University of Twente
School of Management and Governance
Chair of Technology Management
Prof. Dr. Holger Schiele

Master thesis

Development of a Maturity- and Quadrant Model to Assess and Classify E-purchasing solutions

Author: Finn Ströhnisch
M.Sc. Business Administration, University of Twente
Purchasing & Supply Management

1st Supervisor: Prof. Dr. habil. H. Schiele
University of Twente,
Enschede, Netherlands

2nd Supervisor: V. Delke, MSc
University of Twente,
Enschede, Netherlands

Number of pages/words: 98/25856
Bibliography program used: Endnote
Enschede, 25th of July 2019

Acknowledgment

This thesis aims to finalise my studies in order to obtain a Master of Science in Business Administration specialised in Purchasing & Supply Management.

Before starting with the official research, I would like to thank some people who supported me throughout my master studies and the stages of this thesis. First of all, I would like to thank my family for the strong emotional and financial support. Secondly, I would also like to thank Prof. Dr. habil. Holger Schiele for drawing me into the field of purchasing and providing me with great feedback and input on my thesis. I would also sincerely like to thank Vincent Delke, for his supervision, commitment and general support during the process of writing my thesis. Last but not least, I would like to thank all participants of this research who contributed to make this thesis valuable for academics and practitioners.

Finally, I truly hope that you enjoy reading this thesis and that the developed maturity tool supports research within this interesting field.

Enschede, 17th of July 2019

Abstract

The progressing Industry 4.0 drives the need for organisations to implement sophisticated e-purchasing solutions. Moreover, research has shown that the deployment and utilization of innovative e-purchasing solutions lead to a competitive advantage due to reduced transaction costs and better control of corporate spending. Nonetheless, it seems that even organisations that are willing to implement innovative solutions struggle to find their desired software in the jungle of competing vendors, due to no established structure to evaluate and classify vendors towards their Industry 4.0 maturity. Therefore, this thesis provides the first Industry 4.0 oriented maturity model with a linked quadrant matrix to assess, classify and visualise solution vendors. With regards to the research design of this study, the new model is developed based on extensive literature reviews and semi-structured interviews with Industry experts. Furthermore, the demonstration of the model encompasses the assessment of 16 e-purchasing solution vendors. The research ends with the newly developed and evaluated maturity model and linked quadrant matrix. In addition, based on the demonstration of the model an update of the technological progress on the e-purchasing solution market is provided.

Keywords: e-purchasing, e-procurement; e-sourcing; e-ordering; purchase-to-pay; procure-to-pay; source- to-contract; maturity model; quadrant model, quadrant matrix

Contents

List of Figures

List of Tables

List of Abbreviations

AI	Artificial Intelligence
AS2	Applicability Statement 2 (protocol for invoices)
BI	Business Intelligence
CMC	Category Management Cycle
CMM	Capability Maturity Model
CMMI	Capability Maturity Model Integration
CPS	Cyber-Physical Systems
EDI	Electronic Data Interchange
EP	Electronic Purchasing
ENX	European Network Exchange (protocol for invoices)
ERP	Enterprise Resource Planning
E-RA	Electronic Reverse Auction
FCPA	Foreign Corrupt Practices Act
FTP	File Transfer Protocol (protocol for invoices)
GDPR	General Data Protection Regulation
InfoSec	Information systems security,
I4.0	Industry 4.0
IoT	Internet of Things
KPI	Key Performance Indicator
MDM	Master Data Management
M2M	Machine to Machine (Communications)
PO	Purchase Order
P2P	Procure-to-Pay
RFI	Request for Information
RFID	Radio-frequency Identification
RFP	Request for Proposal

RFQ	Request for Quotation
RFX	Catch-all term for RFI, RFP, and RFQ
RPA	Robotic Process Automation
SRM	Supplier Relationship Management
S2C	Source-to-Contract
UBL	Universal Business Language
UI	User Interface
VAT	Value Added Tax
XML	Extensible Markup Language

1. Introducing the need for a model that assess the Industry 4.0 maturity of e-purchasing solutions

1.1. Purchasing organisations face the challenging selection of advanced EP-solutions to achieve a competitive advantage

The importance and strategic aspects of e-purchasing solutions within purchasing departments (PD) have been better understood over the past decades.[1] With the introduction of the first Information management systems in the 90's, the purchasing departments were able to manage their activities efficient through virtual networks. Contemporary, these solutions are commonly part of e-purchasing (EP) and refer to software solutions that facilitate electronic network-based applications which support the purchasing process encompassing the inter, intra and extranet as well as the active management of the supply base in operational and strategic aspects.[2] EP-solutions becoming increasingly important for organisations as the right software is critical to provide a competitive advantage.[3] Hence, the quality of the solutions is considered to be a crucial element in business success.[4]

Nowadays, the global scenario pictures a situation in which the visionary idea of the Fourth Industrial Revolution (I4.0) has been promoted continually by different actors to illustrate the trend towards increased automation, autonomisation, digitisation and the expanded use of information and communication technology within the organisational environment.[5] The drivers of the Industry 4.0 are two-fold, namely the customer-pull as well as the technology-push.[6] On one side, the demand for shorter product development cycles, increased collaboration, resource efficiency and flexibility within the supply chain pull for the fourth industrial revolution. On the other side, technological developments, like the IoT, Big Data processing, and Artificial Intelligence are pushing towards the Industry 4.0.[7] This revolution has a particularly strong impact on purchasing since this function can be considered as "…seismograph for global change – an early indicator of the shocks, disturbances and innovations that today's highly complex international networks of companies are subject to."[8]

[1] See Min and Galle (2003), p. 227.
[2] See Min and Galle (2003), p. 227.
[3] See Al-Qutaish and Abran (2011), p. 307.
[4] See Al-Qutaish and Abran (2011), p. 307.
[5] See Kagermann (2015), p. 23-26.
[6] See Lasi, Fettke, Kemper, Feld, and Hoffmann (2014), p. 239-240.
[7] See Lasi et al. (2014), p. 239.
[8] Knapp et al. (2018), p. 4.

Consequently, purchasing organisation have to transform and adapt to keep up with the happening change in order to provide a competitive advantage. Therefore, one major aspect is the usage of sophisticated EP-software solutions. Subsequently, purchasing organisations rely strongly on innovative e-purchasing solution vendors and their offered products to successfully overcome the challenges of the progressing Fourth Industrial Revolution. Besides the fact that the benefits of innovative EP-solutions are commonly known within the purchasing landscape, the degree of implementation can still regard as low.[9]

1.2. The goal of the research is the development of a maturity model that supports the evaluation and classification of EP-solutions

Research has shown that the implementation of innovative e-purchasing solutions leads to a competitive advantage due to reduced communication and transaction costs.[10] However, it seems that even purchasing organisations that are willing to implement innovative ep-solutions struggle to find their desired innovative solution in the jungle of competing vendors, due to no established possibility to evaluate and classify different e-purchasing solution vendors.[11] Hence, the starting point for the research was the exploration of literature for a suitable model that supports the evaluation and comparison of different solutions. The review resulted in two major recognition. Firstly, literature provides maturity models for the evaluation of purchasing departments regarding their I4.0 sophistication. Nonetheless, the reviewed models do not offer any aspects of the capability requirements of Industry 4.0 oriented e-purchasing solutions.[12] Secondly, it became noteworthy that several renowned analyst firms provide quadrant models, which categorise the largest solution vendors towards their innovativeness without providing detailed insights about the evaluation.[13] Therefore, the available quadrants are not valuable to organisations which are interested in the innovativeness of solutions provided by vendors that are not assessed by the analyst firms. Hence, purchasing organisations have no possibility to assess and compare different e-purchasing solutions by themselves. Based on the aforementioned lack of literature the research aims to develop an I4.0 focused maturity model that enables the evaluation of ep-solutions while providing the possibility to

[9] See Sitar (2011a), p. 122-123; Ehrler (2019), p. n.a.
[10] See Min and Galle (2003), p. 227.
[11] See chapter 2.5.2.
[12] See chapter 2.5.2.
[13] See chapter 2.5.3.

visualise the assessed solutions in a quadrant model. As a result, the following main research question has been formulated: *How to develop a maturity and linked quadrant model to evaluate and compare the Industry 4.0 sophistication of different e-purchasing solutions?* To obtain further insights, the main research question is answered by elaborating four sub-questions: *(1) What characteristics and applications define e-purchasing? (2) What characteristics and technologies define the Industry 4.0? (3) What are the design requirements for a maturity- and quadrant model? (4) How can e-purchasing solutions be classified?*

In order to answer the research questions in a structured way, the exploration follows Peffers et al. (2007) design science research framework for the development of a new artefact. The framework consists of the Problem and Objective definition, Design and Development section, Demonstration stage and Evaluation phase.[14] The Problem and Objective of the artefact are explained in the first chapter. The Design and Development phase in chapter two and four encompasses the gathering of information about e-purchasing, Industry 4.0 and design principles of maturity- and quadrant models. Furthermore, this phase contains expert interviews as part of the iterative development process in order to enhance the maturity model. Subsequently, in line with Peffers et al. (2007) approach, the model has to be demonstrated which leads to the fact that the outcome of the research is twofold. The demonstration of the newly developed model verifies its usability and will be used to assess various e-purchasing solution vendors in order to obtain a market overview and visualised classification in the form of a quadrant model. Lastly, the evaluation of the model is covered in chapter six. The research closes with the newly developed maturity model and linked quadrant matrix that facilitates the visualised classification of e-purchasing vendors.

This research provides relevant contributions to literature and increased practical relevance for purchasing organisations. The results will extend the body of knowledge within the research field of e-purchasing, by providing the first unified model within this research domain and an update about the technological progress on the market. Furthermore, the increased practical relevance is based on the fact that (purchasing) organisations have a tool at hand, which allows themselves to evaluate desired e-purchasing solutions. Moreover, the linked quadrant model facilitates the automated visualised classification of e-purchasing solution vendors. Hence, by assessing various ep-solutions regarding their

[14] See Peffers, Tuunanen, Rothenberger, and Chatterjee (2007), p. 54.

Industry 4.0 sophistication, the developed models assist buying organisation in the process of selecting a solution that fits best to their needs. This, in turn, allows for a higher success rate of buying organisations that attempt to implement e-purchasing solutions, which leads to an increased general digitisation which drives the Industry 4.0 forward.

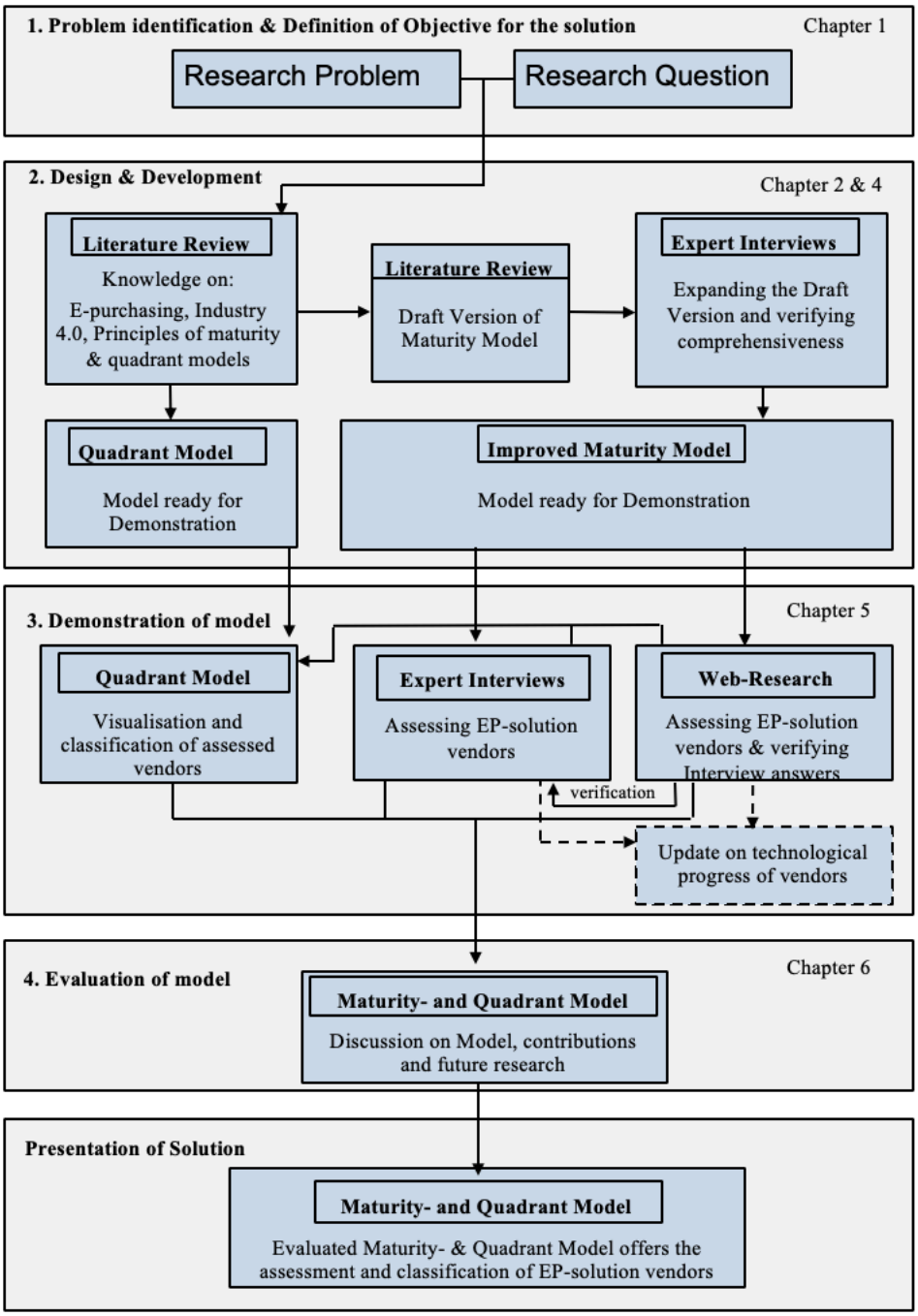


Figure 1: Research Model oriented on the structure of Peffers et al. (2007), p. 54.

2. Literature review about E-purchasing, Industry 4.0 and Maturity- and Quadrant Models serves as basis for the development the model

2.1. Purchasing's relevance increased and encompasses e-purchasing

2.1.1. Purchasing shifted towards a strategic role within the business environment

Prior to 1970's conventional view of purchasing departments can be described as passive operating specialized back office. The main task back then was the support of sequential business function and different departments. The focus of the work relied mainly on a strong procurement function and arms-length relationships to the suppliers were commonly accepted.[15] Hence, if an internal request came up, the purchaser forwarded the request to a few suppliers for competitive offers and "awarded short-term contracts based on price, …, and figured out how to meet not-too-demanding performance measures."[16] After business research produced new insights in the field of purchasing and concurrent business processes required intra-organisational collaboration the purchasing function had been placed in a central position. In the 1980's and 1990's, the new attention for purchasing departments went along with the concomitant strategic importance in terms of competitive advantage for the buying organisations.[17] Furthermore, the ERP System, which has been also introduced in the 90s, centralised the information interface in terms of the financial-, production and purchasing-management which provided (purchasing) managers with more precise and actual information. As a result, the purchasing managers began to realise that supplier management had a major impact on their capability to meet customer needs. Accordingly, the focus on the supply base increased within the responsibility of purchasing. The focal point changed from the lowest price towards getting the right products to customers at the right time, place, condition, cost and quantity.[18] The rapid expansion of the internet embraced new possibilities for purchasing departments. Since the beginning of the 2000s online purchasing management systems have been developed in order to handle inter-organisational coordination and integrative processes with the goal of enhancing the total value of the whole purchasing process.[19]

Seemingly, the role of purchasing has evolved to incorporate long term goals while influencing the strategic direction of organisations. According to Hong and Kwon (2012) the importance of the purchasing functions beyond 2010 manoeuvres towards a more sustainable competitive advantage where strategic networks and integrative collaborative

[15] See Hong and Kwon (2012), p. 454.
[16] Monczka, Handfield, Giunipero, and Patterson (2009), p. 5.
[17] See Hong and Kwon (2012), p. 455.
[18] See Monczka et al. (2009), p. 6.
[19] See Hong and Kwon (2012), p. 455.

value chain management delivers shared values in terms of the whole supply chain. The continually increasing of wide scoped outsourcing requires not only cross-functional integration but also sophisticated integrative processes across the whole organisation.[20] The persistent shift towards Industry 4.0 requires the enhanced exchange of communication and information achieved through e-purchasing systems. The technologies of Industry 4.0 are intended to support the shift by collecting and processing the relevant data over the whole supply chain while supporting intelligent decision making.[21]

Consequently, this thesis follows the two often-referred definitions of Van Weele and Eig (2017) and Schiele (2019) who explain that purchasing is the management of the company's external resources with the aim of ensuring the availability of all goods, services, skills and knowledge needed to carry out, maintain and control the company's primary and supporting activities, on the most favourable terms.[22]

2.1.2. E-purchasing entails e-sourcing and e-procurement

To better understand the subject and to estimate a reasonable groundwork, it is important to define e-purchasing, e-procurement and e-sourcing, because in practice the different terminologies are often used interchangeable.[23] Nonetheless, there is consent among authors that e-purchasing relies on Information & Communication technology.[24] Min & Galle (2003) define e-purchasing as practices that utilize the internet to purchase goods and services, transfer payments, identify potential sources of supply and to interact with suppliers.[25] Furthermore, Giunipero, Ramirez and Swilley (2012) state that e-purchasing tools are "Internet based systems that facilitate buyer–seller transactions (…) and enhance organisational and supply chain performance."[26] Consequently, e-purchasing entails the operative e-procurement as well as the more strategic e-sourcing. Contradicting, Stoll (2007) views E-Purchasing as a synonym of E-procurement and vice versa.[27] Nonetheless, in order to provide a clear separation of the different terms this research orients on Schiele (2019), who describes purchasing and therefore also e-purchasing as preamble term, which

[20] See Hong and Kwon (2012), p. 455.
[21] See Torn (2017), p. 10.
[22] See Van Weele and Eig (2017), p. 20; Schiele (2019), p. 48.
[23] See Lim (2018), p. 1.
[24] See Kollmann (2016) p. 121.
[25] See Min and Galle (2003), p. 227.
[26] Giunipero, Ramirez, and Swilley (2012), p. 279.
[27] See Stoll (2007), p. 17.

encompasses e-procurement and e-sourcing.[28]

E-sourcing can be described as the process of identifying and selecting new suppliers using Internet-based technologies.[29] De Boer, Harink and Heijboer (2002) explain that buying organisations are able to increase the competitiveness in the tendering process by facilitating e-sourcing.[30] Moreover, e-sourcing encompasses tools that facilitate contract lifecycle management, which leads to the possibility to oversee supplier compliance and risks.[31] In addition, analysis such as spend analysis belong to the strategic e-sourcing as well as the management of the supplier base.[32] Following e-sourcing, e-procurement is the operative electronic purchase of the goods from suppliers. Within e-procurement, the negotiated contracts created within the sourcing process are executed. Moreover, the determined payment is electronically managed and processed within the operative e-procurement process.[33] Hence, organisations use e-procurement tools to manage the electronic flow of documents, order transmissions and payments to suppliers.[34]

Accordingly, this research defines e-sourcing as electronic processes that can be used strategically to ensure the optimisation of spend, supplier selection, contracting and the overall supplier management that leads into the operative e-procurement. Subsequently, e-procurement is defined as strictly operational process that facilitates electronic transactional procurement activities and the execution of contracts.

2.1.3. E-purchasing activities explained based on the Category Management Cycle by Schiele (2019)

The Category Management Cycle (CMC) can be defined as an end-to-end value stream encompassing all purchasing stages and therefore all e-purchasing activities at a category level required for organisations to source, procure and pay for goods and services.[35] Therefore, the comprehensive Category Management Cycle by Schiele (2019) has been used as framework to gain a structured classification of the different e-purchasing tools, which support the development of a comprehensive maturity model.[36] The typical

[28] See Schiele (2019), p. 48.
[29] See Presutti Jr (2003), p. 23.
[30] See De Boer, Harink, and Heijboer (2002), p. 26.
[31] See Determine Inc. (2015), p. n.a.
[32] See Gunasekaran and Ngai (2008), p. 160-161; Käkölä and Lu (2015), p. 5364.
[33] See Käkölä and Lu (2015), p. 5364-5365; Determine Inc. (2015), p. n.a.
[34] See Davila, Gupta, and Palmer (2003), p. 11; Monczka et al. (2009), p. 44.
[35] See Schiele (2019), p. 54.
[36] See Schiele (2019), p. 55-58.

purchasing stages can be subdivided into strategic and operative processes.[37] The more strategic processes encompass the demand identification, category strategy, supplier selection, contracting and supplier evaluation.[38] Furthermore, the collective set of strategic (e-) purchasing activities when sourcing goods or services is referred as Source-to-Contract (S2C).[39] Moreover, the operative (e-) purchasing tools for the procurement, order handling and payment are assigned to the Purchase-to-Pay (P2P) process.[40]

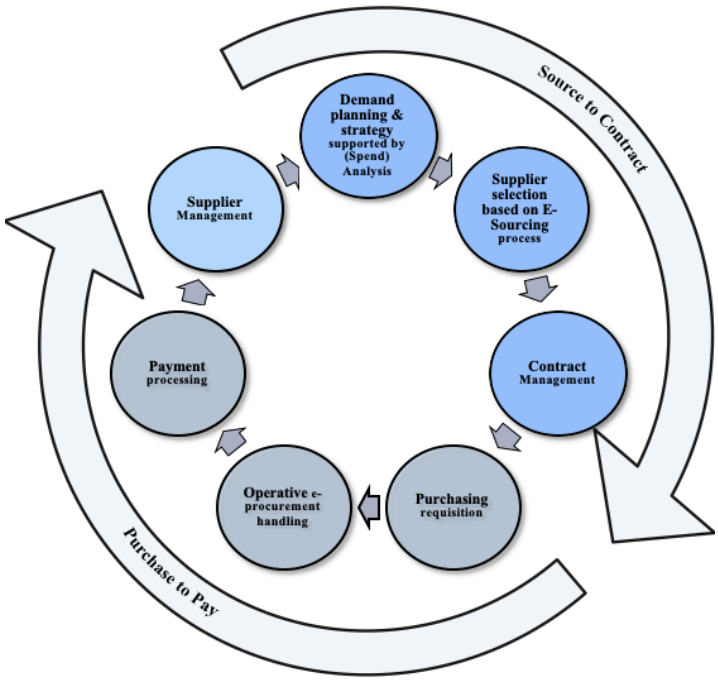


Figure 2: Category Management Cycle based on Schiele (2019), p. 55.

The cycle begins with the demand identification and category strategy. Hereby, the first steps are supported through a (spend) analysis which supports the development of a sourcing strategy.[41] Following, different e-sourcing tools are utilized to facilitate the supplier selection based on specific KPI's or requirements of the buying organisation such as upcoming purchasing projects.[42] Thirdly, the contracting phase encompasses the negotiation and contracting with the supplier, as well as the evaluation of contracts. The end of the contracting phase initiates the beginning of the Purchase-to-Pay (P2P) process.[43]

[37] See Schiele (2019), p. 48; Appelfeller (2019), p. 1.
[38] See Schiele (2019), p. 56-58.
[39] See Appelfeller (2019), p. 8.
[40] See Appelfeller (2019), p. 10.
[41] See Appelfeller (2019), p. 8-10.
[42] See Appelfeller (2019), p. 8.
[43] See Schiele (2019), p. 57-58.

The P2P process encompasses the operative (e-) procurement handling by receiving and approving purchasing requests and the creation of purchasing orders.[44] Palmer and Gupta (2011) explain that the traditional approach of the P2P process focused on the increasing control, which has changed towards the reduction of costs based on increased efficiency and automation.[45] The last step within the P2P process is the processing of invoices which has been substantially automated in the last years.[46] The end of the Category Management Cycle contains the supplier evaluation. The supplier evaluation implies the assessment and management of a supplier's performance after or during the collaboration.[47] The process is supported through e-purchasing tools that aid the quantitative and qualitative supplier evaluation and handling.[48]

2.2. Various steps of the Category Management Cycle are supported by analytical and transactional applications

2.2.1. Source-to-Contract entails e-sourcing, e-marketplace and e-contracting applications

E-Sourcing is the generic term for the process of assessing potential new suppliers using the internet.[49] Elmaghraby (2007) explains that e-sourcing applications attempt to automate the sourcing process, which includes the matchmaking on e-marketplaces, e-auctions and the e-contract management.[50] Hence, e-sourcing and its application can be considered as transactional and will be reviewed separately in the following.

