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Developing a maturity model based approach supporting the decision to adopt International Data Spaces

Ewout Gort, Master's thesis, Business and Information Technology

EMONS GROUP

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Master's thesis

DEVELOPING A MATURITY MODEL BASED APPROACH SUPPORTING THE DECISION TO ADOPT INTERNATIONAL DATA SPACES

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Preface

Dear reader,

This thesis concludes my Master of Business and Information Technology program at the University of Twente. I still see myself driving home on sunny Tuesday afternoon in August, driving on the provincial roads connecting Milsbeek with Enschede. I then was feeling enthusiastic for Emons as a company and the possible subject of the project that Gerard had discussed with me. I was right to be, as even now, after spending hours and hours reading about International Data Spaces and all things related, I will still become excited when talking about it to anyone who asks.

My sincere acknowledgements go to my three supervisors at the University of Twente: Maria, Marten and Sebastian. Without which this work would not have been possible. Their guidance, knowledge, willingness to listen to my thoughts and the occasional nudge to put me back on track were all very valuable.

I would also like to thank the people at Emons Group B.V. and especially Gerard Alders and Marcel Wouterse. Their constant strive to evolve and make Emons Group B.V. better has been an example to me. Their feedback, connections and willingness to help have been vital in bringing this research to were it is now.

Many other people also contributed to this research, I would like to thank them also for their contributions and time. As one of them said to me: “When I was a student I also appreciated it when people were willing to help, I think we should be willing to help each other when help is needed.” If nothing else, I will take this with me during the rest of my career.

Thank you my family and friends, for your interest, willingness to help in any way you could and for providing those well needed distractions. Thank you Daniël and Eric, for being such a good friends. Daniël: I hope I will one day be able to pay you back for al those cans of coke and packages of stroopwafels you bought me during those years of studying together.

Thank you Marjolein for being who you are to me. Thank you for listening to me complain when it was hard, thank you for being excited when I made progress, thank you for putting up with me when we were sharing a single room during the Corona lockdown. During this process it became again very clear that you complement me. You’re amazing!

And now there’s nothing left but to wish you a great read!

Ewout Gort

Management Summary

Every company is faced with a constant stream of new technologies and innovations. Currently companies are faced with the transition towards Industry 4.0 which focusses on creating a digital network of manufacturing companies that are interconnected. One the new and upcoming technologies companies are faced with is that of International Data Spaces.

International Data Spaces enables companies to share data across company borders while protecting the sovereignty of the data based on a platform that ensures trust and security. It allows for peer-to-peer sharing of data, use of applications for the transformation of data and the offering of broker services.

This means that more and more companies are required to make a decision on whether or not they are going to invest in the exploration and adoption of International Data Spaces. This decision is currently hard to make as pre-existing knowledge of the technology is required to make a true an unbiased assessment. Uncertainty in regards to the required effort and expected performance will increase risks for the company assessing the new technology, thus forming a barriers for International Data Spaces adoption.

The goal of this research is thus very simple and is summarised in the following design problem:

- **Improve** International Data Spaces adoption decision making of organisations facing the decision to join an existing International Data Spaces ecosystem as an data provider or data consumer
- **By** designing a maturity model based approach specific for International Data Spaces
- **That** companies can use to determine expected required effort and expected impact of International Data Spaces adoption
- **In order to** reduce bias and uncertainty in the decision making process

The goals, concepts and components of International Data Spaces have been investigated, as well as the current stage of International Data Spaces development and adoption. It was found that International Data Spaces is on the brink of wide-scale commercial adoption, and that the design and development fits its goals of the model. When investigating how IDS is related to other technologies it was closely related to Industry 4.0, mostly as an enabling technology of the Data and Information aspect.

The maturity model development procedure by Becker et al. (2009) was followed. After defining the problem definition and requirements of the model an extensive systematic literature search was performed. The Schumacher et al. (2019) maturity model for Industry 4.0 was selected to base the International Data Spaces maturity model on.

The maturity model is developed in two iterations and is based on both the literature found in the systematic literature review and expert interviews. The developed model contains the following elements:

- Process definition: Describing which step should be followed and how each of the components of the International Data Spaces maturity model is applied.
- Pre-adoption matrix: Maturity dimensions (8) and items (36) that are either ‘required’ or ‘helpful’ to be mature in before starting adoption of International Data Spaces.
- Post-adoption matrix: Maturity dimensions (8) and items (40) that are expected to either be ‘maturing’ or ‘enabled’ by adopting IDS.

- Strategy guide: Discussion of barriers and success factors influencing IDS adoption as well as IDS adoption impact on Industry 4.0 SWOT elements related to each of the defined dimensions of the pre- and postadoption maturity matrix.

After which the model is validated by a single-case mechanism experiment. This concluded that the model seems to produce the intended effects. However it was hard to find comparable studies and sources to reliably quantify these results. However, the results of the assessment were found to be useful by the company the assessment has been conducted for. The model is perceived to add most value by showing current perceived maturity and in triggering decision making in investigating aspects of the organisation not considered before.

The International Data Spaces maturity model developed in this research will add to a very limited scholarly domain regarding Industrial Data Spaces. As such it will provide new insights in how an organisation can become ready for International Data Spaces adoption and what advantage or disadvantages International Data Spaces has for the organisation.

These insights will also help organisations in practice in determining whether or not International Data Spaces is an innovation in which they should invest time and resources. Risks due to limited experience and thus bias or error in assessing the new technology are reduced. This is done by providing the tools for a company to more easily assess the expected effort required for and the expected benefits of Industrial data spaces adoption.

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1 Introduction

Over the last centuries industry and way of working has changed immensely. In the first industrial revolution the power of steam has been the driving force for change. Resulting in new technologies and ways of working. After the first industrial revolution followed the second revolution which is driven by electricity and the third revolution which is driven by automation. Currently we are in the middle of the fourth industrial revolution in which cyber physical system, big data, cloud are all key concepts.

This fourth industrial revolution, known as industry 4.0 focusses on increasing connectivity both internally and externally and is enabled by innovative technology. Data has already been an important asset and enabler during the third industrial revolution. However it is has become one of the pillars of industry 4.0. Technologies such as cloud computing, big data, smart manufacturing, and internet of things aim to improve the ways of gathering and storing data and generating value from this data. This is recognised by the European Union which started the European Cloud Initiative helping create a digital single market in Europe (European commision, 2019).

One such technology is that of Industrial data spaces (IDS), a reference framework claiming to enable easy and secure sharing of data while maintaining sovereignty of data (IDSA, 2019a). The concept of data sovereignty is concerned with enabling the owner of data to keep control of its data at all times. Even when it is shared across company boundaries, and thus normally has crossed the boundary of control. IDS is supported by the International data spaces association (IDSA) which combines the domains of business and research to further develop and implement IDS. The IDS reference architecture has been through several iterations of refinement already and is currently in version 3.0 (Otto et al., 2019). The IDSA is pushing the IDS architecture to become a global standard. In order to become this global standard, it has to prove itself in real-world use cases within and across different domains.

As information is becoming a more and more valuable resource, protection of this information is becoming more and more important. Most commonly however protecting information results in loss of business opportunities related to this information. Sharing data across company borders normally diminishes control over this data. IDS claims to be specifically tailored to enable companies to generate new business models by making data available while keeping control over this data.

Data sharing is also becoming more and more important for other cases as well. Industry 4.0 leverages interoperability and connectiveness of information in order to enable new technologies. Technologies such as supply chain control towers can potentially transform the logistics domain. The success of these technologies is however often dependant on the data provided. Providing more and better data is directly related to their ability to analyse and improve the supply chain.

Any organisation will be faced with the need to constantly evolve and adapt to changes in it is domain in order to remain competitive. This forces them to make decision on the adoption of new technologies. Each of these decisions is based on perceived benefits versus costs, both on short term as well as in the long term. During the initial phase of the decision to adopt the company is already investing resources. This creates a barrier for further investment when the company does not perceive benefits of the technology to outweigh the costs.

Currently uses cases involving IDS are mainly carried by big companies. These companies have more resources for investigating new technologies and are more capable of dealing with risks involved with the adoption of new technologies. They thus often part of the first group of organisations to start adopting new technologies. For a new technology to be also interesting for smaller organisations the amount of resources required to support the adoption decision and implementation should be lowered, as well as the risks following the uncertainties involved with new technologies.

