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Master thesis

Assessing E-Procurement maturity as designed in an E-Procurement Maturity Model and Quadrant Model

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Acknowledgement

Finally, after starting the Master of Science program more than a year ago, it has come to an end. By delivering this master thesis, I present you with research into E-Procurement. I aimed to develop a model that could be used in practical settings as well as for academic research. During my research, the one model turned into two models, providing E-Procurement assessment opportunities at both vendors and users of such software. Hence, I can only be satisfied with this finishing achievement.

I would like to thank my family and friends who supported me all these years. This all would not have been possible without my parents, and the whole experience would have been extremely different without my dear friends. Next, I would also like to thank my colleagues at Supply Value for making me part of their team, giving me useful feedback and supporting me in my research. In particular, I would like to thank my former colleague Manfred Hoogveld for not only providing me with feedback in my research but also guiding me in consulting skills. Of course, I want to thank all interview participants, with everyone giving me new insights into procurement and its digital future.

Thanks to both my supervisors at the University, without whom this thesis and its models would have taken a drastically different shape, not to mention my whole Master's Programme and future career. During lectures of prof.dr.habil Holger Schiele, I was drawn to the field of procurement, and in thesis meetings, I received lots of useful feedback to improve everything presented in this thesis. I would also sincerely like to thank Vincent Delke, MSc, for all his feedback, supervision and support during the thesis process. Starting with one meeting talking about a possible maturity model, he took on a supervising role, and all my work was improved thanks to him.

Finally, I hope you will enjoy reading this master thesis.

Priyan Morsinkhof

Enschede, December 2018.

Abstract

Firms are increasingly recognising procurement as a strategic process in their organisation, and seeing the potential benefits the successful management of procurement has. Many firms already use forms of digital tools to support their procurement processes, but research has shown the digital maturity of these firms has not progressed as expected. Some firms still rely on paper-based processes, making little use of E-Procurement software. This thesis gives insight into the current E-Procurement maturity of organisations, and the results provided a method to measure the maturity both their maturity and that of the E-Procurement tools software vendors currently offer. To achieve these measurement tools, a design research among E-Procurement software vendors was conducted. The study proposes a new E-Procurement Maturity Model, based on interviews and literature, to accurately measure end-user firms based on eight dimensions of digital maturity. Furthermore, the study describes the best practices for the highest E-Procurement maturity in an Industry 4.0 firm, prescribing firms the ideal situation for industry leaders. Finally, the study proposes a new E-Procurement Quadrant Model, to further establish the link between an end-user firm and its relevant software solution options.

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

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List of Abbreviations

AI	Artificial Intelligence
BI	Business Intelligence
CMM	Capability Maturity Model
CMMI	Capability Maturity Model Integration
CPO	Chief Procurement Officer
CPS	Cyber-physical systems
EDI	Electronic Data Interchange
EP	Electronic Procurement
ERP	Enterprise Resource Planning
IoT	Internet of Things
KPI	Key Performance Indicator
MDM	Master Data Management
MRP	Material Requirement Planning
M2M	Machine to Machine (Communications)
PO	Purchase Order
P2P	Purchase-to-Pay / Procure-to-Pay
P4.0	Procurement 4.0
RFI	Request for Information
RFP	Request for Proposal

RFQ	Request for Quotation
RFX	Catch-all term for RFI, RFP, and RFQ
SLM	Supplier Lifecycle Management
SRM	Supplier Relationship Management
S2C	Source-to-Contract
S2P	Source-to-Pay
UBL	Universal Business Language
UI	User Interface
XML	Extensible Markup Language

1. Introduction: Maturity assessments of E-Procurement in Industry 4.0 supported by new models

1.1. E-Procurement: powerful digital tools for procurement in organisations

Nowadays, organisations rely heavily on digital systems to support their employees in business processes. After decades of firms digitising and automating their daily tasks and processes, it is hard to imagine any firm that would prefer to work paper-based instead of through digital systems. Through these digital systems, next to virtual elimination of paperwork, organisations receive a reduction in overhead costs, sourcing costs, time spent in the purchasing process, transparency, overview, and more.[1] For example, industry leaders can process up to ten times more invoices per employee, while also leading to higher employee satisfaction through reducing laborious, monotonous tasks.

However, while there are obvious benefits to digital systems, there are still many firms that do not possess the digital capabilities of their peers. Despite many consulting firms offering business transformation services, research leads to the conclusion many firms are still in the early phases of digital capabilities.[2]

Those digital capabilities include the use of E-Procurement software in the whole procurement process of organisations. Van Weele (2014) defines the procurement process as obtaining goods and services from external sources that are needed for maintaining and developing direct and indirect production activities in the best conditions.[3] The author divides the procurement process into tactical sourcing and operational purchasing. Both of these two parts comprises three distinct phases, resulting in the following six phases of the purchasing process, with its related E-Procurement application (see figure 1).

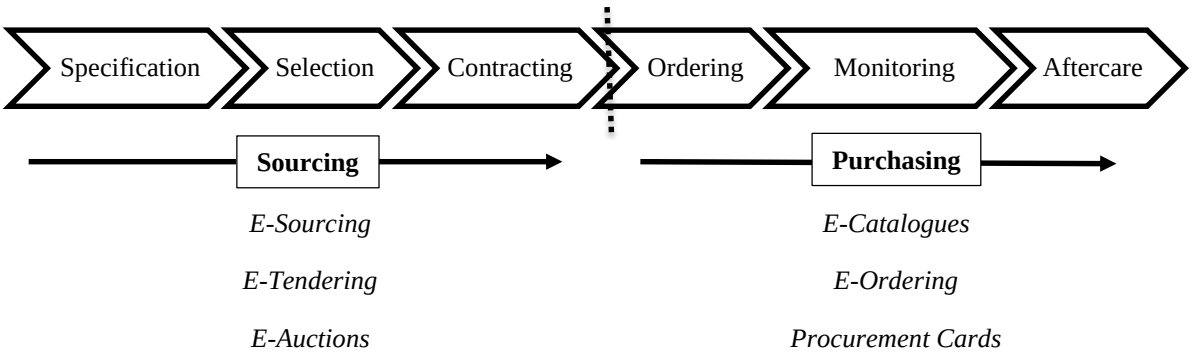

Figure 1. Procurement process and its linked E-Procurement application based on Van Weele (2014, p.7)

[1] See Monczka, Handfield, Giunipero, and Patterson (2014), p. 44.
[2] See Torn (2017), p. 67.
[3] See Van Weele (2014), p. 7.

Nowadays, there are many E-Procurement software suppliers, some of which offer a full Source-to-Pay (S2P) suite or Procure-to-Pay (P2P) suite, while others focus on a specific aspect of the electronic purchasing process. As De Boer, Harink, and Heijboer (2002) state, only focusing on one aspect "underlines the danger of treating E-Procurement as one solution, and therefore the impact of various forms should be investigated separately".[4]

Therefore, for this research the following definition of E-Procurement is used: the use of specific electronic tools, through the Internet as well as other information and networking systems, to support the specific phases in the business-to-business procurement process.

1.2. Introducing Industry 4.0 and Industry 3.0 within current organisations

Industry 4.0 is a concept which was firstly published by Kagermann in 2011 for a project by the German government.[5] It has built the foundation for the Industry 4.0 manifesto published in 2013.[6] While a surge of academic interest in Industry 4.0 can be observed, with new publications increasing almost tenfold in four years, there is still no generally accepted definition of Industry 4.0. Over the next five years, the companies PwC surveyed expect to increase annual revenues by an average of 2.9% and reduce costs by an average of 3.6% per year through application of Industry 4.0.[7] Due to rising investments in Industry 4.0 applications, for example, investing an estimated average of 3.3 percent of annual turnover of German industrial firms,[8] the importance of further research into Industry 4.0 is clear.

Industry 4.0 is commonly understood as the start of the "application of the generic concept of cyber-physical systems,"[9] in which systems can autonomously perform their production and provide machine to machine (M2M) communication, supported by the Internet of Things (IoT) (see figure 2).

[4] De Boer, Harink, & Heijboer (2002), p. 32.
[5] See Kagermann, Lukas, & Wahlster (2011), p. n/a.
[6] See Stock and Seliger (2016), p. 536.
[7] See Geissbaue, Vetso, and Schrauf (2016), p. 6.
[8] See Koch, Kuge, Geissbauer, & Schrauf (2014), p. 7.
[9] Drath and Horch (2014), p. 1.

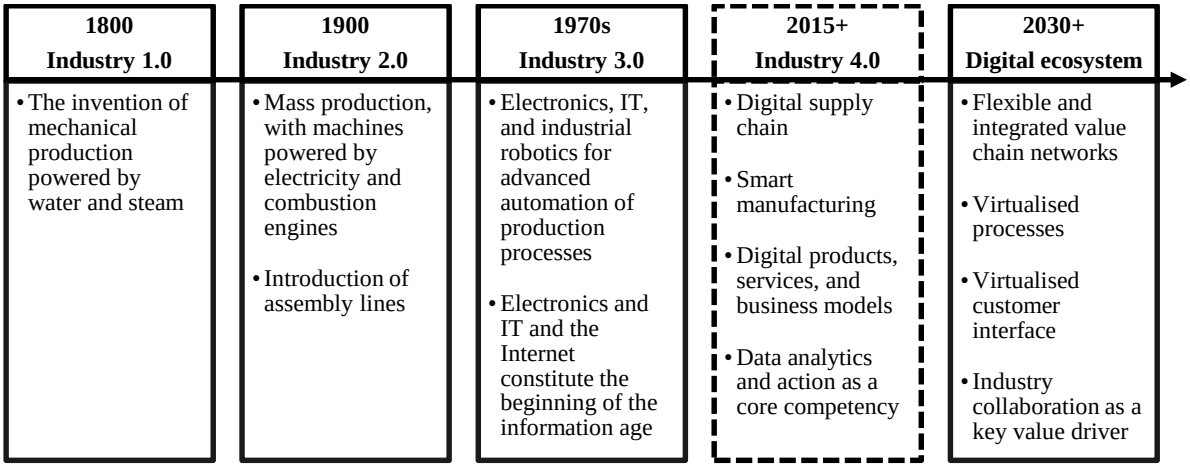

Figure 2. Developments towards Industry 4.0 and future outlook based on Strategy& (2016, p. n/a)

However, the distinction between Industry 3.0 and 4.0 is important because otherwise organisations will try to sell their Industry 3.0 solutions as Industry 4.0 to unsuspecting buying organisations (see figure 3). To distinguish Industry 4.0 from the previous revolution named Industry 3.0, PwC state that "while Industry 3.0 focused on the automation of single machines and processes, Industry 4.0 focuses on the end-to-end digitisation of all physical assets and integration into digital ecosystems with value chain partners."[10] Research by Schiele (2018) shows modern characteristics of Industry 4.0, related to Industry 4.0 (see figure 3).[11]

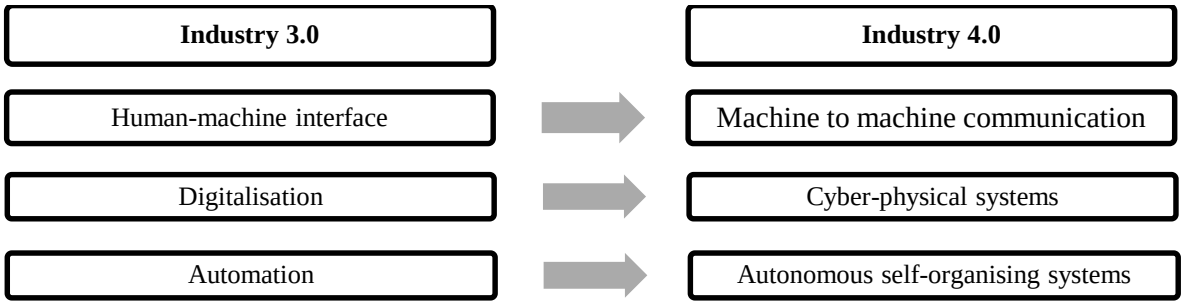

Figure 3. Modern characteristics of Industry 4.0 based on Schiele (2018, p. n/a)

1.3. Consulting firm Supply Value and their use for E-Procurement research

The thesis is the result of research performed both for academic purposes, as for practical purposes. The practical purpose entails the usability for Supply Value, a Dutch procurement consultancy company that advises on procurement activities; clients include firms in the

[10] See Geissbauer et al. (2016), p. 6.
[11] See Schiele (2018), p. n/a.

Dutch public and private sector with companies such as the Dutch National Police, UWV, Port of Rotterdam, and Grolsch. As an independent consulting firm, Supply Value advises in the areas of cost reduction, value creation, and procurement infrastructures, such as the organisation of procurement departments and supporting systems, such as E-Procurement.[12]

Supply Value sees procurement and supply chains as an important function in companies, and aims to their clients' operations with their strategy and company objectives. As a central objective Supply Value aims to reduce cost and risk while increasing the value added in the supply chain so that not only their client benefit but also their partners and suppliers. Supply Value uses a three-step approach to realise sustainable results for their clients:

- Thinking: Supply Value collects and analyses information to give robust solutions
- Support: Supply Value combines the input of both the client and its partners into improvement proposals; by using information from multiple sides they can create a fast improvement process
- Doing: Supply Value helps their clients in implementing strategies and systems, keeping them on track and finally realising concrete results

One of the procurement activities that Supply Value consults on are E-Procurement systems, as there are many of these systems used worldwide and new systems also appear frequently. Supply Value wants to study E-Procurement systems to better inform their customers about the various possibilities, trends, and upcoming functionality. This study is part of the Thinking and Support process that Supply Value uses for providing solutions to their clients. The results will be used to give selection and implementation advice on E-Procurement systems. Supply Value provides the following services concerning E-Procurement:

- Business and procurement consultancy: design and strategy regarding E-Procurement with the goal to improve the effectiveness of the company's strategy, operations, and operational processes
- Implementation consultancy: advise and assisting in the implementation of E-Procurement in the areas of change management, procurement processes, and package knowledge of the implemented procurement system

[12] See Supply Value (2018a), p. n/a.

- Project- and program management: managing project and programs around E-Procurement (e.g., forming a strategy, purchasing the E-Procurement package and implementing the procured package and implementations)

1.4. Research outline: The need for a maturity model and quadrant model addressing E-Procurement in both Industry 3.0 and Industry 4.0

Research shows many advantages to using E-Procurement software, including a reduction in communication costs (i.e., sourcing costs),[13] the faster throughput of orders, higher compliance to preferred suppliers, transparency, and so forth. However, while these advantages are widely known in organisations, the degree of E-Procurement implementation is still low and lots of organisations mainly make use of general Material Requirements Planning (MRP) or Enterprise Resource Planning (ERP) systems. The implementation of Industry 4.0 in purchasing requires organisations to successfully implement the E-Procurement applications of Industry 3.0 first, which are the basis for further development into Industry 4.0 processes.[14] E-Procurement, as is defined in chapter 1.1, is shown to be the missing link between regular ERP-systems and Purchasing / Procurement 4.0 (see figure 4).

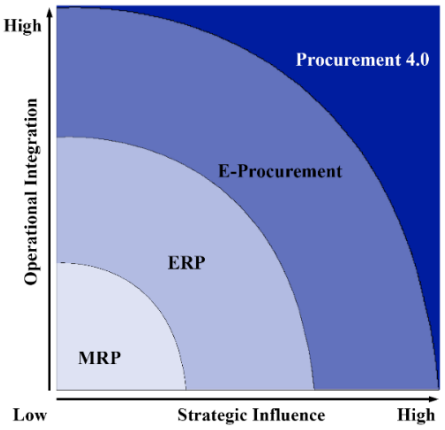

Figure 4. Different layers of software integration based on Kleemann and Glass (2017, p. 11)

By being able to accurately assess the digital maturity of the purchasing function and its possible use of E-Procurement within an organisation, divided into several aspects, an assessed organisation will be more successful in choosing appropriate process improvements, in which E-Procurement software can be used. For consulting firms, a better

[13] See De Boer, Harink, & Heijboer (2002), p. 32.
[14] See Torn (2017), p. 71.

assessment of digital purchasing maturity will lead to better advice, and therefore to better implementation of the software solutions. This, in turn, allows for a higher success rate in organisations who participate in E-Procurement implementation. Next, through the use of a software solution-focused quadrant model, which assesses the maturity of available E-Procurement vendors and their tools, organisations are able to easily find which software tool best fits their need. Several analyst firms are renowned for their quadrant models, in which they categorise some of the largest software vendors into structured quadrants based on vendor organisation and software solution characteristics. However, the software vendors in the quadrants often do not operate fully in the European market, and these quadrants are therefore not valuable to a large amount of organisations. By having a model that also allows smaller software vendors to be rated and connected to the maturity model, end-user organisations are more likely to find a software solution that will fit their specific maturity level.

The research aim of developing both a maturity model and quadrant model leads to the main research question for the research: ***How are the E-Procurement Maturity Model and Quadrant Model designed to successfully determine an organisations maturity level?*** To obtain further insights, the main research question is answered by exploring three sub-questions: *(1) What is the current situation of Industry 3.0 – 4.0 in procurement?; (2) How do Industry 3.0 – 4.0 aspects in procurement relate to E-Procurement maturity levels for both end-users and software vendors?; (3) What is the roadmap for E-Procurement software vendors towards Industry 4.0?*

To visualise the problem statement accompanying these research questions, the following chart is made and depicted in figure 5.

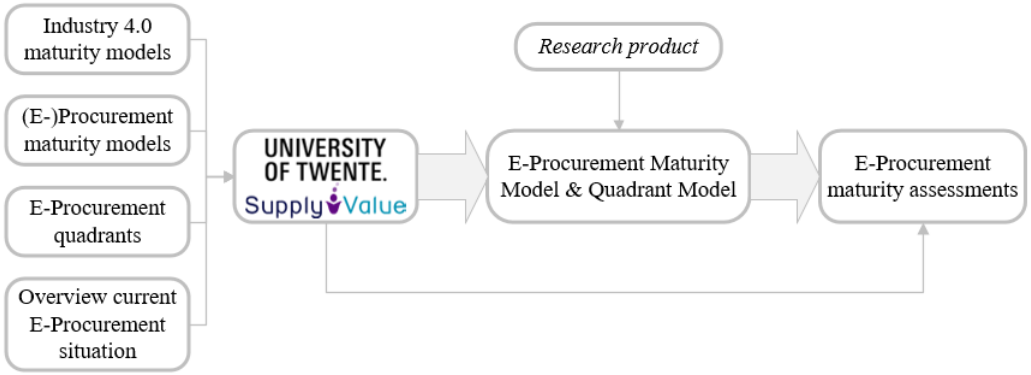

Figure 5. Visualisation of problem statement (own elaboration)

In order to answer the research questions, the research first reviews the current literature on Industry 4.0, E-Procurement, and maturity models. Next, through a design process making use of interviews, the new maturity models are made and iteratively developed. Based on these interview results, a trend analysis of the Industry 4.0 application in E-Procurement is detailed. The research closes with the newly proposed E-Procurement Maturity Model and E-Procurement Quadrant Model.

1.5. Thesis outline: Explanation of each chapter

After the introduction above, the research continues with the second chapter containing the conceptual background regarding Industry 4.0, E-Procurement and Maturity Models, ending with Quadrant Models, based on an extensive literature review. The third chapter concerning methodology describes how the research is structured. Following, the fourth chapter describes the analysis, i.e., interview results, the ideal situation, how the new Maturity Model and Quadrant Model is developed, and the identification and exploration of trends in the E-Procurement industry. Concluding this research, the fifth chapter details the discussion of the research and its results, while the thesis ends by describing the limitations and future research directions.

2. Conceptual Background: Digitalisation of procurement and its maturity

2.1. Systematic literature review of academic and practitioner sources

To establish a conceptual background of E-Procurement, the qualitative research method of a literature review is used. By performing a literature review, insight into the topic leads to further research directions. Both academic sources, as practitioner sources, are reviewed for relevant articles regarding the E-Procurement topics included in the research. Next, information from E-Procurement software vendors (websites, conferences, and personal communication) is used to obtain information about current trends in the E-Procurement market, Industry 4.0, and developments contained within this paradigm.

To find academic sources, the literary databases Scopus, Web of Science, and Google Scholar is used. Based on the two topics of this research, namely Industry 4.0 and E-Procurement, keywords used were 'Industry 4.0', 'E-Procurement,' 'E-Sourcing', 'Procure-to-Pay', and 'Purchase-to-Pay.' Additionally, these keywords will be combined with the use of the keywords 'Maturity', 'Maturity Model,', 'Quadrant' and 'Quadrant Model' to find more specific articles. Furthermore, practitioner sources are found through Google searches with the same keywords used for academic sources. Additionally, websites of software vendors will be reviewed to find specific content regarding subjects that are included in the literature review, for example supply chain risk management, or E-Catalogues.

2.2. Industry 3.0 and 4.0: From digitalisation to autonomy

2.2.1. Four industrial revolutions: From steam-powered industrial machinery towards the Industry 4.0 paradigm

To be able to describe the new industrial revolution, named Industry 4.0, first the previous three industrial revolutions need to be described. By identifying patterns in these revolutions, the distinguishing factors of the fourth industrial revolution are shown.

Firstly, the first industrial revolution consisted of the transition of manual labour towards mechanical labour through the use of steam engines in the 1780s.[15] The centralisation of production towards factories instead of private homes increased productivity extremely,[16] and flourished mechanisations systems and textile industry.[17] Factories produced the same products grouped near each other, close to their core sources, creating industrial centres in

[15] See Drath & Horch (2014), p. 56.
[16] See Drath & Horch (2014), p. 56.
[17] See Hwang (2016), p. 10.

cities. These first industrial centres with heavy use of mechanisation grew rapidly, creating a divergence in industrialised and non-industrialised economies.[18]

Afterwards, the second industrial revolution started in the third quartile of the 19th and the beginning of the 20th centuries,[19] through the main factor of the use of new energy sources, namely electricity, oil, and gas. These new energy sources allowed for the use of continuous production lines and conveyor belts with divided labour, which caused a productivity boost and marks the start of mass production.[20] In the second revolution, two dimensions of demand were addressed, namely volume and variety. Following, the immense steel industry, the railroad and telegraph systems were created, and electrically powered mass production was introduced.[21] The combination of research and capital, with mass production factories at the centre, also lead to the invention and production of the car and the airplane at the beginning of the 20th century. These breakthroughs in transportation further expanded the reach of these industrial centres.