Within the e-sourcing process, e-tendering takes place in the supplier contact step on open or closed online platforms.[51] Typically, these platforms are provided by different e-purchasing vendors such as Coupa or Jaggaer.[52] De Boer et al. (2002) and Knudsen (2003) define e-tendering as the process of using e-RFX tools, such as request for price (RFP), request for information (RFI) or request for quotation (RFQ) in order to collect data about (potential) suppliers and offers in a regular tendering procedure.[53] Furthermore, Oyediran and Akintola (2011) explain that e-tendering empowers the buying professionals by increasing their potential control over the elements of the tender as well as improving and

[44] See Smith (2014), p. 13; Jain and Woodcock (2017), p. 3; Schiele (2019), p. 58.
[45] See Palmer and Gupta (2011), p. 66.
[46] See Jain and Woodcock (2017), p. 3; Schiele (2019), p. 58.
[47] See Schiele (2019), p. 58.
[48] See Appelfeller (2019), p. 9-10.
[49] See Knudsen (2003), p. 727.
[50] See Elmaghraby (2007), p. 409.
[51] See Knudsen (2003), p.728-729.
[52] See Coupa (2019), p. 1; Jaggaer (2019), p. n.a.
[53] See De Boer et al. (2002), p. 26; Knudsen (2003), p. 727-729.

securing the gathered tender information within the e-purchasing software.[54] Consequently, e-tendering aims to increase the competition between the different suppliers by simplifying the RFX process.[55]

One other application within e-sourcing refers to the e-auctions. By now there are various types of e-auctions such as Dutch, English, Japanese or Brazilian auctions.[56] However, the most common form of e-auctions is the e-reverse auction (E-RA). The E-RA is a real-time auction between a buying organisation and different (preselected) suppliers, where the reduction of bids is made in order to gain the business contract. Basically, the lowest bidder is the winner, although different clearly defined characteristics of the goods, such as quantity, quality, delivery, etc. and the related terms and conditions must be complied with.[57] The overall benefit of e-auctions compared to the regular tendering process is the possibility to target a wider supplier base through standardized auctions leading to an agreement. Therefore, a larger number of suppliers is able to participate in a more cost-efficient way. Hence, the buying organisation has an increased chance to find the most capable supplier while receiving important market information by accurately tracking all the bids. However, e-auctions can also bring harm if the focus is purely on the price and underestimate the importance of quality, services and relationships.[58]

E-marketplaces are open web portals that offer a matchmaking between generic buyer requests and supplier offers.[59] Colucci et al. (2005), state that "the purpose of a matchmaking facilitator is then, basically, filtering those supplies (or conversely demands, depending on the point of view), which may be worth pursuing based on a given demand (supply). Obviously, a negotiation process may then ensue, up to the actual transaction."[60] Smart (2010) adds that e-marketplaces may differ between a horizontal scope, offering a wide range of goods or a vertical industry-specific perspective and classifies e-marketplaces as many to many purchasing.[61] Thitimajshima et al. (2017) describe two further main functions of e-marketplaces besides the matchmaking. Firstly, the facilitation of transactions through e-catalogues and auctions and secondly the maintenance of

[54] See Oyediran and Akintola (2011), p. 558.
[55] See Rajkumar (2001), p. 497.
[56] See Capgemini (2018), p. 20.
[57] See Beall et al. (2003), p. 22; Elmaghraby (2007), p. 410-411; Smart (2010), p. 431.
[58] See Hartley, Lane, and Hong (2004), p. 153.
[59] See Colucci, Di Noia, Di Sciascio, Donini, and Mongiello (2005), p. 345-346; Smart (2010) p. 431; Thitimajshima, Esichaikul, and Krairit (2017), p. 129-130.
[60] Colucci et al. (2005), p. 346.
[61] See Smart (2010), p. 431.

institutional infrastructures, such as regulatory and legal frameworks.[62] The current trend within the e-purchasing landscape pictures the shift from closed legacy systems to open e-marketplaces.[63]

The last step within the Source-to-Contract process is the e-contract management. E-contract management refers to the use of IT in order to increase the effectiveness and efficiency of contracting processes between or within organisations.[64] The contracting phase within e-sourcing encompasses mainly two functions. Firstly, the contract administration, which ensures that every involved party meets the contractual requirements. Secondly, the contract closeout encompasses the verification of completeness and the settling of the contract without any open items.[65] A practical example is provided by Coupa's contracting solution. They have a central database for all contracts and support the contract creation by providing templates and automated transfer of supplier information to reduce mistakes. Furthermore, the solution provides an alert function for different stakeholders.[66]

2.2.2. Purchase-to-Payment process entails e-ordering, e-payment and e-catalogue applications

The P2P process as shown as in Figure 2 can be described as the operative e-procurement process.[67] P2P applications are hosted by the buying organisation and can be part within an existing ERP system such as SAP or a stand-alone application which can be integrated into the ERP. The applications allow users to place and track e-orders, search for products (in catalogues) and to receive and pay while automating the Purchase-to-Pay cycle such as the approval of the request, the approval, the cross-checking of the invoice and the release to pay.[68] De Boer et al. (2002) and Knudsen (2003) agree that e-catalogues refer mainly to the requisition of indirect goods.[69]

E-ordering encompasses the process of inquiring and approving requisitions, placing and tracking of orders using internet-based software solutions.[70] Sitar (2011) states that the use of e-ordering is conjoined with the use of e-catalogues and Neupane et al. (2012) explain

[62] See Thitimajshima et al. (2017), p. 130.
[63] See Thitimajshima et al. (2017), p. 130.
[64] See Angelov and Grefen (2008), p.1816.
[65] See Rendon (2008), p. 208.
[66] See Coupa (2019a), p. n.a.
[67] See Schiele (2019), p. 48.
[68] See Smart (2010), p. 431.
[69] See De Boer et al. (2002), p. 26; Knudsen (2003), p. 730.
[70] See Sitar (2011b), p. 688; Neupane, Soar, Vaidya, and Yong (2012), p. 306.

that e-ordering has the most benefit if it includes the automated e-payment integration.[71] Furthermore, Reunis, Santema and Harink (2006) state that the frequent use of e-orders in e-catalogues mitigates maverick buying while increasing the buying compliance within organisational contracts.[72] Moreover, the automatisation of e-ordering and e-payment leads to shorter order cycles while the gathered data provides input for spend analysis with the goal to realise and visualise purchasing objectives.[73]

The automated e-payment is depending on the seamless processing of e-invoices. True e-invoices origin from the Electronic Data Interchange Transaction (EDI) and are based on the Extensible Markup Language (XML) format. E-invoices provide qualified data of the whole process and support the seamless automation of the payment process.[74] However, the majority of SME still uses regular invoices in paper format or emails.[75] Based on recent developments is it possible to transform various types of invoices in the fitting format to support the automated payment process. An example can be seen by the solution of OpusCapita, which is able to convert various types of invoices such as E-mails, Paper, AS2, ENX, FTP and many more. Furthermore, the solution supports the automation of VAT regulations or the three-way matching of invoices.[76] Three-way matching describes the automated comparison of Purchase orders, Order Receipts and the invoice to ensure that all three are complete and accurate.[77]

As before stated, are e-ordering and e-catalogues conjoined. The three main e-catalogue types are the internal multi-vendor product catalogue, punchout method and external multi-vendor product catalogue.[78] Firstly, the internal multi-vendor product catalogue is hosted by the buying organisation. Catalogue changes are typically performed by the procurement department or suppliers. Secondly, the punch-out strategy refers to externally hosted catalogues on the supplier's website. The punchout-scenario enables requesters to access externally hosted catalogues through the own e-procurement application. Lastly, the external multi-vendor product catalogue refers to product catalogues that are hosted on extranets. The idea behind this strategy is that different partner companies achieve cost savings by using synergy effects due to larger order volumes from the same suppliers,

[71] See Sitar (2011b), p. 689; Neupane et al. (2012), p. 326.
[72] See Reunis, Santema, and Harink (2006), p. 322.
[73] See Reunis et al. (2006), p. 322.
[74] See Kollmann (2016), p. 123.
[75] See OpusCapita (2019), p. n.a.
[76] See OpusCapita (2019), p. n.a.
[77] See Castillo (2016), p. 9.
[78] See Puschmann and Alt (2005), p. 127-128.

while standardising processes.[79] For example, Bayer partnered up with Chemfidence and other companies and established the Chemplorer system.[80]

Mehrbod, Zutshi, and Grilo (2014) explain that there are no established catalogue formats. Hence, e-purchasing solution providers have to focus on an advanced translation and integration of various catalogues.[81] Nevertheless, established software vendors support the possibility to transform and optimise many catalogues for the integration.[82]

2.2.3. Analytical applications support strategy formulations

As can be seen in Figure 2, the first step within the Category Management cycle is based on the analysation of data. The gathered data serves as basis for the development of strategy formulations and risk assessments of different suppliers for various categories.[83] The gathered, cleaned and stored data is defined as Master Data.[84] Reliable Master Data is crucial for various applications such as the Spend- and Category Analysis or the Supplier Management.[85]

The Spend Analysis is the procedure of the accumulation, cleaning and analysation of corporate spend with the purpose of decreasing costs and increasing the operational performance.[86] Furthermore, Angeles and Nath (2007) declare that an organisation is not able to maximise their "buying leverage, arrive at intelligent sourcing decisions, ensure compliance with supplier contracts, raise supplier performance, optimize budgeting and planning, and anticipate the impact of changes in cost, inflation, and other factors" without a sophisticated spend analysis.[87] Moreover, low Spend visibility is accountable for a significant percentage of maverick buying.[88] Lamoureux (2018) further explains that a sophisticated spend analysis is mandatory to achieve best-in-class sourcing decisions and Total Value Management.[89] It is noteworthy, that different vendors such as Ivalua or Coupa provide algorithm-based solutions that support the automated classification of business spend.[90]

---

[79] See Puschmann and Alt (2005), p. 128.
[80] See Puschmann and Alt (2005), p. 128; Zillich (2005), p. 3.
[81] See Mehrbod, Zutshi, and Grilo (2014), p. 834.
[82] See Basware (2013), p. n.a.
[83] See Capgemini (2018), p. 36-37.
[84] See Berson and Dubov (2007), p. 8.
[85] See Capgemini (2018), p. 42.
[86] See Trkman and McCormack (2010), p. 6.
[87] Angeles and Nath (2007), p. 107.
[88] See Capgemini (2018), p. 7.
[89] See Lamoureux (2018), p. 12.
[90] See Coupa (2019b), p. n.a.; Ivalua (2019), p. n.a.

Another important function provided by big players such as SAP Ariba or Smart by GEP is the category analysis. The category analysis refers to the in-depth examination of attributes and drivers of specified categories.[91] Thus, the goal is to enhance the stakeholders understanding of supply market characteristics, demand profiles and key category drivers.[92]

The analytical applications in terms of the supplier management refer to the evaluation and calculation of the organisational dependence on their suppliers and the conjoined risk management. In terms of the risk management, vendors such as SAP Ariba, SynerTrade or Zycus include third-party data to enhance information about the supplier base.[93] Moreover, Bottani and Rizzi (2005) explain that the production capabilities, innovativeness, financial stability, geographical location and experience are crucial characteristics of the supplier evaluation.[94] According to Högel et al. (2018), it becomes increasingly important that purchasing organisations are able to manage disruptions based on the loss of critical suppliers by using algorithms to track the supplier's financial performance.[95] The supplier management also includes the automated connection of suppliers, based on supplier portals provided by different vendors.[96] Overall, the analytical applications follow the goal to provide valuable information for the formulation of strategies and the risk assessment.

2.3. Defining Industry 4.0 to establish a clear separation

2.3.1. Various definitions of the I4.0 exist and depend on the perspective of the authors

The objective of this section is to establish an unequivocal definition for Industry 4.0 to build an essential foundation for the development of the final stages within the maturity model and guidance for the classification of e-purchasing vendors.

According to Oesterreich and Teuteberg (2016), the term Industry 4.0 is used as a synonym for the fourth industrial revolution and has been introduced and developed by the German National Academy of Science and Engineering.[97] In literature, Industry 4.0 is described in different ways since there is no commonly accepted definition. These definitions are strongly dependent on the perspective and scope of the authors as for

[91] See SAP Ariba (2018), p. n.a.; Smart by GEP (2019), p. n.a.
[92] See Zycus (2019), p. n.a.; Smart by GEP (2019a), p. n.a.
[93] See SAP Ariba (2019a), p. n.a.; Synertrade (2016), p. n.a.; Zycus (2019a), p. n.a.
[94] See Bottani and Rizzi (2005), p. 256.
[95] See Högel, Schnellbächer, Tevelson, and Weise (2018), p. 5.
[96] See Zycus (2019a), p. n.a.; OpusCapita (2019a), p. n.a.; Smart by GEP (2019b), p. n.a.
[97] See Oesterreich and Teuteberg (2016), p.122.

example Oesterreich and Teuteberg (2016) and Smit et al. (2016) broadly define I4.0 as innovative and advanced manufacturing concept.[98] Furthermore, Herman, Pentek and Otto (2016) understand I4.0 as amalgamation of industrial production, information transparency and communication technologies.[99] Therefore, it can be concluded that Herman, Pentek and Otto (2016) display the Industry 4.0 from a micro-manufacturing perspective. However, Stock & Seliger (2016), describe the Industry 4.0 from a macro value chain-based view by defining it as a decentralized network of value creation modules that are based on a cross-linkage through the entire value chain.[100] Yet, Pfohl, Yahsi and Kurnaz (2015) and Roblek, Meško, and Krapež (2016) define I4.0 from an impact-based view by stating that the fourth industrial revolution is characterised by the sum of all disruptive innovative transformations through the trends and progress in terms of autonomisation, digitalization, modularisation and network-collaboration.[101] From a technology-centred perspective, the I4.0 can be described as the integration of Internet of Things and future-oriented technologies within autonomous cyber-physical systems (CPS) with increased machine to machine interactions.[102] Consequently, based on the technology-centred definitions of Kagermann et al. (2013), Wang et al. (2016) and Sanders, Elangeswaran, and Wulfsberg (2016) and the impact-based description of Pfohl, Yasi and Kurnaz (2015) the following definition for this thesis will be used: The fourth industrial Revolution (Industry 4.0) describes the industry transformation that permeates vertical, horizontal and End to End integration of digitalised, automatised and autonomised industrial processes in linked supply chains, enabled through IoT and future oriented technologies that support the seamlessly communication and analysation of data.

2.3.2. Demarcation of the 3. Industrial Revolution- reviewing the major differences

It seems to be a considerable risk of confusion between Industry 3.0 and Industry 4.0. Many examples and explanations published about Industry 4.0 actually represent contributions to the industrialisation at the level of Industry 3.0.[103] Therefore, the technological main differences will be explained to address a clear separation.

[98] See Oesterreich and Teuteberg (2016) p.122-123; Smit, Kreutzer, Moeller, and Carlberg (2016), p. 20-21.
[99] See Hermann, Pentek, and Otto (2016), p.392.
[100] See Stock and Seliger (2016), p. 537-538.
[101] See Pfohl, Yahsi, and Kurnaz (2015), p. 37; Roblek, Meško, and Krapež (2016), p. 2-3.
[102] See Kagermann, Helbig, Hellinger, and Wahlster (2013), p. 18; Wang, Wan, Li, and Zhang (2016),p. 2-3; Sanders, Elangeswaran, and Wulfsberg (2016), p. 816.
[103] See Torn (2017), p. 18.

Industry 3.0 is based on the development and usage of information technology, that accelerates the automation of production.[104] According to Torn (2017), the technological breakthrough was the development of a logical control system at the end of 1960.[105] Hence, the technological development paved the way for the triumph of the Information and Technology sector and computers throughout the industry and society. As a result, the automation increased, and the digitalisation began. However, the processes follow mainly a siloed approach and focus only in an advanced stage on the horizontal integration within organisations.[106] Furthermore, computers and digitalisation are highly depended on human input, because the machines and computers are not ready to solve problems by themselves. Consequently, the main demarcation between the Industry 3.0 and 4.0 can be explained as the shift from focusing on single processes to an autonomous end to end approach that encompasses the digitalization of all physical assets, as well as the inclusion of digital interlinked supply chains.[107] Hence, the Human-Machine interface, digitalisation and automation within the Industry 3.0 transform to the M2M communication, CPS and autonomous self-optimising systems within the Industry 4.0 environment.[108] However, some authors attribute these shifts to the development of the Industry 3.0. Nonetheless, Industry 3.0 is delimited by the autonomous decision making based on advanced artificial intelligence.[109] Thus, the distinction is crucial to decrease the risk that Industry 3.0 e-purchasing solutions are relabelled as fully Industry 4.0 ready. Hence, the technological progress might not happen or is slowed down significantly.[110]

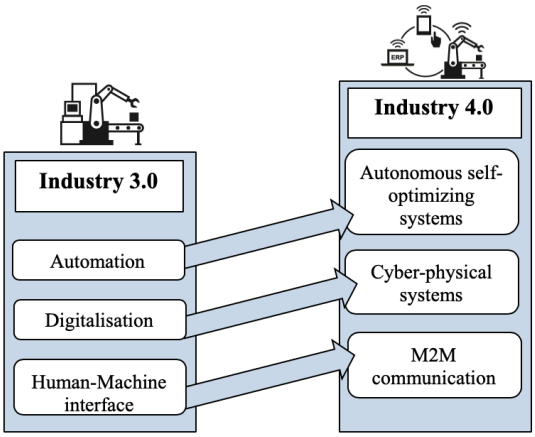


Figure 3: Modern characteristics of Industry 4.0 based on Schiele (2018), p. n.a.

[104] See Zhou, Liu, and Zhou (2015), p. 2147.
[105] See Torn (2017), p. 18.
[106] See Torn (2017), p. 18-20.
[107] See Geissbauer, Vedso, and Schrauf (2016), p. 6.
[108] See Schiele (2016), p. 16-17; Schiele (2018), p. 8.
[109] See Torn (2017), p. 18.
[110] See Torn, Pulles, and Schiele (2018), p. 4.

2.4. New technologies as foundation of Industry 4.0 and future e-purchasing

2.4.1. Clarifying the key driving technologies for future e-purchasing

The goal of this section is to understand the relevance of the most important interrelated technologies and concepts of the Fourth Industrial Revolution in relation to e-purchasing in order to gain fundamental knowledge to develop the maturity model and to establish the e-purchasing vendor classification. The aim hereby lies on the basic insights of the functionality of the different components rather than on the technical details, as the overall work follows a business perspective.

A comprehensive content analysis by Oztemel and Gursev (2018) of 620 publications on technologies within Industry 4.0 declares the core concepts to be: Cyber-physical systems (CPS), Cloud systems, Machine to Machine communication, Smart factories, Big Data, Internet of things (IoT), simulation tools, artificial intelligence and the processing of real-life data.[111] This view is mainly shared by Oesterreich and Teuteberg (2016) who reviewed 280 publications on Industry 4.0 and added robotics as an important technology.[112] Furthermore Kang et al. (2016), analysed various articles related to the Industry 4.0 and state that the major technologies are CPS, IoT, Big Data, Cloud Computing and Sensors.[113] The outcome of the BMS Smart Industry Research Roadmap by the University of Twente towards the Fourth Industrial Revolution is matching with the previously identified major technologies. Moreover, the report declares digital twins, 3D printing and blockchain technology as important.[114]

According to Bienhaus and Haddud (2018), are the key drivers for digitised and Industry 4.0 oriented purchasing activities Artificial Intelligence and Big Data. Additionally, Bienhaus and Haddud (2018) explain that the real-time flow of information requires appropriate sensor technologies.[115] Moreover, Högel et al. (2018) and Biltoft-Knudsen et al. (2018) add that the automation and autonomisation through RPA and AI, as well as Cloud-based data storage and Blockchain technology is crucial for the transformation of purchasing.[116] Furthermore, Choi et al. (2017) explain that Smart Manufacturing connects purchasing, production, logistics and the products through unified CPS.[117] Overall, the

[111] See Oztemel and Gursev (2018), p. 10.
[112] See Oesterreich and Teuteberg (2016), p. 128.
[113] See Kang et al. (2016), p. 117.
[114] See The Industry Working Group of Universiteit Twente (2018), p. 22.
[115] See Bienhaus and Haddud (2018), p. 976.
[116] See Högel et al. (2018), p. 3; Biltoft-Knudsen, Desi, Gardy, Schnellbächer, and Weise (2018), p. 4-6.
[117] See Choi, Kang, Jun, Lee, and Han (2017), p. 290-291.

main technologies regarding future e-purchasing will be reviewed separately in the following.

2.4.2. The success of the IoT depends on standardised information exchange

The Internet of Things (IoT) can be described as a network of sensors that interact and communicate wirelessly.[118] The term IoT was initially assigned to the connection between uniquely identifiable interoperable objects and radio-frequency identification (RFID) technology.[119] Today, the IoT can be defined as a "dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual 'Things' have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network."[120] In addition, Hermann et al. (2016) state that the „IoT allows 'things' and 'objects', such as RFID, sensors, actuators, mobile phones (...) to interact with each other and cooperate with their neighbouring 'smart' components, to reach common goals."[121] The IoT provides the infrastructure that enables the integration of the physical world into virtual computer-based system which can be considered as the first step for the development of self-sensed and self-controlled objects.[122] Furthermore, Kang et al. (2016), declare that the IoT is not only a platform but also provides the interface basis towards the operators.[123]

The radio-frequency identification technology is foundational for the IoT and allows the wireless communication of microchips by transmitting identification information to a reader. Consequently, the RFID-technology enables the identification, tracking and monitoring of objects attached with RFID tags.[124] Besides RFID-technology the Wireless sensor networks (WSN) technology is also foundational for the IoT. WSN refers to dispersed and specialized sensors that are able to monitor and record the physical conditions of objects or environment, such as monitoring the temperature evolution while transmitting the gathered data to a central location.[125]

M2M communication has been already in commercial use within the last decade and is

[118] See Oztemel and Gursev (2018), p.2.
[119] See Da Xu, He, and Li (2013), p. 2233.
[120] Da Xu et al. (2013), p. 2233.
[121] Hermann et al. (2016), p. 3929.
[122] See Kang et al. (2016), p. 120-121.
[123] See Kang et al. (2016), p. 120-121.
[124] See Da Xu et al. (2013), p. 2234; Sun (2012), p. 107.
[125] See Lin, Chen, Zhang, Guan, and Shen (2016), p. 1.

relying on RFID and WSN technology.[126] M2M is focused on the connectivity of objects within closed processes in order to improve the visibility and monitoring. By now, M2M is the most IoT alike technology in commercial use and an important basis for the development of fully fledged IoT systems.[127] The main challenge for the fully-fledged IoT and the main difference to the M2M communication is the vertical and horizontal connectivity and communication between and within different systems in order to achieve the most benefit over the whole value chain Currently, the M2M is the most IoT alike technology in commercial use and an important basis for the development of fully fledged IoT systems.[128]

Overall, the quality of IoT is depended on the technical standards for the information exchange, processing and the communication protocols.[129] Hence, a standardization of the IoT is mandatory for the fundamental success of fully-fledged Industry 4.0 oriented e-purchasing solution.[130] Thus, the IoT supports an increased spend visibility and in-depth insight for the supply usage. As a result of the increased connectivity, mobile purchasing will increase and become a stronger element in the purchasing strategy.[131]

2.4.3. Cloud and Blockchain technology support the transmission of Big Data

The tremendous growing use of sensors, smart devices and networked machines has resulted in the constant generation of high-volume data, also known as Big Data. The term generally refers to a data set that is not processable by traditional data process approaches, due to the complex structure, wide range and size.[132]

Big Data is characterised through the three V´s: Volume, Velocity and Varity. The Volume describes the quantity of the generated data whereas the size of the data determines the potential value and if it can be considered as Big Data.[133] The Variety outlines the diversity of the data gathered from different sources. Moreover, Big Data is often accessible in real-time and cannot be categorized into regular databases.[134] In the field of e-purchasing the gathering of Big Data builds the foundation for predictive analytics and enables more

[126] See Alam, Nielsen, and Prasad (2013), p. 112.
[127] See Alam et al. (2013), p. 113-114.
[128] Alam et al. (2013), p. 113-114.
[129] See Bandyopadhyay and Sen (2011), p. 52-53.
[130] See Spend Matters (2015), p. n.a.
[131] See Jaggaer (2018), p. n.a.
[132] See Hashem et al. (2014), p. 2.
[133] See Hilbert (2016), p. 136-137.
[134] See Hashem et al. (2014), p. 4-5; See Kitchin and McArdle (2016), p. 1-2.

detailed insights into the organisational demand, supplier quality and commodity management.[135]

In the context of the IoT, the handling and transmission of Big Data offer different approaches. The two main approaches are cloud computing which relies on a central database and blockchain technology that follows a decentralized concept.[136] Firstly, cloud computing provides affordable storage to handle the generated data. Moreover, cloud computing "is a model for allowing ubiquitous, convenient, and on-demand network access to a number of configured computing resources (e.g., networks, server, storage, application, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction."[137] Further benefits are the minimisation of infrastructure maintenance costs, user accessibility and increased efficiency.[138]

Secondly, blockchain technology follows the distributed ledger technology. Thus, data is processed, handled and stored based on smart contracts in various servers or a peer to peer network, rather than in a central cloud. The key benefit of the blockchain approach is twofold. Firstly, transparency and data security, as well as nonrepudiation is achieved through decentralisation, because all members within one chain have to verify every activity.[139] Therefore, it is almost impossible to manipulate e-purchasing transaction. Secondly, the possibility of a cloud server downtime has been eliminated, due to the fact that all included devices within the blockchain hold identical information.[140]

2.4.4. Business Intelligence streamlines Data, RPA supports process driven automation and AI supports data driven decision making

It is within Business Intelligence that Big Data can be mined and processed. The processing is based on probability calculations, correlations and the identification of subliminal patterns with the goal produce valuable information and knowledge. The current global digital transformation is based on the processing of Big Data with the perspective to achieve increased profitability and competitive advantages.[141] As a result, organisations make use of advanced algorithms to create a new degree of innovation,

[135] See Smith (2018), p. n.a.
[136] See Kshetri (2017), p. 68.
[137] Mell and Grance (2011) p. 2.
[138] See Kagermann (2015), p. 26
[139] See Schiele et al. (2018), p. 22.
[140] See Kshetri (2017),p. 70.
[141] See Zhong, Newman, Huang, and Lan (2016), p. 573.

intelligence and collaboration within the supply chain. Moreover, Kang et al. (2016) explain that the readiness of intelligent predictive simulation technologies is depended on the autonomy of algorithms in terms of their self-learning and self-maintaining capabilities.[142]

Self-maintaining and self-learning algorithms refer to Artificial Intelligence (AI). Artificial Intelligence and Robotic Process Automation (RPA) are used interchangeably by practitioners.[143] However, both technologies vary largely in their applicability. As aforementioned stated relies AI on the possibility to be self-aware, hence imitating humans' ability to make decisions, to perform tasks and interact with other humans.[144] On the other hand, RPA mimics only human's behaviour based on a fixed and simple set of rules. Consequently, RPA is used to automate processes within a fixed environment without being self-aware.[145] The best way to explain the difference is by using the following example of electronic invoice processing. Firstly, a supplier sends an invoice by email to the buying organisation and the responsible person has to download the invoice, extracts the relevant data, copies the invoice to a specific folder and forwards it to the accountants and so on. However, RPA is suitable to automate the groundwork of retrieving a standardised e-mail, extracting the relevant information based on specific rules, downloading the invoice into a specific folder and forward it to the accountants. Otherwise, AI is required to read and understand the unstructured invoice and extract the relevant information by itself, while making simultaneous decisions on how to proceed.[146] In the example case the used subset of AI is the Natural-Language-Processing (NLP) technology.[147]

2.4.5. CPS as the embedded system of the future

Contrary to traditional embedded systems, which are composed as stand-alone devices, is the focus of cyber-physical systems on networking various devices.[148] Cyber-physical systems can be defined as transformative technologies that manage interconnected systems between computing entities and the surrounding physical world.[149] According to Monostori

[142] See Kang et al. (2016), p. 9.
[143] See CFB Bots (2018), p. n.a.
[144] See CFB Bots (2018), p. n.a.
[145] See Braun (2019), p. n.a.
[146] See CFB Bots (2018), p. n.a.
[147] See Jain and Woodcock (2017), p. 5.
[148] See Jazdi (2014),p. 1-2.
[149] See Lee, Bagheri, and Kao (2015), p. 18.

(2014), the collaboration between the virtual and real world is an on-going process, that provides and uses real-time data which are available on the internet, where the autonomous and cooperative elements act as key drivers of the CPS.[150] Furthermore, Lee, Bagheri and Kao (2015) state that CPS consist of two main components. The first component refers to the advanced connectivity that ensures real-time data acquisition from the physical world and information feedback from the cyber-space, whereas the second component is described as the intelligent processing of data, through advanced analytics that constructs the cyber-space.[151] CPS refer mainly to the intelligent manufacturing approach of the Industry 4.0. However, the sharing of information, autonomous decision-making and advanced communication are based on the cross-linked connection of various value creation modules within the value chain and include further value chain activities such as purchasing, service or sales.[152]

2.5. Maturity- and Quadrant Models support the classification of organisations or processes

2.5.1. Design Principles of maturity models based on Pöppelbuß & Röglinger

In order to construct a valuable maturity model, the design principles by Pöppelbuß and Röglinger as can be seen in Appendix I have been considered. The concept of maturity models is based on the assumption of predictable patterns. Therefore, these models guide and aid in a stage by stage manner how organisational capabilities should evolve to reach the desired level of sophistication. The model serves as an evaluation instrument, in which every maturity level contains the respective characteristics of previously defined objects and their required characteristics.[153] According to Mettler and Rohner (2009), typical classes are organisations, processes, or other objects from a specific application domain.[154] Another distinction draws on the resource-based view of the firm where resources are classified into assets and capabilities.[155] Following Schiele (2007), the assumption is that advanced maturity is associated with better performance.[156]

According to Pöppelbuß and Röglinger (2011), the purpose of maturity models can be divided into three types, namely descriptive, prescriptive and comparative. Fundamental

[150] See Monostori (2014), p. 9-10.
[151] See Lee et al. (2015), p. 19.
[152] See Stock and Seliger (2016), p. 539.
[153] See Pöppelbuß and Röglinger (2011), p. 2.
[154] See Mettler and Rohner (2009), p. 1-2.
[155] See Wade and Hulland (2004), p. 108-109.
[156] See Schiele (2007), p. 274.

for all types is that the characterisation of each stage has to be in a logical relationship and sequence. Firstly, the descriptive purpose refers to the maturity model as a diagnostic tool that asses the current as-is situation, while investigating the current capabilities. Secondly, the model serves a prescriptive purpose if it indicates how a desirable stage can be assessed by providing a guideline for the improvement. Thirdly, the maturity model is used within a comparative purpose to allow internal or external benchmarking. Therefore, sufficient data from similar organisations or processes have to be gathered.[157]

De Carolis et al. (2017) agree with the three types of distinction and further explain that the distinctions picture the regular evolutionary process of a model's lifecycle. Accordingly, every model can be considered as descriptive in the first phase, with the goal to achieve a deeper understanding within its current domain. Consequently, the maturity model can be evolved towards a more prescriptive purpose, based on a deeper understanding of the desired situation and substantial and repeatable improvements. Finally, the comparative purpose depends on the distribution and usage in a wide range in order to gain sufficient data to achieve valid comparison.[158]

The basic principles of every maturity model should address the target group, purpose of use, classification of entities, the central construction of maturity and the target group-oriented documentation.[159] Furthermore, Pöppelbuß and Röglinger (2011) explain that a model with a descriptive purpose has to include the assessment criteria for each maturity stage.[160] Thereby, Maier, Moultrie and Clarkson (2012) add that the descriptions of the different stages should be precise and concise in order to mitigate in-between levels. Moreover, the authors explain that the purpose of the maturity model can be considered as prescriptive if the model includes improvement measure for each maturity stage.[161] However, it is noteworthy that not every maturity model has to meet all design purposes. Instead, the guideline intends to assist researchers and practitioners while designing a new maturity model or comparing existing ones.[162]

[157] See Pöppelbuß and Röglinger (2011), p. 4-5.
[158] See De Carolis, Macchi, Negri, and Terzi (2017), p. 14.
[159] See Pöppelbuß and Röglinger (2011), p. 7-9.
[160] See Pöppelbuß and Röglinger (2011), p. 7-9.
[161] See Maier, Moultrie, and Clarkson (2012), p. 150.
[162] See Pöppelbuß and Röglinger (2011), p. 6.