1.1 Background

This research is conducted at Emons Group B.V.. Emons Group is a Dutch logistics service provider which distinguishes itself by developing innovative and sustainable concepts. In this context, Emons has become part of the ICCOS project. The ICCOS project is an initiative by the Dutch Institute for Advanced Logistics and is focussed on helping Dutch SMEs adopt Industry 4.0 concepts related to supply chain coordination. Partnering organisations include the University of Twente, which is in lead, but also organisations from the industrial domain such as D-Care / King Nederland, Districon, LOGAPS, Veenman, and DeltaGo.

1.2 Motivation

Most companies in the Dutch logistics sector recognizes the importance of IT (Evofenedex et al., 2019). In order to remain competitive the sector needs to constantly evolve and adopt new innovative technologies in their business processes. Technologies such as those developed within in Industrie 4.0.

The research by Evofenedex, TLN & Beurtvaartadres (2019) found that, even though companies recognise the importance of IT in the organisation, most companies deliberately rather wait with adopting innovations until they are proven technologies. This could indicate a tension between the expected benefits of the new innovations and the potential risks involved with investing early.

This is further strengthened by the research of Dennis Schreinders (2019) who found that one of the main barriers of the adoption of Industry 4.0 technologies by organisations in the logistics sector was a feeling of 'not being ready' due to "low level of digitalisation, bounded rationality and the missing of a solid business case". To combat this, Schreinders suggests less experienced companies to learn from experienced cases.

1.3 Problem definition

Several barriers should be overcome in order for Dutch companies to be willing to invest in the adoption of IDS. Domain research by Evofenedx, TLN & Beurtvaartadres (2019) discovered several main reasons for not adopting IT solutions, such as: management is not convinced of the added value, lacking resources (both finances and knowledge), expected complexity of integration and discrepancy between required functionality and offered functionality. Of these, the lacking resources are most prevalent.

According to the IDSA, IDS is being implemented in almost 40 use cases (IDSA, n.d.-c). In a previously performed study it was found that both these use cases as the state of the IDS reference architecture indicate IDS nearing product level implementations. However, these findings from these first implementations are not presented by IDSA documentation or scholarly papers. Resulting in very limited publicly available information regarding IDS implementation and adoption.

The IDSA does support collaboration and knowledge exchange in regards to the adoption and implementation of IDS. However this information is only made available to members of the IDSA organisation. This poses a barrier for organisations that have not yet made the decision to investigate IDS and thus become a member of IDSA, for which a fee is required. Organisations possibly willing to adopt IDS are thus not able to learn from experienced organisations. This could possibly create insurmountable barriers for organisations that do not want to carry the risks related adopting untested innovations.

1.4 Research goal and research questions

The main goal of this research is helping organisations in making the decision to start adoption of IDS. For this a new approach is developed based on maturity models. This tool enables organisations to quickly determine their organisations readiness for IDS adoption and the expected impact of IDS adoption on their organisation. Making the IDS adoption decision easier, reducing costs, and better, reducing risks.

The main research questions are derived from this research goal:

"What maturity model based approach can be developed to support the decision to adopt IDS by an organisation?"

1. What is currently know about IDS adoption and the impact of IDS adoption by an organisation?
2. How does IDS relate to other data sharing technologies and initiatives?
3. What components should a maturity based model to support the IDS adoption decision contain?
4. How can these components be operationalised in a new maturity based model for supporting the adoption decision of IDS?
5. Is this developed model expected to support the decision to adopt IDS?

1.5 Reading guide

This research is structured as follows: Chapter 2 provides an overview of the methodology approaches applied in this research and how these are related to the research questions.

Chapter 3 discusses International Data Spaces (IDS) by providing an overview of what it is, reasons for adopting and reasons not to adopt, and finally the current state of art of the development and adoption of IDS. Building upon chapter 3, Chapter 4 discusses IDS in relation to other technologies and initiatives. This provides insight in the role of IDS in the domain as well as allow this research to identify what knowledge can be extracted from these related domains to be used in establishing the IDS maturity model.

After establishing the context of IDS and how it is related to other technologies the maturity model development can be started. Chapter 5 establishes the problem definition, scope and level of the maturity model to be developed. It also present an exhaustive comparison of existing maturity models for IDS or similar data sharing technologies. These maturity models and related literature will provide the basis for the IDS maturity model to be developed in chapter 7 and 8.

First however, the approach to developing the first and second iteration of the IDS maturity model is presented in chapter 6. In short: the systematic literature search and expert interviews are used as input sources.

The developed model is validated by applying it in a single-case mechanism experiment. Of which the approach, results and conclusions are presented in chapter 9.

Finally, chapter 10 will conclude this research by providing a conclusion and discussion regarding the design and applicability of the model as well as suggesting field of future research.

2 Methodology

2.1 Structure of the research

The main structure of the research is based on the work by Becker et al. (2009). They proposed a seven step procedure model for the development of maturity models. This approach can be roughly mapped to the design cycle by Wieringa (2014), see Table 1. Whenever also a design cycle stage can be mapped to a stage of the maturity model development procedure model by Becket et al. (2009) this research also addresses the corresponding design cycle stage. This means that whenever a stage of the design cycle is reached the research makes sure items of this stage in the Design cycle have been addressed.

Table 1 – Mapping of the maturity model development procedure model by Becker et al. (2009) *to the engineering cycle by Wieringa* (2014).

Research Question	Development of Maturity models	Design cycle
Q1, Q2	Problem definition	Problem investigation
Q3, Q4	Comparison of existing models	
Q3, Q4	Determination of development strategy	Treatment design
Q3, Q4	Iterative maturity model development	
Q5	Conception of transfers and evaluation	Treatment validation
(Not in scope)	Implementation of transfer media	
(Not in scope)	Evaluation	

This research as a whole can best be described to be solution-oriented research. As such it is classified as technical research including the design of an artifact and validating this artifact by simulation (Wieringa, 2014).

The research questions posed will be answered by applying several types of research, see Table 2. First a summary of the method applied in answering each of the research questions is provided. Presenting the basic use of these methods. Each of these methods which will be further elaborated upon in the following chapters. Discussing how these methods are operationalised for use in this research, sometimes basing the approach on previous findings.

Table 2 – General overview of research methods applied in this research.

Research question	Methods	Comments
1	Exploratory research and expert interview	Combining available IDSA documentation, grey literature and scholarly papers. Applying expert interviews to elaborate and validate findings.
2	Exploratory research	Combining available IDSA documentation, grey literature and scholarly papers.
3	Systematic literature review	Follow a structured approach in order to identify all related scholarly publications related to IDS and similar technologies.
4	Expert interviews	Questionnaire (structured) and interviews (semi-structured) Interviews are used to elaborate on and validate questionnaire response.

5	Single case mechanism experiment and technical action research	Based on interviews with employees and documentation made available by the company.

2.2 Exploratory research

In the case that limited scholarly sources are available a systematic literature is not expected to bear the results required. In this case exploratory research or expert interviews can be applied.

Exploratory research will search for alternative sources of information to provide a general insight in the questions posed. For this a combinations of scholarly articles and white and grey literature will be used. For instance, the IDSA and partnering organisations have published several articles regarding its reference architecture and it's development.

This exploratory research does however not always provide an unbiased insight in the subject. In this case, for example, when articles are includes which are published by the IDSA or one of its' member organisations.

2.3 Expert interviews

Expert interview can be applied to quickly gather a lot of information about a subject (Dorussen et al., 2005). Also, expert interviews are often considered to product reliable data as a result of high competence of respondents (Dorussen et al., 2005). However, this is also the main point of failure. The validity of the results depend on the validity of the experts (Dorussen et al., 2005). Selecting the right experts and the right number of experts is thus required for good expert interview based research. It can be hard to determine the validity of the selected experts. Reliability for instance cannot blindly be used an indicator as the possibility exists for only a small number of expert to be 'right' (Dorussen et al., 2005).

Expert interviews are a qualitative research method and several types of expert interviews can be distinguished. One distinction can be made about questions posed, these can be structured, unstructured or semi-structured.

An advantage of conducting a structured expert interview is the ability to maintain uniformity throughout all the interview sessions. This makes comparison during the analysis phase more easy. An example of a structured expert interview method is for instance an interview conducted using email in which the respondent is asked a series of questions and responds to each of these. A structured interview however can restrict the ability of interviewer and interviewee to elaborate and discuss the questions and answers posed.

Non-structured interview methods fit research in which it is not yet clear what answers are expected or even what questions should be posed. For instance in research in which field experience is significant (Bird et al., 2009). An example of non-structured interviews is one where no single line of questioning is established in advance of the interview session. The line of questioning is then led by the response of the interviewee allowing for vastly differing lines of questioning between interview sessions.