Eventually, the third industrial revolution started through the invention of the transistors in 1947, among other inventions, which gave a path to the digital age and information technology as an industrial revolution.[22] Literature does not describe a clear time span of the third industrial revolution, nor is there a clear agreement whether the third revolution has ended at all.[23] In his research, Torn (2017) found that both the first logical control system in 1969, as the oil crisis in 1973 are mentioned as the catalyst for automated manufacturing.[24] With new possibilities through digital programming of automation systems, electrical gadgets, and applications for computers, Industry 3.0 started.[25] Several manufacturing processes could be automated, using machines that can perform standardised physical tasks with little human input.[26] The third industrial revolution increased the dimensions of demand to three, namely by adding the delivery time as a demand, which promoted the use of flexible manufacturing systems.[27]

Finally, the fourth industrial revolution started, bringing us to Industry 4.0 in which system autonomy and smart manufacturing are key points. Industry 4.0 is the product of research

[18] See Rodrigue (2017), p. n/a.
[19] See Hwang (2016), p. 10.
[20] See Drath & Horch (2014), p. 56; Hwang (2016), p. 10.
[21] See Yin, Stecke, & Li (2017), p. 848.
[22] See Hwang (2016), p. 10.
[23] See Torn (2017), p. 18.
[24] See Torn (2017), p. 18.
[25] See Hwang (2016), p. 10.
[26] See Rodrigue (2017), p. n/a.
[27] See Yin et al. (2017), p. 10.

into high-tech strategy by the German government in 2012, named *Industrie 4.0*.[28] In the United States, the terms smart manufacturing and smart factories describe the same concept as Industry 4.0.[29] Authors describe the use of cyber-physical systems (CPS) and Internet of Things (IoT) as defining the concept of Industry 4.0.[30] Use of CPS and IoT is noted to be autonomous within the systems, instead of purely automated.[31] The utilisation of CPSs can lead to acquisition of data through sensors, actuators and metres, which can be processed autonomously and/or communicated to humans for further tasks.[32] The use of these technologies is not only for tactical and strategic purposes, but also to find constraints within operational processes, and mitigate or remove them.[33]

2.2.2. Significant differences and developments in Industry 3.0 to 4.0 detail a focus on higher autonomy

Industry 4.0 is commonly understood as the start of the "application of the generic concept of cyber-physical systems"[34], in which systems can autonomously perform their production and provide machine to machine communication, supported by the Internet of Things. However, this understanding also indicates the importance of making a clear distinction between industrial revolutions, which is stated by Torn, Pulles, and Schiele (2018): "If the distinction between third and fourth revolution is not made clear, however, the danger remains that Industry 3.0 applications are simply relabeled, and no progress is made whatsoever."[35] Therefore, without understanding the line between both stages, progress might not happen, or not fast enough. Moreover, companies might try to buy or sell Industry 3.0 techniques or information labelled as Industry 4.0, without actually being part of the Industry 4.0 concept and advancing their processes and business in general. One example of an exclusive Industry 4.0 feature is the ability to fulfil individual customer requirements with product variants in a very small lot size, down to one-off items.[36]

PwC state that "while Industry 3.0 focused on the automation of single machines and processes, Industry 4.0 focuses on the end-to-end digitisation of all physical assets and

[28] See Kagermann (2013), p. 15.
[29] See Thoben, Wiesner, and Wuest (2017), p. 6.
[30] See Fatorachian and Kazemi (2018), p. 2; Thoben et al. (2017), p. 4; Qin, Liu, & Grosvenor (2016), p. 174.
[31] See Fatorachian and Kazemi (2018), p. 2; Qin et al. (2016), p. 174.
[32] See Fatorachian and Kazemi (2018), p. 4.
[33] See Fatorachian and Kazemi (2018), p. 4.
[34] Drath, and Horch (2014), p. 1.
[35] Torn, Pulles, and Schiele (2018), p. 4.
[36] See Thoben et al. (2017), p. 5.

integration into digital ecosystems with value chain partners."[37] According to PwC, generating, analysing and communicating data seamlessly underpins the gains promised by Industry 4.0, which aligns with many other academic sources mentioned in this paper.[38] Deloitte and IHS Markit define Industry 4.0 to be different from Industry 3.0 in the way that it transforms data to usable information, bringing more possibilities for collecting new data, and consequently using these possibilities to increase worker mobility, while also allowing for new product designs.[39]

New developments and transitions from Industry 3.0 to Industry 4.0 can be categorised in the aspects of automation, digitalisation, and miniaturisation.[40] Firstly, far-reaching automation, mechanisation and autonomy describes how more and more precise technical support will be used in the field, such as the autonomous production of cells that can independently process the production of smaller, more precise steps. Secondly, networking and digitalisation details the increasing digitalisation from producing and manufacturing-aiding tools resulting in an increasing support of data collected with sensors which support, control and analyse the process, which leads to fully digitalised surroundings. Thirdly, miniaturisation is about the smaller and more powerful devices that can be installed on just a few cubic centimetres, to fully support in the context of logistics and production, while a few years ago these devices needed significant more space.

These technological innovations give an outlook for Industry 4.0 of massive increases in productivity, mass customisation, lowering of production costs, reduction in manufacturing and delivery times, and many more features,[41] including aspects such as improved working conditions, improvement in customer satisfaction.[42] Smart factories will consist of workspaces filled with sensors, actors and autonomous setups.[43] More future trends will be, for example, the adaptation to human needs, where machines are designed to follow humans, instead of the reverse. It can be concluded that Industry 4.0 is mainly focused on IT-driven changes and innovations.[44] These developments are expected to not have only technological, but largely multifaceted organisational implications, which results in changes in the industry focus of mainly product oriented, into service oriented industries.[45] Supporting this focus

[37] Geissbauer et al. (2016), p. 6.
[38] See Geissbauer et al. (2016), p. 6.
[39] See Geissbauer et al. (2016), p. 6; West (2017), slide 4.
[40] See Lasi, Fettke, Kemper, Feld, and Hoffman (2014), p. 240.
[41] See Pilloni (2018), p. 7-8.
[42] See Pilloni (2018), p. 7-8.
[43] See Lucke, Constantinescu, and Westkämper (2008), p. 1.
[44] See Lasi et al (2014), p. 241.
[45] See Scheer (2012), p. 10.

shift is shown through increasing use of E-Applications in organisations, corresponding with the IT-driven changes and innovations Industry 4.0 introduces. Within the procurement function, several important aspects need to be detailed to fully grasp the impact of these IT-software tools, and their impact on procurement.

2.3. The use of multiple E-Applications in today's E-Procurement context

2.3.1. The procure-to-pay (P2P) cycle: Developing financial processes towards efficient, compliant and automated ordering

Procure-to-pay, Purchase-to-pay, or just P2P, is the process of acquiring goods and services in a Business to Business setting.[46] According to Murphy (2012), the P2P process typically involves creating a purchase order (PO), authorising the PO, sourcing, provision of the PO to the supplier, material receipt, invoice receipt and authorisation, and finally, invoice payment.[47] When taking into account the broader understanding that in the P2P cycle, before a PO can be generated, a buyer has specific demands that are specified and sourced (i.e., vendor selection after comparing E-Catalogues in a P2P tool),[48] the following process is discerned (see figure 6).

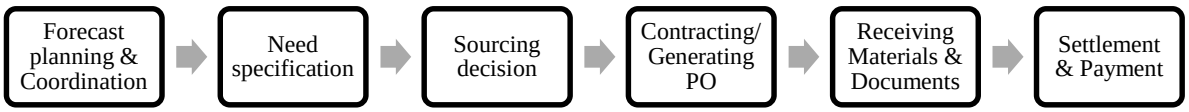

Figure 6. Procure-to-pay process according to Trkman & McCormack (2010, p. 339)

Moreover, while the P2P process describes a significant part of the purchasing process, the P2P process distinguishes itself by the fact that it also includes the payment and financial processes. These two processes are most commonly referred to as Accounts Payable process. Palmer and Gupta (2011) name eight technological categories that are transforming the acquisition cycle, of which payment technology and policy compliance software are categories, next to E-Procurement software itself.[49] While the traditional P2P process was focused mainly on control, organisations are changing their focus towards cost reduction, through process efficiency and automation.[50]

[46] See Hazelaar (2016), p. 12; Vanjoki (2013), p. 7.
[47] See Murphy (2012), p. 2
[48] See Trkman and McCormack (2010), p. 339.
[49] See Palmer and Gupta (2011), p. 74.
[50] See Palmer and Gupta (2011), p. 66.

In the ordering process, the most widely used E-Procurement technology is that of E-Catalogues, containing specifications and prices of all products and services available from suppliers.[51] Specifically, for buying firms the process of matching their demands to offered goods on the market becomes more efficient, while the software can also automatically perform the cross-catalogue comparison, and process contract pricing in real-time.[52] In a comparison, specific suppliers can also be dynamically included or excluded, and ranked according to user-defined criteria,[53] mitigating maverick buying and therefore increases buying compliancy. Moreover, Mehrbod, Zutshi, and Grilo (2014) also describe how suppliers may upload their product E-Catalogue to software vendor portals, to find a call for tenders or new markets for its product.[54] This automated tendering process helps suppliers identify the best suitable opportunities, decreasing the time required to locate and respond.[55] However, while E-Catalogues seem to provide clear advantages for both buyers and suppliers, issues can also be identified. Mehrbod et al. (2014) identify the fact that there are no widely established formats, therefore leading to use of various E-Catalogue formats used in the market.[56] Therefore, a focus on translation and integration of multiple formats in the software is required. Basware (2018) and SAP Ariba (2018a) indicate they support E-Catalogue creation from spreadsheets or directly from back-end systems, which seems to address this issue.[57] When internal demands are met, E-Catalogues prove to be a very useful tool. Benefits include lower advertisement and distribution costs, more flexibility to browsing, updating information, adapting information based on users' preferences, and extending searches to other catalogues.[58] The mentioned adaptation possibilities also include the use of different buyer-specific versions of E-Catalogues, i.e., making use of different prices, discounts, or currencies.[59]

As Hazelaar found in her research, there are multiple possible reasons for performance issues in the P2P process, such as maverick buying (i.e., non-compliant purchasing) and low pooling of demand.[60] Both of these risks can be mitigated in E-Procurement software. By

[51] See Trkman and McCormack (2010), p. 342; Alrobai (2013), p. 2.
[52] See Mehrbod et al. (2014), p.135, SAP Ariba, 2018b, p. n/a.
[53] See SAP Ariba (2018b), p. n/a.
[54] See Mehrbod et al. (2014), p. 135.
[55] See Mehrbod et al. (2014), p. 135.
[56] See Mehrbod et al. (2014), p. 135.
[57] See Basware (2018), p. n/a; SAP Ariba (2018a), p. n/a.
[58] See Alrobai et al. (2013), p. 3..
[59] See SAP Ariba (2018a), p. n/a; Basware (2018), p. n/a.
[60] See Hazelaar (2016), p. 19.

use of software, lists of preferred suppliers and buying channels can be defined, which are automatically used during the ordering process, leading buyers to their preferred supply. One of the recent developments by E-Procurement software vendors is the use of guided buying and digital assistants. Through the use of guided buying, especially non-procurement professionals are supported in their procurement tasks, while procurement professionals are assisted in aiming for higher policy compliance and savings. Users are able to use keyword searches in a webshop-like environment, searching cross-catalogue.[61] Results are automatically adjusted and filtered according to pre-defined settings, with a real-time connection to purchasing budgets, and other internal data. Software vendors are actively developing guided buying through using data analytics and end-user feedback, with market leaders promising guided sourcing and guided contracting possibilities in the future.

A recent development within the P2P process is increasing use of electronic invoices (E-Invoices), a technology originally stemming from Electronic Data Interchange (EDI) transactions. Organisations that use digital tools to assist the payment process often still rely on paper invoice conversion methods. Through OCR (optical character recognition) software, paper invoices are scanned, with the extracted data turned into applicable input in the invoice software. While the end result is a digitally processed invoice, the invoice process itself is still very dependent on human input and corrections, while also not offering the many benefits of true E-Invoices. True E-Invoices are based on Extensible Markup Language (XML), with the most common E-Invoice format being Universal Business Language (UBL), and are created, shared, and processed fully digital. Benefits of electronic invoices and automation of the payment processes include less administration and therefore faster processing, no lost invoices, authorisation transparency, reduced costs, greater use of early payment discounts, and improved supplier relationships.[62] In 2014, the European Union drafted regulations regarding a compulsory use of E-Invoices in government, with mandatory use of E-Invoices within Dutch government starting April 18th, 2019. However, research also shows processing E-Invoices might be more complex, with the added complexity requiring more human intervention, therefore slowing down the process.[63] Hence, caution is still needed when deciding on a transition to E-Invoices within an organisation and its network.

[61] See SAP Ariba (2017), p. 2.
[62] See Murphy (2012), p. 3-4; Digitale Overheid (2018), p. n/a.
[63] See Vanjoki (2013), p. 71.

2.3.2. The source-to-contract (S2C) process: E-Sourcing entails E-Tendering and E-Auctioning through E-Marketplaces, ending with digital contract management

When analysing the sourcing process in relation to E-Procurement, the application of E-Sourcing can be distinguished through separate functions of E-Tendering, E-Marketplaces, and E-Auctioning. With each application having its own use and characteristics, a separate review of each aspect is necessary.

E-Sourcing is often confused with E-Procurement, E-Tendering, and E-Auctioning while each term has its own attributes. Therefore, each term is reviewed to make a clear distinction. Most commonly, E-Sourcing can be defined as "the process of identifying new suppliers for a specific category of purchasing requirements using Internet technology",[64] or as the application of Internet technology to the complete supplier selection process,[65] through use of online negotiations, reverse auctions, and other related tools.[66] E-Sourcing lowers costs for organisations as information becomes more readily available via the marketplaces, instead of having to examine each and every single supplier individually.[67]

E-Sourcing applications typically provide platforms for online negotiations, such as requests for information (RFI's), requests for proposals (RFP's), requests for quotes (RFQ's), lowering negotiation costs.[68] These platforms for the comprehensive RFX process allow for use of E-Tendering, which includes the creation of RFX's, defining award criteria, sending RFX's to suppliers, collecting and structuring responses, and so forth.[69] In practice, E-Tendering is often confused for E-Sourcing, with practitioners using these terms as synonyms.[70] While in E-Sourcing multiple methods may be used leading to a contracted supplier, E-Tendering itself does not include closing the deal with a supplier.[71] Next, one important distinction is to be made within the field of E-Tendering, namely the different processes behind E-Tenders and E-Auctions. While in E-Auctions suppliers bid directly against each other,[72] in E-Tendering there is no such process. E-Tendering consists of

[64] De Boer, Harink and Heijboer (2002), p. 26.
[65] See Presutti (2003), p. 221.
[66] See Engelbrecht-Wiggans and Katok (2006), p. 581.
[67] See Knudsen (2003), p. 727.
[68] See Engelbrecht-Wiggans and Katok (2006), p. 582.
[69] See Harink (2003), p. 65.
[70] See Harink (2003), p. 74.
[71] See De Boer et al. (2002), p. 26.
[72] See Hartley (2004), p. 153.

organisations offering a single proposal,[73] as is done in a regular tender procedure, which can be locked in a digital vault in E-Procurement software.[74]

E-Marketplaces are specific websites that aim to bring buyers and suppliers together to facilitate the electronic purchasing process.[75] These E-Marketplaces are open networks, as opposed to extranets, which are private networks open only to pre-selected business partners.[76] One instance of these extranets is EDI systems, however, other inter-organisational information systems are also included.[77] One important difference between these two types of networks is the amount of strategic information sharing: while in closed networks information sharing and collaboration is stimulated, there is a much lower degree of both aspects in these open networks.[78] Thitimajshima (2017) claims many B2B models are shifting from legacy systems using EDI, to open online platforms such as these E-Marketplaces.[79] E-Marketplaces have three primary functions: matching buyers and sellers, facilitating transactions (e.g., through E-Catalogues and E-Auctions), and maintaining institutional infrastructures, such as legal and regulatory frameworks.[80] A further distinction in E-Marketplaces can be made, namely of buy-side versus sell-side marketplaces.[81] Specifically, buy-side marketplaces aggregate buyers, focusing primarily on efficiencies for corporate buyers, while sell-side marketplaces concentrate on aggregating multiple sellers into a central catalogue and product information repository.[82] One development in the industry is a growing use of neutral marketplaces, driven by third parties such as Amazon or E-Procurement software vendors. While academic interest in E-Marketplaces has risen due to the rise of internet giants such as Alibaba and Amazon, many E-Marketplaces have failed over the years.[83] Already in 2003, Skjøtt and Larsen described the "chicken-and-egg" issue where buyers do not want to participate unless there are a sufficient number of suppliers, while suppliers only want to participate when there are enough buyers.[84] The largest E-Marketplace in E-Procurement is the Ariba Network by SAP Ariba, having more than two

[73] See Harink (2003), p. 74.
[74] See Negometrix (2017), p. n/a.
[75] See Monczka et al. (2014), p. 687; De Boer et al. (2002), p. 26.
[76] See Dai & Kauffmann (2006), p. 111.
[77] See Dai & Kauffmann (2006), p. 111.
[78] See Skjøtt and Larsen (2003), p. 201.
[79] See Thitimajshima (2017), p. 129.
[80] See Bakos (1998), p. 35-37.
[81] See Skjøtt and Larsen (2003), p. 201.
[82] See Skjøtt and Larsen (2003), p. 201.
[83] See Thitimajshima (2017), p. 129.
[84] See Skjøtt and Larsen (2003), p. 201.

million global business connected, processing over US$1 trillion in total commerce each year.[85]

One other tool within E-Sourcing are E-Auctions, most commonly offered on E-Marketplaces,[86] but they are not the majority of E-Sourcing transactions.[87] E-Auctions can take multiple forms, with especially the E-Reverse Auction as a popular form. Instead of a traditional auction, in which buyers offer increasingly higher bids on goods or services from suppliers, in reverse auctions the suppliers bid increasingly lower on the goods or services buyers request. In most cases, E-Reverse Auctions focus on price of goods and services auctioned, with other criteria neglected, although firms are able to design multiple criteria in the software tools.[88] The use E-Auctions enable a large number of suppliers to cost effectively participate in the bidding process, and therefore, a buying firm's potential for finding the most capable suppliers.[89] The strategic benefit of identifying new suppliers is a major benefit, next to the potential for cost savings. Moreover, suppliers also benefit by obtaining market information, better manage excess capacity, and by competing for business from new customers. [90]

The final step in the E-Sourcing process is the contracting phase, which is commonly separated from the preliminary E-Tendering process, being either the end of an E-Auctioning process, or as a separate E-Contract Management process.[91] In the contracting phase, direct transaction costs are lowered through the use of E-Procurement tools, while also decreasing potential maverick buying.[92] Firms that are less mature in contracting and contract management often rely on contracts that are not centrally archived, reducing insight intro contracts and therefore reducing potential contract compliance.[93] While in 2003, Harink described how E-Contract Management was still a new development, now many software vendors provide tools to support contracting.[94] The most recent developments in digital contracting are those making use of new technologies such as Artificial Intelligence. For

[85] See SAP Ariba (2016), p. 1.
[86] See Harink (2003), p. 3.
[87] See Engelbrecht-Wiggans and Katok (2006), p. 582.
[88] See De Boer et al (2002), p. 27; Harink (2003), p. 37.
[89] See Hartley (2004), p. 153.
[90] See Hartley (2004), p.153; Engelbrecht-Wiggans and Katok (2006), p. 581.
[91] See Harink (2003), p. 33; Harink (2003), p. 36.
[92] See De Boer et al. (2002), p. 28.
[93] See Supply Value (2018b), slide 1.
[94] See Harink (2003), p. 44.

example, IBM is working together with SAP Ariba to create a new type of contract intelligence, in which their software can perform a content analysis on contracts, autonomously processing stated agreements, requirements, and possible issues in these contracts.[95] Benefits of using digital contracting tools include increased access to contracts, version control, automatic alerts based on specific contract content, and the use digital signatures for faster processing.[96]

2.3.3. Category management and supply chain risk management: Automated software tools support the controlling process

Category management entails the strategic and tactical management of a distinct category of goods or services that a buying firm purchases, by grouping together similar or related items, managing them like a separate business unit.[97] In category management, the use of portfolio models represents the most established use of strategy tools.[98] Portfolio models in category management are used to classify resources or relationships according to their strategic relevance in different portfolio quadrants to support the decision-making process.[99] The most renowned and cited portfolio model in procurement literature is the Kraljic Matrix (1983), which is a two-by-two matrix that classifies purchasing spend along the dimensions of *supply risk* and *strategic importance.*[100] In the Kraljic matrix, four quadrants are defined, each with their own specific tactics or strategies: non-critical, leverage, bottleneck, and strategic purchases.[101] One other technique is the ABC-analysis, also named Selective Inventory Control, which involves the Pareto-principle, also known as the 80/20 rule. The Pareto-principle describes how in many firms 80% of the consequences stemmed from 20% of the causes, in other words, how 80% of your spend might be with 20% of your suppliers.[102] Successful category management is supported by spend analysis, which is a process that can be largely automated within E-Procurement software. Through E-Procurement tools, both ABC-analyses and Kraljic Matrix-analyses are integrated in the system, and are performed automatically when end-users request it. New developments are autonomous alerts when thresholds are reached, for example, when specific suppliers or portfolio groups have