2.5.2. Review of related maturity models to justify the development of a new model

According to Becker, Knackstedt and Pöppelbuß (2009), the need to develop a new maturity model has to be justified, by reviewing existing models that may provide the same purpose.[163] Moreover, the second objective of this chapter is to gather fundamental insights into the architecture and maturity stages of related maturity models. Therefore, two literature searches have been conducted from February 2019 to March 2019 using Scopus and Google. Scopus has been chosen to gather the most relevant and recent academic maturity model propositions towards the Industry 4.0.

The first search included the following terms: maturity model, capability model, Reifegradmodell and Industry 4.0. This resulted in 56 articles, which were selected based on their abstract with regard to their relevance. Furthermore, publications were only considered when they provided a full maturity model including the dimensions. In order to obtain relevant models from practitioners, hand search was conducted, using Google. Hereby, the focal point was on the publications of the Big4 Consulting firms PWC, KPMG, EY and Deloitte. The goal of this search was to review how the different authors defined the different stages towards Industry 4.0 maturity. Consequently, eleven studies were selected as can be seen in Table 1.

[163] See Becker, Knackstedt, and Pöppelbuß (2009), p. 218.

No.	Type	Author	Year	About	No. of Dimensions	No. of Maturity Levels
1	Aacademic	Ganzarain and Errasti	2016	Offers a strategic path for the I4.0 digitisation of SME.	3	5
2	Aacademic	Leyh et al.	2016	SIMMI 4.0 focuses on the evaluation of IT capabilities.	4	5
3	Aacademic	Schumacher et al.	2016	Focus on manufacturing organisations.	9	5
4	Aacademic	De Carolis et al.	2017	Offers a roadmap for I4.0 digitisation of manufactoring firms.	4	5
5	Aacademic	Gökalp and Sener	2017	Offers holistic approach on assessing Industry 4.0 in manufactoring firms.	5	6
6	Aacademic	Klötzer and Pflaum	2017	Offer digitalisation based on smart products and smart applications.	9	5
7	Aacademic	Asdecker and Felch	2018	Offers an I4.0 maturity model for logistics.	3	5
8	Practitioner	PWC	2016	Focuses on industrial capabilities.	6	4
9	Practitioner	KPMG	2016	The DRA analyses the state and quality of relevant areas of your company from several different perspectives.	4	4
10	Practitioner	Ernst & Young	2018	The DRA and benchmarking tool enables organisations to benchmark its digital maturity across several areas.	7	4
11	Practitioner	Deloitte	2018	The DMM evaluates the digital capabilities to create a holistic view of digital maturity across the organisation.	5	n.a.

Table 1: Overview of Industry 4.0 maturity models

Within all reviewed academic publications, the number of maturity levels is five, except for the paper of Gökalp, Sener and Eren (2017) who propose six levels.[164] Additionally, more commonalities between the levels of maturity become apparent, such as the fact that the model's number 2,3,5,6 and 7 all view self-optimisation as the final stage. Overall, the different maturity levels are closely related and depend on the perspective of the focal point. The result of the review demonstrates that the majority of published models assess either the whole organisation as can be seen by number 1,8,9,10 and 11 or focus on the manufacturing aspects such as number 3,4,5. However, number 2 focuses on the IT capabilities of organisations and number 7 on logistic processes. The maturity models developed by consulting firms also target the whole organisation. While PWC and KPMG describe four stages of maturity, EY considers three stages whereas Deloitte does not provide any insight on the maturity levels.

The second search included the following terms maturity model, capability model, e-procurement, procurement, e-purchasing, purchasing and Industry 4.0 with a limitation to the 4 recent years. This resulted in 12 documents where two met the requirements. Subsequently, the search was expanded by changing the composition of search terms. As a

[164] See Gökalp, Şener, and Eren (2017), p. 11-12.

result, one further document could be obtained. Additionally, Morsinkhof's research was enclosed in the overview. In order to include practitioner models, the publications of the same consulting firms as aforementioned have been reviewed.

No	Type	Author	Year	About	No. of Dimensions	No. of. Maturity Levels
1	Academic	Tontini et al.	2016	Self-evaluation of procurement management maturity, applicable to small and medium-size companies.	4	4
2	Academic	Kleemann and Glas	2017	The maturity model serves as first orientation towards Purchasing 4.0.	8	5
3	Academic	Renault et al.	2018	This paper presents a design of a procurement processes assessment model.	3	n.a.
4	Academic	Morsinkhof	2019	Self-Assessment maturity model for the purchasing department.	7	4
5	Practitioner	PWC	2016	A framework for organisational changes that the 21st-century brings to procurement.	6	n.a.
6	Practitioner	Deloitte	2016	Leveraging advanced concepts today, exploring the possibilities for tomorrow.	4	2
7	Practitioner	Ernst & Young	2017	Offers the assessing of procurement departments incl. as-is situation and desired level.	9	2

Table 2: Overview of Purchasing maturity models

As can be seen in Table 2, the current literature provides no maturity model that focus on e-purchasing in the context of Industry 4.0. Hence, the lack of a maturity model, that supports the assessment of different e-purchasing solutions in the context of Industry 4.0 sophistication has been justified.

Within all reviewed maturity models, the number of maturity levels varies between three and seven. However, Torn (2017) explains that four maturity levels provide two advantages and are preferable to cover the most relevant stages. "First, the boundaries of stages are more clearly defined compared to models with three stages, because the stage in the middle is split in two distinctive groups. Second, the three central stages of models using five stages tend to become ambiguously since the differences between stages are too small."[165] By considering Torn's (2017) explanation, it seems most reasonable that the new maturity model contains four stages.

2.5.3. Gartner's and Capgemini's Quadrant classifies software vendors into 4 types

This chapter reviews the widely recognised quadrant models of Gartner Inc. and Capgemini. Moreover, the architecture in terms of axes and rated aspects will be analysed

[165] Torn (2017), p. 65.

to acquire knowledge for the construction of a quadrant model that captures and visualises the outcome of the new developed e-purchasing solution maturity model.
Gartner's Magic Quadrant has been introduced to provide a graphical positioning of technology suppliers. The quadrant aims to provide an overview of the competing players in selected markets. Therefore, Gartner Inc. bases the visualisation and evaluation on two main criteria, namely the ability to execute (x-axes) and the completeness of vision (y-axes).[166] The final quadrant is subdivided into for types which estimate the classification, as can be seen in the following.

"- Niche Players focus successfully on a small segment, or are unfocused and do not out-innovate or outperform others;
- Challengers execute well today or may dominate a large segment, but do not demonstrate an understanding of market direction
- Visionaries understand where the market is going or have a vision for changing market rules, but do not yet execute well;
- Leaders execute well against their current vision and are well positioned for tomorrow"[167]

Focusing on e-purchasing Gartner Inc. proposed two "Quadrants" in 2018, namely the "Magic Quadrant for Procure-to-Pay Suits" and the "Strategic Sourcing Quadrant". Hereby Gartner has strict rules about the inclusion of vendors. As an example, vendors who want to participate in the "Procure-to-pay" Quadrant had to have "…a minimum of five new clients in 2016 each with annual revenue or operating budget over $1 billion"[168] or as for the "Strategic Sourcing Quadrant", the vendors had to have "…offices of their own, excluding partners, on two or more continents."[169] As a result, Gartner's research excludes regional SME software vendors and their solutions upfront.
The matching vendors have been assessed based on the criteria as can be seen in Table 3. It is noteworthy, that Gartner Inc. does not provide a more transparent explanation on their assessment. In order to obtain data, Gartner Inc. conducts surveys, briefings, interviews, discussions and product demonstrations.[170]

[166] See Canito, Ramos, Moro, and Rita (2018), p. 2.
[167] Black and Thomas (2013), p. n.a.
[168] Edwards, McNeill, Bergfors, Connaughton, and Sommers (2018), p. 26.
[169] Bergfors, Connaughton, Edwards, McNeill, and Sommers (2018), p. 18.
[170] See Canito et al. (2018), p. 2.

Sourcing Suits:	Completeness of vision	Weighting	Ability to execute	Weighting
	Market understanding	Medium	Product or Service	High
	Marketing strategy	Not rated	Overall Viability	Medium
	Sales strategy	Not rated	Sales Execution/ Pricing	Medium
	Offering (product) strategy	High	Market Responsiveness	Medium
	Business model	Not rated	Marketing Execution	High
	Vertical/Industry strategy	Medium	Customer Experience	High
	Innovation	High	Operations	Medium
	Geographic strategy	High		
P2P Suits:	**Completeness of vision**	**Weighting**	**Ability to execute**	**Weighting**
	Market understanding	Medium	Product or Service	High
	Marketing strategy	Not Rated	Overall Viability	Medium
	Sales strategy	Not Rated	Sales Execution/ Pricing	Medium
	Offering (product) strategy	Medium	Market Responsiveness	Not Rated
	Business model	Medium	Marketing Execution	Medium
	Vertical/Industry strategy	High	Customer Experience	High
	Innovation	High	Operations	Medium
	Geographic strategy	Medium		

Table 3: Gartner Inc.'s assessment criteria based on Edwards et al. (2018), p. 26; Bergfors (2018), p.18.

Capgemini is a well-known consulting firm that presented their "Digital Procurement Research Report" in 2018. Capgemini's research report aims to evaluate offered EP-solutions in terms of their width and depth of offering. Therefore, Capgemini conducted a survey consisting of 614 questions to obtain data for the quadrant model. The quadrant is divided into four categories, namely the Compliant, Specialist, Generalist and All Star, which estimate the classification of assessed vendors. Firstly, the Complaints offer solutions that are limited in width and depth and provide basic functionalities. Secondly, the Specialists provide solutions that are limited in width but extensive in depth, such as well-developed contracting solutions. Thirdly, the Generalists offer solutions that are broadly applicable but limited in depth. Lastly, the All Stars provide solutions that are widely applicable combined with a thorough deepness.[171]

The rated aspects of the research encompassed Supplier Management, Strategic Sourcing, Contract Management, Purchasing, Accounts Payable, Reporting & Analytics as well as the Master Data Management in order to determine the score for the width. The depth was based on the following answer possibilities: Yes, No, On the Roadmap. Contradicting to Gartner Inc., Capgemini included any vendor that provides a solution within the e-

[171] See Capgemini (2018), p. 10.

purchasing process.[172] Moreover, Capgemini's research offers more detailed insights into the assessment and graphical positioning.[173] Hence, the report explains, "if a provider covered 5 out of the 29 possible sub-sections, the maximum score was determined based on these specific 5 sub-sections. If the maximum score for these 5 sub-sections together was 1000 points, and the provider gained 500 points, their depth would be 0.5 (50%). This was done for each sub-section individually, to make sure each provider's depth was assessed fairly based on the functionality they could have offered within the sub-sections covered."[174]

[172] See Capgemini (2018), p. 12.
[173] See Capgemini (2018), p. 13.
[174] Capgemini (2018), p. 13.

3. The Methodology provides insights into the Design Science Research approach and data collection

3.1. Following Peffers et al. design science framework to develop an EP-solution Maturity Model

This section contains insights into the research approach adopted for this study. Due to the explorative nature and the practical problem-solving approach the Design Science Research (DSR) framework of Peffers et al. (2007) has been used to structure the research process. Design Research distinguishes itself by an iterative development and validation process for the development of new artefacts that are added to the body of knowledge.[175] Hence, DSR is preferable to support an early phase of research into different sections and builds the basis for future research. Besides these scientific contributions, developed artefacts provide a practical application for the organisational environment into which the solution is realised.[176] Artefacts can be broadly defined as models, methods and constructs.[177] In this context, different authors estimated that the development of maturity models is subject to the application area of the DSR guidelines by Hevner et al. (2004) as they combine state descriptions (i.e., models of distinct maturity levels) with activities (i.e., methods for conducting assessments, recognising need for action, and selecting improvement measures.[178] Hence, the following guidelines have been included to support this research. First, the research has to produce a viable artefact. Second, the objective has to target an important and relevant business problem. Third, the developed artefact has to be demonstrated in an organisational context. Fourth, the research has to provide clear contributions to the research area of the artefact. Fifth, the research has to rely on a rigorous framework.[179]

The development of the e-purchasing solution maturity model begins with the design focused business problem-solving approach within the design science research.[180] Peffers et al. (2007), explain that the problem-centred approach is mostly applicable if the idea for the exploration resulted from research based on a different paper.[181] The approach to develop a maturity model to assess compare different e-purchasing solutions resulted from the lack of a suitable model in literature and the work of Morsinkhof (2007). Morsinkhof's model supports the assessment of Industry 4.0 sophistication within purchasing

[175] See Peffers et al. (2007), p. 72.
[176] See Peffers et al. (2007), p. 72.
[177] See Hevner, Salvatore, Jinsoo, and Sudha (2004), p. 77.
[178] See, Jansz and Back (2011), p. 2-3.
[179] See Hevner et al. (2004), p. 88.
[180] See Peffers et al. (2007), p. 56.
[181] See Peffers et al. (2007), p. 56.

organisations.[182] Hence, it is valuable to develop a stand-alone model which fills the gap in literature but also works complementary to Morsinkhof's maturity model.

By pulling together e-purchasing needs and Industry 4.0 enabled capabilities, a new artefact in the form of the maturity model and connected quadrant model is developed and evaluated. To ensure rigorous results, this thesis follows the structured process by Peffers et al. (2007). Moreover, the research is guided by the principles for design science research by Hevner et al. (2004) as can be seen above.[183]

The research framework is visualised and shown in Figure 4. As the research contains several stages and data sources, it is beneficial to visualise every stage and the used research method. The problem identification and objective have been explained in the beginning. Furthermore, the paper specifies the research problem and objective in order to provide practical relevance and justification for the development of a new maturity model. The design & development phase refers to the second and fourth section of the thesis. Lastly, the demonstration and evaluation of the maturity model have been conducted to review the applicability, obtain a technology update of the market and to classify selected vendors in a linked quadrant model.

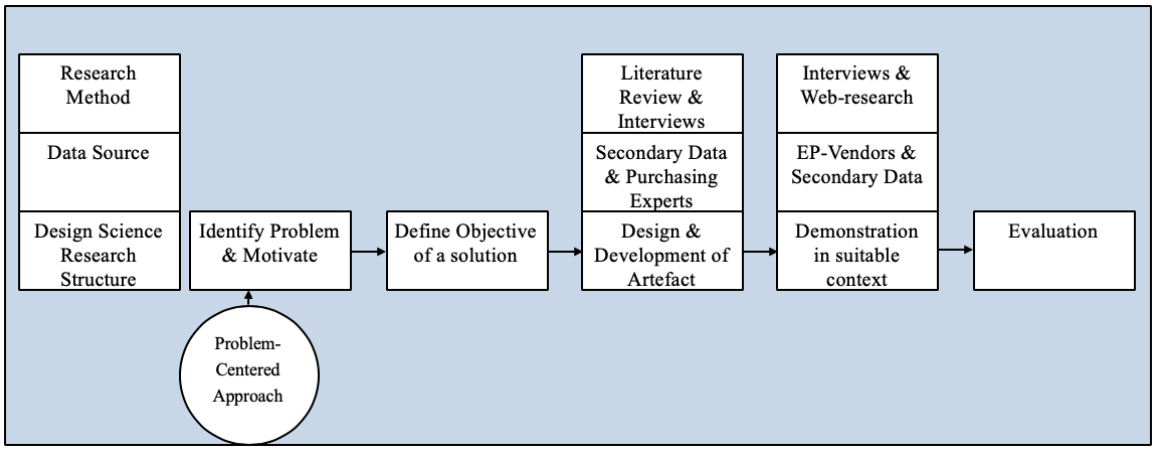


Figure 4: Design Science Research Approach to develop an artefact based on Peffers et al (2007), p. 54.

[182] See Morsinkhof (2018), p. 58-59.
[183] See Hevner et al. (2004), p. 83.

3.2. Data collection for the development of the maturity model consists of Literature and Interviews

3.2.1. Conducting literature reviews to gain knowledge for the model development

The DSR framework can be considered as an umbrella approach which ties together different data collection methods for the purpose of developing an artefact.[184] In the following will be explained how secondary data was used to create the draft version of the model, which has been finalised through the input of semi-structured Interviews with industry experts.

In the beginning, a comprehensive literature review has been conducted, in order to gain in-depth insights into the topics and to establish a draft version of the model to build further upon. The literature review encompasses the topics of purchasing, e-purchasing, e-sourcing, e-procurement, Industry 4.0 and its major technologies. The primary search engines were Scopus and Google Scholar. In order to obtain the most recent information regarding e-purchasing, articles from well-known e-purchasing software vendors have been included.

In order to justify the development of a new maturity model, two structured literature searches on Scopus and Google Scholar from February - March 2019 have been conducted. The first search included the following terms maturity model, capability model, Reifegradmodell and Industry 4.0. The second search included the terms maturity model, capability model and e-procurement, procurement and purchasing with a limitation to the 4 recent years. In addition, hand search has been conducted to include relevant publications of the Big 4 Consulting firms PWC, KPMG, EY and Deloitte. The results lead to the confirmation that there is currently no applicable model which supports the assessment and classification of e-purchasing software solutions.

3.2.2. Conducting Semi-structured Interviews with experts to expand the model

Semi-structured Interviews with purchasing experts have been conducted as part of the iterative development process.[185] With the purpose to verify and optimise the included purchasing dimensions, the selection of the interview partners was based on their professional origin. Therefore, the following criteria had to be fulfilled: professional purchaser or purchasing consultant, knowledge of procurement, sourcing, e-purchasing and basic knowledge of the Industry 4.0. Before approaching the professionals, an interview

[184] See Hevner et al. (2004), p. 83.
[185] See Peffers et al. (2007), p. 54.

guide has been developed. Furthermore, a pilot interview has been conducted with a fellow master student from the track "Purchasing and Supply Management" to point out complications with the comprehensibility and timing.

1)	Which purchasing dimension or subtopic is missing in the conceptualised maturity model? (Reviewing the different dimensions)
2)	How would you describe the construction of the model in the context of usability and comprehensiveness to assess and classify e-purchasing vendors?
3)	Based on your experience, in which stage would you place the most software solutions in your working environment?
4)	General remarks?

Table 4: Guiding questions for Expert-Interviews

In order to establish a certain degree of variation, purchasing managers and purchasing consultants from different companies have been contacted through "Linkedin" in February 2019. The semi-structured interviews followed the interview guide as well as the draft version of the newly developed model. Further questions were asked when the interview partners offered more insight into specific dimensions. All interviews were estimated to last 40-45 minutes and could be conducted by telephone in German. Therefore, the participants received the model three days in advance with instructions and the request to get a little familiar with the model upfront.

No.	Titel	Type	Number of employees (complete organisation)	Duration
1	Interviewer 1	Strategic Purchaser	20.000-30.000	00:48:34
2	Interviewer 2	Purchasing Consultant		00:34:30
3	Interviewer 3	Strategic Purchaser	50.000-60.000	00:46:13
4	Interviewer 4	Strategic Purchaser	800-1000	00:42:48

Table 5: Overview of interviewed Experts for the iterative development process

Consequently, three strategic purchasers and one purchasing consultant have been contacted for the interviews which resulted in 2,7 hours of interview data. The statements and findings of the experts about the comprehensiveness were similar and resulted in valuable feedback about the model which lead to the extension of two dimensions by the Financial Supply Chain and Supplier Risk management sub-dimensions.

3.3. Data collection for the evaluation and classification of vendors consists of Interviews and Web-research

3.3.1 Conducting Semi-structed Interviews with vendors to assess the model and facilitate the classification

The purpose of the data collection is threefold. Firstly, by assessing various e-purchasing solution vendors the proposed evaluation stage by Peffers et al. (2007) has been conducted.[186] Secondly, the gained insights have been used to obtain a market overview with regards to the Industry 4.0 innovativeness of the assessed solutions. Thirdly, the collected data was used to classify the solutions in the linked quadrant model.

The semi-structured interviews with software vendors have been conducted at the two-day fair "BME E-Lösungstage 2019" in Düsseldorf. The reason for this is twofold. Firstly, the fair has a high reputation, as one of the leading fairs in Europe for e-solutions.[187] Hence, the most important and innovative solution providers in the field of e-purchasing attend this event. Secondly, the previous undertaken contact approaches via phone, mail and Linkedin lead to a non-existent response rate. Consequently, 22 vendors have been preselected based on their attendance of the e-solution fair, whereas 10 vendors agreed to participate.

The 9 semi-structured interviews with partial product demonstrations, lasted between 25 to 40 minutes, depending on the scope of the functionality of the solution. During the interviews, it was taken care that only one vendor at a time responded and no further visitor of the fair disturbed the interview. Therefore, the interview approaches were as early as possible, during keynote speeches where the majority of visitors faced presentations in different locations or at the end of the fair. Based on the fact that the vendors had no preparation time an introduction of the model took place up front. After settling all questions regarding the model, the vendors gave answers based on the different dimensions. Hereby, the maturity model functioned as an interview guide. Depended on the responses, additional questions were asked to verify a certain status.

The goal of the semi-structured interviews during the fair were threefold. Besides accessing different solutions to provide a market overview and valuable input for the classification, the interviews functioned as application test by applying the maturity model in the right organisational context, which was meaningful to verify its usability. Hence, the interview partners were asked how they perceived the usability and comprehensiveness of the newly developed model. There was consent among the interview partners that the

[186] See Peffers et al. (2007), p. 56.
[187] See BME Verband (2019), p. n.a.

model is comprehensive and easy to use if the accessor has enough background knowledge. Nonetheless, a few vendors also explained that they would improve the model by applying a different weighting of the criteria based on the importance of the various functions and dimensions. Lastly, it is noteworthy that even though the maturity model asked for the "planned vision or roadmap" of the respective vendors, no vendor could provide a sufficient answer.

No.	Company	Founded	No. of employees	Users	Headquarter	Country
1	Allocation Network GmbH	1998	48	55.000	Munich	Germany
2	Smart by GEP	1999	3364	n.a.	Clark, New Jersey	USA
3	Netwtron GmbH	1998	70	n.a.	Hamburg	Germany
4	MySupply Expertist Vertriebs GmbH	2018	10	n.a.	Hamburg	Germany
5	Onventis GmbH	2000	70	n.a.	Stuttgart	Germany
6	OpusCapita Software GmBH	1984	400	1. Mio	Helsinki	Finland
7	SAP Ariba	1999	3500	11. Mio	Palo Alto, California	USA
8	Zycus Infotech Pvt. Ltd.	1998	1250	n.a.	Princeton, New Jersey	USA
9	SynerTrade S.A.	2000	330	378.000	Neuilly-sur-Seine	France

Table 6: Overview of evaluated e-purchasing vendors: Semi-structured interview

3.3.2. Conducting Web-research to verify interviews and expand the number of assessed solutions

Web-research has been conducted in order to verify the interview responses and different scores of assessed solutions. Furthermore, web-research has been conducted to assess well-recognized vendors such as Basware, Coupa, Ivalua and Jaggaer. The web-research was necessary due to their refusal to participate in an interview. Furthermore, the solution of the small vendor Sievo has been included due to its recognition as "Leader" in the Spend Matters Solution Map.[188]

The web-research for each vendor followed the same procedure. Firstly, the website of the respective vendor has been searched for information, such as Data Sheet, case studies or videos. Secondly, Google was used to obtain further insights into the respective solution. The focus was on reports from well-known research firms, such as Gartner Inc., Forrester

[188] See Sievo (2018), p. n.a.

and Spendmatters. Lastly, YouTube has been used to find user videos of the respective solutions.

No.	Company	Founded	No. of employees	Users	Country	Assessment	Verification
1	Allocation Network GmbH	1998	48	55.000	Germany	Interviews	Web-reserach
2	Smart by GEP	1999	3364	n.a.	USA	Interviews	Web-reserach
3	Netwtron GmbH	1998	70	n.a.	Germany	Interviews	Web-reserach
4	MySupply Expertist Vertriebs GmbH	2018	10	n.a.	Germany	Interviews	Web-reserach
5	Onventis GmbH	2000	70	n.a.	Germany	Interviews	Web-reserach
6	OpusCapita Software GmBH	1984	400	1. Mio	Finland	Interviews	Web-reserach
7	SAP Ariba	1999	3500	11. Mio	USA	Interviews	Web-reserach
8	Zycus Infotech Pvt. Ltd.	1998	1250	n.a.	USA	Interviews	Web-reserach
9	SynerTrade S.A.	2000	330	378.000	France	Interviews	Web-reserach
10	Basware Oyj	1985	1800	n.a.	Finland	Web-reserach	
11	Jaggaer	1996	1100	n.a.	USA	Web-reserach	
12	Coupa	2006	1300	2.7 Mio	USA	Web-reserach	
13	Ivalua	2000	402	n.a.	France , USA	Web-reserach	
14	Netfira GmbH	2006	n.a.	n.a.	Germany	Web-reserach	
15	HCM Customer Management GmbH	2000	n.a.	n.a.	Germany	Web-reserach	
16	Sievo HQ	2003	140	n.a.	Finnland	Web-reserach	

Table 7: Overview of evaluated and verified e-purchasing vendors: Web-research

3.4. Assessing the research quality concerning validity and reliability

Many scientific research methods bear the risk to be performed badly. Therefore, it is important to acknowledge the reliability and validity of the study. The reliability refers to the consistency of the study, meaning that the same findings should be achieved if replicated by different researchers.[189] Threats to the reliability within the interview phase with experts were mitigated by arranging a pilot interview and conducting one-to-one interviews. Moreover, confidentially regarding the interviewees name and organisation has been ensured beforehand. The objective was to obtain answers that were not influenced by colleagues or organisations. Threats to the reliability within the interview phase with e-purchasing software vendors were mitigated by questioning one vendor at the time, while ensuring that no competitor overheard the interview. Due to the special situation, that the interviews were conducted on a fair, the interview answers have been verified by web-research and adapted if necessary.

[189] See Saunders, Lewis, and Thornhill (2016), p.202.

The validity refers to the accuracy of the analysis and generalisability of the results.[190] In this research, content validity was achieved through the following three facts. Firstly, the research followed strictly the proposed structure of Peffers et al. (2007), which ensures rigorous results.[191] Secondly, the evaluation of e-purchasing vendors followed the prepared scoring model which intend to increase the objectivity, as can be seen in the Tables 8 and 18. Thirdly, the market overview and the outcome of the quadrant model pictured a similar situation, which serves as mutually proof of logic.