Semi-structured interviews start with a basic line of questioning which should be completed. However, during the interview it is allowed to ask additional questions such as for clarification of answers provided or for expanding upon previously unknown insights provided by the interviewee.

Several steps should be followed in conducting expert interview research. Libakova & Sertakova (2015) state the following: choice or research topic, preparation and planning, interview, transcript or records, analysis and interpretation of data, preparation of the report.

A benefit of questionnaires is that they can be set-up in a structured manner resulting in structured responses, enabling more easy comparison of results. Questionnaires do however not allow the interviewee to expand, criticize and elaborate upon the questions posed. For this semi-structured interviews are more suitable. In this research semi-structured interviews will thus be applied to validate and expand upon the findings of the questionnaires.

2.4 Systematic literature review

For some questions a more systematic approach to gathering literature can be used. Second research question is suitable for a systematic literature review as it explores concepts which are more abstract and it is more likely that peer reviewed literature already exists. By applying a systematic approach bias in gathering the sample of literature reviewed is minimalised and a complete overview of related articles is retrieved.

In this research an iterative systematic approach is applied following the method defined by Wolfswinkel et al. (2011). This approach consist of five stages and are displayed in Figure 1.

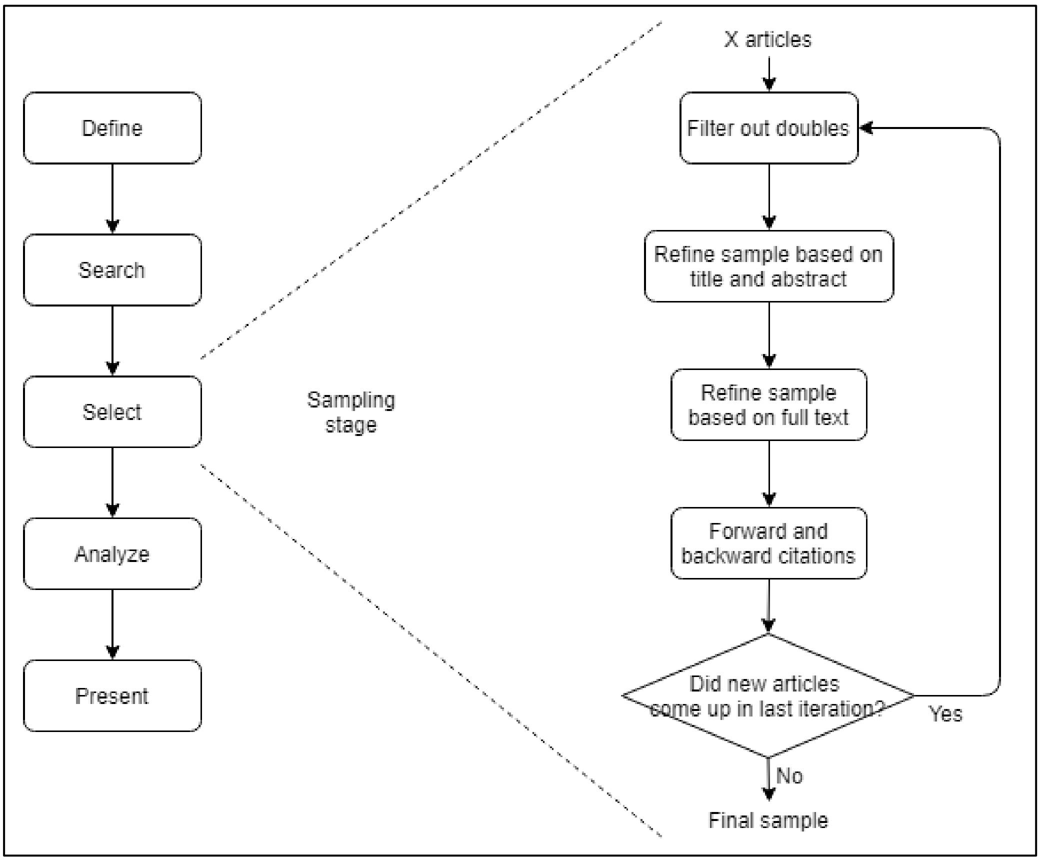


Figure 1 - Five-stage grounded-theory method for reviewing the literature in an area (Wolfswinkel et al., 2011)

The method first defines the criteria for inclusion and exclusion, identifies the fields of research, determines the appropriate sources and decides on specific search terms. Based on this a search is conducted from which a final set body of articles is selected following a iterative approach including reviewing forward and backward citations. The resulting body of articles is analysed and then presented in the final thesis. During the analysis phase concept mapping is applied.

The set of articles can then be used to establish the basis for answering questions 1 through 3. Establishing the generic components derived from currently known literature which can be expanded upon to fit supporting the adoption decision for IDS specifically.

The systematic literature research will uncover the whole of the knowledge available when researching a specific question. It herein relies heavily on the presence, findability and the coherence between the peer-reviewed sources available the domain.

2.5 Single case mechanism experiment and Technical action research

The application of the artifact to a single use case is named a single case mechanism experiment by Wieringa (2014). The specific goal of this experiment is to validate the model developed in the previous stages. This is called technical action research when the use case involves conditions of practice and when the result is used to help the client.

For this two types of inference are to be applied. The first is descriptive inference as the gathered data should be interpreted and converted into descriptions of the things observed. These descriptions can then be applied in abductive inference in which explanations are developed (Wieringa, 2014).

It is important to note that this research will not be technical action research as it will not be applied directly to conditions of practice. The aim is to apply the developed model in a simulated manner in close cooperation with the company selected. This can be classified as applying the model in realistic conditions. The sampling of the company to be selected for the experiment will be done randomly. Any company fitting the purpose of the model will be suitable.

2.6 Scope of research

The research questions posed in this research are focussed the technology of IDS. The resulting model is aimed at companies operating in the industrial domain. Within this domain several types of organisations are active, such as manufacturing companies, logistics, governmental bodies and companies offering supportive services. This research will mainly focus on supporting decision making in organisations that make up the main supply chain such as manufacturing and logistics companies.

2.7 Validity

Several methods for data gathering and validation are applied. In doing so triangulation is achieved in both data sources as research method. For instance, findings gathered from exploratory research can be used in the questionnaires and expert interviews. Experts interviewed will now be able to respond to the findings presented. This is also a form of peer debriefing, which is the checking of decision with peers (Wieringa, 2014). The final model and related approach are validated by applying it to a single use case experiment.

3 International Data Spaces

This chapter discussed what is currently known about IDS and IDS adoption. The chapter is comprised of several sections each discussing different aspects of IDS and IDS adoption. The first section presents International Data Spaces (IDS), discussing the goals of IDS, the IDS Ecosystem and components of IDS. The second section investigates whether or not the IDS reference architecture fits its purpose, the third section explores the reasons to adopt IDS and the reasons not to. The final section discusses the current state of IDS adoption.

3.1 Goals of IDS

The main goal of International Data Spaces (IDS) is to enable data sharing across domains in which the sovereignty of data is protected. In this sovereignty of data is defined in the IDS Reference Architecture Model as “a natural person’s or corporate entity’s capability of being entirely self-determined with regards to its data” (Otto et al., 2019, p. 108). Data sovereignty provides the bases for new business processes and innovation as it enables companies to sell data as an asset without compromising its value (IDSA, 2019b). This way of thinking in applying the concept of data sovereignty to data sharing is new according to IDS and the International Data Spaces Association (IDSA)(IDSA, 2019a; Otto et al., 2019). The IDSA promotes IDS for becoming a global standard.

In order for IDS to enable sovereignty as secure and trusted platform has to be established which supports data privacy. This platform will be able to ensure this through several functionalities such as user management, certification and authentication, encryption and so forth.

In addition to being secure and trusted IDS aims to be applied across domains (Otto et al., 2018). In the sense that data will be shared across company borders and existing supply chains. For this IDS aims to be easy to adopt, technology independent, and re-use and comply with existing technologies (IDSA, 2019a, 2019b).

IDS aims to be a strategic link between several technologies and innovations, making new data sources available (IDSA, 2019a). For instance by connecting various existing and emerging platforms (Achatz et al., 2018; IDSA, 2018, 2019a). For example, the position paper of Achatz et al. (Achatz et al., 2018) mentions the application of IDS as the link between IoT and big data, machine learning, and artificial intelligence. IDS can play a key role within data value chains by enabling the sharing of data between the several steps in the chain, ingesting it, processing it and making it available for analysis (IDSA, 2019b). Thus by ensuring data sovereignty, connectivity, security and trust new business models will become available.