[95] Connect-to-innovate, personal communication, October 3, 2018
[96] See Negometrix (2018), p. n/a; Supply Value (2018b), slide 8.
[97] See Forbes (2015), p. n/a.
[98] See Stange (2017), p. 22.
[99] See Stange (2017), p. 22.
[100] See Kraljic (1983), p. 111.
[101] See Kraljic (1983), p. 111.
[102] See Feldt-Rasmussen (2010), p. n/a.

become increasingly important for the end-user organisation. By using software tools, there is less need for manual work, decreasing the costs while increasing insight into process efficiency, bottlenecks, and savings.[103]

Next, E-Procurement tools do not only support the classification and analysis of goods and services into these quadrants, but also classification into materials or services categories. Accurate classification is a requisite for achieving maximum efficiency in product categories. While there are classification schemes for goods and services such as CPV and eCl@ass, these systems still rely on the same translation and integration possibilities as posed for the E-Catalogue format issue.[104] Basware (2018) and Zycus (2018) indicate their software can perform auto-classification of catalogue items, which should reduce the needed human efforts to maintain these classifications.[105]

Within category management (e.g., portfolio management or supplier management), supply chain risk management is also seen as an increasingly important aspect.[106] Due to increased globalisation, higher customer expectations, and environment volatility, supply chains are more easily exposed to risks.[107] Authors discern two types of supply chain risk, namely operational risk, which concerns processess, people and systems, and disruption risk, which concern man-made or natural disasters such as terrorist attacks, earthquakes, or floods.[108] One example of such disruption risk is that of the flooding disaster in Thailand in 2011, causing a major disruption in production in several industries, leading to significant price increases and parts unavailability.[109] When looking at current tools by E-Procurement software vendors, newly developed analytical and active capabilities are shown. Continuous risk monitoring based on financial, judicial, social media, news sentiment, and other scores are offered by multiple vendors.[110] Naturally, because the software tools are often provided as a comprehensive software solution, risk monitoring is assisted by the large amount of internal and externa data available, and possibilities for information sharing. This supply-chain wide visibility of vulnerabilities is a requirement for successful risk assessment

[103] See Coupa (2018b), p. 3.
[104] See Mehrbod et al. (2014), p. 135; Alrobai (2013), p. 27.
[105] See Basware (2018), p. n/a; Zycus (2018), p. n/a.
[106] See Van Veen (2018), p.39.
[107] See Chen, Sohal, and Prajogo (2013), p. 2186.
[108] See Chen et al. (2013), p. 2187; Sawik (2013), p. 259; Kleindorfer and Saad (2005), p. 53; Van Veen (2018), p. 36.
[109] See Spiller, Reinecke, Ungerman, & Teixeira (2014), p. 40; Sawik (2013), p. 259.
[110] See Coupa (2018a), p. n/a; SAP Ariba (2018c), p. n/a.

processes.[111] Through the use of intelligence sharing within open or closed networks, firms are able to better mitigate potential risks in their firm, leading to a more optimal supply chain. As Chen, Sohal, and Prajogo (2013) found in their research, better collaboration was proven to decrease supply chain risk, through increasing knowledge and reducing variability in process, product and services.[112] Vendors describe continuous monitoring of transactional data, with autonomous alerts or actionable recommendations for supplier management possible, based on risk assessments performed autonomously in the software.[113]

2.4. Maturity models as an academic and practical tool to assess organisations

2.4.1. Organisational maturity is often described based on five maturity levels

The concept of maturity models has seen wide use in the academic world in the last 40 years[114], with the first maturity models published in 1979.[115] Afterwards, in 1993 the Capability Maturity Model (CMM) was introduced by Paulk, Curtis, Chrissi, & Weber. The CMM, and other maturity models aim to describe a path to maturation which is mostly linear, in which an organisation improves considerably regarding the current capabilities.[116] The underlying assumption behind maturity models is that the maturing of separate dimensions in the model leads to the maturation of the total entity as well.[117] Next, besides academic research, organisations can also utilise maturity models themselves for benchmarking purposes, in essence, to compare themselves against other similar organisations.[118]

The first CMM was aimed mainly at assessing software maturity, with organisations having to use various CMM's within their firm to assess different disciplines. To address the struggles with integration, overlap, and inconsistencies that accompanied the original method, the various CMM's were integrated into the Capability Maturity Model Integration (CMMI).[119] Now, many researchers have developed different maturity models, many using the CMM(I) as their base design. Therefore, the CMMI will be detailed to serve as a reference to a base maturity model. The five levels of maturity used in the CMMI are described on the next page.[120]

[111] See Kleindorfer and Saad (2005), p.57.
[112] See Chen et al. (2013), p. 2195.
[113] See Coupa (2018a), p. n/a; SAP Ariba (2018c), p. n/a.
[114] See Cienfuegos (2013), p. 70; Menon, Kärkkäinen, & Lasrado (2016), p. 3.
[115] See Wendler (2012), p. 1317.
[116] See Menon et al. (2016), p. 3.
[117] See Menon et al. (2016), p. 3.
[118] See Cienfuegos (2013), p. 71.
[119] See Royce (2002), p. 3.
[120] See Royce (2002), p. 4-5; White (2018), p. 1.

Level 1, Initial: The first level is characterised by unpredictable results, with process primarily reactive. The firm predominantly relies on the skills of its team to succeed, increasing risk and inefficiency.

Level 2, Managed: The second level is characterised by having a repeatable project performance, with projects planned, performed, measured and controlled. However, the key focus is still only this project-level activities and practices.

Level 3, Defined: The third level is characterised by improved project performance, with consistent cross-project performance leading to organisation-level activities. Organisations are more proactive than reactive and know how to address their deficiencies through clear improvement goals.

Level 4, Quantitatively managed: The fourth level is characterised by improved organisational performance, and predicting organisational results. By using quantitative data, the business is mitigating risks through data-driven insight into process deficiencies.

Level 5, Optimised: The final level is characterised by rapidly reconfigurable organisational performance, shown through flexibility in continuous process improvement. The organisation is stable and in a predictable environment, which allows this agility for innovation.

As detailed above, each following maturity level builds on the foundation of practices of the current maturity level, developing from an initial point to a more advanced state.[121] Therefore, trying to skip a level in the maturity process is more counterproductive than an optimal way of progress.[122]

A maturity model aims to describe different stages and the maturity path of an organisation. When designing a maturity model, several purposes can be distinguished. Pöppelbuß and Röglinger (2011) defined a set of principles based on the purpose of the maturity model.[123]

- Descriptive: The maturity model is used as a diagnostic tool, to assess the current capabilities of the entity under investigation.

[121] See Cienfuegos (2013), p. 71.
[122] See De Haan (2018), p. 34.
[123] See Pöppelbuß and Röglinger (2011), p. 4-5.

- Prescriptive: The maturity model is used to identify desirable maturity levels, and provides guidelines on improvement measures through specific and detailed courses of action.
- Comparative: The maturity model is used for internal or external benchmarking, assuming sufficient historical data from a large number of assessment participants can be collected.

In this study, a prescriptive maturity model is developed, in which the detailed maturity levels provide users with guidelines on improvements and detailed courses of action, all related to E-Procurement. For the design of a maturity model, specific requirements need to be met to substantiate the model. By using the following design principles for a maturity model, the practical applicability of a maturity model will benefit.[124] Next, in addition to the basic design principles, the prescriptive design principles will be taken into account. However, as Pöppelbuß and Röglinger (2011) themselves state, it is not required for each maturity model to meet all design principles.[125] It is merely to assist researchers and to serve as a checklist when designing a maturity model. Based on these statements, the design principles will be taken into account, while considering the specific applicability of each principle.

2.4.2. Maturity models for Industry 4.0 are recent and similar in maturity levels

Industry 4.0, as detailed in chapter 2.2., is a new technological development with many facets for every organisation. Organisations may strive towards implementing its many features and technologies, but in many cases, those organisations are not mature enough to utilise all of those technologies. To assess the maturity, several maturity models have been developed to assess Industry 4.0 or digitalisation as a subject (see table 1). Also, a maturity model that aims at a maturity assessment for digitalisation was added, namely that of Klötzer and Pflaum (2017). While it is named as a model for essentially the digitalisation of a supply chain, it overlaps with Industry 4.0 models through its focus on a smart factory. It takes into account Cyber-Physical Systems, Big Data Analytics, and other aspects, all of which are applicable in an Industry 4.0 maturity model.

[124] See Pöppelbuß and Röglinger (2011), p. 11.
[125] See Pöppelbuß and Röglinger (2011), p. 6.

No.	Author(s)	Year	Type	Model	Levels	Dimensions
1	Lichtblau et al.	2015	Practitioner	IMPULS - Industry 4.0 readiness	6	6
2	Jodlbauer et al.	2016	Academic	Reifegradmodell Industrie 4.0	*(0-10)*	3
3	Schumacher et al.	2016	Academic	Industry 4.0 maturity model	5	9
4	Pricewaterhouse Coopers	2016	Practitioner	Industry 4.0 / Digital operations self-assessment	4	7
5	Klötzer and Pflaum	2017	Academic	Maturity model for digitalisation	5	9
6	Torn	2017	Academic	Industry 4.0 in Purchasing Maturity Model	4	8

Table 1. Overview of Industry 4.0 maturity models

As shown above, Industry 4.0 maturity models are recent developments, with interest from both academics and practitioners. While one model has six levels, the other models have either four or five levels, excluding the model that does not determine specific levels. The model by Jodlbauer, Schagerl, and Brünner (2016) does not make use of specific levels, but uses a scale of zero to ten points. In detail, the levels used in the maturity models show many commonalities (see table 2).

No.	Author(s)	Level 0	Level 1	Level 2	Level 3	Level 4	Level 5
1	Lichtblau et al.	Outsider	Beginner	Intermediate	Experienced	Expert	Top Performer
2	Jodlbauer et al.						
3	Schumacher et al.		Likert score 1	Likert score 2	Likert score 3	Likert score 4	Likert score 5
4	Pricewaterhouse Coopers		Digital novice	Vertical integrator	Horizontal collaborator	Digital champion	
5	Klötzer and Pflaum		Digitalisation awareness	Smart networked products	Service-oriented enterprise	Thinking in service systems	Data-driven enterprise
6	Torn		Digital novice	Vertical Integrator	Horizontal Integrator	Digital champion	

Table 2. Overview of different maturity levels of Industry 4.0 maturity models

When comparing the models, firstly, many commonalities become apparent. Almost the same levels in model 4 and 6 are seen, namely, model 6 based their levels on model 4, showing the academic use of practitioners' research. Interestingly, model 1 uses 6 levels, with the first level (i.e., Level 0) described as being an Outsider. The second level, essentially the first level in all other models, categorises an organisation as a Beginner. Compared to the other models, all other models define the first level more broadly: organisations who are either not yet interested in Industry 4.0, or are interested but are merely beginning their digital journey.

2.4.3. E-Procurement and Procurement 4.0 maturity models show a growing interest in the topic and primarily use five maturity levels

To be able to integrate the aspects of E-Procurement (E-P) and Procurement 4.0 (P4.0) into a new maturity model, existing literature with corresponding maturity models is reviewed. A growing interest in Procurement 4.0 is shown, with more maturity models being developed in recent years (see table 3). While there are three E-Procurement maturity models developed before 2016, the focus on true Procurement 4.0 only started afterwards.

No.	Author(s)	Year	Type	Topic	Model	Levels	Dimensions
1	Sarayrah and Al-Utaibi	2011	Academic	E-P	eProcurement framework	5	12
2	Webster	2011	Practitioner	E-P	Purchase-to-Pay Manifesto Model	4	7
3	Eadie et al.	2011	Academic	E-P	E-Procurement CMM	5	12
4	Geissbauer et al.	2016	Practitioner	P4.0	Procurement 4.0 framework	-	6
5	Pellengahr et al.	2016	Practitioner	P4.0	Pilot study on Procurement 4.0	-	4
6	Busch	2016	Practitioner	E-P	Procurement Maturity Model	5	4
7	Kleemann and Glas	2017	Academic	P4.0	Digital maturity model for Procurement 4.0	5	8
8	Kosmol, Kaufmann, and Reimann	2018	Academic	P4.0	Procurement 4.0 maturity model	5	8

Table 3. Overview of E-Procurement and Procurement 4.0 maturity models

Comparing these maturity models, model 4 and 5 are the only models that do not define levels, while all others do. Model 4 only details important dimensions and describes a best practice situation, whereas model 5 describes the dimensions with a wide array of criteria. Both models do not try to distinguish distinct maturity levels for their assessment, in contrast to every other model that does use maturity levels. The remaining models all use five maturity levels, except for model 2 which uses four levels.

Furthermore, when analysing the distinction in specific maturity levels, influence of the CMM is clear, with model 3 using the five levels using the CMM terminology (see table 4). Models 7 and 8 are alike, both showing the same gradual increase in maturity. However, while many of these models share their use of five levels, this amount also causes the issue of overlap within levels, causing less distinctiveness between the different levels. Therefore, because these stages are so closely related to each other, it is more difficult to identify exactly which level an organisation is in. For example, in model 7 and 8, level 4 and level 5 both showcase a clear degree of being an expert. Distinguishing between a *season expert* or *digital*

champion might prove to be a difficult task, leading to difficulties in accurately measuring a maturity level.

No.	**Author(s)**	**Level 1**	**Level 2**	**Level 3**	**Level 4**	**Level 5**
1	Sarayrah and Al-Utaibi	Likert score 1	Likert score 2	Likert score 3	Likert score 4	Likert score 5
2	Webster	Emerging company	Aligned company	Networked company	Agile company	
3	Eadie et al.	Initial	Repeatable	Defined	Managed	Optimising
4	Geissbauer et al.					
5	Pellengahr et al.					
6	Busch	Initial impact	Capturing Spend	Transactionally Aware	Influence / Outcomes	Dynamic and Fluid
7	Kleemann and Glas	Traditional	Beginner	Established	Expert	Excellence
8	Kosmol, Kaufmann, and Reimann	Digital outsider	Digital newcomer	Developing learner	Season expert	Digital champion

Table 4. Overview of different maturity levels of E-Procurement and Procurement 4.0 maturity models

2.5. Literature review of four E-Procurement quadrants of renowned practitioners

2.5.1. Gartner's Magic Quadrant combines vision with execution

Gartner is a leading research and advisory firm specialised in many fields, primarily those of IT, Finance, Supply chain[126]. It publishes reports and renowned visualisations of resultse, e.g., their hype cycles and Magic Quadrants. Two different models by Gartner have been reviewed, namely the Magic Quadrant for Strategic Sourcing Application Suites (Gartner, 2018a) and the Magic Quadrant for Procure-to-Pay Suites (Gartner, 2018b). Gartner separates the Source-to-Pay process in the two models above, therefore leading to two different quadrants in which several vendors might be positioned in different dimensions of the applicable quadrant.

For the Strategic Sourcing quadrant, Gartner's definition of Strategic Sourcing Application Suites is "related, integrated solutions that support upstream procurement activities; in other words, the strategic work the procurement team does for planning, assessment and performance management."[127] Following this definition, they distinguish four primary capabilities for these solutions: (1) Spend analysis, (2) E-Sourcing, (3) Contract management), (4) Supply base management (SBM), also known as Supplier relationship management (SRM) and supplier lifecycle management (SLM).

[126] See Gartner (2018c), p. n/a.
[127] Gartner (2018a), p. 1.

For the Procure-to-Pay quadrant, Gartner's definition of a P2P suite is "sets of integrated solutions with processes that may be called 'transactional' or 'operational' procurement".[128] Moreover, they assess four distinct capabilities: (1) E-Purchasing, (2) Access to catalogues, (3) E-Invoicing, (4) Accounts Payable Automation.

Research methodology

However, while these two quadrants differ in assessed solutions, both quadrants follow the same research methodology. They make use of (1) interactions with end-user clients, (2) surveys from vendor-supplied end-users, (3) interviews with vendor-supplied references, (4) briefings and product demonstrations, and (5) financial and social media data.

Rated aspects

Moreover, Gartner rate the same in-depth aspects for each of their separate quadrants. These in-depth aspects are dimensions of the two categories on the axes of their quadrant, namely *completeness of vision* and *ability to execute.* The exact scoring and weighting, however, is undefined. To be precise, in both quadrants the following underlying aspects are rated, and related to their respective category (see table 5).

Completeness of vision	**Ability to execute**
Market understanding	Product or Service
Marketing strategy	Overall viability
Sales strategy	Sales execution / pricing
Offering (product) strategy	Market responsiveness / record
Business model	Marketing execution
Vertical/Industry strategy	Customer experience
Innovation	Operations
Geographic strategy	

Table 5. Rated aspects in Gartner's Magic Quadrants

Final quadrant

Ultimately, the following Magic Quadrant with four vendor types is formed (see Figure 7). As shown, companies that rate very high on vision and very high on execution are deemed leaders, while companies that rate high on vision cannot yet execute are categorised as visionaries. Likewise, in cases of low vision but either a high or low ability to execute, companies are deemed challengers or niche players respectively.

[128] Gartner (2018b), p. 3.

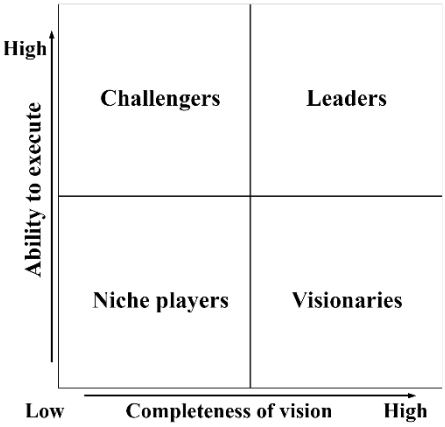

Figure 7. Visual format of Gartner's Magic Quadrant based on Gartner (2018a, p. 3; 2018b, p. 5)

2.5.2. Forrester's Forrester Wave uses a unique linear quadrant categorisation

Forrester is a leading market research firm specialised in researching the existing and potential impact of technology. It maintains several models, but for this research the most suited model is the Forrester Wave, which evaluates software vendors in specific markets and visualises the results in a linear quadrant.[129] The Forrester Wave E-Procurement Q2 2017 is analysed in this research, being the only, and most recent quadrant by Forrester regarding E-Procurement vendor assessments. Unlike Gartner, Forrester does not separate E-Procurement into Strategic Sourcing and Procure-to-Pay, or other similar distinctions.

Research methodology

Forrester makes use of (1) lab evaluations, (2) questionnaires, and (3) demos and/or discussion with client references. After it finishes its own evaluation, it sends it findings to vendors for review, after which they finish their research.

Rated aspects

Specifically, Forrester rate thirteen in-depth aspects for their quadrant, separated into three dimensions in the quadrant. The two axes of their quadrant, *strategy* and *current offering* for x-axis and y-axis respectively, combined with *market presence*, visible through the size of the position marker in the quadrant. The exact scoring and weighting are largely undefined but is indicated to be based on needs of companies with a high amount of end-users. Afterwards, interested parties using the Forrester Wave can individually adjust the weighting of aspects based on their specific organisational demands, leading to a more personalised

[129] See Forrester (2018), p. n/a.

score. To be precise, in both quadrants the following underlying aspects are rated, and related to their respective category (see table 6.).

Strategy	Current offering	Market Presence
Customer success	Requisition creation	Installed base
Product strategy	Approval	Market share of new deals
Corporate strategy	Invoice processing	
	Reporting	
	Supplier adoption	
	Technology	
	Globalisation	
	Cost	

Table 6. Rated aspects in Forrester's Forrester Wave

Final quadrant

Finally, the following Forrester Wave with four vendor types is formed (see Figure 8). As shown below, companies that rate very high on strategy and very high on the current offering are deemed leaders, while companies that rate high on strategy yet lack the current offering are categorised as strong performers, contenders, or in the worst case, challengers. Therefore, in cases of a high ability to execute, yet the lack of a highly rated strategy, companies cannot be considered leaders. Therefore, the structure assumes that both dimensions need to be aligned to be deemed a leader.

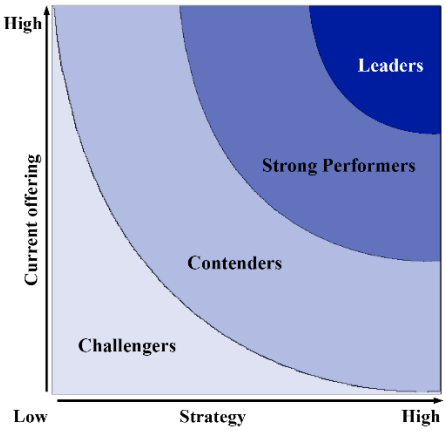

Figure 8. Visual format of Forrester's Forrester Wave based on Forrester (2017, p. 7)

2.5.3. SpendMatters's SolutionMap combines customer scores with analyst scores

SpendMatters is an analyst firm specialised in researching procurement, publishing new content daily on their website, and in total, publishing more research than the traditional

industry analyst firms combined.[130] While not a traditional analyst firm, the SolutionMaps published by SpendMatters provide many procurement professionals deep insight into the E-Procurement landscape[131].

Research methodology

SpendMatters makes use of many of the same research methods as Gartner, Forrester, and similar analysts. They use (1) analyst interactions with vendors and end-users, (2) SpendMatters reports, (3) vendors RFI inputs and materials, (4) vendor product demos, (5) customer survey responses, and (6) analyst phone call to evaluate score with provider.

Rated aspects

SpendMatters rates in-depth aspects belonging to the two axes of their quadrant, *customer score* and *analyst score.* The exact scoring and weighting are defined thoroughly: there is a preliminary weighting composed based on the above research methods, after which it is finalised after all data collection, and ultimately offers adjustable weighting according to a persona-based prospective software buyer. Although it is not rated, the SolutionMap, like the Forrester Wave, shows the relative size of a software vendor through the size of the position marker. The size is based on the amount of customers the vendor has, yet there is no further explanation for the measurement of this aspect. In detail, SpendMatters rate the following aspects for their quadrant (see table 7).