Scoring model within the stage	
(1) Lowest points within the stage	The performance partially meets the requirements within the stage and indicates that the necessary basic performance is available.
(2)	The performance is defective but still meets the requirements as a whole in the stage.
(3)	The performance generally meets the requirements within the stage.
(4)	The performance fully meets the requirements within the stage.
(5) Highest points within stage	The performance meets the requirements within the stage to a particularly high degree.

Table 8: Scoring model within maturity stage to increase validity

[190] See Saunders et al. (2016), p. 202.
[191] See Peffers et al. (2007), p. 50.

4. Development of the Maturity- and Quadrant Model based on literature and qualitative interviews

4.1. Iteratively designing the Maturity Model based on literature and interviews

4.1.1. The literature-based version of the Model entails all e-purchasing activities of the CMC and the associated ideal I.40 situation

The literature-based version of the maturity model consists of seven dimension and supports the evaluation of the as-is situation and planned vision of solution vendors in one approach. For the selection of the dimensions it was fundamental to identify the relevant e-purchasing applications, within the different purchasing stages. When structuring the e-purchasing functionalities, the first considerations were about grouping the different applications in subordinated dimensions based on the Category Management Cycle. Moreover, it is noteworthy that the newly developed model draws inspiration of the dimensions of Morsinkhof´s (2018) model to reach a certain degree of complementarity. Morsinkhof (2018) has chosen the following dimensions to capture the main purchasing activities in the context of the Industry 4.0: Physical and Virtual connection, Purchase to Pay, Controlling / KPI, Sourcing, Suppliers.[192] The Controlling / KPI dimension is extended to included different types of analysis with regards to the functionalities of the software solutions. In addition, the End-User and Software Support dimensions will be included. Consequently, the best-practice scenario for the last stage of each sub dimensions is described in the following, whereas the complete model can be found in the Appendix V.

The dimension “Physical and Virtual connection” has no further sub-dimensions but is highly important in the context of the Industry 4.0 because the fusion of real and virtual systems is one cornerstone of the fourth industrial revolution. Therefore, this dimension will capture to what extent the EP-software solution supports the processing of sensors, Machine to Machine communication or Cyber Physical Systems.

Physical and Virtual	Ideal situation in the context of Industry 4.0
Fusion of physical and virtual systems	The EP-solution supports the seamless integration of real and virtual systems by advanced artificial intelligence. The EP-solution optimises the integration in real-time and supports the processing of machine-to-machine communication, Cyber-Physical Systems and the IoT.

Table 9: Best-practice of the dimension: Physical and Virtual Connection

[192] See Morsinkhof (2018), p. 77-87.

The “Purchase-to-pay” dimension encompasses 5 sub-dimensions, namely the Predictive demand, e-ordering, e-catalogues, Maverick Buying and Monitoring of invoices and payment. The goal within this dimension is to evaluate to what extend the solution supports the operational purchase to pay process by deploying I4.0 technologies, such as RPA, AI and advanced analytics. A best-practice solution supports physical and virtual integration, by engaging prescriptive analytics within a self-learning system.

Purchasing-to-pay	**Ideal situation in the context of Industry 4.0**
Demand prediction	The EP-solution supports the autonomous prescription of future demand based on monitoring internal and external data sources, with data analysis using advanced Artificial Intelligence. Prescriptive analytical output is adjusted in real time and influences procurement immediately through permanent data gathering by the IoT.
E-Ordering	The EP-solution supports the autonomous initiation of requesting, approving and raising an order without human intervention. The EP-solution supports the autonomous ordering without human intervention. Advanced Artificial Intelligence is used as a self-learning system.
E-Catalogues	The EP-solution supports the autonomous comparison of items in different E-Catalogues (during the ordering process). The Ep-solution supports the autonomous real-time updating and verifying of changes within the E-Catalogues. Purchasing personnel has only a monitoring role.
Maverick buying	The EP-solution makes it virtually impossible to order goods outside of previously approved suppliers. New and fitting suppliers are autonomously onboarded and approved. Virtual assistance is supported fully in real-time when buying new items to maximise procurement optimisation and compliant buying.
Processing & monitoring of invoices and payment	The EP-solution supports the fully autonomous processing of invoices and is capable to solve problems autonomously, except for very complicated problems. The derived information is automatically saved and shared both internally and externally in real time (e.g. by blockchain technology, if EP-solution provides compatibility).

Table 10: Best-practices of the dimension: Purchase to Pay

The “Controlling/KPI” dimension encompasses four sub-dimensions, namely the Category-, Inventory and Spend analysis as well as KPI dashboards. The goal within this dimension is to evaluate to what extend the software solution supports advanced analysis that substitutive the strategy formulation and real-time transparency throughout the whole purchasing process. Thus, a mature solution supports AI based data processing capabilities to provide valuable information. It is noteworthy, that the infrastructure for the data gathering has to be existent.

Controlling / KPI	Ideal situation in the context of Industry 4.0
Category Analysis	The EP-solution analyses the complete purchasing landscape such as E-Marketplaces, supplier portals and catalogues (in general everything within the IoT) autonomously to identify new suppliers, goods or services. Furthermore, the analysis includes the organisation's internal purchasing data and further complex Big Data (e.g. market data) in real-time. The output is prescriptive.
Spend Analysis	The EP-solution supports an autonomous performed Spend analysis, including comprehensive Big Data gathering through the IoT. Advanced Artificial Intelligence supports autonomous data processing and self-optimising improvements of future purchasing activities in real-time. The output is prescriptive and human personnel has only a monitoring role.
KPI Dashboard	The EP-solution supports autonomously created KPI dashboards in real time. Advanced AI analytics identifies and processes big data and correlations while providing a precise prescriptive output.
Inventory analysis	The EP-solution supports autonomous performed Inventory analysis, including comprehensive Big Data gathering through the IoT. Advanced artificial intelligence is supported to further analyse results and autonomously improve the purchasing strategy to improve the inventory in real time. The output is prescriptive.

Table 11: Best-practices of the dimension: Controlling / KPI

The “Sourcing” dimension encompasses four sub-dimensions, namely E-Marketplaces, E-Tendering, E-Auctions and E-Contract Management. The goal within this dimension is to evaluate to what extend the vendor’s solution supports the sourcing activities in an electronic environment. In the ideal situation, prescriptive analytics processes the gathered data in real time and influence the supply demand through CPS.

Sourcing	Ideal situation in the context of Industry 4.0
Marketplace and Network	The EP-solution supports the autonomous real-time comparison of items and suppliers within the whole marketplace network. The output of the EP-solution encompasses the prescription of the best fitting supplier based on price development, quality and further KPI's. The EP-solution supports the infrastructure and autonomous forwarding of information to relevant stakeholders or processes. No human input is required.
E-Tendering	The EP-solution supports fully autonomous tendering processes in fully connected systems. The involvement of humans is erased to establish a purely authorising and monitoring role. Many criteria are measured autonomously in the system, not focusing solely on price but also qualitative criteria. The EP-solution supports a prescriptive outcome.

E-Auctions	The EP-solution supports fully autonomous organised auctions within fully connected systems. The involvement of humans is erased to establish a purely authorizing and monitoring role. Many criteria are measured autonomously in the system, not focusing solely on price but also qualitative criteria. The outcome of the auction is prescriptive.
E-Contract management	The EP-solution supports fully autonomous contracting phase in fully connected systems, focusing on Contract Lifecycle Management (CLM). The involvement of humans is erased to establish a purely monitoring role.

Table 12: Best-practices of the dimension: Sourcing

The "Supplier" dimension encompasses four sub-dimensions, namely Supplier evaluation, Data Exchange, Supply Chain Risk Management. The objective of this dimension is to evaluate to what extend the software solution supports the supplier management. In the ideal situation are suppliers autonomous evaluated in real-time. Moreover, the seamless connection to suppliers and exchange of data is supported through mature I4.0 technologies such as Blockchain.

Supplier	**Ideal situation in the context of Industry 4.0**
Supplier evaluation	The EP-solution supports the supplier evaluation autonomously for each supplier, based on many specific KPI's. The past performance and comparative benchmarks with both internal and external sources are included. This is shared in real-time with suppliers to improve future performance, with an added focus on supplier satisfaction. The software is able to serve prescriptive decision implications.
Connection of suppliers / Onboarding	The EP-solution supports the autonomous connection of suppliers. The connection is based on autonomous requests towards suppliers, based on the analysation of (big) data and demand, which has been gathered by the IoT and processed by advanced AI in real time.
Data Exchange	The EP-solution supports the extensive sharing of (big) data with suppliers. The exchange of information is fully transparent within the supply chain (e.g., through Blockchains) and takes place in real time.
Supplier Risk Management	The EP-solution supports the autonomous real-time detection and mitigation of possible risks and disruptions in the supplier base based on prescriptive analytics. Internal and external data is gathered through the IoT.

Table 13: Best-practices of the dimension: Supplier

The last two dimensions refer to the general support by the vendor when utilizing the solution. The first dimension "End-User Support" encompasses the education provided for

end-users about the solution and the purchasing experience of the vendors employees. The second dimension "Software Support" encompasses two further sub-dimensions, namely the Availability and Updates as well as the Security of Data. The goal within this dimension is to access to what extend the software solution supports the accessibility, actuality and security of data through advanced technologies.

End-User support	Ideal situation/ most sophisticated maturity stage
Training of Users	The EP-solution is able to train the users individual through advanced algorithms and a Virtual Assistant on an individual level.
Experience of vendors employees	The personnel has extensive experience in the field of (e-)procurement & (e-)sourcing and is able to support the users in terms of strategic aspects to fully utilize the software's potential.

Table 14: Best-practices of the dimension: Knowledge Support

Software support	Ideal situation/ most sophisticated maturity stage
Availability and Updates	The EP-solution supports real-time availability on every device with a browser, as long as the device is connected to the internet and updates itself continuously.
Security of data	The EP-solution supports the strict protection of Data through autonomously created backups. The software updates on possible cyber risks continuously. Data safety is increased through the usage of blockchain technology.

Table 15: Best-practices of the dimension: Software Support

4.1.2. Including Controlling / KPI and Supplier sub-dimensions based on the feedback of Experts

Based on Peffers et al. (2007) framework and Hevners et al. (2004) guidelines it is advised that the artefact is evaluated and iteratively improved before demonstrating it.[193] Therefore, interviews with three purchasing managers and one purchasing consultant have been conducted in order to estimate the comprehensiveness of the maturity model.

Firstly, the different software dimensions have been reviewed. Hereby all participants stated that the model captures the most relevant purchasing dimensions. However, Interviewer 2 explained that the "Controlling / KPI" dimension should be enhanced and suggested that the dimension should also include lever-analysis. Furthermore, Interviewer 1 stated that an upcoming topic in his firm is the tracking of supplier risk by software as

[193] See Hevner et al. (2004), p. 88; Peffers et al. (2007), p. 54.

well as the financial supply chain. The increasing importance of software solutions that support supplier risk management was also affirmed by Interviewer 2. Furthermore, Interviewer 2 explained that another important category for him in choosing an e-purchasing solution is the support provided by the software vendors in terms of consulting activities after the implementation.

Referring to their own experience with e-purchasing tools the purchasers stated that their firms have catalogues in use for the operative procurement for over a decade. Additionally, Interviewer 4 stated that they use an e-sourcing tool that supports the automated tendering process by advertising the tender request on public portals. Interviewer 1 and 3 explained that their organisation provides an ERP system as well as a supplier portal but no additional e-sourcing software. Furthermore, all Interview partners explained that they have experience with automated Spend Analysis. In addition, Interviewer 1 and 4 use the central storage of contracts within their ERP system frequently. However, Interviewer 3 explained that his department within the company has bureaus in different countries but no central storage regulation. Therefore, they place the contracts on folders of the server, which results in many mistakes and losses of deadlines.

Overall, the participants agreed that the newly developed maturity model is comprehensive and covers the most important purchasing processes. Furthermore, the interviewers agreed that the model itself can be really helpful for determining the sophistication of an EP-solution vendor. However, all participants had problems with the wording and demanded to make it more precise. Consequently, the wording has been improved and the Financial Supply Chain and Potential Savings Analysis dimensions have been included. By including the input of the experts, the newly developed maturity model encompasses seven dimensions and 24 subdimensions.

The Financial Supply Chain dimension refers to the optimisation of the working capital and the optimisation of the overall financial situation of the buying organisation. It includes the leverage of quickly reconciled invoices and enables early-payment discounting, a detailed reporting of the invoice status and the management of cash available for (early) payments. Consequently, this dimension supports the visibility of cash positions, the connection of third-party providers such as Financial Institutes, which increases the supplier relationships.[194]

[194] See Ivalua (2019a), p. n.a.

Supplier	Ideal situation/ most sophisticated maturity stage
Financial Supply Chain Management	The EP-solution supports the autonomous real-time determination of temporary financing possibilities. The Supply Chain Financing is transparent and safe through smart contracts and blockchain. Permanent review of invoices, orders and working capital to ensure financial stability.

Table 16: Best-practices of the sub-dimension: Financial Supply Chain

As explained by Interviewer 2, refers the Potential Savings Analysis to the automated comparison and adjustment of purchasing activities with the goal to uncover savings potential. Hence, it is a part of the overall Spend Analysis but enables direct transparency on potential savings.

Controlling / KPI	Ideal situation/ most sophisticated maturity stage
Potential Savings Analysis	The EP-solution supports autonomous performed Potential Savings Analysis including comprehensive Big Data gathering through the IoT. Advanced artificial intelligence is supported to further analyse results and autonomously improve savings in real time. The output is prescriptive.

Table 17: Best-practices of the sub-dimension: Controlling / KPI

4.1.3. The new maturity stages are based on the degree of integration, automation, autonomisation and analytical capabilities

The construction of the maturity stages is a relevant issue for providing a detailed assessment. While reviewing the different maturity models in chapter 2.5.2. it has shown that most authors divide the maturity into four or five stages. However, Torn (2017) explains that four maturity levels provide two advantages and are preferable to cover the most relevant stages. “First, the boundaries of stages are more clearly defined compared to models with three stages, because the stage in the middle is split in two distinctive groups. Second, the three central stages of models using five stages tend to become ambiguously since the differences between the stages are too small.”[195] Nonetheless, the e-purchasing solution maturity model requires a “zero” stage, for the case that the evaluated EP-solution does not provide a certain functionality.

In addition, the review of related maturity models pointed out that many follow the CMMI approach and target only stages within the I4.0 environment without considering the fact that the most companies are currently in the phase of Industry 3.0 or a transitioning process towards the fourth industrial revolution.[196] However, Morsinkhof (2018) characterised his

[195] Torn (2017), p. 65.
[196] See Torn (2017), p. 67.

models first and second stage to be Industry 3.0 oriented while targeting first I4.0 criteria within the third stage.[197] Subsequently, the fourth stage encompasses the full Industry 4.0 maturity.[198] Hence, the newly developed model adapts Morsinkhof's approach of including Industry 3.0 stages in the beginning.

It is noteworthy, that all previous named maturity models were reviewing the whole organisation and its processes while the newly developed maturity model targets mainly the supported capabilities of the software solutions. As a result, new stages have to be developed, which are unaffected by the documentation and strategy of the analysed solution vendors. Therefore, it is worth remarking the relevance of business intelligence capabilities, and the degree of autonomation as well as the degree of integration and major technologies provided or supported by the EP-solutions.[199] Consequently, the following four maturity stages have been developed:

1. The EP-solution follows a siloed approach and rarely supports the connection to the IT infrastructure. The software is characterised by many manual interventions. The solution output is descriptive and unstructured.

2. The EP-solution supports the connection to different IT systems and vertical integration. The software is reflected by manual interventions and automation. The software output is diagnostic and aims to explain what has happened in the internal purchasing environment.

3. The EP-solution supports full integration within the purchasing process as well as the cross-functional integration throughout the organisation and supply chain. Functions are performed highly automated (based on RPA) and autonomation to a very low extent in the EP-software. Some human interaction is still necessary. The software output aims to make predictive suggestions based on internal and external (recent and historical) data, processed by algorithms.

4. The EP-solution is able to function fully autonomous within the purchasing department. The software is able to use advanced Artificial Intelligence to process

[197] See Morsinkhof (2018), p. 51.
[198] See Morsinkhof (2018), p. 51.
[199] Capgemini (2018), p. 37.

prescriptive analytics based on Big Data and machine-to-machine communication in real-time in order to continuously improve their decision making in the purchasing processes. Information is gathered through the IoT and the software supports the connection to CPS.

4.2. New vendor classifications based on Gartner's and Capgemini's quadrants

The review of Gartner's and Capgemini's quadrants will be used as basis for the classification of the solution vendors and the linked quadrant model. The interlinkage of supported dimensions and the associated Industry 4.0 maturity of the respective dimensions will be used to determine four distinct classifications of solution vendors. Thus, the approach of a traditional quadrant model seems fitting to visualise the classification. Therefore, the dimensions and maturity stages will determine the axes. Hence, the interlinkage of the assessed scores within the newly developed maturity model achieved on the two axes will resolve the vendors position in the new developed Quadrant model. Consequently, the Quadrant Model is able to visualise the current width and sophistication of the solution as well as the planed vision for the years. Thus, if the vendors e-purchasing solution targets a majority of dimensions the vendor will be accredit a high score on the x-axes "Width of Solution offering". If most of the offered solutions are strongly I4.0 oriented in terms of capabilities and technologies supported, the vendor will receive a high score on the y-axes "Depth of Solution offering". In the following, the different classifications will be explained.

I. The *Emerging Contender* offers few solutions related to e-purchasing. Furthermore, the offered solutions use basic technologies without including Industry 4.0 approaches. Therefore, these vendors might be suitable for organisations that are looking to implement basic e-purchasing software solutions. [Left bottom corner of Quadrant Model]

II. The (Transitional) *Innovative Specialist* offers limited e-purchasing solutions. However, the offered solutions have an increased depth and (are on their way to) support many I4.0 capabilities within the business context. [Left top corner of Quadrant Model]

III. The *Established Generalist* offers a brought variety of e-purchasing solutions that cover many Source-to-Pay applications, but their solutions miss the sophistication of Industry 4.0 capabilities. [Right bottom corner of Quadrant Model]

IV. The (Transitional) *Innovative All Star* has a brought offering of e-purchasing solutions. The offered solutions cover many Source-to-pay elements and (are on an innovative way to) support many Industry 4.0 requirements. [Right top corner of Quadrant Model]

Due to the complexity and comprehensiveness of the Industry 4.0 it is valuable to point out that the classifications “Innovative Specialist” and “All Star” have to be carefully viewed and encompass a transition phase towards meeting Industry 4.0 capabilities to a prevailing extent. Hence, theses classifications have been subdivided into the “Transitional” and “Complete” sections. The Transitional Innovative Specialist / Transitional Innovative Allstar support only some I4.0 requirements, whereas the Innovative Specialist / Innovative Allstar meet I4.0 requirements to a particular high extent.

4.3. The maturity model supports two approaches for the assessment of ep-solutions

This chapter provides detailed insights on the maturity model and clarifies the linkage to the quadrant model. The dimensions will be used to determine the width of the offered functions supported by EP-software solution vendors. Subsequently, the maturity of the dimension is assessed through the maturity levels. The maturity model provides 24 dimensions, which count as one point. Moreover, the model contains four maturity stages, which have a total value of 20 points. Consequently, the total amount of points for the widths of supported functionalities is 24 and 480 for the maturity.

In order to visualise the outcome of the model and to classify the e-solution vendors in the quadrant model, a combination of both scorings will be used. Therefore, each dimension supported by the solution will be counted as one point on the x-axes of the quadrant model. Subsequently, the assessed maturity will determine the scoring on the y-axes of the quadrant model, thereby it is important to convert the maturity score into percentages to avoid a distorted visualisation.

The determination of the best fitting score for the solution can be achieved through two approaches. The first one encompasses the simultaneous assessing of the e-purchasing

solution vendor by different independent analysts, users or internals with the goal to calculate a reliable mean value. However, this approach is extremely time consuming and depending on strong support by different evaluators. Therefore, the second approach orients on the following scoring scheme to provide a more reliable assessment.

Scoring model within the stage	
(1) Lowest points within the stage	The performance partially meets the requirements within the stage and indicates that the necessary basic performance is available.
(2)	The performance is defective but still meets the requirements as a whole in the stage.
(3)	The performance generally meets the requirements within the stage.
(4)	The performance fully meets the requirements within the stage.
(5) Highest points within stage	The performance meets the requirements within the stage to a particularly high degree.

Table 18: Scoring model within Maturity Stage to increase validity

In order to clarify the scoring, the following example is provided. The assessed e-purchasing solution supports the "Processing and monitoring of invoices and payment" and has been preselected in the second maturity stage. Therefore, the scoring system lies between 6 and 10 points. As the function is reviewed more in detail, the evaluator decides based on the questions of the model to what extent the software solution supports the established criteria for the stage. On the one hand, if the performance meets a particularly high degree without overcoming the stage the evaluator determines 10 points. On the other hand, if the software solution partially meets the requirements without dropping to the prior lower maturity level, the evaluator gives 6 points. In order to evaluate the planned vision of the software vendor with regards to the e-purchasing dimensions, the assessor follows the aforementioned explanation.

5. Demonstration of the model in the fitting organisational context

5.1. Obtaining insights into the technology progress by assessing various ep-solution vendors

5.1.1. The linkage of physical and virtual systems is rarely supported

The integration of sensor data is only supported by a few solution vendors. However, the greater number of vendors agreed that the linkage of physical and virtual systems becomes more and more important, even if their assessed solutions did not provide this functionality. Nevertheless, most vendors explained their theoretical ability to include sensor data through customised development projects. However, these explanations have been perceived but not included in the assessment, because their solutions did not provide a functional module. Consequently, the vendors SAP Ariba, Zycus, Onventis and Netfira explained and partly presented that their solutions provides modules to include sensor data and therefore the linkage of physical and virtual systems. The solution of SAP Ariba supports the usage of sensor data and M2M communication through an interface module. Furthermore, the representatives of SAP Ariba declared that the module can be used to automatically integrate different types of sensors. Zycus and Onventis also affirmed that their solutions support modules to include and process sensor data automatically. However, the interviewed representatives of Zycus and Onventis could not name in detail what kind of sensors were supported by their solutions.

It is noteworthy that SAP Ariba is the only vendor who supports automated M2M data processing. Consequently, SAP Ariba has been placed in the lower third stage due to its integration capabilities of different sensor data and M2M communication.

5.1.2. The processing of Invoices and payment works almost autonomously and is the most sophisticated dimension within the P2P section

As before mentioned, the P2P section encompasses the demand prediction, e-ordering, e-catalogues, maverick buying and the processing of invoices and payment. The results of demand prediction did not vary greatly except for the solutions of SAP Ariba and Basware. Hereby, SAP Ariba supports the automated tracking of market developments and specific (basic) commodities such as “steal” by including third-party providers as well as their own insights in the Ariba Network. Furthermore, advanced algorithms are used to purify the gathered data to provide valuable information for the purchasing department. The data purification, as well as the advanced data processing, is also a strong point of Basware. The solution of Basware uses internal data to run predictive analytics in order to support

daily operations. Overall, the demand prediction solutions from different vendors, such as SynerTrade, OpusCapita, and Smart by GEP rely on internal calculations, without advanced data purification. Hence, the reliability of the demand prediction has to be considered with even stronger caution.

The digitisation of the e-ordering process is achieved by all assessed software solutions, but the automation varies within the Purchasing Order (PO) creation. Software vendors, such as SAP Ariba, Basware, Ivalua, Jaggaer, Smart by GEP or Zycus support the automated PO creation based on the Purchasing Requisition. Contradicting, SynerTrade and OpusCapita do not offer this functionality. Nonetheless, OpusCapita declared that their team is currently working on the development. Overall, vendors who offer e-ordering support the digitised rejection, forwarding and approval by alerting relevant stakeholders within the solutions. SAP Ariba, Smart by GEP, Zycus, Basware, Coupa and Jaggaer support the "mobile" approval of requisitions. Noteworthy is the "Jaggaer Mobile APP", which allows users to shop from hosted catalogues, managing documents and to approve purchasing requisitions, sourcing events or contracts.

The usage of e-catalogues is supported by all P2P suit providers. The most advanced contributions for locally hosted catalogues are provided by Zycus, Basware and SAP Ariba. Zycus "AI-based tool" and Basware's "highly intelligent algorithms" support automated classifications of all catalogue items to promote the "best fitting" item for the end-user. Furthermore, the solution of SAP Ariba features the tracking of prices for predefined items within different catalogues. Regarding the actuality of catalogues, the solution of Zycus requests automated updates from suppliers in fixed intervals and SAP Ariba's solution supports the automated verification of catalogue changes based on fixed contracts. In addition, the solutions of Basware and SynerTrade enable suppliers to adjust catalogues by themselves, which has to be approved by the purchasing personnel of the buying organisations manually. The majority of ep-solutions support the manual comparison of items based on a side by side evaluation.

By reviewing the adoption of PunchOut catalogues it became visible that the majority of solutions does not offer the possibility to compare different items within multiple punchout and hosted catalogues at the same time. Nonetheless, Ivalua, Zycus, Opus Capita, Smart by GEP and Jaggaer explained that their solution supports the comparison of punchout and hosted catalogues. Consequently, the most advanced approach is provided by Ivalua's "Spend360" solution that offers the possibility to review and compare internally hosted and PunchOut catalogues seamlessly while providing different search functions such as

faceted search options in real-time. Faceted search refers to the opportunity to navigate through the different catalogues by selecting different criteria such as property, characteristics or value. Hence, the comparison is automated.

To mitigate maverick buying all vendors support user-oriented interfaces combined with automated approval workflows and stakeholder notifications. Additionally, SAP Ariba, Smart by GEP, Newtron Onventis, Basware and Jaggaer provide guided buying within their solutions. Moreover, Basware's guided buying function supports the serving of fewer more relevant choices while hiding unnecessary options, which do not apply to the internal purchasing policies. Furthermore, SAP Ariba support the "spot buying" function for items that are not based on fixed contracts or catalogues. "Spot buying" enables end-users to buy desired products from the "Ariba Spot Buy Catalogue" which contains more than 10 million articles and supports guided buying functionalities.

The automated processing and monitoring of invoices and payment is supported by nearly all software solutions. The most sophisticated solutions are provided by SAP Ariba, Zycus, OpusCapita, Basware, Coupa and Jaggaer. All of these solutions rely on AI in terms of Natural Language Processing or Optical Character Recognition to convert various types of invoices such as e-mails, pdfs or scanned paper invoices to a fitting format that allows the autonomous processing. The processing is based on the three-way matching, were the purchasing order, order receipts and invoices are reviewed. In the case of a mistake two possibilities occur. Depended on the programmed workflow, the supplier or relevant stakeholder from the buying organisation gets a notification. Moreover, SAP Ariba and Basware support the PO Flip functionality for the payment process. The PO Flip refers to the automated "flipping" of purchasing orders into e-invoices. Based on the predefined rules, the relevant stakeholder receives a notification for approval, or the invoice gets approved automated, while being forwarded to the accounting system. According to SAP Ariba and Basware, the autonomous processing of invoices combined with the PO Flip function reduces faulty invoices to under 3% by erasing human failure during manual invoice creations.

Overall, the large vendors are in a transition phase towards meeting Industry 4.0 capabilities. On the one hand, the assessed solutions provide a high degree of automation and integration within the P2P process. On the other hand, autonomy is only partly utilized in the processing of invoices and payables. However, further The radar chart in Figure 5 visualises the average technological progress of the assessed e-purchasing solution vendors.