3.2 IDS Ecosystem

A multitude of organisations is active in each data space. In order to structure this the IDS Reference Architecture Model distinguishes between several roles an organisation can have within the data space. The combination of these roles existing and cooperating within the data spaces makes up the IDS Ecosystem. In order for a true IDS to exist al these roles should be present. Some of which only one is required to be present, such as the identity provider, while of some roles a multitude is required.

The IDS Reference Architecture groups the roles in four categories: Core participant, Intermediary, Governance bodies and software and service providers. Table 3 displays this grouping and the roles they contain.

Table 3 – Categories of roles in the IDS Reference Architecture Model (Otto et al., 2019).

#	Category	Roles
1	Core participant	Data owner, Data provider, Data consumer, Data user, App provider
2	Intermediary	Broker service provider, Clearing house, Identity provider, App store provider, vocabulary provider
3	Software/ service provider	Service provider, Software provider
4	Governance body	Certification body, Evaluation facility, International Data Spaces Association (IDSA)

The main roles are the data owner, data provider, data consumer and data user roles. These roles represent the parties directly involved in the exchange and transformation of data. Supporting roles such as those mentioned under the intermediary category help make this process possible. Either by ensuring a trusted and secure platform, e.g. the clearing house and identity provider, or by helping find data sets and applications for processing and transformation of data. Software and service providers are parties offering the technology and knowhow of IDS implementation. These can be the same as the organisation that is eventually using the IDS Connector but a company can also decide to outsource development to a software provider. The final category is that of the governance bodies present. This category contains both the certification bodies as well as the evaluation facilities. The capabilities and subjectivity of these bodies is monitored by the International Data Spaces Association (IDSA). Figure 2 shows how the various roles in the IDS Ecosystem interact.

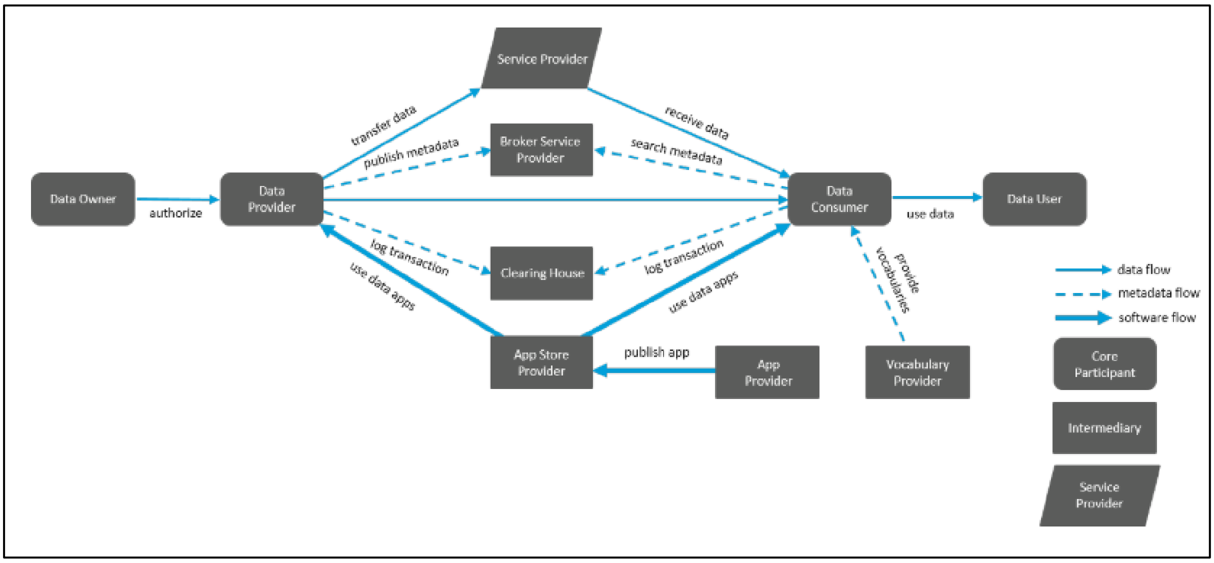


Figure 2 – Interaction between roles in the Industrial Data Space (Otto et al., 2019).

3.3 Core components and organisational components

The international data spaces (IDS) consists of several components. It is a combination of several core components and organisational components and services. Which together aim to enable the goals of IDS and the IDSA. In this section each of these components will be elaborated upon, discussing what they are, why they are part of IDS and their current state of development.

3.3.1 Core components

The following components are considered the main components of IDS:

1. IDS Connector

    - IDS Communication Protocol
2. IDS information model
    - IDS Reference architecture model
    - IDS Ontology
    - IDS Information model library

3.3.2 IDS Connector

The IDS Connector is the main technical component of IDS. IDS Connector are responsible for the complete process of exchanging data. They act as trusted and secure gateways connecting data sources to other IDS connectors applying identity management, data provenance tracking and data processing and transformation. In doing so a trusted platform is created facilitating organisations joining the IDS Ecosystem in various roles.

IDS are run in isolated environments (Otto et al., 2019) in order to enable a secure and trustworthy platform as suggested by Brost (2018). The IDS Connector can run on all sorts of environments, such as servers, IoT devices, cloud, and mobile depending in implementation (IDSA, 2019b).

Depending on implementation a connector can be described as a base free, base, trust, trust+ connector, each step requiring adherence to more strict trust and security requirements during certification.

The secure communication between IDS Connectors is based on the IDS Communication protocol (IDSCP) and encrypted tunnels. One of the capabilities of the IDSCP is the attachment of usage policy information to the exchange of data.

The IDSA does not provide a fully implemented platform as it aims to provide the semantics for systems to be developed and certified (IDSA, 2019a). It does however offer an open source implementation of the IDS base Connector which can be adapted to fit the requirements of a specific use case. Several FIWARE based implementations are available such as presented in Sarabia-Jacome et al. (2019) and Alonso et al. (2018).

3.3.3 IDS Information model

The IDS information model as presented by Otto et al. (2019) consists of three levels of representations: the IDS Reference Architecture Model, the IDS Ontology and the IDS Information Model Library. This is also depicted in Figure 3. The IDSA publishes and maintains each of the representations separately.

These representations can also be called abstractions, starting with the most generic and descriptive of the three, the IDS Reference Architecture, each one becomes less abstract. With the IDS Information Model Library being the most specific and executable.

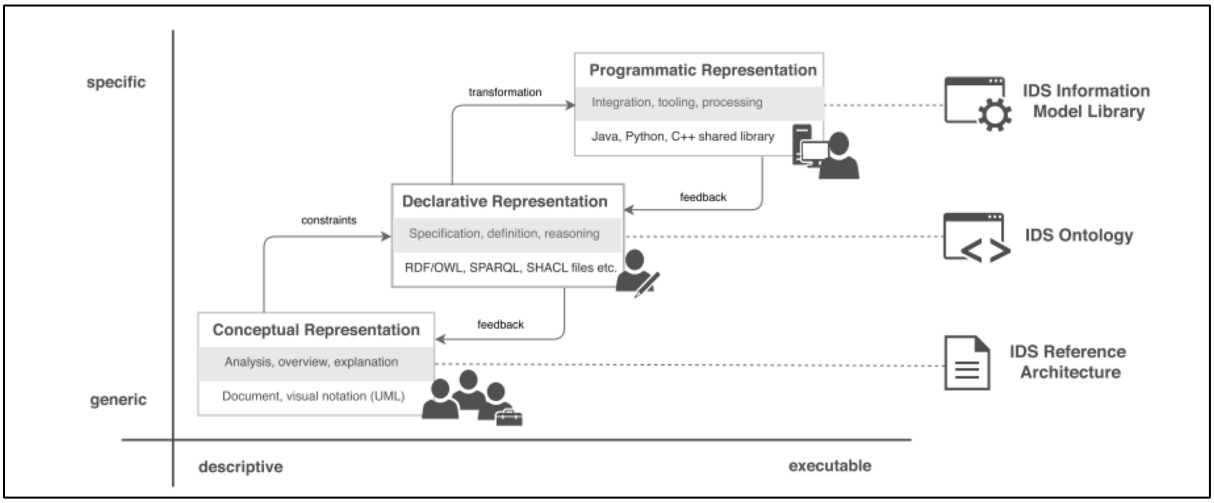


Figure 3 – Representations of the Information Model as presented by Otto et al. (2019).

3.3.3.1 IDS Reference Architecture Model

The IDS Reference Architecture Model (IDS-RAM) presents the conceptual representation of IDS. It is one of the most important components of IDS as it describes IDS functionality and key concepts at an high abstraction level. This high level abstraction provides the foundation on which the more specific models are based on.