Customer Scoring	**Analyst solution**
Recommend this provider	Catalogues
Level of value perceived	Shopping / Requisitioning
Meet the expectations	Ordering
Quick deployment	Receiving
Return on Investment (ROI)	Supplier Network
Total Cost of Ownership (TCO)	Configurability
Business value	Technology
Innovation	General Services

Table 7. Rated aspects in SpendMatter's SolutionMap

Final quadrant

Lastly, the following SolutionMap with four vendor types is formed (see Figure 9). As shown, companies that receive a very high customer score and a very high analyst score are

[130] See SpendMatters (2018a), p. n/a.
[131] See SpendMatters (2018b), p. n/a.

deemed value leaders, while companies that receive high customer scores yet are not scored high by analysts are categorised as customer leaders. Likewise, in cases of low customer scores but either a high or low analyst score, companies are deemed solution leaders or emergent contenders respectively.

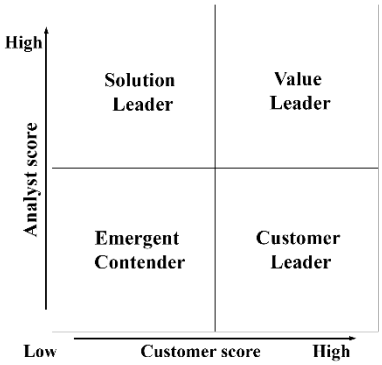

Figure 9. Visual format of SpendMatters' SolutionMap based on SpendMatters (2018b, p. 7)

2.5.4. Capgemini's Digital Procurement Research scores based on an extensive feature survey

Capgemini is a large professional services and business consulting firm, and is one of the largest IT consulting, outsourcing and services companies worldwide, also focusing on digital transformation.[132] While Capgemini has performed research into procurement before, they just recently published their newly developed research, the Capgemini Digital Procurement Research 2018. In their report, they researched 36 E-Procurement software vendors, all positioned in their new Capgemini Digital Procurement Matrix 2018. Furthermore, they also separated their full Procurement Matrix into two matrices for Source-to-Contract and Purchase-to-Pay.

Research methodology

The vast majority of the research was the use of an in-depth feature survey sent to software vendors, which the vendor has to fill in. Based on the responses of the survey, several vendors were selected to give a product demonstration, mainly if their offered functionality was sufficiently distinctive in their survey results.

[132] See Capgemini (2018a), p. n/a.

Rated aspects

The survey had a maximum of 614 questions, while dynamically showing or hiding specific aspects or questions based on responses in the survey (see table 8). The scoring is done through assigning full points for the answer 'yes' to questions, assigning zero points for the answer 'no', and assigning a quarter of the points if the vendor answers a specific feature is planned on the roadmap. Ultimately, a final score leads to an x and y coordinate for width and depth of the offering respectively. The weighting of scores has not been described, but based on the extensive description of the scoring methodology, it can be assumed that each score is weighted equally.

Width / Depth
Supplier Management
Strategic Sourcing
Contract management
Purchasing
Accounts Payable
Reporting & Analytics
Master Data Management

Table 8. Rated aspects in Capgemini's Digital Procurement Matrix

Final quadrant

Ultimately, the following quadrant with four vendor types is formed (see Figure 10). As shown, companies that score high in offering width and offering depth are ranked All-Stars, while companies that score high in width yet do not score high in depth are categorised as generalists. Likewise, in cases of low width but either a high or low analyst score, companies are deemed specialists or compliants respectively.

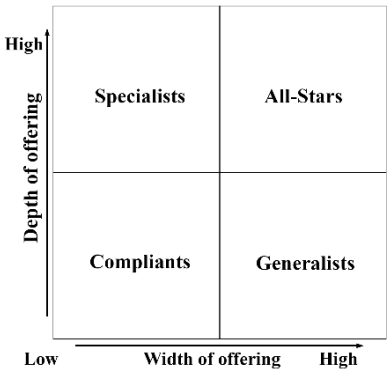

Figure 10. Visual format of Capgemini's Digital Procurement Matrix based on Capgemini (2018b, p. 10)

The four practitioner quadrants summarised

The literature review of the four quadrants above shows a distinct structure and overlap in each model. All four analyst firms use a variety of research methods, with only Capgemini basing the majority of their research on one in-depth survey. Gartner and Forrester both rate software vendors based on their current product and product strategy, requiring vendors to score high on both dimensions to be deemed a leader. SpendMatters, however, scores based on customer and analyst ratings, leading to three different types of distinct leaders. Capgemini falls more in line with SpendMatters by scoring based on width and depth of offering, leading to a leadership status for both very niche-specific Specialists, next to true All-Stars. Therefore, Forrester is the only practitioner who visualises a linear growth in their quadrant.

For this research, the literature review of the four quadrants show a shared methodology that can be used for further analysis and the development of the Quadrant Model. The use of an in-depth feature survey by Capgemini allows for a strong connection of the rated aspects to the Maturity Model. Next, the use of a linear growth model as utilised by Forrester further strengthens the connection to the Maturity Model.

3. Methodology: Conducting a design process based on a multiple-case study

3.1. The research design is based on in-depth semi-structured interviews

As this research focuses on gaining insight into the application of E-Procurement in organisations, the research can be categorised as exploratory research. There are a number of ways to conduct exploratory research: literature review, in-depth individual (expert) interviews, paired or triad interviews, focus groups, or a world cafe.[133] In group-based research, such as focus groups or world cafes, advantages are being able to achieve a high amount of data in fewer contact moments, and being able to build a consensus among participants regarding certain subjects. In individual research, however, in-depth discussions with individual respondents (who possess deep industry and product insight) can also provide a high amount of data, yet less shaped towards a common agreement, but the individual's own perception. To achieve the widest view of the industry, and not merely a summarised overview, the in-depth individual interviews were chosen as research method. Through use of these individual interviews, specific observations could be made, with respondents also not influencing each other's answers, potentially reducing the depth of analysis that would otherwise be attained.

3.2. Sampling and data collection: Industry leaders offer extensive knowledge

The sample for data collection is taken from the global E-Procurement software vendor market, as recognised by industry analysts. By sampling both industry leaders and newcomers, all of which have established their track record based on assessments by renowned analyst firms, a full view of the current market and its future can be developed.

First, all vendors who are named by Gartner in their widely recognised Magic Quadrant for Procure-to-Pay Suites and Magic Quadrant for Strategic Sourcing Application Suites are selected. The selection follows the assumption that these high-profile vendors are able to provide in-depth knowledge and experience with the E-Procurement market. Second, only vendors that have either office locations or relevant contact information in the Netherlands were selected. Third, the list of software vendors was expanded with several widely recognised, niche-focused Dutch vendors based on recommendations by employees of Supply Value. Finally, from the list of software vendors, multiple employees were approached to participate in the research. The main selection criteria for these prospect interviewees were as follows: (1) employed directly by the organisation, (2) direct

[133] See Saunders (2016), p. 171; Ritchie, Lewis, Nicholls, & Ormston (2013), p. 37.

interaction with end-users of their software, (3) knowledge of their software solution, and development thereof, and (4) basic knowledge of Industry 4.0 and technological advancements. These four criteria lead to the final interview selection (see table 9).

All interviewees received one information page and a proposed interview guide for the interview. The information page described through images the topic of the research and the problem statement (see appendix II). The proposed interview guide described in detail the questions that would be asked (see appendix V), guaranteeing the successful use of a semi-structured interview setting.

Company	Software vendor / Consultancy	Job title interviewee	Number of employees	Duration
(A)	Vendor	(1) Senior Solution Consultant	1001-5000	1:01:47
(B)	Vendor	(1) Field Marketing Director (Benelux)	1001-5000	0:57:14
(C)	Vendor	(1) Vice-President (Europe)	501-1000	0:55:38
(D)	Vendor	(1) Marketing Manager (Europe)	201-500	1:00:00
(E)	Vendor	(1) Pre-Sales Manager (Benelux)	201-500	1:19:05
(F)	Vendor	(1) Business Development Manager (Benelux)	201-500	1:16:42
(G)	Vendor	(1) Commercial Director	51-200	1:05:35
(H)	Vendor	(1) General Director	11-50	1:38:26
(I)	Consultancy	(1) Managing Consultant	11-50	0:26:17
		(2) Managing Consultant		0:42:44
		(3) Senior Consultant P2P		0:46:04
(J)	Consultancy	(1) P2P Project leader	1-10	0:30:00

Table 9. Overview of interviewed companies

3.3. Data gathering: Conducting questionnaire based semi-structured interviews provide essential, comparable research data

Data for this research was collected through the use of twelve semi-structured interviews. Eight in-depth semi-structured interviews were conducted with software vendors, where a previously developed interview guide was used (see appendix IV). Next to these eight interviews, four in-depth semi-structured interviews were conducted with consulting practitioners, each having extensive knowledge and experience within the domain of E-Procurement. For these interviews, a different interview guide was used (see appendix VI). For both interview types, the main questions are asked in each interview and several sub-questions were asked when needed, to further guide the interview towards new, relevant information. All interviews were estimated to last 60 minutes and could be conducted as a face-to-face interview or over the phone. All interviews were conducted in Dutch and in the

case of software vendors were held with one interviewee per company, while for the consulting practice three interviewees were from Supply Value, and a fourth one was a consultant for the University of Twente. All interviews except for one were recorded and transcribed, resulting in 9,2 hours of interview data with software vendors, and 2,5 hours with consultants. The unrecorded interview was annotated in more detail to capture all information, to guarantee successful use of the data later in the research.

The vendor interview questionnaire is based on the Industry 4.0 Maturity Model by Torn (2017), which itself is based on the Purchasing Maturity Model by Schiele (2007).[134] Through a focus on Industry 4.0, divided into eight aspects of the Purchasing function, Torn's (2017) model provided a clear format for questions in which both the strategy of E-Procurement software end-users and their software usage could be assessed. The questionnaire used is shown in appendix IV, while a shortened version is shown below (see table 10). To increase validity, a detailed questionnaire is used to systematically gather extensive information from each interviewee.

1)	What is your vision on Industry 4.0 and what is your company's strategy towards this?
2)	What is your company's strategy towards further digitisation of purchasing processes?
3)	What kind of digital processes do you see on average, currently in your customer market?
4)	How does your company see the future purchasing function?
5)	How much will the Industry 4.0 aspect influence this?
6)	What do you see as maturity developments in the sourcing processes of your customers?
7)	What do you see as maturity developments between the collaboration between your customers and its suppliers?
8)	How is (automated) supplier evaluation provided through your software?
9)	What do you see as maturity developments in the P2P-cycle of your customers?
10)	How is maverick buying mitigated in your software?
11)	How is (automated) invoice processing supported in your software?
12)	What are the analytical tools offered in your software?
13)	What do you see as maturity developments in data-analytics by your customers?
14)	How is Big Data used for data-analytics by your customers?

Table 10. Structure and main questions of the vendor interview questionnaire

The consultant interview questionnaire was developed based on the vendor interview questionnaire and the Industry 4.0 Maturity Model by Torn (2017), with a focus on the

[134] See Schiele (2007), p. 284-291; Torn (2017), p. 67-69.

practice of E-Procurement consulting services. The questionnaire used is shown in appendix VI, while a shortened version is shown below (see table 11).

1) What trends do you think there will be in the coming time regarding E-Procurement?
2) Do you use a maturity model/curve when discussing a customer's needs?
3) What do you find lacking in current E-Procurement maturity models?
4) Which questions do you ask a (prospect) customer to gauge their current purchasing maturity, and what their E-Procurement needs are? Please link this to the following eight aspects: (a) *Strategy*, (b) *Processes*, (c) *Physical link*, (d) *Sourcing*, (e) *Purchase-to-Pay cycle*, (f) *Controlling / KPI*, (g) *Suppliers*, (h) *Employees / Users*.

Table 11. Structure and main questions of the consultant interview questionnaire

3.4. Iteratively designing a new Maturity Model and Quadrant Model based on literature review and interview results

To perform data analysis on the interview data, the content analysis method was used through the use of the software tool ATLAS.ti. The content analysis method can be seen "as a research method for the subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns".[135] Before starting the analysis, each transcript was analysed individually to structure the information according to the interview format and remove superfluous information. The initial review of information provided the first classification of possible codes, e.g., of possible technology trends that were mentioned by multiple interviewed subjects.

Next, transcripts of two interviews were coded inductively to generate a coding list. The coding list was used for analysis of the remaining interviews, and codes were adapted or removed if they were found to be an incorrect fit to the collected data. After the single case analysis, the cross-case comparison is performed. Here, all interview transcripts were coded based on the previously established code list and continuously reviewed, in which several patterns and themes were found. A small number of codes were modified, added or merged with other codes to better code interview data and reduce redundancy. For example, the code suppliers portal was merged with code marketplaces, as they were considered as the same subject by interview subjects.

[135] Hsieh and Shannon, 2005, p. 1278.

Developing design principles involves series of testing and refinement cycles, in which data is collected systematically to re-define problems, solutions, and possible principles. [136] The design process is a continuous process, in which reflection on data gathered leads to constant re-design, aimed at iteratively refining the product and theory. [137]

Describing the process, four stages are discerned. Firstly, an analytical phase in which the practical problem by researchers and practitioners is defined and researched. In this research, the analytical phase constitutes the use of a literature review of Industry 4.0 and E-Procurement topics and the problem statement of a missing E-Procurement Maturity Model and Quadrant Model. Secondly, the stage of development of solutions informed by existing design principles. In this research the second phase can be identified by the development of the first draft of the E-Procurement Maturity Model, based on the Industry 4.0 Maturity Model by Torn (2017) and the Big Data Purchasing Maturity Model by De Haan (2018), and the Quadrant Model, based on practitioner quadrants. Thirdly, there are iterative cycles of testing and refinement of solutions (i.e., prototypes) in practice. While in this research there was no assessment of the practical application of both models at actual end-user firms, there were iterative cycles of testing and refinement of the models based on feedback by supervisors from the University of Twente and Supply Value. Based on their feedback, the models were iteratively refined. Finally, through the constant refinement of the design, there was also a constant reflection on the models and its solution to the problem statement. Through the continuous process of designing, refining, and re-designing, the models were iteratively shaped into the final versions that incorporated all previous feedback.

3.5. Assessing the research quality concerning validity and reliability

In scientific research, important criteria for evaluation are reliability and validity. Reliability refers to replication and consistency, meaning that if the same research design were replicated by different researchers, the same findings should be achieved.[138] Threats to reliability for the interview phase of the research were mitigated. More in detail, participant bias was mitigated through arranging interviews with one person per interview, with confidentiality agreed to beforehand, so interviewees would not be influenced by colleagues or mistreated by their organisation. Next to this, by planning the interview far in advance

[136] See Amiel and Reeves (2008), p. 35.
[137] See Amiel and Reeves (2008), p. 35; Kennedy-Clark (2013), p. 112.
[138] See Saunders (2016), p. 202.

and communicating the interview guide at least a week in advance, participant error was mitigated.

Next to reliability, the validity refers to the appropriateness of measured used, accuracy of analysis, and generalisability of the findings.[139] More in depth, it concerns whether the measures used in the research accurately measure the intended variables, both in the research design as in the research methods. Afterwards, it concerns the accuracy of results, and if these results be generalised for broader use. One aspect of validity is content validity, which refers to whether the measurement device provides adequate coverage of the investigated object. In this research, content validity was achieved through feedback and iterative design cycles for the interview questionnaires and the Quadrant survey, both being based in literature research.

[139] See Saunders (2016), p. 202.

4. Results and analysis: Development of the Maturity Model and Quadrant Model, with an additional E-Procurement & Industry 4.0 Trend Analysis

4.1 Developing the Maturity Model based on literature review and interviews

4.1.1. Literature review shows reasons to use four maturity levels to build the Maturity Model

Analysing all different maturity models, there is a clear use of the CMM(I) maturity model. Some maturity models use the same five levels according to the CMMI, while other models use four levels. As stated in the literature review, because of overlap within levels, there is less distinctiveness between the different levels. Therefore, because these stages are so closely related to each other, it is more difficult to identify exactly which level an organisation is in.

When taking into account the maturity model by Schiele (2007), which itself is the basis for the maturity model by Torn (2017), the four levels establish distinct maturity levels. By not using a 'level zero', all firms are considered as a beginner if they do not use digital tools, or if they are only just starting to use digital tools. The zero level by Lichtblau, Stich, Bertenrath, Blum, Bleider, Millack, and Schröter (2015) is therefore disregarded for the new Maturity Model. The fifth level, however, is seen to be used more in the following maturity models. However, as stated before, the fifth level is the most difficult to assess when making use of five maturity levels. Whether a firm is an *Expert* or a *Top Performer*, or likewise, a *Seasoned Expert* or *Digital Champion*, is difficult precisely because both levels indicate a very high maturity. Based on this understanding, for the new Maturity Model, the four level approach will be used.

4.1.2. Semi-structured interviews with software vendors and consultants provide insight for building the eight organisational dimensions in the Maturity Model

From the twelve interviews, the eight main interviews were held at different companies, each of them an E-Procurement software solution provider (i.e., software vendor). Among the respondents, there were both multinational operating vendors (A through F) and vendors operating exclusively in the Netherlands (companies G and H). In total eight vendor interviews were held, until the point that there were many similarities among the answers, and theoretical saturation had been achieved. All the interviews were with a single person who was familiar with the company, its software solutions, technology developments, and had extensive market knowledge. In the remaining four interviews with consultants, for each of the eight dimensions, the question was asked which questions they currently use when

assessing customer maturity. Based on their answers, several additional factors could be identified.

a) Results of E-Procurement about strategy

The interview questions about the strategy were divided into a question about the focus of their software, their vision on Industry 4.0, and their strategy towards dealing with the further digitalisation of procurement. These questions lead to input towards defining aspects and levels for answering the question *"Is digitalisation integrated into the corporate strategy and purchasing strategy?"* in the Maturity Model.

The majority of vendors indicate the function of procurement is shifting: from a purely transactional focus, the function grew towards savings potential, to more recently, a focus on added value, according to the vendors A and D. Vendor B agrees on the focus shift, describing it as changing from a non-focus on procurement in an organisation towards a much higher focus, shown by the increasing employment of a Chief Procurement Officer (CPO). The vendor C details an even further focus and widening of procurement tasks, which it describes not just as procurement, but as total business spend management.

Regarding the vision and strategy towards Industry 4.0, the vendor G indicate Industry 4.0 is a broad market development and not a goal in itself. It should be evaluated to mitigate the risk of disruption. However, vendors B, C, E, G indicate organisations should not buy into the hype but have to look at the usability of the technology. Specifically, vendor G claims he sees a repeat of twenty years ago, "when companies enthusiastically claimed they wanted IT software, consultants implemented it and left with money in their pockets, leaving the company with IT software, but no idea what to use it for. Now, we don't want IT, we want to achieve goals, and we need support for that."[140]

The consultants I1 and I3 detailed how, when defining the strategy with their customers, they asked questions regarding deployment in pilot projects in separate office locations or departments, and whether there would be a broad deployment of modules or only individual modules.

[140] Vendor B, personal communication, August 23, 2018, minute 28

b) Results of E-Procurement about processes & systems

The interview questions about the processes and systems were divided into questions about the average digital process management of their customers, how they see the future of the procurement function, and how Industry 4.0 might influence this. These questions lead to input towards defining aspects and levels for answering the question *"Are our processes standardised, automated and adopting new technologies?"* in the Maturity Model.

Many vendors share the opinion that the operational tasks within procurement, essentially the Procure-to-Pay process, can already be automated highly, with only some human involvement still needed. However, vendors D, E, F, G, and H claim these tasks can be automated fully, aided by pre-approvals, specific requirements managed in the system, or use of machine learning. Because of the possibility for automation and use of digital systems, vendor F sees the operational employee gaining more influence, being able to provide borders in which the system can operate. Additionally, vendors C and D see possibilities for increasing efficiency in managing an organisation's' tail spend. This speed of use, naturally, is a major advantage to E-Procurement software, also underpinned by many other vendors. Namely, restructuring a previously chaotic workflow is mentioned by vendors E and H, next to simplifying the software itself, with vendor C claiming lead times can be shortened. Summarising statements by consultants from all vendors, achieving this speed of use is often done by increasing the ease of use: simplifying user interfaces, reducing the training needed or providing newer, simpler workflows.

Regarding maturity, vendor E describes how the use of software for these operational tasks has higher adoption compared to strategic tools, but it highly depends on the individual organisation. Some large, multinational organisations can be less mature than a smaller organisation, due to the higher flexibility of a smaller organisation.

Next to these operational processes, vendors indicate there will be more standardisation and automation of the strategic procurement processes. Vendor G indicates supplier management will be more automated, with continuous KPI monitoring instead of manual reporting.

The human involvement in processes and systems in the current systems is still deemed to be high. With specific examples described in their respective dimensions, consultants describe in general how the process flows still rely heavily on human involvement. Even with the support of digital systems, consultants I2, I3 and J indicate decisions and actions are still made by humans. Vendor G describes a possible shift of human interpretation of contracts, supplier performance and other aspects towards systems and algorithms. One point

of the previously detailed ease of use is the adoption of technologies such as chatbots, digital assistants and guided buying, which vendor C, D and E mention. By implementing these technologies in the software, end-users are guided through workflows, and efficiency and accuracy are increased. Vendor A describes a high degree of possible autonomy in processes and systems, detailing how systems can autonomously give suggestions in systems. An example would be clause suggestions in the contracting phase, an example also described by vendor C.

c) Results of E-Procurement about the physical level

The physical level has not been included in each interview as a separate section with corresponding questions, because during the research it was found the physical aspect has only a low connection to the E-Procurement vendors in the research scope. However, each interview transcript was analysed for data regarding the physical aspect, which leads to input towards defining aspects and levels for answering the question *"Is the connection between physical and virtual systems established?"* in the Maturity Model.