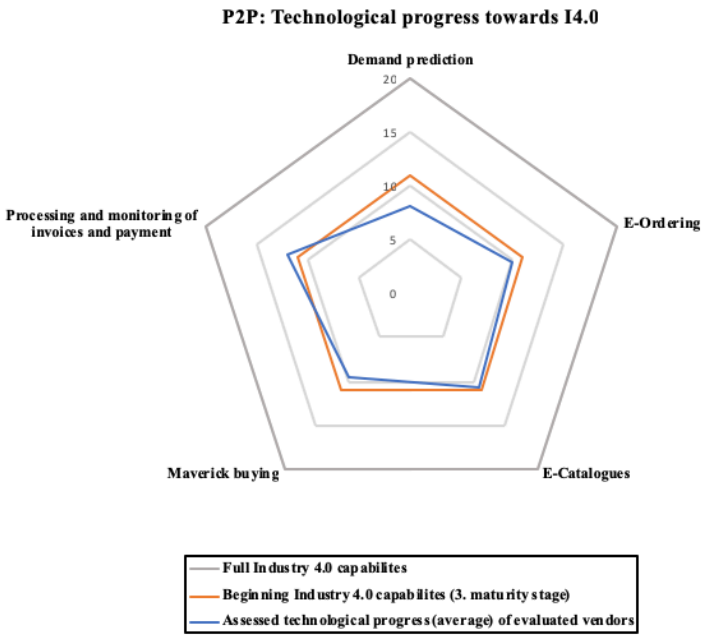


Figure 5: Radar chart: Detail view on P2P results (average of 16 assessed vendors)

5.1.3. Advanced analysis support purchasing transparency and support strategy foundation

The innovative pioneers support predictive analytics to enhance forecast visibility. Pioneering in this field are SAP Ariba, Zycus, Ivalua and Sievo. All four vendors declared that their solutions support the transparency and predictions of Spend Data based on internal and external data. Therefore, all solutions rely on AI-based processing technologies to classify, clean and enrich spend data, which increases the reliability of their forecasts. Zycus explained that their solution can be used to make spend predictions for up to six months. Moreover, Ivalua stated that their solution supports self-learning algorithms to correct anomalies within the gathered spend data. Regarding the data gathering, Sievo refers to its advanced automated extraction capabilities from any source system. Consequently, Sievo and Zycus point out that their solutions support the automated advanced identification of potential savings.

Vendors, such as OpusCapita, Smart by GEP, Basware, Coupa and Jaggaer explained that their solutions also support the automated purification and processing of data to enable an almost real-time analysis of current situations. Jaggaer stated that their “Spend Radar” application supports an interface to include third-party data to increase the quality and reliability using advanced algorithms to process high volume data 90% faster than competing solutions. The lowest ranking has been achieved by Newtron who explained that the data purification has to be conducted manually.

Category analysis provide insights of market drivers, cost structures and margins and are supported by SynerTrade, Zycus, OpusCapita, Smart by GEP, Jaggaer, Coupa and SAP Ariba. Whereas, Zycus and Jaggaer provide separate modules for category analysis, the other vendors explained that their category analysis is part of the Spend module. SynerTrade uses “commodity bots” (advanced algorithms) and machine learning, a subset of Artificial Intelligence to automate the analyzation of logistic performance, information about the commodity as well as cost drivers within the commodity and market. Zycus referred to their “I Cost” module, which enables the automated identification and calculation of market trends of different commodities based on the underlying cost drivers. Furthermore, Zycus stated that their solution supports the automated integration of market data. Moreover, Jaggaer’s “Category 360” tool enables category analysis by automating the aggregation and processing of existing category information. Jaggaer explained that the “360 category tool” analyses all buying elements within a commodity, including preferred vendors, contract rates and other not specified variables to point out the most advantageous opportunity. Moreover, this application supports an interface for the automated integration of third-party market data.

Due to the different structures of the assessed solutions, the “KPI Dashboard” refers to the generally supported dashboards within the solutions. The majority of solutions support configurable automated dashboards that are easily adaptable for the user’s purpose. As previously stated, is the main difference between the automated purification of data and the associated “real-time”. Jaggaer’s dashboards rely on automatically purified data which enables an almost real-time overview. On the other hand, Onventis and Newtron’s dashboards require a manual purification of data. Furthermore, it is noteworthy that Coupa supports unique benchmarking capabilities to compare the organisational performance for over 35 purchasing KPI’s against the market benchmark. The market benchmark resolves from Coupa’s network platform and is updated nightly.

The answers about inventory analysis were twofold. Vendors such as SynerTrade, SAP Ariba, Smart by GEP argued that it is not a part of the purchasing department. However, vendors such as Zycus, OpusCapita, Basware, Coupa and Jaggaer offer solutions to include inventory data to improve the purchasing departments. Zycus for example, explained that their solution includes an interface to upload inventory data by hand. Hence, the tracking is based on manual interventions.

Regarding Savings Analysis, most vendors could not provide a sufficient answer except for Jaggaer and Sievo. Jaggaer’s solution provides the automated data gathering through their

"360 Category Analysis" which enables the collaboration of cross-functional teams in order to point out potential synergy effects. In addition, Sievo's analytical module supports the automated identification of consolidation and savings opportunities. The vendors SynerTrade and OpusCapita indicated that their solution provides this function but could not name specific insight on the degree of automation or "intelligence".

Overall, the technological progressing is more diverse as for the P2P section. Some assessed solutions provide AI for the data processing and creation of analysis, whereas others still rely on manual data purification and basic calculations.

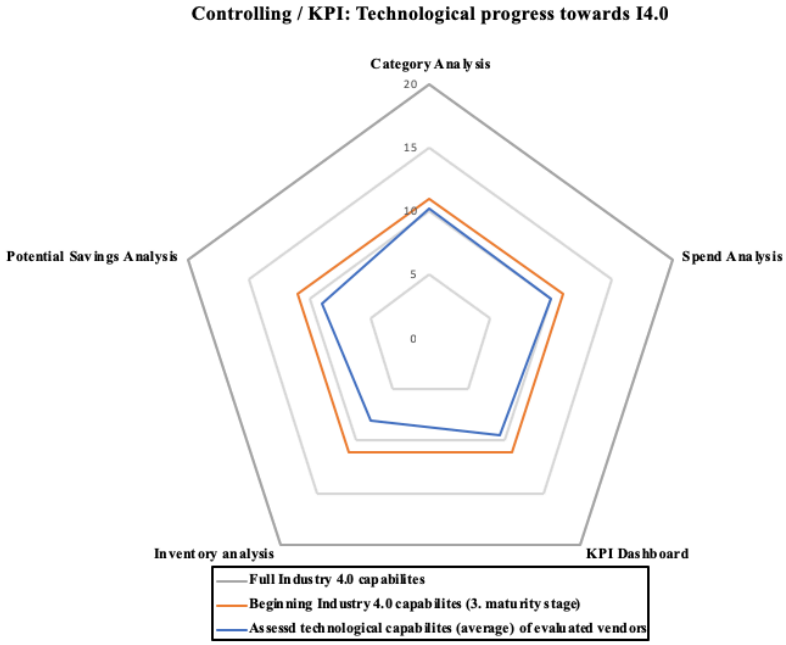


Figure 6: Radar chart: Detail view on Controlling/ KPI results (average of 16 assessed vendors)

5.1.4. The majority of solutions provide a sourcing workflow which is automated but relies on manual approving's and adjustments

All sourcing tools rely on network platforms provided by the different vendors that facilitate sourcing options within their solution. The main differences between the networks can be seen by the acceleration of finding new suppliers for the sourcing process and the size of the network. The biggest networks are provided by SAP Ariba, Jaggaer, Basware and Coupa with each providing over 1.8 million connected businesses. However, also smaller networks exist such as Newtron's with around 80.000 supplying and 1000 buying organisations. The identification of new suppliers through network searches is supported by the majority of solutions. SAP Ariba, Jaggaer, Coupa and Smart by GEP support faceted search function which leads to partly automated suggestions for the best fitting supplier.

SAP Ariba's strategic sourcing module encompasses a broad set of predefined RFX types. Furthermore, the solution supports an automated workflow with notifications, one-click approvals of different stakeholders, and team grading collaboration scorings for different sourcing events. Moreover, it is possible to share information with suppliers within the software and to automatically transfer gathered RFX to the auction process. The automated approval workflow and exchange of information within the organisation, as well as the distribution of multiple RFX to different suppliers is also provided by the majority of solutions. Furthermore, Zycus, SynerTrade, Smart by GEP, SAP Ariba offer interfaces to upload excel data into the sourcing module to enhance pricing tables or previous gathered RFX's. Moreover, different vendors such as Zycus, Ivalua and OpusCapita provide quick sourcing events, that can be set up within short time, by relying on predefined templates. Consequently, the majority of vendors provide the automated comparison of RFX's. It is notable that Jaggaer's solution supports the simulation of different awarding systems while including Total Cost analysis.

Reverse and forward auctions are supported by all vendors. Solution providers, like SAP Ariba, Coupa, Basware, Zycus, Jaggaer, Ivalua and SynerTrade have an enhanced portfolio of different types of auctions such as Dutch or Japanese. In addition, Sap Ariba, Smart by GEP and Basware provide also multi-stage auctions. Furthermore, these vendors provide bid displays and tie preventions. Even though the invitations for an auction can be automatically distributed based on RFX's, the auction process has to be new initiated. Hereby, Ivalua's sourcing module and Jaggaer's "soft auction" function offer the most convenient way by automatically transforming the RFX process to a reversed auction, including the first offer as starting bid. Lastly, it is noteworthy that MySupply is currently working on an innovative sourcing tool, which supports the decision making for sourcing events. Their tool is based on the game theory. However, the solution is not on the market yet but has been presented in a trial version.

The last step within the Source-to-Contract process refers to the e-contract management. As previously explained offer different solutions the possibility to automatically transfer the data from sourcing events to the contract management function to decrease the contracting time and input error. All assessed solutions support the storage of contracts in a central database. In addition, vendors such as SAP Ariba, Zycus, Coupa, Smart by GEP, Onventis, and Basware provide a free text search to find relevant information within the stored contracts. The majority of vendors also support the automated workflow within the company. Basware, SAP Ariba, Zycus, SynerTrade, Smart by GEP and Jaggaer support the

possibility of E-signings and automated distribution to suppliers for their approval. Referring to the transparency of savings, the solutions of Zycus, Coupa, Jaggaer and Smart by GEP allow the automated tracking of "contract spend" by matching contract and spend data. Hence, the purchasing teams have a real-time visibility of the contract status.

Overall, most assessed solutions provide automated notifications workflows for relevant stakeholders and a high degree of integration within the sourcing process. Moreover, the first beginnings of real decision support have been recognized.

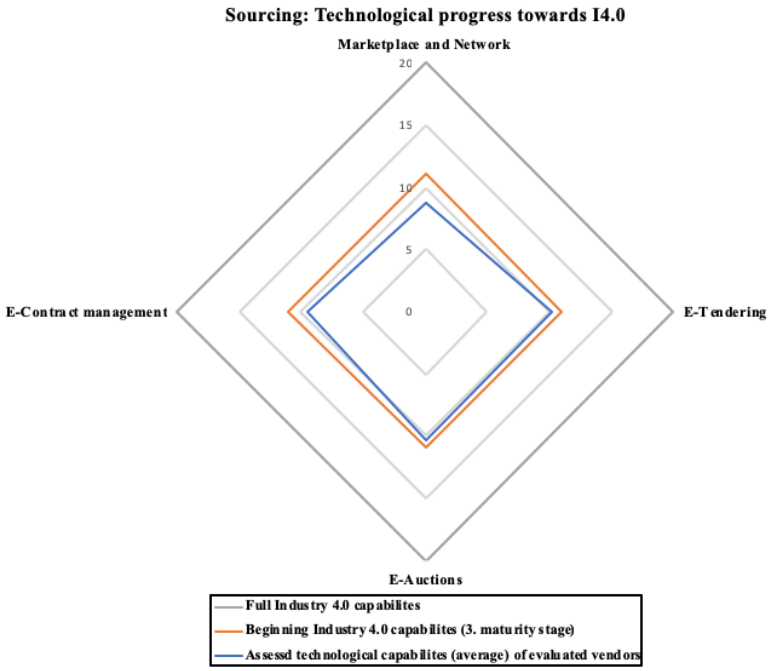


Figure 7: Radar Chart: Detail view on Sourcing results (average of 16 assessed vendors)

5.1.5. Innovative solutions include external data for the Supplier Management

The Supplier evaluation is based on internal data processing through partly automated internal valuation arches, which are used to assess subjective human based KPI's and automated supplier score cards which capture "hard" KPI's such as lead time or product quality. SAP Ariba uses data from the Ariba Network as well as the internet through "thousands of crawlers" who track information about targeted geographical areas or suppliers. Thereby, the solution relies on advanced analytics to recognize patterns and let the algorithms train by itself. Based on the "intelligent" analysation the solution supports the forecasting of the supplier development. However, the processed external data is not in real-time and the representative of SAP Ariba stated that he knows only one German company who uses this combination by now. Even though Coupa and Jaggaer also include third-party data from their network platform, their solutions provide no predictions on the

supplier development. Solution providers such as HCM, Netfira, SynerTrade, Smart by GEP, Newtron, Onventis, OpusCapita and Zycus use no network data for the evaluation but support also the automated analysation of "hard" supplier KPI's as well as the partly automated workflow for the "soft" factors. Consequently, the assessed solutions provide configurable alarms and automated notifications based on fixed rules. Another, important finding is that that the solutions of Zycus, OpusCapita, Newtron, Basware and Jaggaer provide increased supply chain transparency by providing the functionality of letting suppliers review the own status.

The Supplier Risk Management is provided by few assessed software solutions. The vendors SAP Ariba, SynerTrade, Smart by GEP, Coupa and Jaggaer and Ivalua work with third-party institutes to receive a more comprehensive overview of suppliers and possible risks. SAP Ariba, SynerTrade and Zycus work with not further specified credit protection agencies. Basware uses Dun & Bradstreet and Mastercard Track to include sanction lists, law enforcement reports, financial regulation statements and over 300 million company profiles to enrich their supplier database and risk management. Coupa's solution includes financial and judicial scores from third-party data sources like Dun & Bradstreet, Thomson Reuters and risk domains (InfoSec, FCPA, GDPR). In addition, news sentiments from Yelp are integrated. Jaggaer partnered up with the renowned supply chain risk firm "Riskmethods" to identify risks from strikes, geographical, political instability and further factors. Moreover, the solution is able to identify risks beyond Tier 1 suppliers and displays everything in a comprehensive dashboard.

The optimisation of the financial supply chain is targeted by SAP Ariba, Basware, Coupa and Ivalua. These vendors offer dynamic discounting functions to optimise the cashflow for buyers as well as suppliers. SAP Ariba supports the invoice and payable process and can be fully automated. Hereby, the buying organisation is able to define fixed rules based on the supplier relationship, type of commodity or cash flow to automate early payment options. Additionally, Ivalua's "Working Capital Management" and Coupa's "Supply Chain Finance" tool support the interaction to third-party financial institutes. Historically, Supply chain finance programs have been offered independently by financial institutes. Nonetheless, the vendors did not provide in depth insights about the automatisation. Hence, it can be concluded that the process requires increased manual support. However, it is noteworthy that Basware's solution captures and process all invoices (compared to others that can only handle PO invoices). Hence, full financial insights are provided and

available in the 360-degree reporting analysis. Thus, real-time dynamic accounting is enabled.

Overall, the majority of assessed solution vendors support the digitised handling of the supplier base and a high integration. However, the data gathering and processing differs in terms of manual handling and automation significantly.

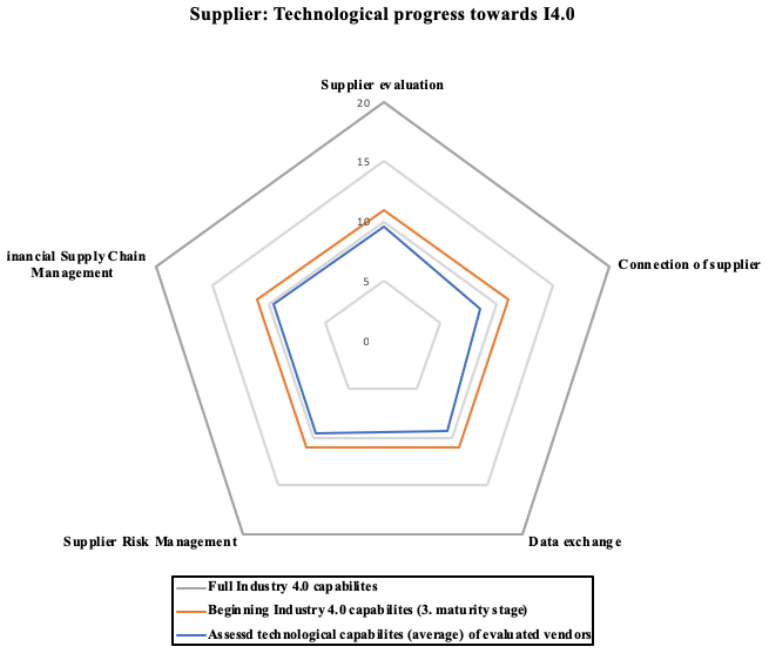


Figure 8: Radar Chart: Detail view on Supplier results (average of 16 assessed vendors)

5.1.6. All software vendors provide SAAS solutions and included trainings to educate end users

No assed software vendor provides smart virtual assistance within their solutions to educated end-users. Nevertheless, all vendors provide specialized trainings, videos, telephone and email services. However, the trainers are often part of a partner consultant agency and are not directly employed by the vendors. Hence, longer lead times and higher costs for the end-user organisation. Additionally, it is noteworthy, that Newtron explained as only vendor that their solution includes a tutorial function. Furthermore, 24/7 live service is supported by the majority of vendors, eg. Basware provides support 24/7 live support in over eight different languages. The solution of MySupply provides a very intuitive interface which is easy to understand even though if the purchasing and software knowledge is basic. However, the simplicity of MySupply is owed to the little extension of the software. All assed vendors abide international regulations to secure the data, while providing several back up cloud servers and emergency plans to ensure no loss of data. However, no assed vendor supports blockchain or different technologies to secure the data.

Furthermore, all solutions are designed to maintain the majority of functions as Software-as-a-Service (SAAS).

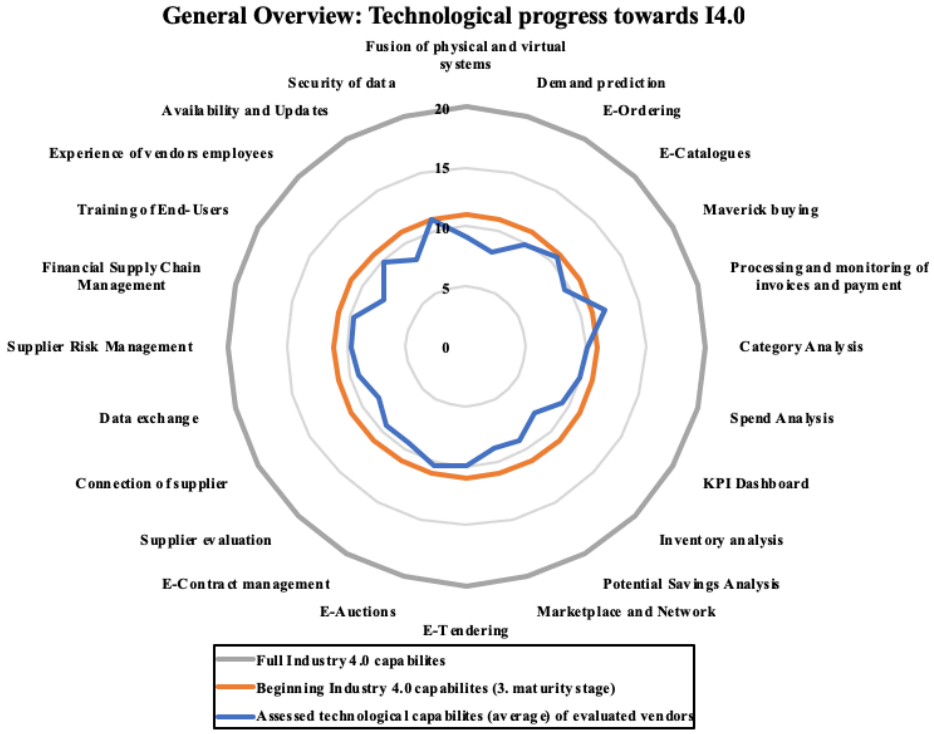


Figure 9: Radar Chart: General Overview of results (average of 16 assessed vendors)

5.2. Presentation of assessed vendors in the Quadrant Model

5.2.1. Classification of EP- software solution in the quadrant model

This section presents the visualised comparison of the assessed vendor solutions. As in chapter 4.2. stated distinguishes the classification between four main types. Namely, the "Emerging Contender", "Innovative Specialist", "Established Generalist and "Innovative Allstar". As before explained characterises the "Emerging Contender" a vendor who provides little e-purchasing solutions, with limited innovations and is therefore depicted in the left bottom corner of the quadrant. The (Transitional) "Innovative Specialist" offers a limited number of e-purchasing solutions. However, the offered EP-solutions have an increased depth and (are on an innovative way to) support many I4.0 capabilities within the e-purchasing context and is therefore found in the top left corner. The Established Generalist offers a brought variety of EP-solutions that cover many Source-to-Pay applications, but their solutions miss the sophistication of Industry 4.0 capabilities. Hence, the Established Generalist is presented in the right bottom corner. The (Transitional) Innovative All Star has a brought offering of EP-software solutions. The offered solutions cover many Source-to-pay elements and (are on an innovative way to) support many

Industry 4.0 requirements. Hence, the Innovative All Star is depicted in the right top corner. In the following, five linked quadrant models will be presented, namely the General Overview, P2P detail view, Controlling/KPI detail view, Sourcing detail view and Supplier detail view. It is remarkable, that no separate detail view for the fusion of physical and virtual systems is displayed, due to the fact that only SAP Ariba, Zycus, Onventis and Netfira supported this function.

5.2.2. No evaluated EP- vendor meets Industry 4.0 capabilities to a high extent

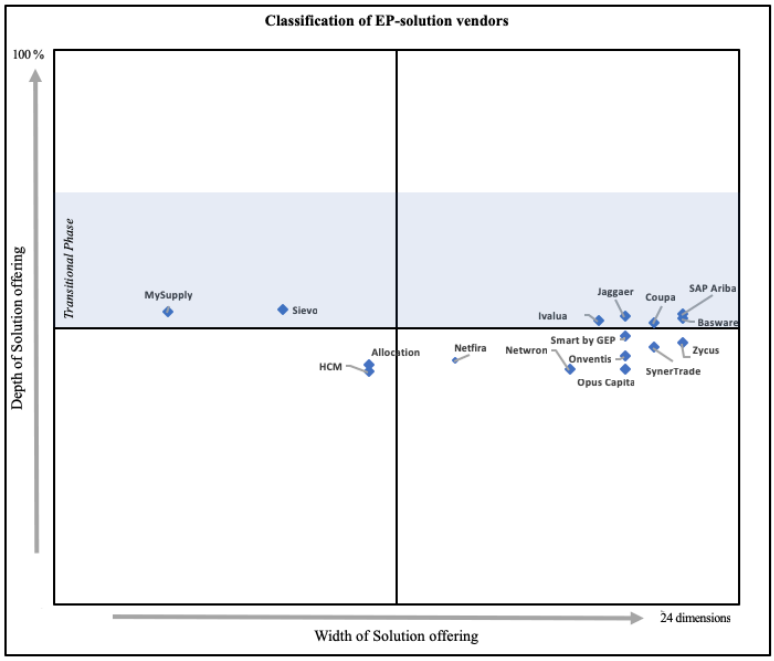


Figure 10: Classification of assessed vendors – General Overview

The quadrant provides a general overview of the assessed solutions. It is noteworthy, that the majority of vendors is within a close range and in the "Transitional Innovative All Star" section. This might have two reasons. Firstly, the largest proportion of assessed vendors provide full suit solutions. Hence, these vendors score on the far right of the quadrant model. Secondly, even though the most vendors advertise their technological superiority, it has been pointed out that none of the vendors could stand out from a technological Industry 4.0 point of view. This might be due to the fact that the sample chosen oriented on the international top-fair e-Lösungstage, where a strong competition is represented. However, also smaller vendors could be assessed properly and were able to score within a close range or even higher, such as Sievo.

Lastly, it is meaningful, that no vendor provides extremely sophisticated Industry 4.0 solutions. Hence, no vendor scored in the upper 25 percent of the quadrant, but some

vendors are in the before elaborated transition phase towards this position. Thus, the visualisation of the quadrant supports the statements from the section 5.1.

5.2.3. The P2P quadrant displays a strong focus on operative purchasing solutions

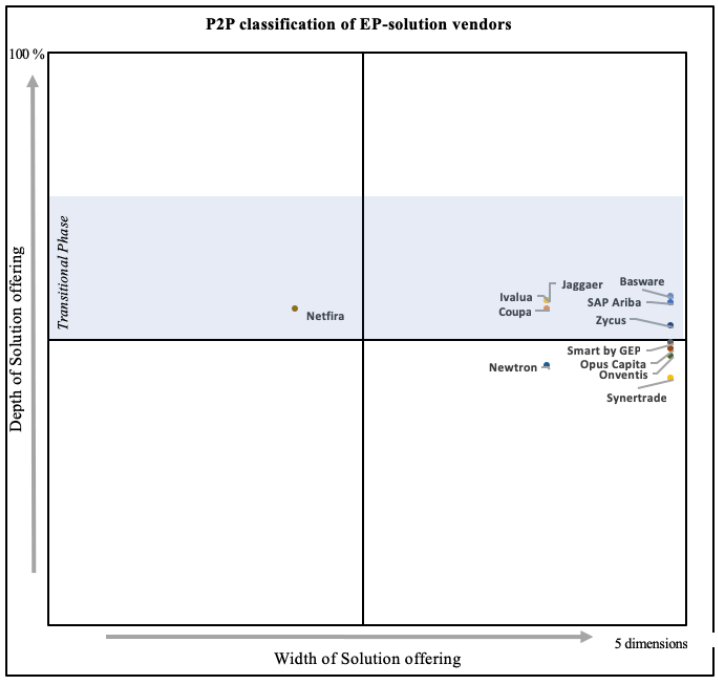


Figure 11: Classification of assessed vendors – Purchase-to-Payment

The "P2P-Quadrant" shows that many vendors provide a width operative e-purchasing solution. In addition, many assessed vendors are pictured within the "Transitional Innovative All Star" section. Compared to the "General Overview Quadrant" the results displayed have a higher sophistication towards meeting Industry 4.0 capabilities. Hence, the visualisation supports the fact that many vendors provide forward oriented P2P functionalities, such as advanced Invoice processing capabilities. Moreover, the degree of integration in this section is in particular high, due to advanced e-ordering possibilities. Nonetheless, no vendor stands out in this P2P detail view or reaches a very sophisticated Industry 4.0 maturity.

5.2.4. Many smaller vendors scored lower in the Controlling / KPI classification

The distribution and placement of supported Controlling / KPI solutions is more diverse than the "Overall Classification" and "P2P-Quadrant". The highest ranking has been achieved by Sievo, who provides key competencies within this section. Herby, the vendor supports outstanding data extraction capabilities and AI based Spend Data processing. Many full suit solution providers achieved also a "Transitional Innovative All Star"

position and vary mostly in the width of solutions offered. However, the visualisation supports the recognition that many smaller full-suit vendors lack of innovative analytical solutions.