The IDS-RAM consists of five layers and three perspectives crossing these layers. These layers are from top to bottom: business, functional, process, information, system. The business layer mainly describes the roles in the IDS Ecosystem and how these roles interact with each other.

The functional layer describes the functionalities of IDS, an overview of these aspects is provided in Table 4. The process layer describes the three main processes of IDS enabling these functionalities: 1) onboarding, 2) exchanging data and 3) publishing and using data apps.

The information layer describes the common and domain agnostic language of IDS (Otto et al., 2019), supporting the description, publishing and identification of digital resources and the consummation of these digital resources. The IDS Ontology and IDS Information Model Library can mainly be considered part of this layer.

The system layer describes the technical components enabling these layers above, it distinguished for instance the IDS Connector and the requirements pertaining its architecture.

The three perspectives address the core values of IDS, namely the secure exchange of data and the sovereignty of data. The security perspectives describes aspects such as secure communication, identity management, trust management, creating a trusted platform, data access & data usage control and data provenance tracking.

The certification perspective describes the multi-layer certification hierarchy and the processes and structures involved in this certification hierarchy. Certification is one of the key methods insuring trust in the ecosystem aiming to prevent tampering of data of connectors and enabling use management.

Governance perspective is concerned with the compliance to negotiated rules and processes. It describes key management processes, a responsibility matrix and the governance of data as an economic good.

Table 4 – Functional aspects of IDS as derived from the IDS Reference Architecture Model (Otto et al., 2019).

Group	Aspects
Trust	Roles, Identity management, User certification
Security and data sovereignty	Authentication and authorisation, usage policies and usage enforcement, trustworthy communication, Security by Design, technical certification
Ecosystem of data	Data source description, brokering, vocabularies
Standardized interoperability	Operation, data exchange
Value adding apps	Data processing and transformation, data app implementation, providing data apps, installing and supporting data apps
Data markets	Clearing and billing, usage restrictions and governance, legal aspects

3.3.3.2 IDS Ontology

The IDS Ontology presents the declarative representation of IDS. It's main function is to map the conceptual representation of the IDS Reference Architecture Model to the programmatic representation. It provides a machine readable version of the abstract concepts of the information model presented in the Reference Architecture Model.

This machine readable presentation, or IDS Ontology is available on GitHub. The Ontology provided on GitHub is based on the Resource Description Framework (RDF) and the Web Ontology Language (OWL). These are well known standards in the domain of the semantic web and linked data.

3.3.3.3 IDS Information Model Library

The IDS Information Model Library presents the programmatic representation of IDS. It is the lowest level of abstraction provided by the IDSA. It provides documented software libraries to software developers in specific languages. Such as for instance Java, Python, C++. This allows software to quickly integrate the IDS information model in their own application as such an library can be developed for each programming language independent of IDS. Similar to the IDS Ontology and the IDS Connector, the IDS Information Model library is available on GitHub under an Open Source licence scheme.

3.4 Organisational components and services

In the previous chapter the core components containing the technical aspects of IDS and the information model were discussed. This chapter will elaborate on the organisational components of IDS.

3.4.1 International Data Spaces Association

The main organisational components of IDS is the International Data Spaces Association (IDSA). This organisations mission can be summarized as to be the connection between research and development of IDS and the funding and implementation of IDS by companies. Responsibilities are comprised of three things: 1) fostering the general conditions and governance of IDS as an international standard, 2) the development of IDS as a standard applied in use cases, 3) and to support certifiable software solutions and new business models (*The Association - International Data Spaces Association*, n.d.).

The IDSA is comprised of over more than 100 member organisations including Fortune 500 companies (IDSA, n.d.-b). Version 1.0 of the IDS Reference Architecture Model was published by Fraunhofer, which later became one of the founding members of the IDSA. It is also supported by the European Union providing a grant within the context of the Horizon 2020 research and innovation program.

Some members of the IDSA operate as regional Hubs. These hubs are often centres of applied research acting as local conduits between research and practical application of the research. Driving innovations. As they are often locally based they act as knowledge bases for organisations interested in IDS. Hubs operate as local drivers, making connections between companies, operating as knowledge institute and welcoming new members of the IDSA.

The IDSA and members are also cooperating in taskforces, working groups and communities. Examples of these are the taskforce legal framework, the logistics data space community and the working group use cases & requirements. These are the main contributors to the development of IDS, ensuring development of IDS is based on the input from member organisations from research as well as from member organisations applying IDS in real world use cases.

3.4.2 Certification

As prescribed by the IDS Reference Architecture Model certification and authentication are vital for enabling trust and security in the IDS Ecosystem. This certification is split in two types: organisation certification and connector certification. This certification is one of the main components enabling user authentication and management. This way any party connecting to IDS can be identified as well as the specific connector they are using.

The IDSA is in lead in establishing the certification processes and in appointing independent organisation in charge of carrying out these evaluation and certification processes. This means that the IDSA is not directly involved in the certification of organisations and connectors. However, they are in charge of competence monitoring of the certification bodies.

3.4.3 Use cases

Use cases are the centre of all efforts to implement and develop IDS. The IDSA has defined a six-step process, use case quality criteria and characteristics and nine levels of use case maturity in order to govern the use of use cases.

Currently over 40 use cases are being implemented and more than 60 prospective use cases are being investigated (IDSA, n.d.-c).

Previous research based on 32 use cases identified that all use cases implemented the IDS connector, as expected. While only 52% of these use cases implemented an IDS Broker and only 32% implemented an IDS App store. A complete listing of the components implemented in the use cases can be found in Table 5.

Table 5 – Summary of the components implemented by the analysed use cases as found in …

IDS Component	**IDS Connector**	**Broker service provider**	**App store**	**Vocabulary provider**	**Clearing house**	**Identity provider**
Number of use cases (%)	100%	~52%	~32%	~19%	~10%	~10%

Based on this research a distinction is made based on the IDS components implemented by an use case. The first type of use cases implements the IDS connector as a data provider and data consumer and possibly one of the other components of IDS. This type is categorised as ‘attribute testing’ and its main purpose is to demonstrate and validate a single aspect of component of the IDS Ecosystem.

The second and third types revolve around the Marketplace capabilities of IDS. Requiring IDS Connectors in the roles of data provider, data consumer and broker service providers. The first type is the ‘marketplace’ implementation which only extends these roles by possibly adding an IDS App store in the resulting ecosystem. The ‘secure marketplace’ or ‘trusted marketplace’ type also implements one of the Vocabulary, Clearing House and Identity provider roles of IDS.

The final type of IDS Use case is that of the IDS Ecosystem. In this use case all types of IDS components and roles are present. This type of use case would come closest to the IDS Ecosystem to exist in the real world and can be a testbed or even a first version of this. None of the use cases found in the previous research fit this type.

In order to monitor use case progress the IDSA has established a ten step use case maturity scale (IDS Template Use Case Status Sheet V1, n.d.). This scale describes the process of first describing the use case idea to having IDS running in an enterprise context:

0. Use case is described as idea
1. Use case intended (at primary enterprise)
2. Use case prepared
3. Use case functionality defined
4. Use case technically specified
5. Requirements have been derived
6. Use case is projected
7. Use case implementation started
8. Use case realized with IDS
9. IDS Running in enterprise context

In addition, each use case is subject to a set of quality criteria (IDS Template Use Case Quality Criteria V1, n.d.) and characteristics. These are monitored throughout the process. These criteria include several key aspects of the purpose of IDS. For instance: the use case should combine multiple data sources, data types and data assets. More than one company should collaborate in the use case and the use case should support new ‘smart’ business models and services.

3.5 Purpose fit of IDS dimensions

In this chapter, an analysis is performed of the fit of IDS in regards to its intended purpose. The three step approach following the framework for the analysis of software reference architectures as presented by Angelov et al. (2012) is applied. This approach is will first be discussed in more detail. After which findings and results are discussed.

3.5.1 Approach

This chapter discussed how the framework for the analysis and design of reference architectures by Angelov et al. (2012) is applied to IDS, see Figure 4. This is a multi-step approach which ultimately determines which type of reference architecture IDS is. Secondly, this can be used to identify and discuss the fit of IDS with its type.