Most E-Procurement software is based on supporting the procurement processes of indirect materials, as opposed to direct materials, which was evident during the vendor interviews. None of the vendors interviewed had a high focus on supporting the direct materials procurement process, except for vendor A. Vendor A has a wide product offering with a separate software suite for direct materials management. However, this tool was outside of the scope of the interviewees knowledge and therefore did not lead to valuable input.

Only the vendor G indicated a possible use of the link with physical and virtual systems, namely sensor input being sent to the contract management module of an E-Procurement suite. By use of M2M communications, these sensors could relay quality measurements to the system autonomously, after which the system could autonomously adjust supplier ratings based on performed analyses. Afterwards, these adjusted supplier ratings lead to changes in preferred suppliers, suggestions in the system, or likewise. Additionally, sensors in the physical production facility or warehouse could autonomously send inventory level measurements to the system, which can lead to suggestions or automated purchase orders in the system. Therefore, for the physical level, the focus is primarily on inventory management, demand generation, and autonomous ordering, all based on system input by digital sensors.

d) Results of E-Procurement about Purchase-to-Pay (P2P)

For the P2P dimension, the interview questions were divided into the automation of the ordering phase, how maverick buying could be mitigated, and what kind of invoice monitoring capabilities were present and used by end-users. These questions lead to input towards defining aspects and levels for answering the question *"Is the process of Purchase-to-Pay automated?"* in the Maturity Model.

As stated in the general processes and systems dimension, almost all vendors agree that the operational P2P process can be fully automated. Vendors C and H indicate that automation relies on functioning processes, and by restructuring some processes they already achieved efficiency gains, which further increased when the support of E-Procurement software was added. However, vendor D states that while 100% digitalisation is possible, 100% automation is more difficult. Because procurement of indirect materials mainly involves humans purchasing items, it is difficult for systems to automate the process of need identification completely. Likewise, vendor E states that only very specific requisitions are unable to be processed automatically or autonomously.

Vendors D, E, and F claim the use of E-Catalogues can provide more ease and speed of use for end-users, in which they cite punch-out catalogues as examples. By making more use of E-Catalogues, buying firms can reduce their tail spend, or at least make tail spend more analysable for future reference. By utilising these E-Catalogues, the chance of maverick buying is also lowered, impacted by the ease of use for buyers to buy compliantly within their E-Procurement tools. Regarding maturity, consultant I1 claims E-Catalogues are still used too little within buying firms.

When asked about maverick buying, vendors mostly answered that mitigating this form of non-compliant purchasing is not merely something for software, but also for process workflows and human behaviour. As vendors stated before, ease of use and user satisfaction are of high priority for all aspects of software, but it is of more importance regarding maverick buying. Vendors A, B, D, E and H state a system should be easy to use, while inherently supporting the users in buying compliantly. Guided buying in a webshop-like experience, after covering all spend categories and onboarding a large number of suppliers, promotes compliant buying without the user feeling like they are caged by requirements. Moreover, vendors F and H indicate that one of the causes of maverick buying is the lack of insight into contracted parties for their purchased goods. These vendors claim that, because of their lack of insight, some companies might have as much as 40 to 60 per cent maverick

buying. Furthermore, vendor F claims that "the percentages of maverick buying between firms can vary by a huge amount, if they already use a tool it will be very different than if they do not have any tools at all".[141]

Vendors B and E indicated that P2P is not a task purely for procurement, but also general business and finance. They indicated that especially the finance department is a large driver for automation of the P2P process, with an emphasis on the invoicing process. By automating invoices, relying on automated invoice matching systems, and so forth, human involvement can be reduced, and further growth in efficiency can be seen. Surprisingly, vendor F mentions how some organisations still manually code invoices received digitally, while in an automated system between buyer and supplier, a purchase order could directly be translated to a matching invoice.

For the whole invoice monitoring process, vendors C, D, F, and H indicate the software maturity is very high, with the vendor F claiming invoice monitoring is at the centre of P2P-tools, and "P2P-tools are almost always integrated within a financial system".[142] Vendor H states they expected all invoices nowadays to be in true digital formats (XML, EDI, and so forth), but regarding maturity, they state that small to medium size organisations might still receive 70 to 80 percent of their invoices on paper or as PDF's. However, some of their customers do have suppliers that send completely correct invoices, which flow directly through their system without any human involvement and are booked directly into the financial administration, so-called *touchless invoices*.

e) Results of E-Procurement about controlling & KPI's

Researching the controlling & KPI capabilities and maturity, the questions were divided into the available analytics tools, the use of these tools by end-users based on their maturity, and the use of Big Data. These questions lead to input towards defining aspects and levels for answering the question *"Do we have complete, real-time transparency?"* in the Maturity Model.

The vendors B, D, E, and G describe how their software has an analytical layer built into the whole system, measuring each step in a process or workflow, the spend compliance, supplier performance, and so forth. These analytics are shown through reports based on user profiles in software by vendors D and E.

[141] Vendor F, personal communication, August 17, 2018, minute 45
[142] Vendor F, personal communication, August 17, 2018, minute 63

One aspect of the complete, real-time transparency aspect details the use of clean, harmonised data in one dataset, also known as Master Data Management (MDM). Vendors A, D, E, F, and G describe MDM-functionality as the structuring of data into databases, shifting from non-organised to organised data. The same vendors believe that because their software is built by one, unified dataset, they offer more analytical insight than competitors who might have spread data across different, unlinked modules. Vendor G states the use of structured input fields instead of blindly uploading processed documents as one important aspect of MDM.

Regarding maturity, vendors E and H state many customers are only starting to make use of (analysing) data. Even larger companies that have more data might have low maturity in efficiently utilising that data, according to vendors D and E. One of the customer demands is benchmarking of spend data, according to the vendor G. Based on Big Data, these benchmarks could show trends per business sector, or provide analysis into specific categories. When asked about maturity, vendors D and H indicated spend analysis is an essential aspect for each organisation, even those of low maturity.

Also, the use of Big Data is becoming more mature, with the software vendors enabling smaller and larger organisations to use it through new analytical tools. One example of Big Data is given by consultant I3, who indicates companies already use the technology for comparing their KPI measurements, although their use is based on mostly historical data. Vendor G claims mostly the larger organisations can fully utilise the power of Big Data. Moreover, vendor G aims to be more of a source of Big Data while not developing these analytical tools itself, therefore positioning itself more as a data warehouse. The aim towards data warehousing is supported by consultant J, who details how different data warehouses can be linked to one analytical tool to provide real-time insights.

When asked about data security, cybersecurity, and related aspects, all vendors answer there are laws and regulations for these aspects, and customer demands for specific certificates. Vendors note data security as a non-issue, being merely common rules each software vendor adheres to. Data ownership, however, does differ between vendors. While vendor F notes they are not the owners of their customers' data, and therefore cannot use customer data for benchmarking or other analyses, other vendors disagree. Vendors A, B, C, G and H all indicate their customers sign forms agreeing to use of customer data to be processed for anonymised benchmarks, amongst other analyses. They utilise customer data not only for the vendor's own insight but because these benchmarks and analyses are one of their customer demands.

f) Results of E-Procurement about sourcing

For the sourcing process and its relation to E-Procurement, the broad interview question was how software vendors see these processes changing at end-users, depending on their maturity. The question was divided into aspects concerning demand prediction, market analysis, creating specifications based on software input and the contracting process. These questions lead to input towards defining aspects and levels for answering the question *"Is the strategic procurement process supported?"* in the Maturity Model.

Vendors F and G describe how demand prediction is one aspect that is being used more, namely for firms that have seasonal buying. Through simple data analysis, the software can easily predict the needs of its end-users purchasing needs, with new features and further refinement of data analysis continually being developed.

Asked about market analysis performed by their customers, vendors E and F indicate most of their analysis is still done based on their internal data. Based on distinct classifications suppliers can assign themselves in sourcing tools, buyers can more easily find these suppliers or get more accurate suggestions in their systems to guide them, but there is no concrete development in classifications. However, vendor F also states the use of E-Catalogues and E-Marketplaces do offer a lot of market analysis features for end-users.

When describing E-Marketplaces and Supplier Portals, the larger vendors A, B, and F, claim their marketplace to be a strong asset for their end-users. Through these networks, buyers can easily procure goods from a wide range of suppliers, while promoting collaboration with those suppliers. One counterpoint, however, is that because many vendors offer their marketplace, suppliers have the extra workload of managing multiple portals (Vendor E). Consultant J mentions the number of different marketplaces as a reason for a lacking adoption of E-Marketplaces currently in the market.

E-Auctions are a development that did not prove to be a widely discussed topic in the interview, with only the vendor G mentioning the topic multiple times. Vendor G is specialised in the Source-to-Contract phase, and might, therefore, have more knowledge about the subject, and be more inclined to mention the functionality. Consultant I1 states there are many claims from vendors about E-Auctions, yet there is a small amount of E-Auction use at end-user organisations. The technology is available, but the employees responsible are often uneducated in how to effectively use these tools. Therefore, as consultant I2 also claims, many auctions and competitions are still processed manually.

When describing the specifying process and how maturity is developing there, vendors B and E claim that supporting the specification process mainly applies to manufacturing firms. Technical buyers can buy their required materials directly based on CAD-schemes or Bills of Materials, with the software autonomously connecting these input schemes towards applicable suppliers, with a preferred supplier list that might have been created manually before the start of a project. Optimisations in which goods to order from which supplier are made autonomously in the system, leading to the most cost-effective orders, or another pre-defined goal.

The contracting process is assisted by contract management modules, which some vendors have very advanced versions of. Vendors A, B, and E agree on the statement that the contracting process can be automated to a very high point, while vendors C, F, and G are more hesitant, and claim there is still a constant need for human involvement. More, in particular, vendors C and G state that the legal department within an organisation usually has a low digital maturity, which slows down possible developments within procurement. Continuing on that statement, the human need for control is also apparent in the sourcing process when employees need to let go of control. Vendor H describe how firms might agree with ordering and contracting of low-impact goods to be automated within the system, yet for contracts with higher impact, they are too hesitant to let the system make these decisions and contractual agreements for them. Further defining these goods with low impact, a relation to non-critical items as mentioned by Kraljic (1983) is made, while goods with high impact can be seen as strategic items[143]. Vendors E and F state that there is a trend towards collaborative contract authoring between buyer and supplier, made possible through their software. Vendor A claims their software can give autonomous suggestions for contract clauses, based for example on autonomous risk assessment, which vendor D also claims to support, with artificial intelligence used for those autonomous analytical capabilities.

g) Results of E-Procurement about suppliers

To gain more insight into developments in the role of suppliers in E-Procurement, questions are asked about the changes in the buyer-supplier relationship (focusing on software), how supplier evaluation is performed, and how data is exchanged. These questions lead to input towards defining aspects and levels for answering the question *"Are the suppliers prepared, willing, and able?"* in the Maturity Model.

[143] See Kraljic (1983), p. 111.

The main finding when researching the supplier aspect was that all vendors and consultants agreed on a change in the relationship between a buying firm and its suppliers. The same shift in focus, as also described in the process & systems paragraphs, can be seen in the supplier relationship management. Where before the focus was mainly on prices, and relationships were commonly disturbed by demanding lower rates, many organisations are increasingly focusing on establishing and maintaining a good relationship with their suppliers (Vendors C and D). Vendor C even stated a sizeable German bank was setting up internal programs to become the preferred customer of their suppliers, a concept proposed by Schiele (2012). [144]Vendor B states this focus shift may have been caused by the economic recession (i.e., suppliers going bankrupt), or natural disasters (e.g., earthquakes in Thailand). Many organisations were faced with suppliers who were unable to provide goods or services, which showed their dependency on suppliers. This dependency gave buying firms reason to invest more time and effort in their relationships, mitigating chances of these possible disruptions in the future.

Vendors A, B, C, and F indicate that in the whole supply chain, more digitalisation and sharing of those digital files is taking place. Through the sharing of information, for example, through a supplier portal or marketplace, each firm can improve their performance based on best practices, leading to increased performance in the whole supply chain. Vendor C describes the sharing of information as community intelligence and takes it a step further by explaining how sharing of supplier evaluation data is the next step. For example, evaluation reports could be shared within a network of firms that each buys from the same supplier. When changes in behaviour, risks or likewise at the supplier are shared, other buying firms can act much quicker than they would have, if they were not sharing that information digitally.

Specifically, when describing supplier evaluation and use of technology, vendors B, D, F, G, and H indicate many aspects can be automated, such as the autonomous measuring of KPI's, spend volumes, number of disputes or delivery times. Next to these measurements, automatic sending of vendor surveys, autonomously updating ratings of those vendors, and receiving reports or alerts when thresholds are reached are all possible. Additionally, third-party sources can be integrated to provide benchmarks or further insight into analytics.

[144] See Schiele (2012), p. 44.

h) Results of E-Procurement in relation to employees & users

For the aspect of employees & users, the question was asked how the capacity and needs of this group were developing. The responses lead to input towards defining aspects and levels for answering the question *"Are the employees prepared and willing?"* in the Maturity Model.

As the employees & users aspect is inherently the underlying factor in each aspect as mentioned earlier, many observations have already been detailed. Especially the ease of use was stated to be of the utmost importance by every one of the interviewed vendors. Vendors C, E, and even claim there should be no training required anymore, implying the software should be extremely easy to use, with vendor G wanting to make the whole RFX-process 'dummy-proof'. One common development, mentioned by vendors A, B, E, and F, is the focus on a webshop-like experience for purchasers, resembling the B2C-type of purchasing. One development vendor G indicates is simplifying tools so that even employees that do not possess traditional procurement skills can still purchase their goods quickly and in an efficient, correct way. The focus on ease of use and usability is shared by consultants, although consultant I2 states there is still too little actual development into usability. Enhancing the ease of use also mitigates the resistance to change, which especially each interviewed consultant claims as an obstacle in E-Procurement adoption. The software vendors B, F, and G underpin the statement that reducing the resistance to change is very important in achieving optimal use of E-Procurement software.

4.1.3. The ideal situation of E-Procurement and Industry 3.0-4.0 based on the literature review and interview results is categorised as the final maturity stage

In the Maturity Model, eight dimensions are applied and specified to a best-practice scenario of E-Procurement within an organisation. Based on the previous literature review and the results of the interviews, an ideal situation for the use of E-Procurement in an Industry 3.0-4.0 organisation is formulated. The same structure from the previous paragraph will be used, based on the model of Industry 4.0 and Purchasing by Torn (2017). Each aspect of the eight dimensions will be discussed separately to describe the most optimal way, as defined for the ideal standard, summarised in the last stage of the model.

Strategy: The organisation has a corporate digitalisation strategy structured in an often updated roadmap, in which procurement has a major influence. Adoption of Industry 4.0 concepts for procurement autonomy has a large focus.

Processes & Systems: Operational, tactical and strategic procurement processes are handled autonomously, in which self-learning, predictive capabilities have taken over all human involvement. Further adoption of Industry 4.0 for organisational processes has a maximum focus.

Physical level: Physical and virtual systems are seamlessly integrated, with machine to machine communication and cyber-physical systems enabling autonomous ordering based on physical sensors.

Purchase-to-Pay: The P2P-process is fully automated, with ordering through E-Catalogues, invoice monitoring processes being fully autonomous and making use of Artificial Intelligence, with data shared internally and externally.

Controlling / KPI: Through the use of Big Data and Artificial Intelligence in E-Procurement software, the organisation has full insight for controlling and KPI's (e.g., spend analysis and category management).

Sourcing: The sourcing process is performed highly autonomously, with E-Procurement software analysing E-Marketplaces, Supplier Portals and other sources, while also able to set-up E-Auctions without human involvement. Contracting and contract management is performed autonomously, leaving human involvement in a purely monitoring role.

Suppliers: There is a close, digital collaboration with suppliers in a digital supply chain, with supplier evaluation, performed and benchmarked autonomously. Risks are detected throughout the whole procurement process and mitigated through autonomous alerts and changes in the E-Procurement software.

Employees / Users: Employees have in-depth knowledge about procurement processes and E-Procurement software, and have a direct influence on the digitalisation of their function.

4.1.4. Combining the collected data to develop the Maturity Model describes four stages for E-Procurement maturity

The new model is based on the guidelines of Schiele (2007), which describes four different stages, and newer work by Torn (2017) and De Haan (2018). Taking into account these guidelines of Schiele (2007), the following stages are discerned.

Stage 1	A particular best practice activity/tool/method is known within the organisation
Stage 2	A position or person is assigned to perform the task
Stage 3	The process for completing the task is defined and documented as well as applied
Stage 4	Cross-functional integration in the company is assured while basic requirements are met

Table 12. Four maturity stages according to Schiele (2007, p. 278)

The stages in the Maturity Model mainly correspond with De Haan's (2018) work, which itself draws inspiration from Torn's (2017) maturity model. Likewise, the first stage is categorised by the fact that while E-Procurement software is known, it is not utilised. Next, E-Procurement software is available but utilised only by specific purchasing personnel, with its usage deemed low. The third categorisation can be made through the much higher use of E-Procurement software with specific tasks delegated to the software's autonomous capabilities, while the final stage is described by high use of, and large focus on E-Procurement software and technological innovation. The four stages used in the Maturity Model for E-Procurement in Industry 3.0-4.0, from digital novice to digital innovator, are described as follows:

Digital Novice: "The purchasing processes are mostly defined, and ERP-systems are used within the organisation. There is no use of specialised EP-software."
Digital Newcomer: "The purchasing processes are standardised and digitised. EP-software is available but used only by specific purchasing personnel."
Digital Performer: "EP-software is fully integrated into purchasing processes, and is cross-functionally integrated throughout the organisation. Some aspects are performed autonomously in the EP-software, but still, some human interaction is necessary."
Digital Innovator: "EP-software is fully aligned with the corporate strategy; the software is utilised fully autonomous within the purchasing department. The systems use Big Data analytics and machine to machine communications to perform and continuously improve their tasks."

4.2. Developing the Quadrant model

4.2.1. Building the Quadrant Model based on a literature review of four quadrants

Results of research methods used in four quadrants

Analysing the used research methodology of the four reviewed quadrants, many similarities can be distinguished. All researchers belong to large consulting organisations, and therefore can use multiple methods of research. Gartner, Forrester, and SpendMatters all make use of

interactions with vendors and end-users, briefings and product demonstrations, requests for more information from vendors, and surveys. Based on their large size, they can collect a much higher amount of data than a single researcher would be able to. Capgemini, however, only utilised a survey method for its research, combined with requests for information and/or product demonstrations when deemed necessary. Basing their research on this in-depth survey, they were able to collect data on a very high amount of software vendors, while also being able to analyse them truly in-depth based on their software features.

Based on these research methodologies, the in-depth survey method is chosen as the primary data collection method. Through the use of an in-depth survey, many vendors can be approached to achieve a large initial sample size, while also collecting in-depth information about their software solutions. Compared to other research methods, the survey method is less time intensive with larger sample sizes, and therefore more suitable for this research.

Results of rated aspects used in the four quadrants

Gartner and Forrester both analyse the vision or strategy of a software vendor, and the execution or current offering of this vision or strategy. When assessing which vendor claims to be the most innovative, yet also delivers on their promises of innovation, this rating system seems logical. Dividing the strategy part into multiple parts (e.g., marketing strategy, sales strategy, business model, and so forth) lays a good foundation for a total score for a firm's strategy. SpendMatters, however, analyses based on customer and analyst scoring. Where Gartner includes customer scores under their execution level, Forrester places it under their strategy dimension. The focus on customer scoring, while providing valuable input, requires the availability of extensive customer connections, which is unsuitable for this research, and therefore the approach of Gartner and Forrester seems more suited. Capgemini rates differently from all three competitors, based on the nature of their in-depth survey. In their research, the width and depth of a software solution are assessed. Width refers to the different Source-to-Pay elements covered in their software, and depth to the level of detail in these elements. The depth dimension seems to correspond with the execution and current offering dimensions of Gartner and Forrester respectively, and provide further reason to establish the same dimension in the Quadrant Model. To establish a link with the Maturity Model, the rated aspects for the depth of the software solution are separated into aspects included in the Maturity Model. Using many of these same aspects establishes a strong connection between the maturity level of an organisation, and the maturity level of a software solution.

Building on the survey method used by Capgemini, their rational scoring scheme seems fitting for the Quadrant Model. By using one standard scoring scheme for the in-depth features based on 'yes, no, on roadmap,' scores per software element are comparable with each other, and provide a logical final score. For the specific innovation focus of the Quadrant Model, the answer scheme can be broadened to provide more insight into the specific (autonomous) support given by these software solutions.

Final quadrant

When comparing the final quadrants of these four firms, three look very similar, while Forrester uses a unique approach. Their approach seems more fitting to the linear growth of a software vendor and its solutions, as connected to the linear growth of an end-user organisation assessed in the Maturity Model. Gartner and others make use of a traditional quadrant, which does not seem to fit for the Quadrant Model. Namely, in their quadrant, a vendor that has a very strong product, yet has almost no innovation strategy, is deemed a challenger. This categorisation does not fit with the assumption that in the Quadrant Model, there is a strong focus on innovation. Therefore, in the Quadrant Model, these two dimensions should be interlinked with each other, and shown as the linear growth as depicted in the Forrester Wave.

4.2.2. Developing the Quadrant Model with four distinct software vendor types

Now, having performed an extensive literature review and analysis of currently available E-Procurement vendor quadrants, the Quadrant Model is developed. The proposed research methods, research aspects, and the final quadrant are detailed as follows.

Proposed research methods

The primary research method is an in-depth feature survey sent to software vendors, which the vendor has to fill in. When reviewing results, the researcher can request more information from the vendor if needed, possibly involving documents explaining specific features, phone calls, or live product demonstrations. Through the use of the survey method, a large selection of software vendors can be made towards the aim of achieving a large sample size.

Proposed research aspects

The survey developed contains 112 questions, with a majority of questions utilising a matrix structure to choose answers. Specifically, this matrix structure establishes a total of 189

scored questions, divided into 18 questions for the *innovation strategy* score and 171 in-depth feature questions for the *current product* score. Through Qualtrics survey software, the survey dynamically shows or hides specific questions based on previous responses in the survey. The scoring is done through the following two scoring schemes (see table 13).