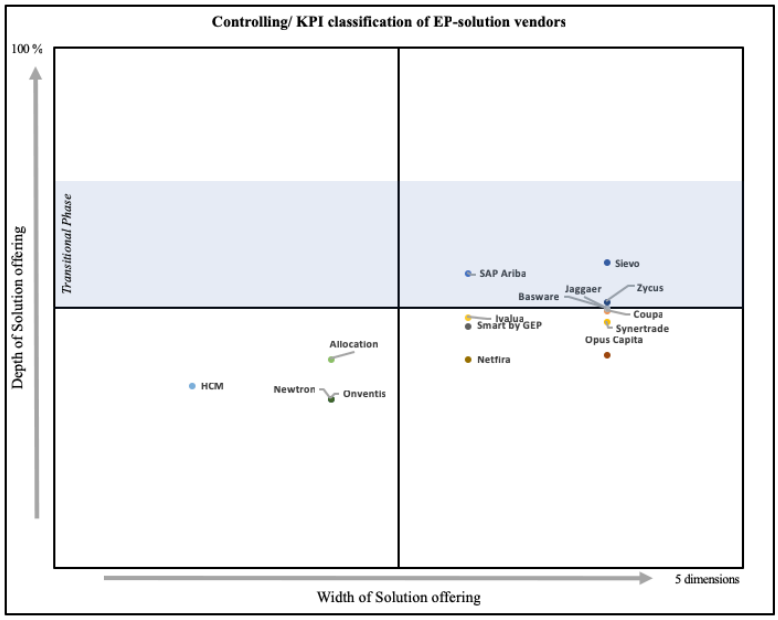


Figure 12: Classification of assessed vendors – Controlling / KPI

5.2.5. Majority of vendors support a brought width of S2C solutions

The "Sourcing Quadrant" displays many assessed vendors in the stage of „Established Generalists". However, leading vendors are placed in the "Transitional Innovative All Star" section. Moreover, Sievo can be considered as "Transitional Innovative Specialist" due to its comprehensive and strongly integrated "Contract Management" solution. It is noteworthy, that most Sourcing solutions scored on average lower compared to the P2P solutions. This confirms the statements of various e-purchasing vendors that it is less complicated to decrease human input and increase automation in purely operative processes.

Figure 13: Classification of assessed vendors – Sourcing

5.2.6 Supplier Management solutions differ mainly in the width of functionalities

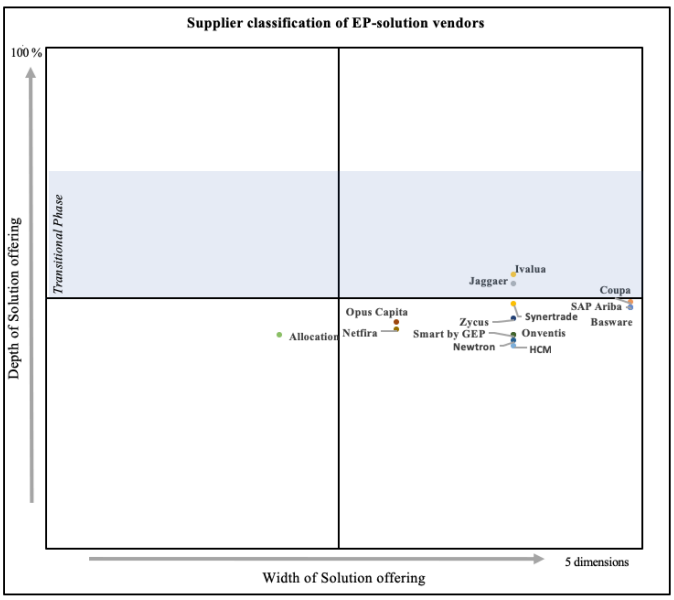


Figure 14: Classification of assessed vendors – Supplier

The “Supplier Quadrant” displays the majority of assessed vendors in the “Established Generalist” stage. As can be seen in Figure 14, the technological sophistication of various solutions is in a close range with each other. However, SAP Ariba, Coupa and Basware provide the most comprehensive solution, whereas Jaggaer and Ivalua provide the most sophisticated solution. Allocation, as relatively small vendor lacks a width supplier solution with a high sophistication. Overall, the visualisation mirrors the statements from chapter 5.1.4, that most solutions provide a high horizontal and vertical integration but human intervention is largely required.

6. Discussion on model evaluation, contributions and future research

6.1. Evaluation of Maturity Model as last step of Peffers et al. (2007) approach

The evaluation phase is the last step of Peffers et al. (2007) structure used in this research. The evaluation verifies how well the developed artefact supports a solution to the problem. This step involves the comparison of the objectives of a solution to the observed results and could include any appropriate evidence or logical proof.[200] Based on the nature of the problem and the developed artefact, the evaluation is based on the development and demonstration phase as part of the semi-structured interviews. Firstly, as part of the iterative development process the interviewees were asked for the comprehensiveness and comprehensibility of the model in order to assess diverse e-purchasing solution vendors. The participants agreed that the overall maturity model is comprehensive and encompasses all relevant e-purchasing solutions for the assessment. Secondly, the assessed vendors have confirmed that the structure of the model is comprehensible. Nonetheless, some vendors stated, that they would prefer variable weightings for the different sub-dimensions, based on the associated importance. Thirdly, the visualised classification in form of the quadrant model offered that the maturity model supports the assessment of different vendors, regardless of size or width of solution provided. Moreover, the visualised outcome is in line with the captured technological progress of the assessed solutions. Hence, the similarity of both results serves as logical proof of the functionality of the model. Overall, the unified model fulfils its purpose and enables the assessment and classification of various e-purchasing solution providers.

6.2. Theoretical contributions by providing a new maturity- and quadrant model

This research aimed to contribute to the current literature in the field of e-purchasing by filling the gap identified in the problem statement. While literature provides different Industry 4.0 maturity models for the assessment of purchasing organisations and quadrant models which classified selected international e-purchasing software solutions, the identified gap pointed out that literature lacks a model that enables the assessment, classification and comparison of diverse e-purchasing software solution vendors regardless of size or number of functionalities. Thus, the research started with the aforementioned theoretical design science research framework by Peffers et al. (2007) to structure the creation of a new artefact. The literature review provided fundamental insights on e-

[200] See Peffers et al. (2007), p.56.

purchasing, Industry 4.0 and relevant design principles for the development of the maturity model and its linked quadrant model, which facilitates the visualised comparability. Moreover, the draft version of the maturity model has been verified and enhanced through the input of purchasing experts. Subsequently, following the structure of Peffers et al. (2007) the necessity emerged to demonstrate the finalised model in the fitting organisational context.[201] In doing so, vendors of different sizes have been interviewed using the model to assess and classify their e-purchasing solutions. In addition, seven further vendors have been assessed and classified using the model based on web-research. On the one hand, this phase was used to verify the linkage of the visualised classification in the quadrant model. On the other hand, the demonstration resulted in an update about the technological progress of the vendor market in terms of the Industry 4.0 sophistication.
Based on the iterative development process and extensive demonstration, the main theoretical contribution of this research is addressed by presenting the first unified maturity- and quadrant model that supports the assessment and classification of e-purchasing solution vendors. By orienting on the proposed maturity stages of Morsinkhof, the maturity model provides a realistic assessment scheme towards Industry 4.0 requirements, considering that many organisations are still in the Industry 3.0 or a transition phase.[202] The linked quadrant model supports four classifications and allows the visualised comparison of assessed e-purchasing solution vendors. Due to the complexity of Industry 4.0 requirements the classifications include transition phases as explained in chapter 4.2. This is in particular valuable because it pictures which vendors have taken the first step towards meeting Industry 4.0 capabilities to a full extent.

6.3. Managerial implications for purchasing organisations and e-purchasing solution vendors

The findings of this research have led to the development of a new assessment tool for the evaluation of e-purchasing solution vendors and yield useful insights into the technological progress on the ep-solution market. Firstly, the developed maturity model and linked quadrant model provide e-purchasing organisations and further interested parties with a tool to systematically evaluate and classify current and planned I4.0 sophistication of e-purchasing solution vendors. In addition, the linked quadrant model supports the visualised classification and comparison of e-purchasing solution vendors. Thus, the model provides

[201] See Peffers et al. (2007), p. 54.
[202] See R.-J. Torn (2017), p. 67.

value for purchasing organisations struggling to determine an e-purchasing vendor that fits to their organisational needs and correspondingly maturity stage. Hence, the model promotes the ongoing digitisation and Industry 4.0 by facilitating the process of implementing solutions with an innovative Industry 4.0 sophistic. Secondly, the update on the technological progress of the e-purchasing solution vendor market provides purchasing organisations and solution vendors with the possibility to compare their solutions with the obtained benchmark as can be seen in Figure 9. Consequently, the benchmark decreases chances that purchasing organisation acquire backwards oriented solutions

6.4. Limitations and future research regarding the newly developed model

As every other research bears this study limitations. Beginning with the development of the maturity model. The model is based on an extensive literature review and feedback loops with interview experts. Nevertheless, the model has been designed to be consistent with Morsinkhof's (2018) previous work. Therefore, it is not possible to omit the circumstance that inconsistence aspects have been overlooked or where not compatible with the overall framework of Morsinkhof's model. Next, the sample size of nine interviewed and seven web-researched vendors represents a sufficient amount of responds to provide an update of the technological progress of e-purchasing solutions. Nevertheless, it is possible that further findings would have been obtained if the sample size would have been larger. Moreover, it is noteworthy that the vendor selection oriented on the e-Lösungstage and represents therefore renowned solutions. Lastly, the evaluation of the vendors has been conducted by one researcher, whereas the thesis points out that a higher number of accessors would increase the reliability, based on a reliable mean analysis. Thus, the assessed results have to be viewed with caution.

The developed and evaluated maturity and quadrant models can be considered as first unified model that displays the transparent evaluation and classification of various e-purchasing solution vendors. Firstly, the whole model should be evaluated and tested based on a larger sample. Wieringa (2014) explains that an increased sample size enhances the generalisation, which leads to an improved "Street credibility".[203] Moreover, it is advised to challenge the proposed architecture of the model to verify if the used number of four maturity stages withstands an increased number of levels. Lastly, it is remarkable that a weighting score based on the importance of the dimension could enhance the model.

[203] See Wieringa (2014), p. 4.

Bibliography

1. **Al-Qutaish, R., & Abran, A. (2011).** A maturity model of software product quality. *Journal of Research and Practice in Information Technology, 43*(4), 307.

2. **Alam, M., Nielsen, R. H., & Prasad, N. R. (2013, 3-5 July 2013).** *The evolution of M2M into IoT.* Paper presented at the First International Black Sea Conference on Communications and Networking (BlackSeaCom).

3. **Angeles, R., & Nath, R. (2007).** Business-to-business e-procurement: success factors and challenges to implementation. *Supply Chain Management: An International Journal, 12*(2), 104-115.

4. **Angelov, S., & Grefen, P. (2008).** An e-contracting reference architecture. *Journal of Systems and Software, 81*(11), 1816-1844.

5. **Appelfeller, W. (2019).** E-Supplier Relationship Management und die digitale Transformation der Beschaffung. In T. Kollmann (Ed.), *Handbuch Digitale Wirtschaft* (pp. 1-26). Wiesbaden: Springer Fachmedien Wiesbaden.

6. **Bandyopadhyay, D., & Sen, J. (2011).** Internet of things: Applications and challenges in technology and standardization. *Wireless Personal Communications, 58*(1), 49-69.

7. **Basware. (2013).** Basware expands cooperation with major Swedish automotive manufacturer to provide catalog management and supplier onboarding services. Retrieved May 01, 2019 from https://investors.basware.com/pr-story?itemid=DF20A1DEE44C1242

8. **Beall, S., Carter, C., Carter, P. L., Germer, T., Hendrick, T., Jap, S., Kaufmann, L., Maciejewski, D., Monczka, R., Petersen, K. (2003).** The role of reverse auctions in strategic sourcing. *CAPS research.* Retrieved May 15, 2019 from http://lilgerry.com/beall2003ecom.pdf

9. **Becker, J., Knackstedt, R., & Pöppelbuß, J. (2009).** Developing maturity models for IT management. *Business & Information Systems Engineering, 1*(3), 213-222.

10. **Bergfors, Connaughton, Edwards, McNeill, & Sommers. (2018).** Magic Quadrant for Strategic Sourcing Application Suites. Retrieved April 14, 2019 from https://www.gartner.com/en/documents/3884503/magic-quadrant-for-strategic-sourcing-application-suites

11. **Berson, A., & Dubov, L. (2007).** *Master data management and customer data integration for a global enterprise*: McGraw-Hill, Inc.

12. **Bienhaus, F., & Haddud, A. (2018).** Procurement 4.0: factors influencing the digitisation of procurement and supply chains. *Business Process Management Journal, 24*(4), 965-984.

13. **Biltoft-Knudsen, Desi, Gardy, Schnellbächer, & Weise. (2018).** Meeting The Need For Procurement Speed. Retrieved 10.04.2019 from https://www.bcg.com/de-de/publications/2018/meeting-need-procurement-speed.aspx

14. **Black, D., & Thomas, J. (2013).** How Gartner Evaluates Vendors and Markets in Magic Quadrants and MarketScopes. Retrieved May 15, 2019 from https://www.gartner.com/doc/2560415/gartner-evaluates-vendorsmarkets-magic#a-356148118)

15. **BME Verband. (2019).** BME e-Lösungstage 2019. Retrieved April 02, 2019 from https://www.bme.de/2019/10-bme-eloesungstage-2019/

16. **Bottani, E., & Rizzi, A. (2005).** A fuzzy multi-attribute framework for supplier selection in an e-procurement environment. *International Journal of Logistics: Research and Applications, 8*(3), 249-266. doi: https://doi.org/10.1080/13675560500240445

17. **Braun, A. (2019).** Robotic Process Automation vs. Artificial Intelligence: What's the Difference? Retrieved June 29, 2019 from https://www.maketecheasier.com/robotic-process-automation-vs-artificial-intelligence/

18. **Canito, J., Ramos, P., Moro, S., & Rita, P. (2018).** Unfolding the relations between companies and technologies under the Big Data umbrella. *Computers in Industry, 99*, 1-8.

19. **Capgemini. (2018).** Digital Procurement Research 2018: Uncovering the solutions that bring you forward. Retrieved April 05, 2019 from https://www.capgemini.com/nl-nl/wp-content/uploads/sites/7/2018/10/Capgemini-Digital-Procurement-Research-2018_web-version1.pdf

20. **Castillo, F. (2016).** *Managing information technology*. Switzerland: Springer International Publishing.

21. **CFB Bots. (2018).** The Difference between Robotic Process Automation and Artificial Intelligence. Retrieved May 10, 2019 from https://medium.com/@cfb_bots/the-difference-between-robotic-process-automation-and-artificial-intelligence-4a71b4834788

22. **Choi, S., Kang, G., Jun, C., Lee, J., & Han, S. (2017).** Cyber-physical systems: a case study of development for manufacturing industry. *International Journal of Computer Applications in Technology, 55*(4), 289-297 . doi:10.1504/IJCAT.2017.10006845

23. **Colucci, S., Di Noia, T., Di Sciascio, E., Donini, F. M., & Mongiello, M. (2005).** Concept abduction and contraction for semantic-based discovery of matches and negotiation spaces in an e-marketplace. *Electronic Commerce Research and Applications, 4*(4), 345-361.

24. **Coupa. (2019).** Coupa Procure-to-Pay (P2P) Solution Retrieved April 15, 2019 from https://www.coupa.com/pdf/datasheet/coupa-procure-to-pay-p2p-solution-ds.pdf

25. **Coupa. (2019a).** Coupa Contract Managment. Retrieved April 15, 2019 from https://www.coupa.com/products/contract-management/

26. **Coupa. (2019b).** Coupa Spend Analysis. Retrieved April 15, 2019 from https://www.coupa.com/products/spend-analysis/

27. **Da Xu, L., He, W., & Li, S. (2013).** Internet of Things in Industries: A Survey. *IEEE Transactions on Industrial Informatics, 10*(4), 2233-2243. doi:10.1109/TII.2014.2300753

28. **Davila, A., Gupta, M., & Palmer, R. (2003).** Moving procurement systems to the internet:: The adoption and use of e-procurement technology models. *European management journal, 21*(1), 11-23.

29. **De Boer, L., Harink, J., & Heijboer, G. (2002).** A conceptual model for assessing the impact of electronic procurement. *European Journal of Purchasing & Supply Management, 8*(1), 25-33.

30. **De Carolis, A., Macchi, M., Negri, E., & Terzi, S. (2017, 3-7 September 2017).** *A maturity model for assessing the digital readiness of manufacturing companies.* Paper presented at the IFIP International Conference on Advances in Production Management Systems, Hamburg, Germany.

31. **Determine Inc. (2015).** eSourcing vs. eProcurement: What are the differences? Retrieved April 15, 2019 from https://www.determine.com/blog/sourcing-vs-procurement

32. **Edwards, McNeill, Bergfors, Connaughton, & Sommers. (2018).** Magic Quadrant for Procure-to-Pay Suites. Retrieved April 16, 2019 from https://www.gartner.com/en/documents/3876770/magic-quadrant-for-procure-to-pay-suites0

33. **Ehrler, M. (2019).** How to choose the best e-procurement tool. Retrieved April 16, 2019 from https://www.jaggaer.com/choosing-the-right-eprocurement-solution/

34. **Elmaghraby, W. (2007).** Auctions within e-sourcing events. *Production and Operations Management, 16*(4), 409-422.

35. **Geissbauer, Vedso, & Schrauf. (2016).** Industry 4.0: Building the digital enterprise. Retrieved April 16, 2019 from https://www.pwc.de/de/digitale-transformation/industry-4-0-building-your-digital-enterprise.pdf

36. **Giunipero, L., Ramirez, E., & Swilley, E. (2012).** The Antecedents and Consequences of E-Purchasing Tools Usage in Supply Management. *Journal of Marketing Theory and Practice, 20*(3), 279-292. doi:10.2753/MTP1069-6679200303

37. **Gökalp, E., Şener, U., & Eren, P. E. (2017), 4-5 October 2017).** *Development of an assessment model for industry 4.0: industry 4.0-MM.* Paper presented at the International Conference on Software Process Improvement and Capability Determination, Palma de Mallorca, Spain.

38. **Gunasekaran, A., & Ngai, E. W. T. (2008)**. Adoption of e-procurement in Hong Kong: an empirical research. *International Journal of Production Economics, 113*(1), 159-175.

39. **Hartley, J. L., Lane, M. D., & Hong, Y. (2004).** An exploration of the adoption of e-auctions in supply management. *IEEE Transactions on Engineering Management, 51*(2), 153-161.

40. **Hashem, I., Yaqoob, I., Anuar, N., Mokhtar, S., Gani, A., & Ullah Khan, S. (2014).** *The rise of "Big Data" on cloud computing: Review and open research issues*. *Information systems, 47,* 98-115.

41. **Hermann, M., Pentek, T., & Otto, B. (2016, 05-08 January 2016).** *Design principles for industrie 4.0 scenarios.* Paper presented at the 49th Hawaii International Conference on System Sciences (HICSS), Hawaii, USA.

42. **Hevner, Salvatore, Jinsoo, & Sudha. (2004).** Design science in information systems research. *MIS quarterly, 28*(1), 75-105.

43. **Hilbert, M. (2016).** Big data for development: A review of promises and challenges. *Development Policy Review, 34*(1), 135-174.

44. **Högel, M., Schnellbächer, W., Tevelson, R., & Weise, D. (2018).** Delivering on Digital Procurement's Promise. Retrieved June 30, 2019 from https://www.bcg.com/de-de/publications/2018/delivering-digital-procurement-promise.aspx

45. **Hong, P., & Kwon, H.-B. (2012).** Emerging issues of procurement management: a review and prospect. *International Journal of Procurement Management 4, 5*(4), 452-469.

46. I**valua. (2019).** Strategy & Analytics. Retrieved April 15, 2019 from https://www.ivalua.com/solutions/process/strategic-sourcing/strategy-analytics/

47. **Ivalua. (2019a).** Supply Chain Financing. Retrieved April 15, 2019 from https://www.ivalua.com/solutions/business/working-capital-management/

48. **Jaggaer. (2019).** Das Jaggaer Lieferantennetzwerk. Retrieved April 16, 2019 from https://www.jaggaer.com/de/netzwerk/

49. J**ain, K., & Woodcock, E. (2017).** A roadmap for digitizing source-to-pay. Retrieved June 30, 2019 from https://www.mckinsey.com/business-functions/operations/our-insights/a-road-map-for-digitizing-source-to-pay

50. **Jansz, S., & Back, A. (2011, 4-7 January 2011).** *Towards a Maturity Model for E-Collaboration - A Design Science Research Approach.* Paper presented at the 44th Hawaii International Conference On System Sciences, Hawaii, USA.

51. **Jazdi, N. (2014, 22-24 May 2014).** *Cyber physical systems in the context of Industry 4.0.* Paper presented at the 2014 IEEE International Conference on Automation, Quality and Testing, Robotics AQTR, Cluj-Napoca, Romania.

52. **Kagermann, H. (2015).** Change through digitization—Value creation in the age of Industry 4.0 *Management of permanent change* (pp. 23-45): Springer.

53. **Kagermann, H., Helbig, J., Hellinger, A., & Wahlster, W. (2013).** *Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Securing the future of German manufacturing industry; final report of the Industrie 4.0 Working Group*: Forschungsunion.

54. **Käkölä, T., & Lu, Y. (2015, 5-8 January 2015).** *Best Practices for International eSourcing of Software Products and Services from the Service Providers' Perspective.* Paper presented at the 48th Hawaii International Conference on System Sciences, Hawaii, USA.

55. **Kang, H. S., Lee, J. Y., Choi, S., Kim, H., Park, J. H., Son, J. Y., Do Noh, S. (2016).** Smart manufacturing: Past research, present findings, and future directions. *International Journal of Precision Engineering and Manufacturing-Green Technology, 3*(1), 111-128.

56. **Kitchin, R., & McArdle, G. (2016).** What makes Big Data, Big Data? Exploring the ontological characteristics of 26 datasets. *Big Data & Society, 3*(1). doi:https://doi.org/10.1177/2053951716631130

57. **Knudsen, D. (2003).** Aligning corporate strategy, procurement strategy and e-procurement tools. *International Journal of Physical Distribution & Logistics Management, 33*(8), 720-734.

58. **Kollmann, T. (2016).** *E-Business–Grundlagen elektronischer Geschäftsprozesse in der Digitalen Wirtschaft.* (Vol. 6). Wiesbaden: Gabler Verlag.

59. **Kshetri, N. (2017).** Can blockchain strengthen the internet of things? *IT professional, 19*(4), 68-72.

60. **Lamoureux, M. G. (2018).** *The Strategic Sourcing Lifecycle: A Brief Introduction.* Retrieved April 05, 2019 from https://www.coupa.com/products/strategic-sourcing/sourcing-optimization/

61. **Lasi, H., Fettke, P., Kemper, H.-G., Feld, T., & Hoffmann, M. (2014).** Industry 4.0. *Business & Information Systems Engineering, 6*(4), 239-242.

62. **Lee, J., Bagheri, B., & Kao, H.-A. (2015).** A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems. *Manufacturing Letters, 3*, 18-23. doi:https://doi.org/10.1016/j.mfglet.2014.12.001

63. **Lim, M. (2018).** What is the Difference Between Procurement and Purchasing? Retrieved April 05, 2019 from https://blog.procurify.com/2014/02/07/what-is-the-difference-between-procurement-and-purchasing/

64. **Lin, F., Chen, C., Zhang, N., Guan, X., & Shen, X. (2016).** Autonomous Channel Switching: Towards Efficient Spectrum Sharing for Industrial Wireless Sensor Networks. *IEEE Internet of Things Journal, 3*(2), 231-243. doi:10.1109/JIOT.2015.2490544

65. **Maier, A., Moultrie, J., & Clarkson, P. J. (2012).** Developing maturity grids for assessing organisational capabilities: Practitioner guidance. *IEEE Transactions on Engineering Management, 50*(1).

66. **Mehrbod, A., Zutshi, A., & Grilo, A. (2014).** A vector space model approach for searching and matching product e-catalogues. *Advances in Intelligent Systems and Computing, 281*, 833-842. doi:10.1007/978-3-642-55122-2_71

67. **Mell, P., & Grance, T. (2011).** The NIST definition of cloud computing. Retrieved June 30, 2019 from https://nvlpubs.nist.gov/nistpubs/Legacy/SP/nistspecialpublication800-145.pdf

68. **Mettler, T., & Rohner, P. (2009)**. Situational maturity models as instrumental artifacts for organizational design. Retrieved May 15, 2019 from https://www.researchgate.net/publication/44939464_Situational_Maturity_Models_as_Instrumental_Artifacts_for_Organizational_Design doi:10.1145/1555619.1555649

69. **Min, H., & Galle, W. (2003).** E-purchasing: Profiles of adopters and nonadopters. *Industrial marketing management, 32*. doi:10.1016/S0019-8501(02)00266-3

70. **Monczka, R. M., Handfield, R. B., Giunipero, L. C., & Patterson, J. L. (2009).** *Purchasing and supply chain management*: South-Western.

71. **Monostori, L. (2014).** Cyber-physical production systems: Roots, expectations and R&D challenges. *Procedia Cirp, 17*, 9-13.

72. **Morsinkhof, P. (2018).** *Assessing E-Procurement maturity as designed in an E-Procurement Maturity Model and Quadrant Model.* (Master's thesis), University of Twente.

73. **Neupane, A., Soar, J., Vaidya, K., & Yong, J. (2012, 17-19 August 2012).** *Role of public e-procurement technology to reduce corruption in government procurement.* Paper presented at the Public Procurement Research Center, Seattle, USA.

74. **Oesterreich, T., & Teuteberg, F. (2016).** Understanding the implications of digitisation and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry. *Computers in Industry, 83*. doi:10.1016/j.compind.2016.09.006

75. **OpusCapita. (2019).** Elektronische Rechnungsstellung. Retrieved April 15, 2019 from https://www.opuscapita.de/loesungen/business-network/e-invoicing

76**. OpusCapita. (2019a)**. Unsere Einkaufslösungen: Supplier Portal. Retrieved April 15, 2019 from https://www.opuscapita.de/loesungen/source-to-pay/sourcing

77. **Oyediran, O. S., & Akintola, A. A. (2011).** A Survey of the State of the Art of E-Tendering in Nigeria. *Journal of Information Technology in Construction (ITcon), 16*(32), 557-576.

78. **Oztemel, E., & Gursev, S. (2018).** Literature review of Industry 4.0 and related technologies. *Journal of Intelligent Manufacturing*, 1-56.

79. **Palmer, R. J., & Gupta, M. R. (2011).** Technology-Driven Convergence of Business Processes in the Acquisition Cycle: Implications for Accountants and Educators. *Journal of Emerging Technologies in Accounting, 8*(1), 65-87.

80. **Peffers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007).** A design science research methodology for information systems research. *Journal of management information systems, 24*(3), 45-77.

81. **Pfohl, H.-C., Yahsi, B., & Kurnaz, T. (2015, 26-27 September 2015).** *The Impact of Industry 4.0 on the Supply Chain.* Paper presented at the Hamburg International Conference of Logistic (HICL), Hamburg.

82. **Pöppelbuß, J., & Röglinger, M. (2011, 9-11 June 2011).** *What makes a useful maturity model? a framework of general design principles for maturity models and its demonstration in business process management.* Paper presented at the 19th European Conference on Information Systems ECIS, Helsinki, Finland.

83. **Presutti Jr, W. D. (2003).** Supply management and e-procurement: creating value added in the supply chain. *Industrial marketing management, 32*(3), 219-226.

84. **Puschmann, T., & Alt, R. (2005).** Successful use of e-procurement in supply chains. *Supply Chain Management: An International Journal, 10*(2), 122-133.

85. **Rajkumar, T. M. (2001).** E-procurement: business and technical issues. *Information Systems Management, 18*(4), 52-60.

86. **Rendon, R. G. (2008).** Procurement process maturity: Key to performance measurement. *Journal of Public Procurement, 8*(2), 200-214.

87. **Reunis, M. R. B., Santema, S. C., & Harink, J. H. A. (2006).** Increasing e-ordering adoption: A case study. *Journal of Purchasing and Supply Management, 12*(6), 322-331.