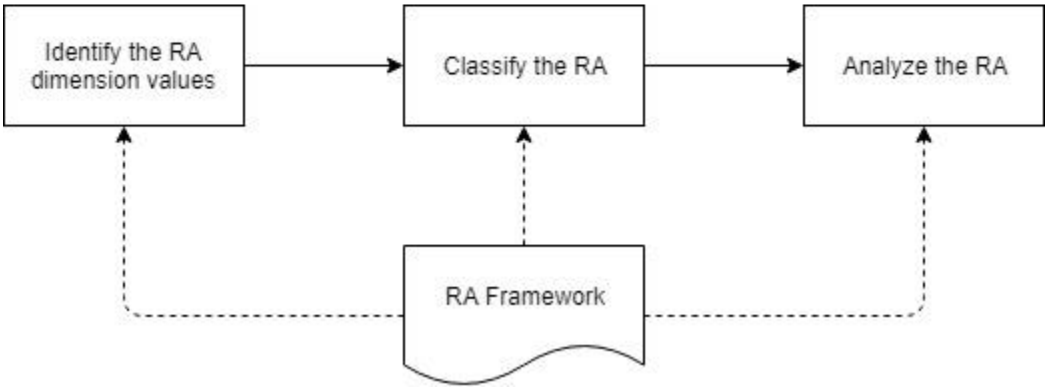


Figure 4 - Framework usage in the analysis of a reference architecture

3.5.1.1 Dimension values

The framework has specified eight sub-dimensions based on the context, goals and design dimensions. The context dimension is comprised of the three sub-domains. The first (C1) addresses the intended recipients of the reference architecture for which two values are possible: single organization and multiple organizations. The second (C2) sub-domain is concerned with addressing the stakeholders that are involved in the design of the architecture. The third sub-domain (C3) addresses when the reference architecture is defined. Two values are defined: preliminary and classical. Preliminary reference architectures are designed when the demanded technologies are not developed yet. Classical reference architectures are reference architectures which are designed the underlaying technologies of the architecture are already present during the design of the architecture.

The goal dimension is the second dimension specified. It encompasses only one sub-domain. This subdomain (G1) is concerned with addresses the reason for defining a reference architecture and only two values are defined: Standardization and facilitation. Standardization describes reference architectures which are develop with the aim of improving interoperability of architectures. Facilitation describes reference architectures created to aid in the design of architectures.

The third and final dimension is the design dimension and encompasses four sub-dimensions. The first sub-domain (D1) addresses what information the reference architecture describes, such as: components and connectors, interfaces, protocols, algorithms and policies and guidelines. A reference architecture can describe multiple values. In this case, the sub-domains D2, D3 and D4 can be stated for each of these values individually. The second sub-domain (D2) addresses at what level of details the reference architecture is defined. It's values are defined as being detailed, semi-detailed and aggregated. The third sub-domain (D3) is addresses the level of abstraction of the reference architecture. For this sub-domain are also only three values defined: abstract, semi-concrete and concrete. The fourth and final sub-domain (D4) addresses the level of formalization of the reference architecture. For this three values are defined: informal, semi-formal, and formal.

3.5.1.2 Mapping dimension values to the multidimensional space and analysis

After identifying the values for each of the sub-dimensions specified a mapping can be made to one of the types and variants defined in the framework as proposed by Angelov et al. (2012). One of these types is presented in **Error! Reference source not found.**. This could results in mapping more t han one type to the reference architecture. For each of the types mapped an analysis is performed. When more than one type is mapped to the reference architecture, divergent values are analysed.

Table 5
Type 5 reference architectures.

Dimension	Values
G1: Why	Facilitation
↓	↓
C1: Where	Multiple organizations
C2: Who	Research centers (D), Software design organizations (D, R), User organizations (R)
C3: When	Preliminary
↓	↓
D1: What	Components, algorithms, protocols
D2: How	Detailed or semi-detailed components and algorithms Aggregated or semi-detailed protocols
D3: How	Abstract elements
D4: How	Formal or semi-formal element specifications

Figure 5 - Example of a type of reference architecture as identified by Angelov et al. (2012)

3.5.2 Mapping of values

Each construct, concept or artefact can be described by its attributes. The approach of Angelov et al. (2012) utilizes eight dimension in as three step approach, as discussed in the previous section. This first step will assign values to each dimension based on the IDS Reference architecture. A summary of the assigned values is presented in Table 6.

Table 6 – Summary of IDS values mapped to the eight dimensions presented by Angelov et al. (2012).

	Dimension	**Value**			
G1	Why	Facilitation			
C1	Where	Multiple organizations			
C2	Who	Research centres, non-profit organisations, User organisations			
C3	When	Preliminary			
D1	What	Components and connectors	Policies and guidelines	Protocols	Algorithms
D2	How	Detailed	Semi-detailed	Semi-detailed, detailed	Semi-detailed, detailed
D3	How	Semi-concrete	Semi-concrete	Semi-concrete	Semi-concrete
D4	How	Semi-formal	Semi-formal	Semi-formal	Semi-formal

3.5.2.1 Goal dimension

The first dimension is sub-dimension G1, which is concerned with the goal of the reference architecture. One of the long term goals of the IDSA is for IDS to become a global standard, which would fit the 'standardization' value. Which is linked to reference architectures that focus on interoperability. The main goal of IDS is to enable sovereign data sharing across domains. IDS claims that the concept of sovereignty of data is new (IDSA, 2019a; Otto et al., 2019), which would fit the 'facilitation' value. Which is linked to aiding in the development of new and innovative systems. As the goal of standardisation is of long term, IDS is considered to be currently aimed more at facilitation than standardization.

3.5.2.2 Context dimensions

IDS is clearly designed to be applied in multiple and different organizations, even originating from different domains. It often describes and provides core functionality which is to be adopted or extended for application in the specific domain of the participating organisation (Otto et al., 2019). It does not restrict in which domains it is applied. In respect to sub-dimension C1, the value 'multiple organisation' is thus selected to be fitting for IDS.

Sub-dimension C2 is concerned with the stakeholders that are involved in the design of the reference architecture. The IDSA is involved in the design of IDS as a non-profit organisation and the Fraunhofer-Gesellschaft is involved in the design of IDS as a research centre. Via working groups and use cases, user organizations are involved in the design of IDS. A case could be made for software organisations to be involved in the design of IDS. However, in the case of IDS, software organisations are part of the user group and are even defined in the reference architecture to be part of the IDS Ecosystem. The European Union and other governmental bodies are involved in the development of IDS but this involvement is mostly limited to funding. As such, governmental bodies are not named as a separate group involved in the design of the reference architecture.

The fourth sub-dimension, C3, is concerned with the timing of reference architecture design. The IDS is designed to be implemented. One of the main concerns of IDS is to re-use existing technologies as to ease adoption and thus prevent to "reinvent the wheel" (Otto et al., 2019, p. 10). However, IDS is not limited to existing technologies. If innovative functionality is required, the reference architecture will provide the guidelines for the development of this new technologies. The value of IDS to be 'preliminary' is thus fitting.

3.5.2.3 Design dimensions

The design sub-dimension of D1 or the 'what is described'-sub-dimension is key to the design dimension. Each of the components of IDS identified in D1 are assigned values to map how detailed they are described (D2), how concrete they are described (D3), and how they are presented (D4).

A list of possible components for the D1-subdimension is provided by Angelov et al. (2012). IDS can be distinguished to contain descriptions of components and connectors, policies and guidelines, protocols, and algorithms.

The components and connectors component is described in detail. It is often presented at more than one aggregation level and for some components additional documentation and even basic implementations are provided, examples of this are the information model and the IDS Connector. These are meant to be extended when implementing use cases to fit the specific requirements of the use case and domain. The components and connector components are thus described in semi-concrete manner and often presented using semi-formal notation. Policies and guidelines are generally described in less detail by the reference architecture compared to the components and connectors. The policies and guidelines component is this assigned the value of semi-detailed for the D2 sub-dimension.

IDS also contains protocols discussing the interaction of different between components. Examples of this are the IDSCP and the processes described in the process layer of the architecture. As well as protocols, IDS contains algorithms supporting the operation of components of which data usage control mechanisms are an example. Both are described in semi-detail in the reference architecture and are elaborated upon by additional documentation provided by the IDSA. Protocols and algorithms are thus generally defined in IDS in semi-detail in semi-concrete descriptions and presented semi-formally. However, the additional descriptions and implementations of the protocols and algorithms would fit the detailed description value. Is it chosen to assign both semi-detailed as detailed values to the protocols and algorithms components.

3.5.3 Classifying and analysing the IDS Reference Architecture

The IDS reference architecture is clearly a type 5 reference architecture. This is based mainly on the why-sub-dimension (G1) and when-sub-dimension (C3) of IDS. A type 5 architecture describes innovative reference architectures that are used in the design of systems needed in the future. IDS can be considered a standard type 5 as the who-sub-dimension (C2) does not only contains research centres but also other stakeholders such as user organisations. In contrary to a variant 5.1 type reference architecture that is designed from an 'outside' perspective, mainly by research centres, focussing on futuristic research design not yet ready for system implementation and user involvement.