Type of focus	Points	Type of support
Very high focus	5	
High focus	4	Autonomous support
Considerable focus	3	Automatic support
Moderate focus	2	Manual support
Low focus	1	Implemented in <2 year
	0.5	On roadmap >2 year
	0	No support

Table 13. Scoring scheme for innovation strategy left, current product right

In detail, the following aspects are assessed, divided into the two dimensions (see Table 14). Ultimately, a separate score is made for their respective dimension. The score for the *innovation strategy* dimension leads to the x-coordinate, and the score for the cu*rrent product* dimensions leads to the y-coordinate. Combined, they form the position in the Quadrant Model of the assessed organisation.

Innovation strategy	Current product	Current product (continued)
Roadmap	E-Catalogues, E-Marketplaces	Data analysis
Industry 4.0 adoption	E-Sourcing, E-Auctions	Cat. management/ sourcing cockpit
Technology use	Supplier portals	Spend analysis
Technology focus	Contracting & Contract management	Data security
Industry trend focus	Demand prediction	Supplier onboarding
	Ordering, maverick buying	Supplier collaboration
	E-Invoicing	Supplier evaluation
	Accounts payable	Supply chain risk management
	Master data management	Training & support

Table 14. Rated aspects in the Quadrant Model

Proposed final quadrant

As shown in the quadrant, companies that rate very high on innovation strategy and very high on the current offering are deemed leading innovators, while companies that rate high on strategy yet lack the current offering are categorised as visionary performers, challengers, or in the worst case, niche players (see figure 11). Therefore, in cases with a strong current

product, yet the lack of a highly innovative strategy, companies cannot be considered leaders. This assumption further envelops the Quadrant Model's focus on innovation in E-Procurement. Descriptions of the four types named in the Quadrant Model are as follows.

Niche players: "The innovation strategy is either of a low focus, or the current product does not offer any depth."
Challengers: "The innovation strategy has a considerable focus, and the current product offers a medium amount of depth."
Visionary performers: "The innovation strategy has a strong focus, and the current product does offer a high amount of depth."
Leading innovators: "The innovation strategy is a core focus of the firm, and the current product offers an extraordinary amount of depth."

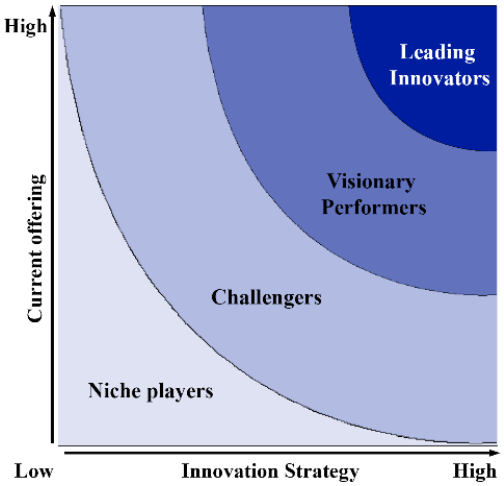

Figure 11. Visual format of the Quadrant Model (own elaboration)

4.3. Trends and the future of E-Procurement observed from interviews with E-Procurement vendors and consultants describe a high focus on technology

One trend in the E-Procurement market is the development of new financing possibilities. Vendors A, B, F, and H each indicate they have recently launched supply chain financing possibilities, through cooperation with either banks or other financial institutions. Supply chain financing entails reverse factoring, which is to say buying firms can stretch their payment terms (i.e., paying their suppliers at the last possible moment), while suppliers get their payments directly. The dynamic discount offered on invoices by these suppliers is then taken as profit by the financing party, therefore providing advantages for each party. Combined with the increase in the use of supplier relationship management, and the focus

on responsibility and dependency in the supply chain, this financial support development seems fitting as a trend in the E-Procurement market.

The analytical capabilities within the software are increasing, as stated by vendors B, D, E, and G. The use of Big Data has seen more use for firms in all maturity stages, with vendors choosing to either use historical data, or use new networked tools to analyse data real-time. With firms using the data within these tools as a data warehouse, consultant I2 claims they can use business intelligence tools (such as PowerBI or Qlik) to provide reports or real-time dashboards with further insight into their processes and workflows. Additionally, vendors B, C, D are experimenting with the use of artificial intelligence (AI), and algorithms, with vendor D stating research towards AI, constitutes one-tenth of their research budget. The terminology, however, is named as a problem by vendors B and H. The use of the term AI might seem to make the technology more important or high-class than it is. The vendor H claims that software which automatically classifies and processes invoices from an energy company as 'energy costs for the current quarter' is also a form of AI. True capabilities for autonomous suggestions for contract clauses, which vendors A and D describe, are in their early phases. Combining both Big Data and AI, vendor G claims these software solutions will all gravitate towards predictive capabilities. Showing past performance or giving suggestions for future actions will not be deemed enough anymore, but real-time predictions based on possible steps to take will be the norm. One example was the prediction of prices of commodities based on historical data, social feeds, risk monitoring, and so forth. Concluding, the trend of deeper analytical insight shows growth in maturity at both end-user firms as well as software solutions, making a case of wide integration of this aspect into the Maturity Model and Quadrant Model. While in lower maturity levels a low rate of analytics is accepted, an extensive use of data analytics is prescribed for high maturity levels.

The technology trend of the availability of application program interfaces (API) and integration features is one that is mentioned by vendors A, B, F, G, and H and each of the consultants. They all describe how, through API's and integration features, end-users can have a linked system that allows more insight into their firm. By opening up their platforms towards third-party developers, their customers can receive made-to-measure modules which the vendors themselves sometimes do not provide. The focus on interoperability of systems also makes it easier for specialised tools to be made part of the primary systems. Therefore, for the Maturity Model and Quadrant Model, the use of API and interoperability is integrated into the higher maturity levels as a best practice.

While blockchain is a term that has seen increased use in the last few years, the vendors who participated in the interviews primarily shared the view that, based on their research, there is too little focus on practical usability. Vendor G states blockchain "gave us the feeling of a solution looking for a problem".[145] While uses within procurement can be found, especially for transparency in the supply chain, vendors B, D, G, and H indicated that they are either ceasing research into the technology or reducing their effort by a significant amount. Vendor E was very enthusiastic about the possibilities blockchains can offer but also agrees that the technology as it is, is not yet mature enough to be implemented or deployed within end-user firms. However, while these vendors indicate blockchains are currently not fully developed, this shows a clear development path for software vendors on the road to full Industry 4.0 integration. Therefore, blockchains are integrated into the Maturity Model and Quadrant Model for the highest level, serving as a best practice for both end-user firms as well as software vendors.

The technology trend of chatbots and digital assistants being implemented in software, however, is seen as important, and as a feasible development. While partly related to artificial intelligence, chatbots and digital assistants can make use of much simpler coding to guide end-users with their tasks. Vendors D and E both claim they have already deployed chatbot technology to improve the ease and speed of use for end-users, together with a reduction in required software training. Following, in the models this ease of use through technologies such as chatbots and digital assistants is integrated. For example, the Maturity Model prescribes the use of guided buying in the third and fourth maturity level to reduce maverick buying.

[145] Vendor G, personal communication, August 28, 2018, minute 21

5. Discussion: Assessing E-Procurement Maturity successfully through two models

5.1. Contribution to literature: E-Procurement specific Industry 3.0-4.0 Maturity Model and E-Procurement Quadrant

The Maturity Model developed during this research aims to fill the gap identified in the problem statement. While there are Industry 4.0 maturity models and E-Procurement maturity models, there is criticism that most of these models are too far reaching into Industry 4.0. Specifically, many organisations are not even utilising the full Industry 3.0 solutions yet, so assessing Industry 4.0 maturity only results in categorising the majority of organisations into the first level.[146] Hence, this newly developed Maturity Model is the first model that aims to provide a more realistic assessment scheme by integrating Industry 3.0 aspects into the first two levels. Therefore, through this model, many organisations can be assessed on their E-Procurement maturity, providing a categorisation of their maturity and concretely defined further steps towards digitalisation.

Based on customer and consultant demand, as also mentioned by consultant J, the need for an E-Procurement quadrant that focuses not only on the large, multinational software vendors is discerned. While they can be deemed as leaders in their field, they are not applicable to all organisations and are especially unsuitable for smaller organisations not tasked with business spend of several hundred million dollars. Therefore, the development of the Quadrant Model solves the issue by providing a framework for assessing software solution maturity, applicable for further research into smaller software vendors. The Quadrant model then connects to end-user maturity as measured by the Maturity Model. Through the use of the in-depth feature survey, researchers can efficiently attain a large sample size of software vendors, and get precise results.

5.2. Managerial implications: Efficiently assessing the current E-Procurement maturity and blueprint for an optimal Industry 4.0 E-Procurement organisation and software vendor

The findings in this research have lead to two new models which can be used by academic researchers and consulting firms. The Maturity Model is used to assess the current maturity an organisation has regarding the use of E-Procurement and related Industry 4.0 trends. The Quadrant Model is used to determine the maturity of the vendors themselves, by measuring their software solutions based on an in-depth feature survey. By having both these models and being able to establish a link between maturity levels at both end-user organisations and

[146] See Torn, 2017, p. 67.

relevant software vendors, researchers and consulting firms can give better advice on which aspects and dimensions organisations should focus on.

Furthermore, the research has led to the blueprint for an optimal Industry 4.0 E-Procurement organisation, which describes a best-practice situation that organisations can work towards. Next to this, the Quadrant Model describes aspects of strong innovation through software technologies, rating them on their use of these technologies. When software vendors participate in further Quadrant Model research, their results will give software vendors insight into the maturity of their current software, while also providing new development directions.

5.3. Limitations and future research: Theoretical research calls for practical validation

This research made use of research methods to design a maturity model based on both existing models, literature review and interview data. Therefore, while the model is designed to be consistent with previous work of Torn (2017), this consistency also implies new aspects could have been overlooked, or impossible to integrate with the underlying frameworks.

Next to this, there was a selection bias of multinational companies, essentially the software vendors, for interviews. While the motivation to select these companies for the research follows the assumption that these companies have a comprehensive overview of the whole E-Procurement market, new technologies and extensive market knowledge, this selection might have influenced results during the research, nonetheless. These larger companies might, for example, be more actively focused on technologies that are specifically interesting to them, such as the use of Big Data analysis. For smaller software vendors, these technologies might be less attainable, resulting in a shift in development focus.

During the research, both of the final models were not tested among end-user organisations or software vendors, because of time limitations. The Maturity Model has a deep foundation in literature and interview data, has seen lots of iterations during feedback cycles, and proves to serve as an extensive assessment tool aimed explicitly at E-Procurement aspects.

The Maturity Model and Quadrant Model proposed in this thesis are only a few of many ways to assess the E-Procurement maturity of an organisation or software vendor. As shown in the literature review, there are multiple Industry 4.0 and E-Procurement models, each using their own dimensions and levels. For future research, it might be interesting to design a Maturity Model that does not use the maturity models by Schiele (2007), Torn (2017), or

likewise, to release some constraints that accompany keeping the new model consistent with the base model. For example, a new model could add a maturity level, changing it to a total of five levels (i.e., complying with the CMMI structure), or changing the structure of eight assessed dimensions. Following this path, the input of smaller companies (both end-users or software vendors) could be incorporated, making the models more in-depth and therefore, more accurate in maturity assessment.

As a next step, the testing and practical validation of both models could prove for interesting research. Previous research uses older maturity models, categorising organisations in primarily the first maturity level; using the new Maturity Model, it would be interesting to see if there is more distinction in organisations in the first few levels, as the model aims to provide. Moreover, for the Quadrant Model, there is even more indication to perform research into testing and practical validation, using the developed survey. The end result of this research could be an E-Procurement Quadrant with mainly European software vendors, providing insight into these companies that has previously only been available for the largest, multinational companies on the market.

Bibliography

1. **Alrobai, A. A., Roobaea, R. S., Al-Badi, A. H., & Mayhew, P. J. (2013).** Investigating the usability of e-catalogues systems: modified heuristics vs. user testing. *Journal of Technology Research, 4*, 1-13.
2. **Amiel, T., & Reeves, T. C. (2008).** Design-based research and educational technology: Rethinking technology and the research agenda. *Educational Technology and Society, 11*(4), 29-40.
3. **Bakos, Y. (1998).** The emerging role of electronic marketplaces on the internet. *Communications of the ACM, 41*(8), 35-42. doi:10.1145/280324.280330
4. **Basware. (2018).** Basware eMarketplace. Retrieved on November 2, 2018 from: https://www.basware.com/en-us/solutions/network-services/invoice-receiving/supplier-management/marketplace
5. **Blom, W. (2016).** *E-Procurement 2020: Trend analysis and market study.* (Master thesis, Tilburg University).
6. **Busch, J. (2016).** Reframing Maturity Models: Empirical Perspectives on Radically Improving Procurement Performance. Retrieved November 3, 2018 from https://spendmatters.com/research/reframing-maturity-models/
7. **Capgemini. (2018a).** Company Profile & Key Figures. Retrieved on November 23, 2018 from https://www.capgemini.com/company-profile-key-figures
8. **Capgemini. (2018b).** Digital Procurement Research 2018. Retrieved on October 20, 2018 from https://www.capgemini.com/nl-nl/wp-content/uploads/sites/7/2018/10/Capgemini-Digital-Procurement-Research-2018_web-version1.pdf
9. **Chen, J., Sohal, A. S., & Prajogo, D. I. (2013).** Supply chain operational risk mitigation: a collaborative approach. *International Journal of Production Research, 51*(7), 2186–2199. doi:10.1080/00207543.2012.727490
10. **Cienfuegos, I. J. (2013).** *Developing a risk management maturity model: a comprehensive risk maturity model for Dutch municipalities* (Doctoral dissertation). Retrieved November 3, 2018 from: https://ris.utwente.nl/ws/portalfiles/portal/6059052/thesis_I_Cienfuegos+Spikin.pdf
11. **Coupa. (2018a).** Coupa Risk Aware. Retrieved on November 2, 2018 from https://www.coupa.com/pdf/datasheet/20171117-RiskAware_datasheet-coupa.pdf

12. **Coupa. (2018b).** Procure-to-Pay Data Sheet. Retrieved on November 2, 2018 from https://www.coupa.com/pdf/datasheet/Procure-to-Pay.pdf
13. **Cuylen, A., Kosch, L., & Breitner, M. H. (2016).** Development of a maturity model for electronic invoice processes. *Electronic Markets, 26*(2), 115-127. doi:10.1007/s12525-015-0206-x
14. **Dai, Q., & Kauffman, R. J. (2006).** To be or not to B2B: Evaluating managerial choices for e-procurement channel adoption. *Information Technology and Management, 7*(2), 109–130. doi:10.1007/s10799-006-8103-9
15. **De Boer, L., Harink, J. & Heijboer, G. (2002).** A conceptual model for assessing the impact of electronic procurement. *European Journal of Purchasing and Supply Management, 8*(1), 25-33. doi:10.1016/S0969-7012(01)00015-6
16. **De Haan, L. (2018)**. *The integration of Big Data in purchasing, as designed in a new Big Data Purchasing Maturity model (*Master thesis). Retrieved July 2, 2018 from https://essay.utwente.nl/75197/1/DeHaan_MA_BMS.pdf
17. **Digitale Overheid. (2018).** Elektronisch factureren. Retrieved November 23, 2018 from: https://www.digitaleoverheid.nl/overzicht-van-alle-onderwerpen/dienstverlening-aan-burgers-en-ondernemers/efactureren/
18. **Drath, R., & Horch, A. (2014).** Industrie 4.0: Hit or hype? [industry forum]. *IEEE Industrial Electronics Magazine, 8*(2), 56-58. doi:10.1109/MIE.2014.2312079
19. **Eadie, R., Perera, S., & Heaney, G. (2011).** Key process area mapping in the production of an e-capability maturity model for UK construction organisations. *Journal of Financial Management of Property and Construction, 16*(3), 197-210. doi:10.1108/13664381111179198
20. **Engelbrecht-Wiggans, R., & Katok, E. (2006).** E-sourcing in procurement: Theory and behavior in reverse auctions with noncompetitive contracts. *Management Science*, *52*(4), 581-596. doi:10.1287/mnsc.1050.0474
21. **Fatorachian, H., & Kazemi, H. (2018).** A critical investigation of industry 4.0 in manufacturing: Theoretical operationalisation framework. *Production Planning and Control, 29*(8), 633-644. doi:10.1080/09537287.2018.1424960
22. **Feldt-Rasmussen, L. (2010, March 24).** The origin of the ABC Analysis [Blog post]. Retrieved November 11, 2018, from https://blog.abcsoftwork.com/2010/03/the-origin-of-the-abc-analysis/
23. **Forbes. (2015).** What Is Category Management? Retrieved on November 20, from https://www.forbes.com/sites/jwebb/2015/12/23/what-is-category-management/

24. **Forrester. (2017).** The Forrester Wave: eProcurement, Q2 2017. Retrieved July 10, 2018 from https://www.ariba.com/-/media/aribacom/assets/pdf-assets/the-forrester-wave-eprocurement-q2-2017.pdf
25. **Forrester. (2018).** Frameworks & Methodologies. Retrieved on November 23 from https://go.forrester.com/research/frameworks-methodologies/
26. **Gartner. (2018a).** Magic Quadrant for Strategic Sourcing Application Suites, August 2018. Retrieved August 22, 2018 from https://www.gartner.com/doc/3884503/magic-quadrant-strategic-sourcing-application
27. **Gartner. (2018b).** Magic Quadrant for Procure-to-Pay Suite, May 2018. Retrieved July 10, 2018 from https://www.gartner.com/doc/3876770/magic-quadrant-procuretopay-suites
28. **Gartner. (2018c).** Gartner About Us. Retrieved on November 23 from https://www.gartner.com/en/about
29. **Geissbauer, R., Vedso, J., & Schrauf, S. (2016).** Industry 4.0: Building the digital enterprise. Retrieved on September 10, 2018 from https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf
30. **Harink, J.H.A. (2003).** *Internet-technologie in inkoop: de kinderschoenen ontgroeid*. (PhD dissertation). Retrieved November 7, 2018 from https://research.utwente.nl/en/publications/internet-technologie-in-inkoop-de-kinderschoenen-ontgroeid-2
31. **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. doi:10.1109/tem.2004.826010
32. **Hazelaar, R. (2016).** *From standardisation , through integration and automation , into machine-to-machine communication.* (Master Thesis). Retrieved July 2, 2018 from http://essay.utwente.nl/71548/1/Hazelaar_MA_BMS.pdf
33. **Hsieh, H., Shannon, S. (2005).** Three Approaches to Qualitative Content Analysis. *Qualitative Health Research, 15*(9). 1277-1288. doi:10.1177/1049732305276687
34. **Hwang, J. S. (2016).** The fourth industrial revolution (industry 4.0): Intelligent manufacturing. *SMT Surface Mount Technology Magazine, 31*(7), 10-15.
35. **Investopedia. (2018).** Pareto Analysis. Retrieved November 25, 2018 from https://www.investopedia.com/terms/p/pareto-analysis.asp

36. **Jodlbauer, H., Schagerl, M., & Brünner, M. (2016).** Reifegradmodell Industrie 4.0 - Ein Vorgehensmodell zur Identifikation von Industrie 4.0 Potentialen. Paper presented at the *Lecture Notes in Informatics (LNI), Proceedings - Series of the Gesellschaft Fur Informatik 259,* 1473-1487
37. **Kagermann, H., Lukas, W. D., & Wahlster, W. (2011).** Industrie 4.0. *Ingenieur.de,* Retrieved August 15, 2018 from: http://www.ingenieur.de/themen/produktion/industrie-40-mit-internet-dinge-weg-4-industriellen-revolution
38. **Kagermann, H. (2013).** Securing the future of German manufacturing industry: Recommendations for implementing the strategic initiative INDUSTRIE 4.0. Retrieved from: https://www.acatech.de/wp-content/uploads/2018/03/Final_report__Industrie_4.0_accessible.pdf
39. **Kennedy-Clark, S. (2015).** Reflection: Research by Design: Design-Based Research and the Higher Degree Research student. *Journal of Learning Design, 8*(3)
40. **Kleemann, F. C., & Glas, A.H. (2017).** *Einkauf 4.0 - Digitale Transformation der Beschaffung*. Springer Gabler, Wiesbaden, Germany.
41. **Kleindorfer, P. R., & Saad, G. H. (2005).** Managing Disruption Risks in Supply Chains. *Production and Operations Management, 14*(1), 53–68. doi:10.1111/j.1937-5956.2005.tb00009.x
42. **Klötzer, C., Pflaum, A. (2017).** *Toward the Development of a Maturity Model for Digitalization within the Manufacturing Industry's Supply Chain*. In Proceedings of the 50th Hawaii International Conference on System Sciences.
43. **Kosmol, T., Kaufmann, L., Reimann, F. (2018).** *Leapfrogging and co-evolution, toward a maturity model for the digital transformation to Procurement 4.0.* In Proceedings of International Purchasing & Supply Education & Research Association Conference 2018..
44. **Kraljic, P. (1983).** Purchasing must become supply management. *Harvard Business Review, (83509),* 109–117. https://doi.org/10.1225/83509
45. **Lasi, H., Fettke, P., Kemper, H. -., Feld, T., & Hoffmann, M. (2014).** Industry 4.0. *Business and Information Systems Engineering, 6*(4), 239-242. doi:10.1007/s12599-014-0334-4
46. **Lichtblau, K., Stich, V., Bertenrath, R., Blum, M., Bleider, M., Millack, A., & Schröter, M. (2015).** *Industrie 4.0-Readiness*. Impuls-Stiftung Des VDMA.

