www.tamr.com/supplier-analytics-2/
TARGIT Decision Suite	TARGIT	https://www.targit.com
ThoughtSpot	ThoughtSpot	https://www.thoughtspot.com/de
WebFOCUS	Information Builders	https://www.informationbuilders.com/
Workday Prism Analytics	Workday	https://www.workday.com/de-de/applications/prism-analytics.html
Wrangler	Trifacta	https://www.trifacta.com/
Yellowfin BI	Yellowfin	www.yellowfinbi.com
Zoomdata	Zoomdata	https://www.zoomdata.com/product/self-service-bi-analytics/

Appendix 11 - Optimizing Machine Spare Parts Inventory Using Condition Monitoring Data

Outlet: Operations Research Proceedings 2016, Hamburg, Germany

Abstract

In the manufacturing industry, storing spare parts means capital commitment. The optimization of spare parts inventory is a real issue in the field and a precise forecast of the necessary spare parts is a major challenge. The complexity of determining the optimal number of spare parts increases when using the same type of component in different machines. To find the optimal number of spare parts, the right balance between provision costs and risk of machine downtimes has to be found. Several factors are influencing the optimum quantity of stored spare parts including the failure probability, provision costs and the number of installed components. Therefore, an optimization model addressing these requirements is developed. Determining the failure probability of a component or an entire machine is a key aspect when optimizing the spare parts inventory. Condition monitoring leads to a better assessment of the components failure probability. This results in a more precise forecast of the optimum spare parts inventory according to the actual condition of the respective component. Therefore, data from condition monitoring processes are considered when determining the optimal number of spare parts.

DOI Link: https://doi.org/10.1007/978-3-319-55702-1_61

Appendix 12 - Maintenance Planning Using Condition Monitoring Data

Outlet: Operations Research Proceedings 2017, Berlin, Germany

Abstract

Maintenance activities of machines in the manufacturing industry are essential to keep machine availability as high as possible. A breakdown of a single machine can lead to a complete production stop. Maintenance is traditionally performed by predefined maintenance specifications of the machine manufacturers. With the help of condition- based maintenance, maintenance intervals can be optimized due to detailed knowledge through sensor data. This results in an adapted maintenance schedule where machines are only maintained when necessary. Apart from time savings, this also reduces costs. An decision support system with optimization model for maintenance planning is developed considering the right balance between the probabilities of failure of the machines and the potential breakdown costs. The current conditions of the machines are used to forecast the necessary maintenance activities for several periods. The decision support system helps maintenance planners to choose their decision-making horizon flexibly.

DOI Link: https://doi.org/10.1007/978-3-319-89920-6_72

Keywords: Predictive maintenance, Condition-based maintenance, Condition monitoring, Machine availability, Sensor data

Appendix 13 - Combining Machine Learning and Domain Experience: A Hybrid-Learning Monitor Approach for Industrial Machines

Outlet: Lecture Notes in Computer Science

Abstract

To ensure availability of industrial machines and reducing breakdown times, a machine monitoring can be an essential help. Unexpected machine downtimes are typically accompanied by high costs. Machine builders as well as component suppliers can use their detailed knowledge about their products to counteract this. One possibility to face the challenge is to offer a product-service system with machine monitoring services to their customers. An implementation approach for such a machine monitoring service is presented in this article. In contrast to previous research, we focus on the integration and interaction of machine learning tools and human domain experts, e.g. for an early anomaly detection and fault classification. First, Long Short-Term Memory Neural Networks are trained and applied to identify unusual behavior in operation time series data of a machine. We describe first results of the implementation of this anomaly detection. Second, domain experts are confronted with related monitoring data, e.g. temperature, vibration, video, audio etc., from different sources to assess and classify anomaly types. With an increasing knowledge base, a classifier module automatically suggests possible causes for an anomaly automatically in advance to support machine operators in the anomaly identification process. Feedback loops ensure continuous learning of the anomaly detector and classifier modules. Hence, we combine the knowledge of machine builders/component suppliers with application specific experience of the customers in the business value stream network.

DOI Link: https://doi.org/10.1007/978-3-030-00713-3_20

Keywords: Machine monitoring, Hybrid learning, Long Short-Term Memory Neural Networks, Product-service systems

Appendix 14 - DASC-PM v1.0 - Ein Vorgehensmodell für Data-Science-Projekte

Outlet: Whitepaper

Abstract

Das Thema Data Science hat in den letzten Jahren in vielen Organisationen stark an Aufmerksamkeit gewonnen. Häufig herrscht jedoch weiterhin große Unklarheit darüber, wie diese Disziplin von anderen abzugrenzen ist, welche Besonderheiten der Ablauf eines Data-Science-Projekts besitzt und welche Kompetenzen vorhanden sein müssen, um ein solches Projekt durchzuführen. In der Hoffnung, einen kleinen Beitrag zur Beseitigung dieser Unklarheiten leisten zu können, haben wir von April 2019 bis Februar 2020 in einer offenen und virtuellen Arbeitsgruppe mit Vertretern aus Theorie und Praxis das vorliegende Dokument erarbeitet, in dem ein Vorgehensmodell für Data-Science-Projekte beschrieben wird – das Data Science Process Model (DASC-PM). Ziel war es dabei nicht, neue Herangehensweisen zu entwickeln, sondern viel-mehr, vorhandenes Wissen zusammenzutragen und in geeigneter Form zu strukturieren. Die Ausarbeitung ist als Zusammenführung der Erfahrung sämtlicher Teilnehmerinnen und Teilnehmer dieser Arbeitsgruppe zu verstehen. Als Zielgruppe des Dokumentes sind all diejenigen zu sehen, die direkt oder aber auch indirekt an Data-Science-Projekten beteiligt sind. Grundlegende Kenntnisse über den Komplex der analytischen Informationssysteme werden dabei vorausgesetzt. Das Vorgehensmodell soll dazu dienen, allen Interessengruppen von Data-Science-Projekten ein Verständnis der not-wendigen Aufgaben und Zusammenhänge zu vermitteln. Zudem kann es von Studierenden genutzt werden, um sich dem Themenfeld zu nähern. Die Data Science befindet sich noch am Anfang ihrer Entwicklung. Deshalb soll dieses Dokument nicht als abgeschlossenes Werk betrachtet werden. Wir wünschen uns sehr, dass es zukünftig in der Durchführung von Data-Science-Projekten Berücksichtigung findet. Dadurch gewonnene Erkenntnisse sollen sowohl genutzt werden, um die bestehenden Ausarbeitungen in Frage zu stellen, als auch, um sie zu vervollständigen und zu detaillieren. Falls Sie Verbesserungsvorschläge zum Vorgehensmodell haben oder sich aktiv an seiner Weiterentwicklung beteiligen möchten, freuen wir uns über eine Kontaktaufnahme. Das nächste Treffen der virtuellen Arbeitsgruppe ist für September 2020 geplant. Unser Dank gilt allen Teilnehmerinnen und Teilnehmern der Arbeitsgruppe. In produktiver und konstruktiver Atmosphäre haben wir ein unserer Meinung nach nutzbringendes und verständnisförderndes Ergebnis erzielt – und dabei auch selbst viel Neues über Data Science gelernt. Hamburg, im Februar 2020

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