By identifying IDS as a type 5 architecture an analysis can be performed concerning divergences from typical dimension values. In the case of IDS two relevant divergence can be distinguished, the first in the what-sub-dimension (D1) and second in the 'how concrete'-sub-dimension (D3).

The divergence of the what sub-dimension is concerned with the policies and guidelines component assigned to IDS in the previous chapter. This component is not present in the typical values for this type. However, in the case of IDS it does fit the intended purpose. IDS is able to better support interest from different domains by stating relevant policies and guidelines concerning IDS and IDS implementation.

The second divergence is concerning the 'how concrete'-sub-dimension. In typical type 5 architectures components are described in an abstract manner. IDS describes most components at a semi-concrete level by elaborating on abstract concepts, defining definitions and even providing extendable descriptions of some core elements.

In both cases it is important to note the innovative aspects of typical type 5 reference architectures. The policies and guidelines component is often hard to define at this time. IDS has been capable to establish policies and guidelines. These are even described in semi-detail, for which the re-use of existing technologies can be an explanation. In addition, IDS seems to not be a purely innovative architecture. Its accompanying documentation and publications focus on supporting IDS implementation which has already impacted how concrete concepts in IDS can be defined.

An logical next step for IDS would be to evolve into a type 3 reference architecture, focussed on defining the 'best' based on currently available knowledge and technology. IDS is already well on its way of becoming a type 3 reference architecture with the only congruency being having the preliminary focus instead of a classical focus in the when-sub-domain.

Type 1 reference architectures describe standardization, a main long term goal of the IDSA. For this the goal of the IDS reference architecture has to change. It main focus should shift from supporting the development of new systems and technologies to describing a standard way of working and operating. Elements of this are already in place, which is in line of the long term goal. The interface components should be more elaborated upon in order to evolve into this phase.

3.6 Impact of IDS

It is important to know of the expected impact of adopting IDS into an organisation for this organisation to be able to make the decision to adopt. This chapter will discuss the expected advantages and opportunities provided by IDS as well as expected disadvantages and risks of IDS.

Before these are discussed however, it is important to discuss how IDS adoption can differ between organisations and use cases.

3.6.1 Influencing factors of IDS impact

IDS can be considered an enabling technology, as such the impact of IDS is heavily affected by 'what is enabled'. In other words, IDS impact is affected by the use case that is being implemented and the characteristics of the organisation it is being adopted by.

IDS use cases can differ from each other on several aspects. The first aspect is the IDS Ecosystem which the use case is joining. The use can for instance be about joining an already existing and commercially active IDS Ecosystem, an Ecosystem which is still in development or starting development of a new ecosystem.

The second aspect is about the role the organisation is going to take in the IDS Ecosystem. A difference can be made between being a data provider, data consumer, broker provider and app store provider. Or any of the supporting roles such as vocabulary provider, identity provider and clearing house. Any organisation can also be implementing more than one of these roles. For example by being a data provider and data consumer as well as an app store provider.

The third aspect of the use case is the selected method of implementing and configuring the IDS Connector. A company can choose to develop all software for the connector and have it certified and configured in house. This allows for the most custom implementation possible however also requires more expertise and also have more impact on expertise regarding IDS. However a company could also possibly outsource implementation, work with a technology partner or adopt the open source connector. Each requiring different levels of capabilities and having different levels of impacts on the organisation. For instance when a connector is adopted which has a lower trust level due to less implemented components, less types of data can be shared and thus value creation options are limited by this choice.

Also the characteristics of an organisation also affects the expected impact of adopting IDS. Characteristics as the type of value proposition, size, existing information systems, employees knowledgeability, role and position in the supply chain, existing collaboration with customers and partners all affect the process of adopting IDS and thus also the impact of this adoption process.

3.6.2 Reasons to adopt IDS - Advantages and opportunities of IDS adoption

IDS aims, of course, to provide benefits for its user. And even though use cases and companies can be very different, some aspects of IDS can be generalised. The IDSA makes several claims about the benefits of IDS adoption. Previous research indicated that no studies are found to quantify or validate these claims. Neither in scholarly research as in IDSA documentation. It has to be said that it would be hard to substantially quantify the impact of IDS given the intangible nature of the benefits.

The main benefit of IDS is its capability to enable data sharing while guarding data sovereignty. Ensuring data sovereignty enables data exchange between companies and even across security domains (IDSA, n.d.-a).

This provides several advantages and opportunities. The first of which is that it enables new business models to be developed within the IDS Ecosystem (IDSA, 2019b, 2019a). This is because use of data increases the value of these digital resources, however use of data normally also puts the resource at risk for misuse, alteration and copying. (Achatz et al., 2018; IDSA, 2018).

An example of a new type of business model that has become feasible is demonstrated by the research of Pant & Yu (Pant & Yu, 2018) who investigate IDS in the context of coopetition. They provide a modelling approach and find IDS to be an example of a successful win-win scenario. An indication which is also found by Chakrabarti et al. (2018). They found cycloid dependencies in the strategic rationale diagram, indicating a strategic motivation for data exchange within the IDS.

The second is applying IDS as a strategic link between data sources, by ensuring sovereignty more data sources can be connected (Otto, 2018). In doing so it becomes an enabler of technologies, such as applications and project in the fields of AI, IoT, and big data. Examples of such projects within the EU are GAIA X and AI4EU (IDSA, 2019b). GAIA X is for instance an initiative by the European Union to ensure free sharing and storage of data.

A third advantage of IDS is that it pushes for becoming a global standard. The webinar by Brost (n.d.) discusses for instance IDS in relation to a the new specification called DIN SPEC 27070, which specifies requirements to be met by a secure gateway (IDSA, 2019a). This allows for IDS to more easily gain market share. This also makes other standards more likely to line up with IDS and thus make interoperability more easy to establish. Also, by becoming a standard governance and design has become not 'of just one party'. It prevents vendor lock-in and allows for any party to comply with the requirements and offer IDS services.

The fourth advantage is the combination of peer-to-peer data sharing data and the federated design regarding governance. This makes IDS to be a trusted and secure platform for data exchange while also allowing for governance. Such trust and willingness to share information is mandatory for the creation of new agile business networks (Dalmolen et al., 2015).

The final advantage is that of connectivity. By allowing for easy implementation and configuration of IDS connectors any party can become part of an IDS Ecosystem. This also allows for small and medium sized enterprises to gain access to new business models.

3.6.3 Reasons not to adopt IDS - Disadvantages and risks of IDS adoption

The previous section discussed benefits of IDS. These benefits are often mentioned in publications of the IDSA, even though no real proof or quantification is provided. The IDSA does not state many disadvantages or risks of IDS specifically, as was also found in earlier research. Some risks and disadvantages of IDS can however be logically deduced and will this be discussed in this section.

The first disadvantage or risk of IDS is the scope of the functional requirements. It is focussed on enabling the sovereign exchange of data bus but does not pose any requirement besides that. For instance, no requirements are stated in regards to performance of the connectors. The IDSA is clear about this, stating that IDS only provides the non-domain specific semantics to make sovereign and secure data exchange possible (IDSA, 2019a). It is up to a specific implementation to apply these semantic in a specific use case.

The second disadvantage or risk of IDS is a logical results of its main goal: ensuring data sovereignty. A big part of the functionality described in the IDS Reference Architecture Model is to enable this main goal. In cases where there's no need for ensuring data sovereignty IDS will this be a to complex and costly solution (IDSA, 2019a). For instance when data is not exchanged over company border but instead only internally. Never leaving the 'safe' environment of the company's own existing systems and access controls.

The third is that a value chain needs to already exist for initial IDS adoption to be a success (IDSA, 2019b). Collaboration is key in IDS, without it no value can be created.

In line with this is the fourth risk of IDS, namely interoperability. It is important that the IDS Connectors that are developed are capable of easily connecting to existing cloud solutions, on premise systems, mobile systems, and so forth. When IDS is only capable of connecting to other IDS connectors data cannot enter or leave the ecosystem. Any gateway requires both an input as an output.

The final risk is that of migration. It is not always clear how existing standards relate to IDS. As many domains have own standards for parts of IDS. These standards will need to find a place in IDS, which is developed to be suited for this. However no discussions, reports or studies were found presenting use cases in which such a migration has taken place. An example of a possible migration is the IShare initiative which is being adopted by Dutch companies in order to structure user management. Can these companies easily switch to IDS or posed this adoption of IShare a barrier for IDS adoption?