47. **Lucke, D., Constantinescu, C., & Westkämper, E. (2008).** Smart factory-a step towards the next generation of manufacturing. In *Manufacturing systems and technologies for the new frontier* (pp. 115-118). Springer, London.
48. **Mehrbod, A., Zutshi, A., & Grilo, A. (2014).** *A vector space model approach for searching and matching product E-catalogues.* In Proceedings of the eighth International Conference on Management Science and Engineering Management (pp. 833-842). Springer, Berlin, Heidelberg. doi:10.1007/978-3-642-55122-2_71
49. **Menon, K., Kärkkäinen, H., & Lasrado, L. A. (2016).** *Towards a maturity modeling approach for the implementation of industrial internet*. Paper presented at the Pacific Asia Conference on Information Systems, PACIS 2016 – Proceedings.
50. **Monczka, R. M., Handfield, R. B., Giunipero, L. C., & Patterson, J. L. (2014).** *Purchasing and Supply Chain Management*. Boston: Cengage Learning.
51. **Murphy, C. (2012).** Electronic invoice authorization – providing the foundation for an efficient accounts payable department. *Credit Control 33*(2), 80-85.
52. **Negometrix. (2017).** How does e-Tendering work for suppliers? Retrieved November 22, 2018 from: https://support.negometrix.com/en/support/solutions/articles/9000092067-how-does-e-tendering-work-for-suppliers
53. **Negometrix. (2018).** Contractmanagement. Retrieved on November 27, 2018 from https://www.negometrix.com/nl/modules/contractmanagement-private-sector/
54. **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.
55. **Pellengahr, K., Schulte, A. T, Richard, J., Berg, M. (2016).** Pilot study on Procurement 4.0. *The digitalisation of Procurement, Frankfurt.*
56. **Pilloni, V. (2018).** How data will transform industrial processes: Crowdsensing, crowdsourcing and big data as pillars of industry 4.0. *Future Internet, 10*(4). doi:10.3390/fi10030024
57. **Pöppelbuß, J., & Röglinger, M. (2011, June).** What makes a useful maturity model? a framework of general design principles for maturity models and its demonstration in business process management. In *ECIS* (p. 28). Retrieved on October 20, 2018 from http://aisel.aisnet.org/ecis2011/28

58. **Presutti, W. D. (2003).** Supply management and e-procurement: Creating value added in the supply chain. *Industrial Marketing Management, 32*(3), 219–226. doi:10.1016/S0019-8501(02)00265-1

59. **Pyymäki, I. (2018).** *Performance measurement and implementation of E-Procurement system in indirect purchasing.* (Master thesis). Retrieved from http://essay.utwente.nl/75940/1/Pyym%C3%A4ki_MA_BMS.pdf

60. **Qin, J., Liu, Y., & Grosvenor, R. (2016).** A categorical framework of manufacturing for industry 4.0 and beyond. *Procedia CIRP,52*, 173-178. doi:10.1016/j.procir.2016.08.005

61. **Reinhard, G., Jesper, V., & Stefan, S. (2016).** Industry 4.0: Building the digital enterprise. *PriceWaterhouseCoopers*, p.1–39. Retrieved November 10, 2018 from: https://i4-0-self-assessment.pwc.nl/i40/landing/

62. **Ritchie, J., Lewis, J., Nicholls, C. M., & Ormston, R. (2013)**. *Qualitative research practice: A guide for social science students and researchers*. Thousand Oaks: Sage.

63. **Rodrigue, J.-P. (2017).** The four industrial revolutions. Retrieved October 30, 2018 from https://transportgeography.org/?page_id=1363

64. **Royce, W. (2002).** CMM vs. CMMI: From Conventional to Modern Software Management. Retrieved November 1, 2018 from: https://www.ibm.com/developerworks/rational/library/content/RationalEdge/feb02/ConventionalToModernFeb02.pdf

65. **SAP Ariba. (2016).** Ariba Network for Suppliers. Retrieved on November 4, 2018 from https://www.ariba.com/ariba-network/ariba-network-for-suppliers

66. **SAP Ariba. (2017).** Guided Buying FAQ. Retrieved on November 2, 2018 from https://www.ariba.com/-/media/aribacom/assets/pdf-assets/guided-buying-faq.pdf

67. **SAP Ariba. (2018b).** SAP Ariba Catalog Solution. Retrieved on November 2, 2018 from: https://www.ariba.com/-/media/aribacom/assets/pdf-assets/sap-ariba-catalog.pdf

68. **SAP Ariba. (2018c).** SAP Ariba Supplier Risk Management. Retrieved on November 2, 2018 from https://www.ariba.com/solutions/solutions-overview/supplier-management/supplier-risk

69. **Sarayrah, A. A., & Al-Utaibi, G. A. (2011).** The eProcurement in Jordan: Measurements of Private Sector eMaturity. *Information Technology Journal 10*(10), 1867-1881.

70. **Saunders, M., Lewis, P., & Thornhill, A. (2016).** *Research methods for business students.* Essex: Pearson education.

71. **Sawik, T. (2013).** Selection of resilient supply portfolio under disruption risks. *Omega, 41*(2), 259–269. doi:10.1016/j.omega.2012.05.003

72. **Scheer, A. W. (2012).** Industrierevolution 4.0 ist mit weitreichenden organisatorischen Konsequenzen verbunden. *Information Management & Consulting, 3*, 10-11.

73. **Schiele, H. (2007).** Supply-management maturity, cost savings and purchasing absorptive capacity: Testing the procurement–performance link. *Journal of Purchasing and Supply Management, 13*(4), 274-293

74. **Schiele, H. (2012).** Accessing supplier innovation by being their preferred customer. *Research-Technology management, 55*(1), 44-50. doi:10.5437/08956308X5501012

75. **Schiele, H. (2018).** *Lecture 1 Introduction and Industry 4.0* [PowerPoint Slides]. Retrieved July 2, 2018 from http://blackboard.utwente.nl

76. **Schumacher, A., Erol, S., & Sihn, W. (2016).** A maturity model for assessing Industry 4.0 readiness and maturity of manufacturing enterprises. Paper presented at the *Procedia CIRP, 52*, 161-166. doi:10.1016/j.procir.2016.07.040

77. **SpendMatters. (2018a).** About Spend Matters. Who is Spend Matters? Retrieved on November 23, 2018 from http://spendmatters.com/about/

78. **SpendMatters. (2018b).** SolutionMap E-Procurement, Q3 2018. Retrieved September 11, 2018 from http://spendmatters.com/2018/09/04/q3-2018-solutionmap-e-procurement-invoice-to-pay-and-procure-to-pay-release-notes/

79. **Spiller, P., Reinecke, N., Ungerman, D., & Teixeira, H. (2014).** *Procurement 20/20: Supply Entrepreneurship in a Changing World*. Hoboken, New Jersey: John Wiley & Sons.

80. **Stange, R. (2017).** *Strategic management at the level of purchase categories: A multiple case study to explore purchase category strategy development in practice.* (Master thesis). Retrieved from http://essay.utwente.nl/74287/13/Stange_MA_BMS.pdf

81. **Strategy&. (2016).** Industry 4.0: Opportunities and challenges for consumer product and retail companies. Retrieved August 20, 2018 from https://www.strategyand.pwc.com/reports/retail-industry4.0

82. **Supply Value. (2018a).** Over Supply Value. Onze missie en visie. Retrieved November 10, 2018 from https://www.supplyvalue.nl/over-ons/

83. **Supply Value. (2018b).** *Contractmanagement* [PowerPoint Slides]. (Internal documents*)*

84. **Thoben, K. D., Wiesner, S., & Wuest, T. (2017).** Industrie 4.0" and smart manufacturing–a review of research issues and application examples. *Int. J. Autom. Technol*, *11*(1).

85. **Thitimajshima, W., Esichaikul, V., & Krairit, D. (2018).** A framework to identify factors affecting the performance of third-party B2B e-marketplaces: A seller's perspective. *Electronic Markets*, *28*(2), 129-147. doi:10.1007/s12525-017-0256-3

86. **Torn, I. A. R. (2017).** *The future of purchasing and Industry 4.0: How Purchasing can Progress and Benefit the Fourth Industrial Revolution*. (Master Thesis) Retrieved July 2, 2018 from http://essay.utwente.nl/74248/1/Torn_MA_BMS.pdf

87. **Torn, I. A. R., Pulles, N., & Schiele, H. (2018).** *Industry 4.0 and how purchasing can progress and benefit from the fourth industrial revolution*. In Proceedings of International Purchasing & Supply Education & Research Association Conference 2018.

88. **Trkman, P., & McCormack, K. (2010).** Estimating the benefits and risks of implementing E-Procurement. *IEEE Transactions on Engineering Management, 57*(2), 338-349. doi:10.1109/TEM.2009.2033046

89. **Van Veen, J. (2018, November).** Investeren in het beheersen van leveranciersrisico's. *Deal!*, 36-39

90. **Van Weele, A. J. (2014).** *Purchasing and supply chain management*. Hampshire: Cengage learning.

91. **Wendler, R. (2012).** The maturity of maturity model research: A systematic mapping study. *Information and software technology*, *54*(12), 1317-1339.

92. **Webster, J. (2011).** Purchase-to-Pay Manifesto: Benchmark your business agility with a purchase-to-pay model. Retrieved on October 14, 2018 from http://media.cygnus.com/files/cygnus/whitepaper/SDCE/2013/JUN/basware-cash-flow-manifesto-20_10958927.pdf

93. **West, A. (2017).** Industry 3.0 vs. 4.0 - Vision of the new manufacturing world. Retrieved August 20, 2018 from

https://www.coilwindingexpo.com/berlin/__media/Speaker-presentations-2017/Day-3-Alex-West,-Industry-3-0-v-4-0-compressed.pdf

94. **White, Sarah. (2018).** What is CMMI? A model for optimizing development processes. Retrieved on November 3, 2018 from: https://www.cio.com/article/2437864/developer/process-improvement-capability-maturity-model-integration-cmmi-definition-and-solutions.html

95. **Yin, Y., Stecke, K. E., & Li, D. (2017).** The evolution of production systems from Industry 2.0 through Industry 4.0. *International Journal of Production Research, 56*(1-2), 848-861. doi:10.1080/00207543.2017.1403664

96. **Zycus. (2018).** Catalog Management Software. Retrieved on November 2, 2018 from https://www.zycus.com/solution/procure-to-pay/E-Procurement/catalog-management-software.html

Appendices

I. Invitation letter for an interview (Dutch)

Beste [geadresseerde],

Vanuit de Universiteit Twente en leidend inkoopadviesbureau Supply Value doe ik onderzoek naar de volwassenheid en geboden ondersteuning door elektronische inkoop- en bestelsoftware (e-Procurement). De resultaten van het onderzoek geven e-Procurement-leveranciers en -afnemers inzicht in de huidige functionaliteiten en trends in de markt. Hiernaast wordt een academisch Industry 3.0-4.0 maturity model met deze resultaten bijgewerkt. Het onderzoek wordt uitgevoerd onder zowel grote als kleine leveranciers van e-Procurement-software.

Als leidende leverancier van e-Procurement-software wil ik uw bedrijf graag opnemen in mijn onderzoek. Voor het onderzoek zou ik graag een interview met u of één van uw collega's plannen. In dit interview worden er vragen gesteld over welke trends u ziet in de markt voor e-Procurement-software en de toekomstplannen voor uw software. Ook wordt er ingegaan op de ondersteuning van uw software al naar gelang de inkoopvolwassenheid van uw klanten. Dit interview zal circa één uur in beslag nemen. De voorkeur gaat uit naar een face-to-face interview bij u op locatie, maar uiteraard is telefonisch ook mogelijk. Hiernaast zal er een enquête gestuurd worden waarbij er dieper wordt ingegaan op de functies van uw software voor een specifieke benchmark.

Er zijn meerdere voordelen voor u als bedrijf om mee te werken aan dit onderzoek. Het onderzoeksrapport geeft u inzicht in de functionaliteiten van de huidige software beschikbaar in de markt, en hoe uw eigen software hiermee vergeleken kan worden. Dit rapport is aldus een benchmark waarbij potentiële afnemers van uw software eenvoudiger de aansluiting bij hun bedrijfsvoering kunnen inschatten. Daarnaast krijgt uw bedrijf en software gratis promotie doordat het onderzoeksrapport ruim wordt verspreid in het netwerk van Supply Value en de Universiteit Twente.

U bent vrij om deze e-mail door sturen naar een collega als u denkt dat hij of zij hier gerichter op in kan gaan. Als u verder nog vragen heeft hoor ik graag van u. Ik hoop van harte dat u mee wil werken aan het onderzoek en wacht uw reactie af.

Met vriendelijke groet,

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II. Interview guide

Interview guide

Bij aanvang van het interview

- Goedkeuring van de geïnterviewde voor ethische verantwoording, ondertekening consentformulier door geïnterviewde en onderzoeker
- De interviews zullen ongeveer 60 minuten in beslag nemen
- Toestemming vragen voor het opnemen van het interview
- Anonimiteit van de geïnterviewde wordt beschermd (aangegeven dat de details anoniem verwerkt worden door middel van codes voor naam)

Afnemen van het interview

- Interview vragen zie onderstaand voor zowel interne medewerkers als externe medewerkers

Afronding van het interview

- Controleren of alle vragen zijn behandeld
- Aanvullende documentatie vragen, wanneer noodzakelijk
- Bedanken van de geïnterviewde
- Interview afsluiten

III. Ethical approval form

Toestemmingsverklaringformulier (informed consent)

Titel onderzoek: Developing an E-Procurement in Industry 3.0-4.0 Maturity Model

Verantwoordelijke onderzoeker: Dhr. P.K. Morsinkhof

In te vullen door de deelnemer

Ik verklaar op een voor mij duidelijke wijze te zijn ingelicht over de aard, methode, doel en [indien aanwezig] de risico's en belasting van het onderzoek. Ik weet dat de gegevens en resultaten van het onderzoek alleen anoniem en vertrouwelijk aan derden bekend gemaakt zullen worden. Mijn vragen zijn naar tevredenheid beantwoord.

Ik begrijp dat film-, foto, en videomateriaal of bewerking daarvan uitsluitend voor analyse en/of wetenschappelijke presentaties zal worden gebruikt.

Ik stem geheel vrijwillig in met deelname aan dit onderzoek. Ik behoud me daarbij het recht voor om op elk moment zonder opgaaf van redenen mijn deelname aan dit onderzoek te beëindigen.

Naam deelnemer: ……..

Datum: ……..... Handtekening deelnemer: ...……..

In te vullen door de uitvoerende onderzoeker

Ik heb een mondelinge en schriftelijke toelichting gegeven op het onderzoek. Ik zal resterende vragen over het onderzoek naar vermogen beantwoorden. De deelnemer zal van een eventuele voortijdige beëindiging van deelname aan dit onderzoek geen nadelige gevolgen ondervinden.

Naam onderzoeker: Dhr. P.K. Morsinkhof

Datum: ……..... Handtekening onderzoeker: ...……

IV. Interview questionnaire for external respondents (E-Procurement vendors)

Introductie van het onderzoek

Toelichting van het onderwerp en de focus van mijn studie en onderzoek. Korte toelichting op Industry 4.0, op te stellen model en de verschillende aspecten hierin.

Korte informatie over het bedrijf en de geïnterviewde persoon

1. Hoe zou u uw bedrijf en haar diensten in het kort kunnen beschrijven?
2. Wat is uw functie binnen het bedrijf en hoelang bent u hier al werkzaam?
3. Heeft u ook nog andere functies gehad binnen dit bedrijf?
4. Op welke manier bent u betrokken bij het inkoopproces van uw klanten?

Algemene vragen

5. Welke trends denkt u dat er de komende tijd zullen zijn op het gebied van e-Procurement?
6. Welke focuspunten heeft uw bedrijf zelf de komende jaren? Oftewel, wat is uw brede roadmap?

Modelgerichte vragen

1. **Strategie**
    a. Welke specifieke fases van het complete Source-to-Pay-proces ondersteunt uw software, en waar ligt jullie focus?
        i. *Source-to-contract*: Specification > Selection > Contracting
        ii. *Purchase-to-pay*: Ordering > Expediting > After-care
    b. Wat is uw visie op Industry 4.0 / Procurement 4.0 en hoe gaat uw bedrijf hier mee om bij het ontwikkelen van de software?
    c. Wat is de strategie van uw bedrijf voor verdere digitalisatie van inkoopprocessen?
        i. Bijvoorbeeld meer focus op operationele, tactische of strategische kant?
        ii. Hoe wordt dit gestructureerd, heeft u hiervoor een roadmap inzichtelijk?

2. **Processen**
    a. Wat voor mate van digitale procesvoering ziet u gemiddeld het vaakst bij uw klanten vóór de implementatie van uw software?
        i. Denk hierbij aan welke taken wel/niet gedigitaliseerd zijn en waarom niet. Fases source-to-pay. Operationeel vs strategisch.
    b. Hoe ziet uw bedrijf de toekomstige procesvoering van de inkoopfunctie?
        i. Welke aspecten zullen helemaal gestandaardiseerd zijn?
        ii. Opvolgend, welke aspecten zullen helemaal geautomatiseerd zijn? In hoeverre is hier nog input van de mens voor nodig?
        iii. In hoeverre zal het aspect van Industry 4.0 mee spelen? Denk hierbij aan Big Data analytics, Artificial Intelligence, machine-to-machine communications.

3. **Purchase-to-pay (P2P)**
    a. Wat ziet u veranderen in de P2P-cyclus bij uw klanten naarmate zij verder professionaliseren?
    b. Specifiek, in hoeverre is automatisering van de P2P-fase Ordering mogelijk?

c. Hoe wordt maverick buying (inkoop buiten contracten om) vermeden binnen uw software?
d. Wat voor functies biedt uw software om inkomende facturen (geautomatiseerd) te monitoren, analyseren, evalueren, enzovoorts?

4. **Controlling / KPI**
   a. Wat voor analyse-tools biedt uw software?
   b. Hoe ziet u het gebruik van data-analyse bij uw klanten groeien naarmate zij hun procesvoering professionaliseren (volwassener worden)?
   c. Hoe wordt Big Data nu in uw software gebruikt voor data-analyse intern bij de klant?

5. **Sourcing**
   a. Wat ziet u veranderen in de sourcing-processen van bedrijven naarmate zij verder professionaliseren? Bijvoorbeeld meer gebruik van…
      i. Verwachte vraag voorspellen, bijvoorbeeld o.b.v. gedane inkooporders
      ii. Marktanalyse (nieuwe leveranciers, artikelen, e-Marketplaces, e-Catalogues)
      iii. Specificaties opstellen voor in te kopen producten/diensten o.b.v. data-analyse, suggesties voor vergelijkbare goederen
      iv. Contracteren automatiseren

6. **Suppliers**
   a. Wat ziet u veranderen in de samenwerking tussen uw klant en haar leveranciers (op het aspect van e-Procurement)?
   b. Hoe is leveranciersevaluatie in uw software mogelijk, en in hoeverre is dit geautomatiseerd?
   c. Is data-uitwisseling tussen klanten en leveranciers real-time of op aanvraagbasis?

7. **Employees / Users**
   a. Hoe ervaart u de capaciteit en wens van de werknemers van uw klanten om hun werkwijze te veranderen?

Afsluitend

1. Zijn er nog andere zaken die betrekking hebben op inkoop en e-Procurement, die nog niet aan bod gekomen zijn, maar die wel van toepassing kunnen zijn?
2. Heeft u nog vragen of andere aanvullende opmerkingen?

V. Interview questionnaire for internal respondents (consultants)

Introductie van het onderzoek

Toelichting van het onderwerp en de focus van mijn studie en onderzoek. Korte toelichting op Industry 4.0, op te stellen model en de verschillende aspecten hierin.

Algemene vragen

7. Wat is voor jou e-Procurement? Denk aan de definitie en reikwijdte van Source-to-contract, Purchase-to-pay.
8. Hoeveel, en wat voor projecten heb jij uitgevoerd binnen het kader van e-Procurement?
9. Welke trends denk jij dat er de komende tijd zullen zijn op het gebied van e-Procurement software?

Modelgerichte vragen

8. Maak je gebruik van een maturity model/curve als je bij een klant de klantbehoefte bespreekt?
    a. Wat mis jij nu in een maturity model voor e-Procurement wat jij verwerkt wil zien?
9. Mijn model behandelt de acht onderstaande aspecten met meerdere vragen per aspect. Welke vragen stel jij nu aan een nieuwe/potentiële klant om te peilen wat hun huidige (inkoop)volwassenheid is, en waar hun behoefte ligt voor e-Procurement? Kan je dit koppelen aan deze acht aspecten?
    a. Strategie
    b. Processen
    c. Physical link
    d. Sourcing
    e. Purchase-to-pay cycle
    f. Controlling / KPI
    g. Suppliers
    h. Employees / Users
10. Zijn er bepaalde aandachtspunten waar je specifiek op let bij een nieuwe klant voor e-Procurement?
11. Op welke manier bepaal je of de voorgestelde oplossing overeenkomt met de besproken klantbehoefte?
12. Zijn er zaken bij e-Procurement-adviesklanten die pas later aan het licht kwamen?

Afsluitend

3. Zijn er nog andere zaken die betrekking hebben op consultancy voor e-Procurement, die nog niet aan bod gekomen zijn, maar die wel van toepassing kunnen zijn?
4. Heb je nog vragen of andere aanvullende opmerkingen?

VI. Quadrant Model questionnaire for E-Procurement vendors

Please refer to the separate file ‘Quadrant_Survey_In_Print_2018_12_12’

VII. Final E-Procurement Maturity Model

For the digital version, please refer to separate file 'Maturity Model Final Version 26112018'.