88. **Roblek, V., Meško, M., & Krapež, A. (2016).** A complex view of industry 4.0. *Sage Open, 6*(2). doi:10.1177/2158244016653987

89. **Sanders, A., Elangeswaran, C., & Wulfsberg, J. (2016).** Industry 4.0 implies lean manufacturing: research activities in industry 4.0 function as enablers for lean manufacturing. *Journal of Industrial Engineering and Management, 9*(3), 811-833.

90. **SAP Ariba. (2018).** SAP Ariba Spend Analysis- Data Sheet. Retrieved April 15, 2019 from https://www.ariba.com/-/media/aribacom/assets/pdf-assets/sap-ariba-spend-analysis-datasheet.pdf?la=en-us&hash=143116B9886776FA3E62B02E251963B1D92D295F

91. **SAP Ariba. (2019a).** SAP Ariba Supplier Risk. Retrieved April 15, 2019 from https://www.ariba.com/de-de/solutions/solutions-overview/supplier-management/supplier-risk

92. **Saunders, M., Lewis, P., & Thornhill, A. (2016).** *Research methods for business students* (6 ed.). Harlow: Pearson Education Limited.

93. **Schiele, H. (2007).** Supply-Management Maturity, Cost Savings and Purchasing Absorptive Capacity. *Journal of Purchasing and Supply Management, 13*(4), 274-293. doi:10.1016/j.pursup.2007.10.002

94. **Schiele, H. (2016).** Industrie 4.0 in der Beschaffung. *Wing business, 4*, 15-18.

95. **Schiele, H. (2018).** *Lecture 1 Introduction and Industry 4.0* [PowerPoint Slide]. Retrieved July 3, 2018 from http://blackboard.utwente.nl

96. **Schiele, H. (2019).** Purchasing and Supply Management. In H. Zijm;, M. Klumpp;, A. Regattieri;, & S. Heragu (Eds.), *Operations, Logistics and Supply Chain Management*. Switzerland: Springer International Publishing AG.

97. **Sievo. (2018).** Sievo Recognized as a Value Leader in Spend Analytics by Spend Matters. Retrieved May 20, 2019 from https://sievo.com/blog/sievo-recognized-as-a-value-leader-in-spend-analytics-by-spend-matters

98. **Sitar, C. (2011a).** The Barrieres of Implementing E-Procurment *Studia Universitatis Vasile Goldiş, Arad - Seria Ştiinţe Economice, 21*(2), 120-124.

99. **Sitar, C. (2011b).** The role of the e-procurement in the purchasing process. *The Annals of the University of Oradea, 1*(2), 687-691.

100. **Smart, A. F. (2010).** E-procurement and its impact on supply management – evidence from industrial case studies. *International Journal of Logistics Research and Applications, 13*(6), 423-440. doi:10.1080/13675567.2010.486760

101. **Smart by GEP. (2019).** Spend Management Software Retrieved April 15, 2019 from https://www.smartbygep.com/procurement-software/spend-management

102. **Smart by GEP. (2019a).** What is Category Analysis? Retrieved April 15, 2019 from https://www.smartbygep.com/insight/procurement-glossary/category-analysis

103. **Smart by GEP. (2019b).** Comprehensive Supplier Intelligence and Risk Management. Retrieved April 15, 2019 from https://www.smartbygep.com/procurement-software/supplier-management/supplier-base-intelligence

104. **Smit, Kreutzer, Moeller, & Carlberg. (2016).** *Industry 4.0*. Retrieved June 30, 2019 from Policy Department A: Economic and Scientific Policy: http://www.europarl.europa.eu/RegData/etudes/STUD/2016/570007/IPOL_STU(2016)570007_EN.pdf

105. **Smith, P. (2014).** Why Supplier Management should be central to your procurement thinking. *OFS Portal LLC.* Retrieved June 30, 2019 from https://ofs-portal.com/wp-content/uploads/2016/04/Supplier-Management-140326v4.pdf

106. **Smith, P. (2018).** Jason Busch on Big Data, Social and Procurement Tech Futures. Retrieved June 30, 2019 from http://spendmatters.com/uk/jason-busch-big-data-social-procurement-tech-futures/

107. **Spend Matters. (2015).** What to Do With Purchasing Information Provided by the Internet of Things. Retrieved April 20, 2019 from http://spendmatters.com/2015/08/06/what-to-do-with-purchasing-information-provided-by-the-internet-of-things/

108. **Stock, T., & Seliger, G. (2016).** Opportunities of sustainable manufacturing in industry 4.0. *Procedia Cirp, 40*, 536-541.

109. **Stoll, P. P. (2007).** *Handbuch E-Procurement: Grundlagen, Standards und Situation am Markt*. Wiesbaden: Springer-Verlag.

110. **Synertrade. (2016).** Was zusammengehört, wächst zusammen – SynerTrade und riskmethods kündigen strategische Partnerschaft an. Retrieved May 10, 2019 from https://synertrade.com/de/fokus/nachrichten-presse-veroffentlichung/2016/06/synertrade-riskmethods-strategische-partnerschaft/

111. **The Industry Working Group of Universiteit Twente (2018).** BMS Smart Industry Research Roadmap. Retrieved June 30, 2019 from https://www.utwente.nl/en/bms/research/bms-research-themes/industry/bms-smart-industry-research-roadmap.pdf

112. **Thitimajshima, W., Esichaikul, V., & Krairit, D. (2017).** A framework to identify factors affecting the performance of third-party B2B e-marketplaces: A seller's perspective. *Electronic Markets, 28*(2), 129-147.

113. **Torn, I. A. R.-J., Pulles, N. J., & Schiele, H. (2018, 25-28 March 2018).** *Industry 4.0 and how purchasing can progress and benefit from the fourth industrial revolution.* Paper presented at the 27th Annual IPSERA Conference 2018, Athens, Greece.

114. **Torn, R.-J. (2017).** *The Future of Purchasing and Industry 4.0: How Purchasing can Progress and Benefit the Fourth Industrial Revolution.* (Master's Thesis), University of Twente.

115. **Trkman, P., & McCormack, K. (2010).** Estimating the benefits and risks of implementing e-procurement. *IEEE Transactions on Engineering Management, 57*(2), 338-349.

116. **Van Weele, A. J., & Eig, M. (2017).** *Strategische Beschaffung, Grundlagen, Planung und Umsetzung eines integrierten Supply Management*. Wiesbaden: Vieweg+Teubner Verlag.

117. **Wade, M., & Hulland, J. (2004).** The resource-based view and information systems research: Review, extension, and suggestions for future research. *MIS quarterly, 28*(1), 107-142.

118. **Wang, S., Wan, J., Li, D., & Zhang, C. (2016).** Implementing smart factory of industrie 4.0: an outlook. *International Journal of Distributed Sensor Networks, 12*(1), 3159805.

119. **Wieringa, R. (2014).** Empirical research methods for technology validation: Scaling up to practice. *Journal of Systems and Software, 95*, 19-31.

120. **Zhong, R. Y., Newman, S. T., Huang, G. Q., & Lan, S. (2016).** Big Data for supply chain management in the service and manufacturing sectors: Challenges, opportunities, and future perspectives. *Computers & Industrial Engineering, 101*, 572-591.

121. **Zhou, K., Liu, T., & Zhou, L. (2015, 15-17 August 2015).** *Industry 4.0: Towards future industrial opportunities and challenges.* Paper presented at the International Conference on Fuzzy Systems and Knowledge Discovery (FSKD), Zhangjiajie, China.

122. **Zillich, C. (2005).** Was von Marktplätzen übrig blieb. Retrieved June 30, 2019 from https://www.computerwoche.de/a/was-von-marktplaetzen-uebrig-blieb,558000,3

123. **Zycus. (2019).** Category Management. Retrieved April 15, 2019 from https://www.zycus.com/blog/glossary/category-management/

124. **Zycus. (2019a).** Software für Lieferantenmanagement. Retrieved April 15, 2019 from https://www.zycus.com/solution/supplier-management.html

Appendix I: Interview guide of the maturity model

Interview guide for the E-Purchasing Software Solutions Maturity Model

Warm up:

I. What is your current position in the company?

II. Briefly introduction of the model in order to explain the scope of the research.

The maturity model contains 7 dimensions with subtopics, namely

- Physical & Virtual linkage,
- Purchase to Pay (predictive demand, E-ordering, E-catalogues, Maverick Buying, Monitoring of invoices and payment)
- Controlling (Category analysis, Spend analysis, KPI, Inventory Analysis),
- Sourcing (E-marketplace, E-sourcing, Reverse-Auctions, E-contract management),
- Supplier (Supplier Evaluation, Data exchange, Connection of Supplier, Supply Chain Risk, Financial Supply Chain Management)
- Knowledge support (Training of End-Users, Experience of vendors employees)
- Software support (Availability and Updates, Security of Data)

Questions are ordered by their importance

I. What purchasing dimension or subtopic is missing in the conceptualized maturity model? (Reviewing the different dimensions)

II. How would you describe the construction of the model in the context of usability and comprehensiveness to pre-select and/ or benchmark EP-solutions?

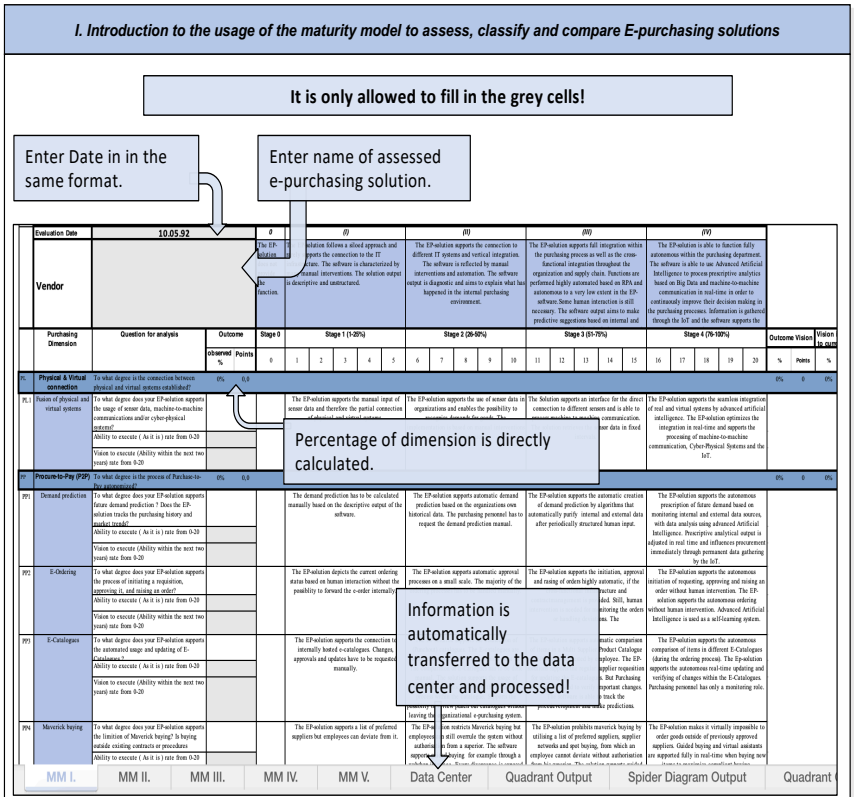
III. Based on your experience, in which stage would you place the most software solutions in your working environment?

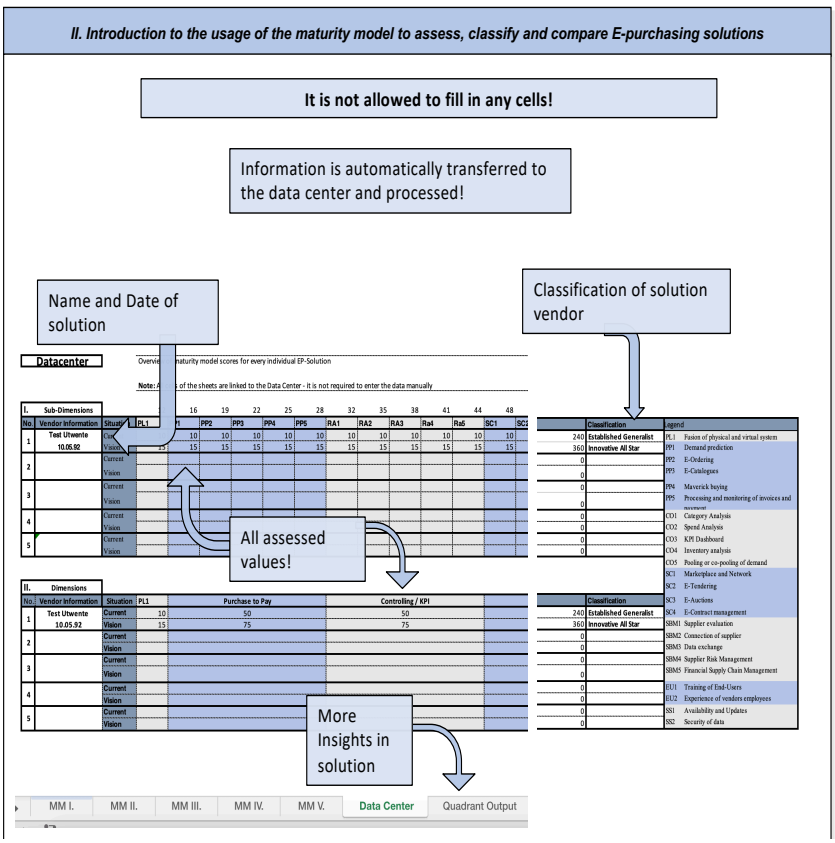
IV. General remarks?

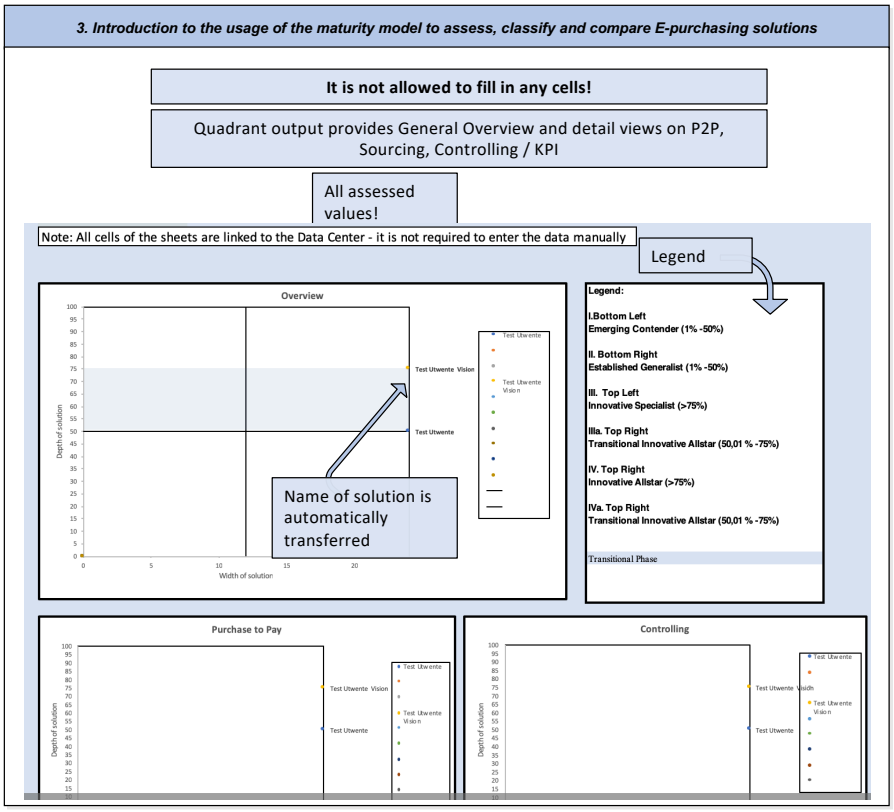
Appendix II: Checklist for design principles - Pöppelbuß and Röglinger (2011, p.7)

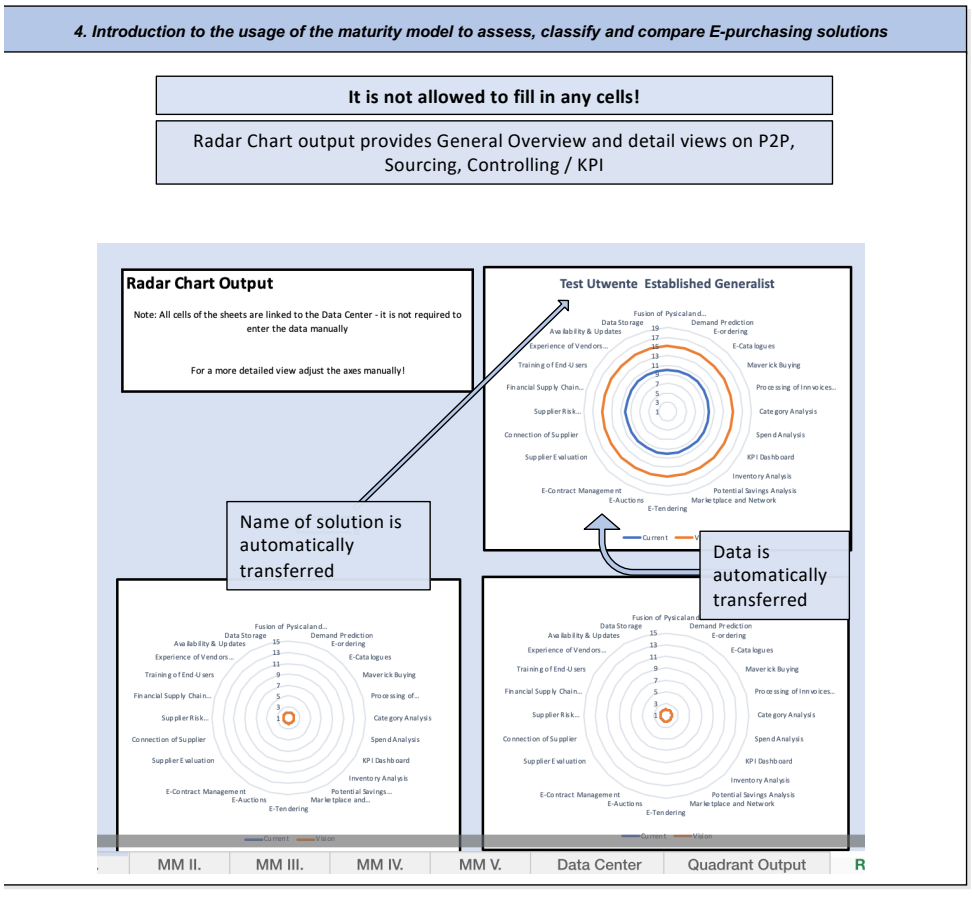
Group		Design Principles
(1) BASIC	1.1	**Basic information** a) Application domain and prerequisites for applicability b) Purpose of use c) Target group d) Class of entities under investigation e) Differentiation from related maturity models f) Design process and extent of empirical validation
	1.2	**Definition of central constructs related to maturity and maturation** a) Maturity and dimensions of maturity b) Maturity levels and maturation paths c) Available levels of granularity of maturation d) Underpinning theoretical foundations with respect to evolution and change
	1.3	**Definition of central constructs related to the application domain**
	1.4	**Target group-oriented documentation**
(2) DESCRIPTIVE	2.1	**Intersubjectively verifiable criteria for each maturity level and level of granularity**
	2.2	**Target group-oriented assessment methodology** a) Procedure model b) Advice on the assessment of criteria c) Advice on the adaptation and configuration of criteria d) Expert knowledge from previous application
(3) PRESCRIPTIVE	3.1	**Improvement measures for each maturity level and level of granularity**
	3.2	**Decision calculus for selecting improvement measures** a) Explication of relevant objectives b) Explication of relevant factors of influence c) Distinction between an external reporting and an internal improvement perspective
	3.3	**Target group-oriented decision methodology** a) Procedure model b) Advice on the assessment of variables c) Advice on the concretization and adaption of the improvement measures d) Advice on the adaptation and configuration of the decision calculus e) Expert knowledge from previous application

Appendix III: Explanation Maturity Model Tool






3. Introduction to the usage of the maturity model to assess, classify and compare E-purchasing solutions
It is not allowed to fill in any cells!
Quadrant output provides General Overview and detail views on P2P, Sourcing, Controlling / KPI
All assessed values!
Note: All cells of the sheets are linked to the Data Center - it is not required to enter the data manually
Legend
Overview
Depth of solution
Width of solution
Test Utwente Vision
Test Utwente
Name of solution is automatically transferred
Legend:
I.Bottom Left
Emerging Contender (1% -50%)
II. Bottom Right
Established Generalist (1% -50%)
III. Top Left
Innovative Specialist (>75%)
IIIa. Top Right
Transitional Innovative Allstar (50,01 % -75%)
IV. Top Right
Innovative Allstar (>75%)
IVa. Top Right
Transitional Innovative Allstar (50,01 % -75%)
Transitional Phase
Purchase to Pay
Controlling


4. Introduction to the usage of the maturity model to assess, classify and compare E-purchasing solutions
It is not allowed to fill in any cells!
Radar Chart output provides General Overview and detail views on P2P, Sourcing, Controlling / KPI
Radar Chart Output
Note: All cells of the sheets are linked to the Data Center - it is not required to enter the data manually
For a more detailed view adjust the axes manually!
Test Utwente Established Generalist
Name of solution is automatically transferred
Data is automatically transferred
MM II.
MM III.
MM IV.
MM V.
Data Center
Quadrant Output

Appendix IV: Data for the assessment and classification of e-purchasing vendors

	SAP Ariba	Synertrade	Zycus	OpusCapita	SmartbyGEP	Newtron	Onventis	Allocation	my supply	Basware	Coupa	Jaggaer	Ivalua	Sievo	HCM	Netfira
Fusion of physical and virtual systems	11		10				10									6
P2P																
Demand prediction	11	7	8	7	7		7			10						
E-Ordering	11	8	11	8	11	8	10			11	11	11	10			9
E-Catalogues	10	9	11	11	11	10	10			11	10	12	12			
Maverick buying	11	8	9	**9**	9	9	9			12	12	9	9			
Processing and monitoring of invoices and payment	13	11	13	13	11	9	11			13	11	13	14			13
Controlling/KPI																
Category Analysis	11	12	12	8	8			9		11	8	11	10	12		
Spend Analysis	12	10	11	8	11	7	7	7		11	11	12	10	12		
KPI Dashboard	11	11	12	9	9	6	6			10	10,5	10	9	12	7	9
Inventory analysis			6	8						8	10					
Savings Analysis												7		11		
Sourcing																
E-Marketplace/ Network	**11**	8	8	8	10	8	8			8	11	10	8			8
E-tendering	11	10	11	8	11	9	9	10	11	10	11	11	11		10	8
E-Auctions	11	11	10		11	9	9	10	12	11	10	10	11			
E-Contract management	11	9	11	6	11	6	11	6		11	11	11	11	11	6	
Supplier																
Supplier evaluation	11	11	11,5	7	9	9	6	9		11	11	11	11,5		8	7
Connection of supplier	9	8	8	9	8	7	11	8		8	8	9	9		9	8
Data exchange	10	11	8	11	8	8	8			8	8	11	12		7	11
Supplier Risk Management	11	9	9		*9*	9	9			*10*	*11*	11	11		7	
Financial Supply Chain Management	**7**									11	11					
Employees /Users																
Training of Users and Support	8	8	9	7	8	8	8	8		8	8	9	8	7	8	8
Experience of vendors employees	9	9	9	9	11	11	11	9		11	9	9	9		11	11
Software Support																
Availability and Updates	9	8	9	8	9	8	8	8	8	9	9	9	8	9	8	8
Security of data	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11

Appendix V: Maturity Model to assess e-purchasing solutions

Digitised tool & model as separate file: “Maturity_Model_TOOL_Ströhnisch_Final_2019” & Maturity_Model_July_2019_Simple

E-Purchasing Software Solution Maturity Model towards Industry 4.0 maturity

	Evaluation Date					***0***	***(I)***					***(II)***					***(III)***					***(IV)***				
	Vendor					The EP-solution does not provide the function.	The EP-solution follows a **siloed approach** and **rarely supports the connection to the IT infrastructure**. The software is characterised by **many manual interventions**. The solution output is **descriptive and unstructured**.					The EP-solution supports the **connection to different IT systems** and **vertical integration**. The software is reflected by **manual interventions** and **automation**. The software output is **diagnostic** and aims to explain what has happened in the **internal purchasing environment**.					The EP-solution supports **full integration** within the purchasing process as well as the **cross-functional integration throughout the organisation and supply chain**. Functions are performed highly **automated (based on RPA)** and **autonomation to a very low extent** in the EP-software. Some **human interaction is still necessary**. The software output aims to make **predictive suggestions based on internal and external** (recent and historical) data, **processed by algorithms**.					The EP-solution is able to function **fully autonomous** within the purchasing department. The software is able to **use Advanced Artificial Intelligence** to process **prescriptive analytics** based on **Big Data** and **machine-to-machine communication** in **real-time** in order to **continuously improve** their decision making in the purchasing processes. Information is **gathered through the IoT** and the software supports the **connection to CPS**.				
	Purchasing Dimension	**Question for analysis**		**Outcome**		**Stage 0**	**Stage 1 (1-25%)**					**Stage 2 (26-50%)**					**Stage 3 (51-75%)**					**Stage 4 (76-100%)**				
				observed %	**Points**	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
PL	**Physical & Virtual connection**	To what degree is the connection between physical		0%	0,0																					
PL1	Fusion of physical and virtual systems	To what degree does your EP-solution supports the usage of sensor data, machine-to-machine communications and/or cyber-physical systems?	Are various types of sensor data processed? How automated/seamless is the data transfer? Is the software able to process M2M, CPS and IoT? Supports the solution the autonomous purification and real-time adaption?				The EP-solution supports the **manual input** of **sensor data** and therefore the **partial connection of physical and virtual systems.** The output is **descriptive** and **unstructured**.					The EP-solution supports provides an **interface for the integration of sensor data. The software supports** the **use of sensor data** in organisations (and enables the possibility to recognise demands for goods).The implementation and data purification is based on **manual interventions** and **automation**. The output is **diagnostic** and **partly structured**.					The Solution supports an **interface for the highly automated connection to different sensors** and is able to **process machine to machine communication**. The solution retrieves the sensor data in **fixed intervals**. The output is **automatically purified** through advanced analytics.					The EP-solution supports the **seamless integration of real and virtual systems** by **advanced artificial intelligence**. The EP-solution optimises the integration in **real-time** and supports the processing of **machine-to-machine communication, Cyber-Physical Systems and the IoT**.				
		Ability to execute (As it is) rate from 0-20																								
		Vision to execute (Ability within the next two years) rate from 0-20																								
PP	**Procure-to-Pay (P2P)**	To what degree is the process of Purchase-to-Pay autonomised?		0%	0,0																					
PP1	Demand prediction	To what degree does your EP-solution supports future demand prediction?	Is the demand prediction automatically calculated? Are external data sources (e.g. tracking of market trends) processed for the demand prediction? How automated/seamless is the data transfer? Supports the solution the autonmous purification and real-time adaption?				The demand prediction has to be **calculated manually** based on the **descriptive output** of the software. **No complete workflow** across the organisation.					The EP-solution supports the **automated demand calculation** based on the organisations **own historical data**. The purchasing personnel has to **request the demand prediction manual**. **Human intervention for data purification** is necessary.					The EP-solution supports the **automated creation** of demand predictions through algorithms that **automatically purify internal and external data** after periodically structured human input. The output **provides suggestions** for improvement. Further **human adjustments** occur for **unexpected deviations** and **decision making**.					The EP-solution supports the **autonomous prescription** of future demand based on **monitoring internal and external data sources**, with data analysis **using advanced Artificial Intelligence**. The Prescriptive analytical output is **adjusted in real-time** and influences procurement immediately through **permanent data gathering by the IoT**.				