E-Procurement in Industry 3.0 - 4.0 Maturity Model - Final Version 20181126									
						Digital Novice (I)	*Digital Newcomer (II)*	*Digital Performer (III)*	*Digital Innovator (IV)*
						The purchasing processes are mostly defined and ERP-systems are used within the organisation. There is no use of specialised EP-software.	The purchasing processes are standardised and digitised. EP-software is available but used only by specific purchasing personnel.	EP-software is fully integrated into purchasing processes, and is cross-functionally integrated throughout the organisation. Some aspects are performed autonomously in the EP-software, but still some human interaction is neccessary.	EP-software is fully aligned with the corporate strategy; the software is utilised fully autonomous within the purchasing department. The systems use Big Data analytics and machine-to-machine communications to perform and continuously improve their tasks.
	Purchasing Element	Question for analysis	% observed	Points		Stage 1 (0-25%)	Stage 2 (26-50%)	Stage 3 (51-75%)	Stage 4 (76-100%)
ST	Strategy	*Is digitalisation integrated in the corporate strategy and purchasing strategy?*	0%	0,0					

ST1	Corporate digitalisation strategy	Does your organisation have a corporate digitalisation strategy? Is there a corporate roadmap for further digitalisation? Does top management show vision, goals and support toward corporate digitalisation?				The corporate strategy does not involve digitalisation related integrations, and there is no roadmap. There is low attention to digital techniques next to moderate ERP-system usage. Top management shows limited knowledge or support for digitalisation.	The corporate digitalisation strategy is well described involving several digitalisation techniques, described in a broad roadmap that is sometimes updated. Top management has goals for digitalisation and shows a medium level of support.	There is a periodically updated structured roadmap for the corporate digitalisation strategy, designed with a long-term view and clearly defined vision by top management. There is a strong focus on digitalisation and autonomous processes.	The corporate digitalisation strategy is structured in a often updated roadmap, aimed at systematic digitalisation, adoption of Industry 4.0 concepts across departments, and autonomous processes, with structured evaluation and adjustment procedures.
ST2	Digitalisation strategy for purchasing	Does your organisation have a strategy for digitalisation of purchasing? Is the purchasing digitalisation strategy involved in the corporate strategy?				Procurement has low influence on digitalisation strategy, but EP-software usage is being researched.	Procurement has limited influence on digitalisation strategy, with EP-software being deployed and moderately used by purchasing personnel.	Procurement has considerable influence, with strong EP-software usage by employees, and EP-software autonomously supporting certain aspects within the purchasing process.	Procurement has major influence on the company's digitalisation strategy. A comprehensive Procurement 4.0 concept exists and is being implemented throughout the company.
PR	Processes	*Are our processes standardised, automated and adopting new technologies?*	0%	0,0					
PR1	Standardisation	To which degree are the purchasing processes standardised for improving use of EP-software? Which tasks are digitally automated or could be automated in the near future for adoption in EP-software?				The purchasing processes are well defined, but not consequently followed. There are no automated processes and next to ERP-system adaptability, there is no regard to standardisation for EP-software adaptability.	The purchasing processes are largely standardised with an aim of future digitalisation and automation within EP-software. EP-software is used by trained purchasing personnel.	The purchasing processes are digitally connected to each other, and cross-functionally through the company. Use of EP-software is integrated and promoted within the processes. People are responsible for further standardisation and adaptation to EP-software.	The operational, tactical and strategic purchasing processes are integrated in the autonomous flow and there is a continuous monitoring system for controlling. The EP-software has self-learning capabilities to continuously and autonomously improve its performance.

PR2	System autonomy	To what degree is the EP-software totally autonomous and integrated, and is human involvement erased in decision making? How are the EP-software and purchasing processes continuously controlled and monitored?				Decisions are made manually, based on KPI's, information from dashboards, or comparable sources within their own department from the ERP-system. The processes are only controlled, monitored and improved by human intervention.	EP-software is utilised to provide extra information for responsible persons when making decisions, but decisions are still made and processed through human interaction with ERP-systems and EP-software.	The EP-software is fully integrated cross-functionally in the company and is able to autonomously make decisions that have low to medium impact. Human interaction involves only medium to high impact decisions and a controlling function.	The systems are fully integrated, autonomous and have a predictive system, where all the human involved tasked are taken over by systems. The processes are continuously monitored, improving and are self-learning.
PR3	Adoption of Technologies	Which technologies of Industry 4.0 are adopted to support the purchasing process (e.g., Artificial Intelligence, Blockchain, Cyber-Physical Systems, Digital Twins, or 3D Printing)?				There is no planned adoption of new technologies as framed within Industry 4.0. The organisation uses an ERP-system and knows about EP-software, but does not know about Industry 4.0 or plan to adopt new technologies.	The term Industry 4.0 is known but there is no specific focus on adopting on these features. The organisation has implemented EP-software and does aim to utilise it more in the future.	There is a heavy focus on Industry 4.0 features, with several features such as Artificial Intelligence or blockchains already in use, and there are concrete plans to adopt certain features in the near future.	Adopting Industry 4.0 features has a maximum focus within the organisation, focusing on increasing current use of already available features and maintaining a structured roadmap to adopt new technologies.
PL	Physical level	*Is the connection between physical and virtual systems established?*	0%	0,0					
PL1	Fusion of physical and virtual systems	How far advanced is the development of new structures and methods to support the fusion of physical and virtual systems? Is purchasing supported by machine-to-machine communications and/or cyber-physical systems?				There is no use of a connection between the physical and virtual systems, and there are no plans to establish this connection.	Use of sensors in manufacturing allow the possibility to recognise demands for goods through EP-software. Ordering still happens manually based on these alerts.	Demands are recognised and communicated autonomously through machine-to-machine communication between sensors and systems, with autonomous ordering of low-to-medium impact items.	Demand generation is supported autonomously by both machine-to-machine communication and cyber-physical systems, with autonomous ordering of a majority of items. Real and virtual systems are seamlessly integrated, with continuously self-learning systems.

PP	Purchase-to-Pay (P2P)	*Is the process of Purchase-to-Pay automated?*	0%	0,0					
PP1	Predictive demand	To which degree can future demand be predicted and how fast can the organisation react upon changes of supply and demand?				There is no demand prediction created manually or automated, nor is it communicated to suppliers.	Demand is predicted by the EP-software based on analysis of the organisations' own historical data and online catalogues, only when purchasing personnel manually requests this in the system. This prediction is used only internally.	The predictive demand is automatically created based on internal and external data in EP-software after periodically structured human input. After manual review, this prediction is sent to the suppliers.	Predictions for future demand are based on both monitoring internal and external data sources, with data analysis using Artificial Intelligence. Predictions are adjusted in real time and influence procurement immediately through cyber-physical systems.
PP2	Ordering	Is the process of initiating a requisition, approving it, and raising an order automated and performed through EP-software? How autonomous is the ordering of Direct Materials?				The ordering processes are not automated within the organisation, but involve human interaction with an ERP-system. There is no special process for ordering Direct Materials.	The ordering processes are automated on a small scale through use of EP-software, which trained purchasing personnel sometimes uses. The majority of ordering processes is still handled manually. Direct Materials are sometimes ordered based on Bills of Materials.	The EP-software of the organisation initiates, approves and raises orders autonomously, but still human intervention is needed for checking of medium-to-high impact orders. After human input and review, Direct Materials are often ordered based on Bills of Materials.	The process of initiating a requisition, approving it, and raising an order is fully automated through EP-software without human intervention. Ordering of Direct Materials happens without human intervention based on Bills of Materials. Artificial Intelligence is used as a self-learning system.

PP3	E-Catalogues	To which degree are E-Catalogues utilised in the ordering process?				There is no use of E-Catalogues but there are plans to implement them in the ordering process.	There is regular use of E-Catalogues and Punchout catalogues during ordering, with purchasing personnel using EP-software to manage them and perform updates when needed.	There is automatic comparison of items in E-Catalogues and Punchout catalogues when requested through human input. The E-Catalogues are updated regularly through EP-software, with purchasing personnel only verifying important changes.	The software autonomously compares items in different E-Catalogues during ordering. The E-Catalogues are real-time through autonomously updating and verifying changes in the EP-software, with only a global monitoring role for human involvement.
PP4	Maverick buying	Is buying from suppliers outside existing contracts or procedures, so-called maverick buying, delimited in the systems?				Maverick buying is prohibited as a company policy, but processes and systems are not designed to decline these orders and maverick buying happens occassionally.	Maverick buying is restricted by the used EP-software but employees can still overrule the system without authorisation from a superior. There is a low use of guided buying or virtual assistants when buying new items.	The EP-software prohibits maverick buying by utilising a list of preferred suppliers, supplier networks or supplier portals, from which an employee cannot deviate without authorisation from his superior. Guided buying and virtual assistants are often used to buy new items. Spend under contract is 90% or higher.	It is virtually impossible to order goods outside of previously approved suppliers or without utilising EP-software for automated sourcing and ordering processes. Guided buying and virtual assistants are mandatory when buying new items to maximise compliant buying. Spend under contract is 95% or higher.

PP5	Monitoring	Is the processing of incoming invoices and payments, and the checking whether orders meets their agreed conditions automated? Is the derived information shared internally and with supply partners, and included in future purchases?				The monitoring processes are not automated within the organisation, but largely manual with human interaction. The derived information is not shared internally, but stays within the purchasing department.	Monitoring processes are (partly) automated but all deviations have to be solved manually. The derived information is manually shared internally.	Monitoring processes are automated but medium to large deviations have to be solved manually. More than 70% of invoices and payments are processed fully autonomously. The derived information is manually shared both internally and externally.	Monitoring processes are fully automated and the system itself is capable to solve problems, except for very complicated problems. More than 90% of invoices and payments are processed autonomously. The derived information is automatically saved and shared both internally and externally.
CO	Controlling / KPI	*Do we have complete, real-time transparancy?*	0%	0,0					
CO1	Master Data Management (MDM)	How advanced is Master Data Management in the organisation?				There is no focus on, or use of master data management. There are only separate files and tools used, with output combined and adjusted manually by employees, and sometimes input into the ERP-system for further use.	The ERP-system has been linked to the EP-software to gradually perform MDM tasks. There is a focus on increasing use of the ERP- and EP-software to improve MDM compliance.	EP-software autonomously performs a majority of MDM tasks (e.g., data gathering, maintenance, distribution) based on limited human input. There is a high focus on integrating the remaining company's systems into the MDM EP-software.	MDM is of great importance, with procedures and system linkages in place to ensure there is one single data set utilised by all different systems. There is continuous, autonomous MDM in the system through the whole organisation.

CO2	Category Management / Sourcing cockpit	How advanced is the category management? Is there a sourcing cockpit available, and what does it show?				Category management is only performed through manual analyses and limited ERP-system usage. There is no sourcing cockpit available.	There is structural use of ERP-systems and limited use of EP-software to perform category management, with also a basic sourcing cockpit with few generic KPI's available. Data can be extracted from a data warehouse.	EP-software performs a majority of category management tasks (e.g., portfolio and eCl@ss-classification) based on limited human input, automatically generates required data and autonomously gives alerts to end-users in the sourcing cockpit based on many generic KPI's.	EP-software is used to autonomously perform category management, and continuously improves itself through the use of Big Data and Artificial Intelligence, by giving strategic suggestions in the sourcing cockpit based on many specific KPI's.
CO3	Spend Analysis	How advanced are the spend analysis capabilities of the organisation? To which degree does monitoring and data processing for spend analysis take place?				There is no procedure for (digital) spend analysis, there are only basic insights accessible through the ERP-system. Data is manually monitored and processed for further analysis.	Spend analysis is supported by EP-software for trained purchasing personnel, who manually make decisions based on this information.	EP-software autonomously performs spend analysis, which is monitored periodically in a structured way by persons who can make manual decisions based off the analysis.	Spend analysis is done autonomously, with use of Big Data and Artificial Intelligence to further analyse results and autonomously improve future purchasing orders.
CO4	Security of data	How are data and services in digital systems protected against misuse (e.g., unauthorised access, modification, or destruction)? How is the privacy of data guaranteed (e.g., with usage analytics or confidential information)?				The firm has little knowledge on cyber-security. There is no collaboration with partners to face this challenge.	The organisation sometimes takes part in meetings with partners to discuss cyber security and how to ensure protection.	The organisation regularly takes part in meetings with partners to discuss cyber security and how to ensure protection. People in the organisation are responsible to achieve cyber security targets.	Data and services in digital systems are strictly protected by the firm and they provide openness on how this is done. Cyber safety is regularly checked by independent organisations.
SC	Sourcing	*Is the strategic procurement process supported?*	0%	0,0					

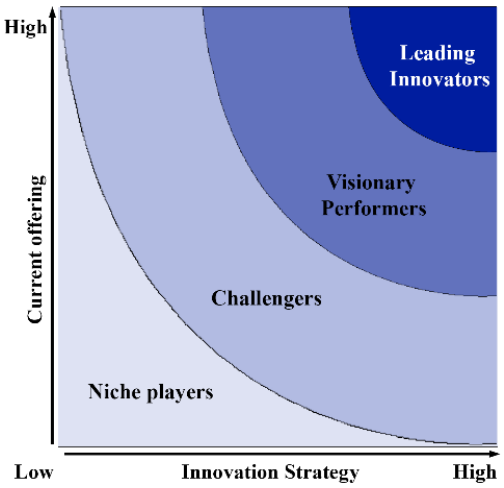
SC1	Market analysis	To which degree is market analysis (e.g., the identification of new suppliers, goods, or services) automated, and aided by software?				There is little use of market analysis, which is done manually and mostly based on own experiences and earlier purchases.	Market analysis is performed through manual requests in EP-software by specific staff. The software is able to analyse E-Marketplaces, E-Catalogues and supplier portals through specific human instructions.	The EP-software performs a systematic and periodical market analysis based on requirements set by specific staff, supplemented with data from its own analysis tools.	E-Marketplaces and EP-software supplier portals are analysed autonomously by the EP-software to identify new suppliers, goods or services based on the organisations' purchasing data and Big Data (i.e. market trends).
SC2	E-Marketplaces	To which degree are E-Marketplaces utilised in the selecting process?				There is no use of E-Marketplaces but there are plans to implement them in the selecting process.	There is a subscription to E-Marketplaces and they are regularly used, with EP-software supporting purchasing personnel in the utilisation.	There is automatic comparison of sourced items in E-Marketplaces when requested through human input. Based on human input, the EP-software performs limited negotiation for better offers on the marketplaces.	The EP-software autonomously compares items in different E-Marketplaces, and continuously, autonomously negotiates best offers on these E-Marketplaces with no human input required.
SC3	E-Sourcing	To which degree is the process of Requests for Information, Proposal, or Quotation (RFI, RFP, or RFQ), summarised as RFX, aided by software?				The RFX process involves only manual processes, with only basic insights accessible through the ERP-system. RFX's are manually monitored and processed for further analysis.	There is regular use of software to aid the RFX process, with trained purchasing personnel using EP-software to manage drafting, distributing and receiving the RFX's, primarily for low impact RFX's. Many results are processed manually.	The RFX processes are highly autonomous and connected both internally and externally through the strong use of EP-software. The majority of RFX's of low-to-medium impact orders happens autonomously in EP-software. Only high impact orders require human input and authorisation in EP-software.	The RFX processes are fully autonomous and organised in fully connected systems through EP-software, and 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.

SC4	E-Auctions	To which degree is the auctioning process automated and aided by software?				The auction process involves only manual processes, with only basic insights accessible through the ERP-system. Auctions are manually monitored and processed for further analysis.	The auction process is aided by specific EP-software, but only for specific staff, who manually make decisions based on this information. Usage is primarily for low impact auctions.	The auction processes are highly autonomous and connected both internally and externally through the strong use of EP-software. The majority of auctioning of low-to-medium impact orders happens autonomously in EP-software. Only high impact orders require human input and authorisation in EP-software.	Auctioning is fully autonomous and organised in fully connected systems through EP-software, and 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.
SC5	Contracting	To which degree is the contracting phase automated and aided by software? Is the process ready to erase human involvement in the contracting phase, or is it already executed?				The contracting processes are not automated nor there is a connection between departments. All contracting is based on manual work, with little help of ERP-systems.	The contracting processes are connected internally, and EP-software is utilised in a medium degree for contracting of low impact orders. The process is in an early phase to erase human involvement.	The contracting processes are highly autonomous, and connected both internally and externally through the strong use of EP-software. The majority of contracting for low-to-medium impact orders happens autonomously, with human input primarily used for high impact contracting.	The contracting phase is fully autonomous and organised in fully connected systems through EP-software, also focusing on Contract Lifecycle Management (CLM). The involvement of humans is erased to establish a purely monitoring role.
SU	Suppliers	*Are the suppliers prepared, willing and able?*	0%	0,0					

SU1	Digital supply chain	Do the suppliers have the capabilities and willingness to collaborate on the digital transformation process of procurement? Is there a concept for digital integration or an integrated supply chain?				Suppliers are currently lacking the capabilities to join the digital transformation process. There is no focus on digital integration or an integrated supply chain, neither by suppliers or by the organisation.	Suppliers are capable and sometimes willing to join the digital transformation process, with small pilot programs started by the organisation. The organisation is in the early phase for an integration concept.	Suppliers are actively encouraged by a structural plan to become capable to join the digital transformation process, with close digital collaboration with all key suppliers already established. The organisation has a concept for digital integration.	There is a close digital collaboration with the majority of suppliers, now focusing on establishing this with remaining suppliers. This is realised through integrated supply chains where all parties are fully involved. The company has an extensive concept for digital integration.
SU2	Supplier evaluation	How is supplier evaluation performed? Is this evaluation shared with the supplier?				Supplier evaluation is not performed or only for key suppliers. This is done manually through (Excel-) analyses by staff, aided by limited reports from the ERP-system.	Supplier evaluation is performed for the majority of suppliers through supplier surveys, aided by the ERP-system and limited use of EP-software. Only a few standard KPI's are measured. This evaluation is shared yearly with the supplier.	Supplier evaluation is performed automatically for each supplier based on standard and some specific KPI's and past performance, with EP-software able to give purchasing personnel specific reports and analyses. These are regularly shared with suppliers.	Supplier evaluation is performed autonomously for each supplier based on many specific KPI's, past performance and comparative benchmarks with both internal and external sources. This is shared real-time with suppliers to improve future performance, with an added focus on supplier satisfaction.
SU3	Data exchange	Which data is shared with suppliers and how transparant is this exchange of information? Does the sharing of data take place in real time?				Sharing of data with suppliers occurs only when this is explicitly requested and/or necessary, through human input.	Data is regularly shared manually with suppliers on the basis of mutual benefits, which are agreed beforehand.	There is a seamless and extensive sharing of purposeful (big) data between buyer and suppliers, a majority through autonomous systems. Both buyer and supplier feel responsible to exchange knowledge for developments.	Extensive sharing of purposeful data with suppliers. The exchange of information is fully transparant within the supply chain (e.g., through Blockchains) and takes place in real time.

SU4	Supply chain risk management	How are risks and disruptions in the supply chain detected, mitigated and/or prevented?				There is low attention to detecting or preventing supply chain disruptions, with only manual analyses by purchasing personnel.	There is a limited view in detecting supply chain risks and disruptions. The first steps for preventing and detecting are taken, with risk reviews for key suppliers, aided by EP-software and website subscriptions.	Through the use of EP-software, it is possible to detect risks and disruptions for most suppliers autonomously in an early phase, after which human input decides further actions based on these alerts.	Possible risks and disruptions in the supply chain are detected and mitigated and/or prevented autonomously, by having integrated real-time analytics (from internal and external sources, including Blockchains) through EP-software. Risk reports are integrated in the whole EP-software suite.
US	Employees / Users	*Are the employees prepared and willing?*	0%	0,0					
US1	Capacity	Do employees possess the required capabilities (willingness to learn, holistic thinking, proactivity, inventiveness) to enable the transition towards the digitalisation of purchasing? Is learning and development stimulated by management?				The employees understand the purchasing processes and are capable to execute it in the systems. There is no EP-software related knowledge involved.	The employees deeply understand the purchasing function, trained purchasing personnel are capable to understand EP-software in the digital environment, while also able to suggest new features in the software.	All purchasing employees deeply understand the purchasing function and the use of advanced EP-software, which aids them through autonomous processes. There is a structured process for providing feature requests by all personnel.	All employees have a deep understanding of the processes behind all systems. They are able to fully execute all purchasing and EP-software related tasks, and are prepared for the strategic (i.e., preparational and collaborational) role of future procurement.
US2	Involvement	To what extent are employees involved in the digitalisation of the purchasing function?				Employees are seldom invited to team meetings from the purchasing department, and only occasionally receive new information. Employees are not involved in adopting EP-software techniques and hardly receive new information.	Employees are sometimes invited to team meetings for the purchasing department and for EP-software. Sharing knowledge on digitalisation stays primarily within their own departments.	Employees are regularly invited to team meetings for the purchasing department and EP-software. Employees are responsible for systematically sharing knowledge on digitalisation cross-functionally through the company.	Employees are structurally invited in team meetings and have direct influence on the development in the digitalisation of the purchasing function and integration of EP-software.
TS	Total score		0%	0,0					

VIII. Final E-Procurement Quadrant Model



Descriptions of the four types named in the Quadrant Model are as follows.

Niche players: "The innovation strategy is either of a low focus, or the current product does not offer any depth."

Challengers: "The innovation strategy has a considerable focus, and the current product offers a medium amount of depth."

Visionary performers: "The innovation strategy has a strong focus, and the current product does offer a high amount of depth."

Leading innovators: "The innovation strategy is a core focus of the firm, and the current product offers an extraordinary amount of depth."

The measured criteria for the two axes are as follows.

Innovation strategy	**Current product**	**Current product (continued)**
Roadmap	E-Catalogues, E-Marketplaces	Data analysis
Industry 4.0 adoption	E-Sourcing, E-Auctions	Category Management / sourcing cockpit
Technology use	Supplier portals	Spend analysis
Technology focus	Contracting & Contract management	Data security
Industry trend focus	Demand prediction	Supplier onboarding
	Ordering, maverick buying	Supplier collaboration
	E-Invoicing	Supplier evaluation
	Accounts payable	Supply chain risk management
	Master data management	Training & support

IX. Checklist for basic and descriptive design principles according to 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**
(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