PP2	E-Ordering	To what degree does your EP-solution supports the process of initiating a requisition, approving and raising an order?	Is the ordering process guided through a workflow and notifications? Is the ordering process automated/autonomous and is the PO creation touchless? Is the approval process accelerated through a mobile approval solution (mobile phone application)?			The EP-solution **depicts the current ordering status** based on **human interaction without the possibility to forward the e-order internally**. E-ordering process is not fully covered by solution and requires the **operation outside of the solution.**	The EP-solution **guides the automated workflow regarding the requisition creation** & supports the **approval processes**. The solution supports the **notification** of different stakeholders. The majority of **ordering processes and approvals has to be handled manually**. Ordering w**orkflow across organisation is supported.**	The EP-solution **supports the initiation, approval and raising of orders highly automated (automated PO creation)** if the cross-functional infrastructure and contract management is provided. Still, h**uman intervention is needed for monitoring the orders** or **handling deviations**. **Mobile PO approval is supported** by software solution.	The EP-solution supports the **autonomous initiation of requesting, approving and raising** an order **without human intervention**. The EP-solution supports **autonomous ordering optimisation** in **real-time** without human intervention. **Advanced Artificial Intelligence** is used as a **self-learning system.**
		Ability to execute (As it is) rate from 0-20							
		Vision to execute (Ability within the next two years) rate from 0-							
PP3	E-Catalogues	To what degree does your EP-solution supports the automated usage and updating of E-Catalogues ?	Is the connection to hosted and punchout catalogues provided? Does the EP-solution provides a seamless/automated comparison of punchout and hosted catalogues? Is a Webshop-interface (Online-shopping experience) provided? Is the catalogue integration and updating automated and is the software able to track the price development of different items? Does the software supports suggestions/prescriptions for the best fitting item?			The EP-solution supports the connection to **internally hosted e-catalogues**. **Changes**, **approvals** and **updates** have to be **requested manually**.	The EP-solution supports the connection of **(Punchout)** catalogues. The E-catalogues are **updated when supplier want to (for example providing catalogue data to the buying firm for the automated interface)**. The **comparison** of E-Catalogues has to be done **manually**. The solution supports the usage of **standardised protocols to start the requisition process within the catalogue**. Supports the possibility to review punchout catalogues **without leaving the organisational e-purchasing system**.	The EP-solution supports the **automated comparison** of items in **hosted**, **punchout** and **Multi-Supplier Product Catalogues (MSPC)** when requested by an employee to point out **suggestions for the best fit**. Moreover, the software supports an easy **integration of contracted goods to internal catalogues**. The EP-solution supports an i**ntuitive "online shopping" like interface**. The EP-solutions supports the possibility that **suppliers can change catalogues** through a portal by themselves. But **Purchasing personnel is asked to verify important changes**. The software is **able to track price development.**	The EP-solution supports the **autonomous comparison** and **prescription** of items in different E-Catalogues (during the ordering process). The Ep-solution supports the **autonomous real-time updating** and **verification of changes** within the E-Catalogues. Purchasing **personnel** has **only a monitoring role**.
		Ability to execute (As it is) rate from 0-20							
		Vision to execute (Ability within the next two years) rate from 0-							
PP4	Maverick buying	To what degree does your EP-solution supports the limitation of Maverick buying? Is buying outside existing contracts or procedures delimited?	Provides the solution a list of preferred suppliers, supplier suggestions within the network and Spot buy solutions for emergency purchases? Is guided buying through a webshop interface provided? Is an approval workflow provided? Are divergences exposed and suggestions provided?			The EP-solution **supports a list of preferred suppliers** but **employees can deviate** from it. **No fixed workflow for approval** of superior managers.	The EP-solution restricts Maverick buying through an **approval workflow**. The software supports **guided buying** for example through a **webshop interface**. **Every divergence is exposed** by the EP-solution. **Requisition processes are easily set up**.	The EP-solution prohibits maverick buying by utilising a list of **preferred suppliers, supplier networks** and **spot buying**, from which an employee **cannot deviate without authorisation** from his superior. The solution supports guided buying and **virtual assistants** while comparing recent and historical data and making **suggestions for the best fitting supplier/item**.	The EP-solution makes it **virtually impossible** to order goods outside of previously approved suppliers. **New and fitting suppliers are autonomously onboarded and approved. Virtual assistants** is supported fully in **real-time** when buying new items to maximise procurement optimisation and compliant buying.
		Ability to execute (As it is) rate from 0-20							
		Vision to execute (Ability within the next two years) rate from 0-							

PP5	Processing and monitoring of invoices and payment	To what degree does your EP-solution supports the processing of incoming invoices and the payment, and checking whether orders meet their agreed conditions automated? Is the derived information shared internally and with supply partners, and included in future purchases?	Is a (self-serving) supplier portal function supported? How automated and integrated is the invoice & payment workflow? Are PO-Flipping and n-way matching supported? Is the autonomous conversion of various invoice formats (pdf, xml, email's, etc.) supported?			The EP-solution offers a **portal function**, where suppliers can send their invoices. The information is **not shared internally** but **stays within the siloed process as** well as in the purchasing department.	The EP-solution supports a **manual workflow to process invoices**. The **processing and data transfer is partly automated**. Deviations have to be solved manually. The derived information is **manually shared**.	The EP-solution supports the highly **automated monitoring and processing of invoices** and **payment (PO Flip & N-Way matching).** Large deviations have to be **solved manually**. The derived information is **automatically shared internally and externally** (Self-serving supplier invoicing portal). The EP-solution **provides AI-technology to transform and handle various types of invoices** such as PDF, XML, Emails.	The EP-solution supports the **fully autonomous processing** of invoices and is capable to **solve problems autonomously**, except for very complicated problems. The derived information is **automatically saved** and **shared both internally and externally** in **real time** (e.g. by **blockchain technology**, if EP-solution provides compatibility).
		Ability to execute (As it is) rate from 0-20								
		Vision to execute (Ability within the next two years) rate from 0-								
RA	**Controlling/ KPI**	To what degree does your EP-Solution supports the real-time transparency within the		0%	0,0					
RA1	Category Analysis	To what degree does your EP-solution supports the analysis of category economics , i.e. what drives the market? (e.g. Price, Margins, Cost structure, Growth rate)	How automated is the analysis performed? Are external data sources included for the analysis? Is the solution able to process complex data from various sources (e.g. Big Data processing)? Provides the output suggestions or prescriptions?			The EP-solution supports **descriptive category information** for **few KPI's**, which has to be **evaluated manually** based on personnel experiences and earlier purchases.	The EP-solution supports the **automated category analysis** if **manually requested**. **Internal historical** data are included. **Manual interventions are necessary** to purify the information. The **output is diagnostic** and pictures the internal development of the category.	The EP-solution performs a **systematic and periodical category analysis** based on requirements set by specific staff. The software is able to **include external data from marketplaces and catalogues**. The data is **analysed and purified** by the software's own analytical capabilities. The output provides insight into the **category development and makes predictive suggestions**.	The EP-solution analyses the **complete purchasing landscape** such as **E-Marketplaces, supplier portals and catalogues (in general IoT) autonomously** to **identify new suppliers, goods or services**. Furthermore, the analysis includes the organisation's internal purchasing data and further **complex Big Data** (e.g. market data) in real-time. The output is **prescriptive**.
		Ability to execute (As it is) rate from 0-20								
		Vision to execute (Ability within the next two years) rate from 0-								
RA2	Spend Analysis	To what degree does your EP-solution supports spend analysis? To which degree does monitoring and data processing takes place?	How automated is the analysis performed? Is a drill-down function provided? Are external data sources included (e.g. for benchmarking or suggestions)? Provides the output predicitions or prescriptions?			The EP-solution supports spend analysis when **manually requested**. Data has to be **manually monitored** and **purified** for further analysis. The output is **descriptive**.	The EP-solution supports the **automated spend** analysis and includes **internal data**. The spend analysis enables **detailed insights into sub-dimensions**. Purchasing personnel has to make **manual intervention** about the data included. **Manual decisions** have to be made based on the **diagnostic output**.	The EP-solution supports a **highly automated** spend analysis which processes **internal data almost in real-time**. The process has to be monitored periodically in a structured way. The analysis proposes suggestions for improvement. **Human input is partly necessary** to handle untypical deviations. **Smart Algorithms are used to purify** the gathered internal & external data. In an advanced stage, the spend analysis **suggests optimisations and predictions**.	The EP-solution supports an **autonomous** performed Spend analysis, including **comprehensive Big Data** gathering **through the IoT. Advanced Artificial Intelligence supports autonomous data processing and self-optimising improvments of future purchasing activities in real-time.** The output is **prescriptive and human personnel has only a monitoring role.**
		Ability to execute (As it is) rate from 0-20								
		Vision to execute (Ability within the next two years) rate from 0-								

RA3	KPI Dashboard	To what degree does your EP-solution supports the automatic visualisation of a KPI dashboard, that includes for example the tracking of procurement savings?	Is the dashboard visualisation automated? How is the dashboard output calculated (e.g. automated data purification based on advanced algorithms)? Are dashboard templates provided and easily adaptable? Is the output predictive and are suggestions supported?			The EP-solution supports the **visualisation of a KPI dashboard**. Data has to be **entered manually**. Output is **only descriptive but not diagnostic.**	The EP-solution supports the **automated visualisation** of KPI dashboards. The data has to be **manually purified**. **Historical data is included**. The derived information **is diagnostic** and has to be shared manually. **Fixed set of Dashboards** - no easy configuration.	The EP-solution supports **highly automated** KPI dashboards. The **KPI prediction** is displayed in an advanced phase of the stage. **Internal and external data is processed** and **purified by algorithms. Easy configurable** dashboards.	The EP-solution supports **autonomously** created KPI dashboards in **real time**. **Advanced AI analytics** identifies and **processes big data** and correlations while providing a **precise prescriptive output.**
		Ability to execute (As it is) rate from 0-20							
		Vision to execute (Ability within the next two years) rate from 0-20							
RA4	Inventory analysis	To what degree does your EP-solution supports Inventory analysis? Does the EP-solution predicts the optimal future inventory and costs of storing?	How automated is the analysis performed? Rule-based ordering support provided? Are suggestions provided? Is the autonomous optimisation in real-time provided?			The EP-solution supports **Inventory Analysis when manually requested**. Data has to be **manually added**, **monitored and purified** for further analysis. The output is **descriptive.**	The EP-solution supports the **automated Inventory analysis**. **Rule-based automation** of reordering decreases operative purchasing. The output is **diagnostic** and includes **internal historical data**. Purchasing personnel has to make **manual intervention** about the data included.	The EP-solution supports **highly automated** performed Inventory analysis with a **predictive output and suggestions**. The analysis is supported by **algorithms that purify the data**. The process has to be monitored periodically in a structured way by personnel who can make **manual decisions based on the analysis**.	The EP-solution supports **autonomous performed** Inventory analysis, including **comprehensive Big Data gathering through the IoT. Advanced artificial intelligence is supported** to further analyse results and **autonomously improve the purchasing strategy** to improve the i**nventory in real time**. The output is **prescriptive**.
		Ability to execute (As it is) rate from 0-20							
		Vision to execute (Ability within the next two years) rate from 0-20							
RA5	Potential Savings Analysis	To what degree does your EP-solution supports the identification of pooling potential?	How automated is the analysis performed? Are external data sources processed? Is co-pooling supported? How is the output calculated (e.g. automated data purification based on advanced algorithms? Is the output predictive and are suggestions supported?			The EP-solution supports Potential Savings Analysis when **manually requested**. Data has to be **manually added**, **monitored** and **purified** for further analysis. The output is **descriptive** and savings potential has to be **analysed manually**.	The EP-solution supports the **automated Potential Savings Analysis,** but **manual intervention is necessary to purify data**. The EP-solution includes **internal historical data** to generate **diagnostic output**.	The EP-solution supports **highly automated Potential Savings Analysis** with a **predictive output**. Also, **Co-pooling is supported if the infrastructure in the network/marketplace** is given. The process has to be monitored periodically in a structured way by personnel who can make **manual decisions based on the analysis.**	The EP-solution supports **autonomous performed Potential Savings Analysis** including comprehensive **Big Data gathering through the IoT. Advanced artificial intelligence is supported to further analyse** results and **autonomously improve Saving options in real time**. The output is **prescriptive**.
		Ability to execute (As it is) rate from 0-20							
		Vision to execute (Ability within the next two years) rate from 0-20							

SC	Sourcing	To what degree is the strategic procurement process		0%	0,0				
SC1	Marketplace and Network	To what degree does your EP-solution supports Marketplaces/ Networks to accelerate the matching of new suppliers.	Are detailed supplier profiles available in the network? Does the network provide the possibility to find new suppliers and items? How automated is the discovery/search for new suppliers			The EP-solution **supports a network which serves only as a platform** to facilitate the **automation** and **transaction** between buyer and pre-known supplier.	The EP-solution supports a **marketplace network** where **buyers can find new suppliers** based on **manual and partly automated searches**. The marketplace network **provides detailed company information and supplier profiles.**	The EP-solution supports a **marketplace network** where new suppliers can be **automatically found and compared**, based on **criteria** defined by the purchasing personnel. The solution supports **suggestions** for best fitting suppliers.	The EP-solution supports the **autonomous real-time comparison** of items and suppliers within the whole marketplace network. The output of the EP-solution encompasses the **prescription of the best fitting supplier** based on **price development, quality and further KPI's.** The EP-solution supports the infrastructure and **autonomous forwarding of information** to relevant stakeholders or processes. **No human input is required**.
		Ability to execute (As it is) rate from 0-20							
		Vision to execute (Ability within the next two years) rate from 0-20							
SC2	E-Tendering	To what degree does your EP-solution supports the tendering process (Requests for Information, Proposal, or Quotation (RFI, RFP, or RFQ)?	Is a workflow and guidance for the e-tendering process & creation provided? Are different e-sourcing templates provided? Is an automated RFX comparison			The EP-solution supports the **virtualisation of the tendering process**. **Manual interventions are necessary** to feed the software with data. The tendering process has to be **manually monitored** and **processed for further analysis**.	The EP-solution supports the **partial automation of the tendering** process and **guidance**. **Internal historical data is included** to point out previous suppliers. The Ep-solution provides **templates and the automated comparison of RFX.** The **diagnostic output** has to be processed manually.	The EP-solution supports a **highly automated tendering** process based on the connection of **internal and external data sources** (such as including "new suppliers" from the network. The majority of low-to-medium impact tendering happens highly automated by **advanced algorithms**. Only high impact orders **require human input and authorisation in the software**. The EP-solution supports a **high integration** and **suggestions** on how to proceed.	The EP-solution supports **fully autonomous tendering** processes in **fully connected systems**. The involvement of humans is erased to establish a **purely authorising and monitoring role**. Many **criteria are measured autonomously** in the system, not focusing solely on price but also qualitative criteria. The EP-solution supports a **prescriptive outcome.**
		Ability to execute (As it is) rate from 0-20							
		Vision to execute (Ability within the next two years) rate from 0-20							
SC3	E-Auctions	To what degree does your EP-solution supports auctioning processes?	Is guidance and automation for the e-auction process provided? Are different e-auctions (Dutch, Japanese, multi-stage) provided? Provides the outcome suggestions or prescriptions? How automated and integrated is			The EP-solution supports the **virtualisation of the auctioning process. Manual interventions are necessary** to feed the software with data. Auctions are **manually monitored** and **manually processed** for further analysis.	The EP-solution supports **automated guidance** to the auctioning process. **Internal historical data** are included **automatically, but manual interventions are still necessary to a high extent**. The Auction outcome is diagnostic and supports **various automated analysis.**	The EP-solution support a **highly automated auction process and supplier suggestions**, based on the connection between **internal and external data sources and suppliers**. Furthermore, the solution supports **various types of auctions** or at least more than 3. Moreover, the solution supports the **Multi-Stage approach** for auctions. The software supports **outcome predictions and what if scenarios**. Still, some **human involvement is necessary.**	The EP-solution supports fully **autonomous and organised auctions** within fully connected systems. The **involvement of humans is erased to establish a purely authorizing** and **monitoring role**. **Many criteria are measured autonomously** in the system, not focusing solely on price but also qualitative criteria. The **outcome of the auction is prescriptive.**
		Ability to execute (As it is) rate from 0-20							
		Vision to execute (Ability within the next two years) rate from 0-20							
SC4	E-Contract management	To what degree does your EP-solution supports automated or autonomous contract management?	Are templates for the contract management provided? Is a workflow provided to include all relevant stakeholders? How are contracts stored and are alarms for changes automated? How transparent and integrated are the stored contracts (e.g. Spend tracking, search functions)? How automated and integrated is the data transfer to create contracts?			The EP-solution provides **templates** for contract management. The **distribution and storage of contracts are based on human involvement**. The solution provides a central storage module for contracts but **no guidance** on contract creation. All **information has to be insert manually**.	The EP-solution provides **templates** and **alarm functions** within the contract management based on **internal data**. The contract creation is supported through a **guiding workflow across the organisation.** The historic contracting information is **centrally archived**. The process is still **depended on human involvement**.	The EP-solution supports **automated contract** management based on internal data **processed** by **smart algorithms**. The EP-solution supports the automatic **contracting workflow** if the infrastructure is available and **auto-fill functions**. Moreover, the EP-solution supports the **"searching"** within contracts saved/uploaded in the contract module. Human input primarily used for **verification and smaller adjustments**.	The EP-solution supports fully **autonomous contracting** phase in **fully connected systems,** focusing on **Contract Lifecycle Management** (CLM). The involvement of **humans** is erased to establish a **purely monitoring role.**
		Ability to execute (As it is) rate from 0-20							
		Vision to execute (Ability within the next two years) rate from 0-20							

SBM	Suppliers	To what degree does your EP-solution supports the		0%	0,0				
SBM1	Supplier evaluation	To what degree does your EP-solution supports the supplier evaluation?	Are hard KPI's measured automatically? Is a workflow provided to support scorecards for soft KPI's? Is the supplier analysis automated and supports the seamless comparison between suppliers? Are external data sources used to enrich supplier information and benchmarking?			The EP-solution supports the **untreated data collection** about **current suppliers**. The output is **descriptive** and pictures the recent situation. Purchasing personnel has to **conduct analysis** by them self. Hard KPI's are not tracked automatically and the solution provides **no workflow for scorecards or questionnaires**.	The EP-solution supports the **automated supplier evaluation and comparison**. Only a **few standard hard KPI's are measured** using i**nternal available historical data**. The evaluated data is only **partly purified** and needs **manual interventions**. **Soft KPI's** are captured through **scorecards/questionnaires** that follow a flexible workflow.	The EP-solution supports the **highly automated supplier evaluation** for every supplier, based on **standard and some specific KPI's** and **past performance**. The solution supports **external data for benchmarking** and **enrichment of supplier data.** The EP-solution is able to give purchasing personnel **predictive reports** and analyses based on **purified data**. The EP-solution supports **automated evaluation sharing** and **development plans** with suppliers on a regular base.	The EP-solution supports the **supplier evaluation autonomously** for each supplier, based on **many specific KPI's**. The **past performance** and **comparative benchmarks** with both **internal and external sources** are included. This is shared in **real-time** with suppliers to improve future performance, with an **added focus on supplier satisfaction**. The software is able to serve **prescriptive decision implications**.
		Ability to execute (As it is) rate from 0-20							
		Vision to execute (Ability within the next two years) rate from 0-20							
SBM2	Connection of supplier	To what degree does your EP-solution supports the connection of new suppliers?	Is a supplier self-service portal provided? How advanced is the data transfer and data purification? (Workflow for supplier approval, automated classification, checking for duplications, etc.? Is external data used to enrich supplier information during the onboarding-process? Are the connection, classification and verification of suppliers autonomously supported by the solution?			The EP-solution has an **input mask** for the **manual entering** of supplier information. **High manual interventions** require extensive contact to supplier before registration.	The **suppliers have to register in a portal**. The **data is automatically transferred** to the buying organisation's ERP or Supplier Management tool. **Deviations** and specific information/certificates have to be **handled manually**.	The **segmentation** into different supplier classes **is highly automated.** The Ep-solution uses internal and **external data to enrich supplier information. The data is purified through advanced algorithms. Manual intervention** is necessary for specification.	The EP-solution supports the **autonomous connection of suppliers**. The connection is based on **autonomous requests towards suppliers**, based on the **analysation of (big) data and demand,** which has been **gathered by the IoT** and processed by **advanced AI in real time**.
		Ability to execute (As it is) rate from 0-20							
		Vision to execute (Ability within the next two years) rate from 0-20							
SBM3	Data exchange	To what degree does your EP-solution supports the data exchange across the value chain including suppliers? And how transparent is this exchange of information?	Is the sharing of data supported within the EP-solution, or does the data has to be extracted? What type of data/information can be shared? Is the shared data stored and is repeatable accessible? How automated/autonomous is the data sharing (eg. How automated is the workflow?)			The data has to be **extracted** and **shared manually.**	The EP-solution supports the **automated data exchange (Documents, Attachments) with suppliers** based on **supported workflow approval**. Focus on **PO's** and **Invoicemanagemnt**.	The EP-solution supports a **seamless and highly automated** sharing of purposeful data (Larger files, Forecasts, Reports) **across organisation** and **suppliers** within the software solution. **Manual intervention is only partly necessary.** Valuable data can be **shared through solution**. The shared data is **stored** and **repeatable visibl**e for suppliers and buying organisation.	The EP-solution supports the **extensive sharing of (big) data** with suppliers. The exchange of information is **fully transparent** within the **supply chain** (e.g., through **Blockchains**) and takes place in **real time**.
		Ability to execute (As it is) rate from 0-20							
		Vision to execute (Ability within the next two years) rate from 0-20							

SBM4	Supplier Risk Management	To what degree does your EP-solution supports the detection and mitigation of risks and disruptions in the supply chain? Does the solution targets financial risks? Does the solution support the analyzation of the Supply Chain?	Is an alarm function provided? Are external data sources included for the Supplier Risk Management? How advanced are the risk calculations? Is decision support provided? Are Tier 2 and further suppliers within the supply chain included within the Risk Management?			The EP-solution provides **no attention** to detect supplier risks. Supplier Risk has to be analysed by purchasing personnel based on the **descriptive output**.	The EP-solution supports **alarms and notifications** of **supplier risks** and **disruptions**. The software uses **internal historical data** to **expose potential critical changes in the supplier base**. Decision making has to be done by personnel. Hereby the EP-solution relies on **basic calculations**.	The EP-solution supports the detection of **possible risks and disruptions** for most suppliers **highly automated** based on **internal and external data**. The output is **predictive** based on **purified data**. The EP-solution **provides risk information beyond Tier 1** suppliers and **proposes suggestions**.	The EP-solution supports the **autonomous real-time** detection and mitigation of **possible risks and disruptions** in the supplier base based on **prescriptive analytics**. **Internal and external data** is gathered through the **IoT**.
		Ability to execute (As it is) rate from 0-20							
		Vision to execute (Ability within the next two years) rate from 0-							
SBM5	Financial Supply Chain Management	To what degree does your EP-solution supports Financial Supply Chain Management?	Is information of the working capital included? How transparent is the process (sharing payment status with suppliers autonomously? Are financing possiblites included? Does the solution autonomously optimizes the financial situation while relying on advanced technology?			The EP-solution provides **no attention to the Working Capital** and the **Financial Supply Chain**. Purchasing personnel has to **analyse the financial situation manually**.	The EP-solution supports **information about the working capital**. And enables **rule-based dynamic discounting functions**. The software uses **historical data to expose potential improvements** or **shortage of working capital. The output is diagnostic.**	The EP-solution supports detailed information about the Working Capital. Information about the **payment status is automatically distributed to the supplier**. Selected **financing partners are connected to the solution** and **automatically suggested**. EP-solution provides **predictive decision support**.	The EP-solution supports the **autonomous real-time** determination of **temporary financing possibilities**. The Supply Chain Financing is **transparent** and **safe through smart contracts** and **blockchain**. **Permanent review** of invoices, orders and working capital to ensure **financial stability**.
		Ability to execute (As it is) rate from 0-20							
		Vision to execute (Ability within the next two years) rate from 0-							

EU	**End-User Support**	To what degree supports the solution End-User training and		0%	0,0				
EU1	Training of End-Users	To what extent is the training of users supported? To what degree does your EP-solution supports the training of End- Users?	Is phone or email support provided? Are instruction videos and 24-hour live support provided? Does the soluton includes a tutorial function, a virtual classroom or individual (online) training programs? Is an AI based Virtual Assistant provided?			The EP-solution vendor provides the instructions **per document** and **telephone.**	The EP-solution vendor provides **standardised videos** on its website. The vendor provides **24-hour live support**.	The EP-solution is **very intuitive** and provides **well-developed tutorial functions** that **guide end-users through all functionalities** of the software. Furthermore, the vendor provides **various educational programs such as virtual classrooms** and **individual training programs.**	The EP-solution is able to train the users individual through **advanced algorithms** and **Virtual Assistants** on an individual level.
		Ability to execute (As it is) rate from 0-20							
		Vision to execute (Ability within the next two years) rate from 0-							
EU2	Experience of vendors employees	How experienced are your employees within e-procurement and e-sourcing?	Are your employees able to utilize the operational purchasing functionalities and can provide strategic sourcing support? Are you mostly relying on external consultants?			The Vendor provides **personnel with low purchasing experience**. No help to utilize the potential of the software. **Personnel is able to explain how the software works.**	The personnel have **experience in e-procurement** and is able to support the end-users to utilize the **operational functionality** of EP-solution. Otherwise, **vendor relies largly on external consultants**. Higher costs for customers & slower ability to act.	The (own) personnel have **extensive experience** in specialised fields of **(e-)procurement** and **(e-) sourcing**. The vendor does **not depend on external consultants** which enhances a **faster ability to act**.	The personnel have extensive experience in the field of (e-)procurement & (e-)sourcing and is able to support the users in terms of **strategic aspects** to fully **utilize the software's potential**.
		Ability to execute (As it is) rate from 0-20							
		Vision to execute (Ability within the next two years) rate from 0-							
SS	**Software Support**	How available and secure is the		0%	0,0				
SS1	Availability and Updates	To what degree does your EP-solution supports the overall availability and actuality?	Is your solution cloud based? Is the solution supported on mobile devices?			The EP-solution is based **on-premises** and has to be **manually updated**.	The EP-solution is based as **cloud solution** and supports the **real-time availability** on **mobile devices** with **limited functions (for example an approval app)**. The **updating is automated if requested** by end-users.	The EP-solution supports the **real-time availability** on **mobile devices** with nearly all functions (for e.g on the IPAD/Iphone). The software updating is **automated at regular intervals.**	The EP-solution supports **real-time availability on every device** with a browser, as long as the device is connected to the internet and **updates itself continuously**.
		Ability to execute (As it is) rate from 0-20							
		Vision to execute (Ability within the next two years) rate from 0-							
SS2	Security of data	To what degree does your EP-solution supports the data security? How are data and services in digital systems protected against misuse (e.g., unauthorised access, modification, or destruction)?	How are data and services in digital systems protected against misuse (e.g., unauthorised access, modification, or destruction)? Are backups automatically stored on various servers? How regulary is the updating ?			The EP-solution supports **manual backups** to secure data.	The EP-solution supports **automated backups** to secure **data on premises**.	The EP-solution supports the protection of data by **automated backups** of the whole servers. Updates to **mitigate commonly known cyber risks happen automated.** The backups are **stored within cloud servers**.	The EP-solution supports the strict protection of Data through **autonomously created backups**. The software **updates on possible cyber risks continuously**. Data safety is increased through the usage of **blockchain technology**.
		Ability to execute (As it is) rate from 0-20							
		Vision to execute (Ability within the next two years) rate from 0-							
TS	**Total score**	**Deepth of Solution:**		**0%**	**0,0**				**Deepth of Solution:**
		Width of solution:		**0**					**Width of solution:**