3.7 Current state of IDS adoption

This section will discuss what is known about past and current IDS adoption projects. First the Dutch ecosystem will be discussed, identifying the state of art, drivers and barriers of IDS adoption in this context.

A lot of data sharing initiatives are taking place in the Dutch ecosystem. These initiatives are most often initiated by single companies, creating a scattered field initiatives and standards.

The Dutch practical research centre TNO, which backed by Dutch Government, has become an IDS Hub. Their internally developed IDS Connector is quite far along. IDS is also being picked up by Dutch companies, such as SCNN and KPN.

Currently there are no commercially active data spaces in the Dutch domain. The same goes for some of the supporting roles such as the identity provider. However, this doesn't have to be a problem as these roles would also be implemented by companies outside the Dutch domain. The German company Truzzt has declared to be implanting all roles distinguished by IDS.

TNO has indicated some drivers and barriers of IDS in the Dutch ecosystem. These are discussed in the rest of this section.

One of the main drivers of IDS in the Dutch ecosystem is that of IDS being backed by governing bodies and big companies. For instance the support and backing by the European Union. The governance and standardization components of IDS are what sets it apart from other initiatives, focussed on collaboration. This helps in paving the way for smaller companies by helping IDS overcome initial obstacles and by 'proofing value' of IDS.

Also, a second driver is the developments in regards to offering IDS-as-a-service. This approach is for instance being offered by Deutsche Telekom as an service offering. This would make it much more easy for interested organisation to implement IDS. Making IDS much more accessible for SMEs.

One of the main barriers could be in regards to migration to IDS. Specifically, the migration from an similar technology which has already been adopted. In the Dutch domain an example of this is IShare, a standard for sharing data in an uniform and consistent manner. Which is also part of the capabilities of IDS. It is to be seen whether adoption of IShare will hinder IDS adoption.

The second barrier is how IDS has chosen to implement identity providers. Because of this the IDS Identity provider functionality does not completely fit already existing standards. Making it hard to use one of the many existing identity provider services within the IDS Ecosystem.

3.7.1 Use cases state of art

In previous research 25 use cases were analysed of which 2 scholarly. Each use cases was mapped unto one of the stages of the Technology Life cycle by Nolte (2008) based on Hansen, Hoepman & Jensen (2015). The result of this is presented in Table 7.

Table 7 – Number of use cases per stage of the technology life cycle by Nolte (2008) *based on Hansen, Hoepman & Jensen* (2015).

Stage	**Idea**	**Research**	**Proof of Concept**	**Pilot**	**Product**	**Outdated**
Number of use cases (%)	0 (0%)	1 (4%)	9 (36%)	6 (24%)	9 (36%)	0

4 IDS in relation to other initiatives

In this chapter IDS is discussed in relation to other initiatives. The purpose of this is to establish how IDS is related to them. This discussion is mainly based on work from previous research which has done an extensively exploratory literature search for publications, scholarly and otherwise, related to IDS and related technologies. As such this works is based also on IDSA published documents, which are cited as normal.

By defining IDS in the context of others technologies, it is possible for this research to determine what other fields of research might contain helpful publications in answering the research questions.

4.1 European Union

The IDS reference architecture does not specify one specific context or domain to be applied to. On the contrary, it is designed to be applied across domains, surpassing international borders and standards. One of the main goals of the IDSA is for IDS to become an international standard (IDSA, n.d.-a). It his hard specify all the legislation, standards and regulations which could be relevant to IDS. IDS development originates in the European Union and thus IDS has recognized mostly European legislation, standards and regulations.

The main development of IDS originates in Germany where Fraunhofer ISST is located. However, the development of IDS is not limited to Germany and has become part of several strategies of the European Union such as the Strategic Value Chain of the Industrial IoT, Digitizing European Industry (DEI)(IDSA, 2019a). In addition, IDS is one of the project to receive a grant from the European Union's Horizon 2020 research and innovation program. Other project receiving grants under this program are listed on the IDSA website and can be found in Table 8.

IDS also predicts that it could be a key enabler for applications and project in the fields of AI, IoT, and big data. Examples of such projects within the EU are GAIA X and AI4EU (IDSA, 2019b). GAIA X is an initiative supported by the European Union for the development of an European cloud service (Gyles & VPNOverview, 2019). The main purpose of GAIA X is to create a European data economy by ensuring sovereignty and security of European data. In order to achieve this cloud provides are connected and free movement of data is enabled. IDSA believes IDS and GAIA can supplement each other. IDS technologies can be used as a key technological enabler in achieving the GAIA X goals and thus reducing the time to market of the GAIA project (IDSA, 2019a) by providing the infrastructure components and a interoperable standard (IDSA, 2019b).

Table 8 – Other EU projects receiving grants under the Horizon 2020 research and innovation program.

Eu projects (IDSA website)
Additive ManufacturABLE (AMABLE)
Boost 4.0
AI4EU
QU4LITY
DIH2
Musketeer
MARKET 4.0
MIDIH
OPEN DEI
LEVEL UP

The European Union has recently implemented the General Data Protection Regulation (GDPR) (European Commission, 2016). This EU law is concerned with protecting the digital privacy and security of the personal information of people. In almost all companies personal data is stored, however this is most often only for administrative internal purposes. IDS is a reference architecture which enables data exchange between companies and even across security domains (IDSA, n.d.-a). As such, GDPR will have impact on the design of the IDS reference architecture.

4.2 Cooperation with other initiatives

The IDSA states to have agreements of formal cooperation with several other organisations that are providing relevant standards (IDSA, 2019a). In addition to this, the position paper by Achatz et al. (2018) discusses the IDS in relation to several standards. The third document to mention cooperation is reference architecture. As it also discusses it's relation to other relevant standards. The most import of these discussions are elaborated upon in the next sections, a summary of the related standard discussed in each source is presented in Table 9.

Table 9 – Listing mentioned cooperation of IDS with other organisations and initiatives

Reference architecture version 3.0	Formal cooperation	Position paper by Achatz. et al.
Platform Industrie 4.0	Platform Industrie 4.0	RAMI4.0
FIWARE Foundation	FIWARE	
iShare	iShare	
	Responsible Research and Innovation (RRI)	
Industrial internet consortium	Industrial internet consortium (IIC): IIRA reference architecture	IIRA
Industrial Valuechain Initiative	Industrial Valuechain initiative (IVI)	IVI
OPC Foundation	OPC-F	
Alliance for Internet of Things		IoT-A
Big Data Value Association		
Data Market Austria	DMA	
Data Trading Alliance	DTA	
eCl@ss *(vocabulary)*		
Standardization Council Industrie 4.0		

World Wide Web Consortium		
ISO42010		
4+1		

4.2.1 Industry 4.0 – RAMI 4.0

The term Industry 4.0 aggregates a set of current innovations that have or are expected to have a revolutionary impact on the way industry operates. It is also known as Industrie 4.0 in Germany where it originates from, or Smart industry. The concept states that there have been three previous industrial revolutions, the first was the result of the invention of the steam engine. The second occurred following the application of electricity and application of production lines. The third revolution started following the digital innovations in the second halve of the twentieth century. The Industry 4.0 revolution expands onto the third revolution and is characterized by relationships and networks. It is about another way of thinking. The new way of thinking sees the organisation as a distributed network of intelligent system as opposed to the currently most common perspective of an organisation as a pyramidal structure (Cimini, Pinto, & Cavalieri, 2017).

Some main key concepts of Industry 4.0 are interoperability, virtualization, decentralization, real-time capabilities, service orientation and modularity (Cimini, Pinto, & Cavalieri (2017) based on Hermann et al. (2016)). Industry 4.0 technologies allow for more flexible, autonomous and effective data exchange. Allowing the implementation of new innovative technologies that allow for more personal and agile product development (Oztemel & Gursev, 2020).

The IDS reference architecture is being developed within the Industry 4.0 era. The IDSA sees IDS to be one of the enabling technologies of Industry 4.0. Where Industry 4.0 is concerned with the application of the above 9 field of innovations in the industry domain, IDS will be concerned with developing the technology needed to enable the exchange of data across domains (Figure 6)(Otto et al., 2018). For instance, in the domain of big data analytics and artificial intelligence. In this context IDS can be one of the key technologies for making data sources available. By enabling easy, secure and sovereign data exchange more data sources will be accessible (IDSA, 2019a; Sarabia-Jacome et al., 2019)

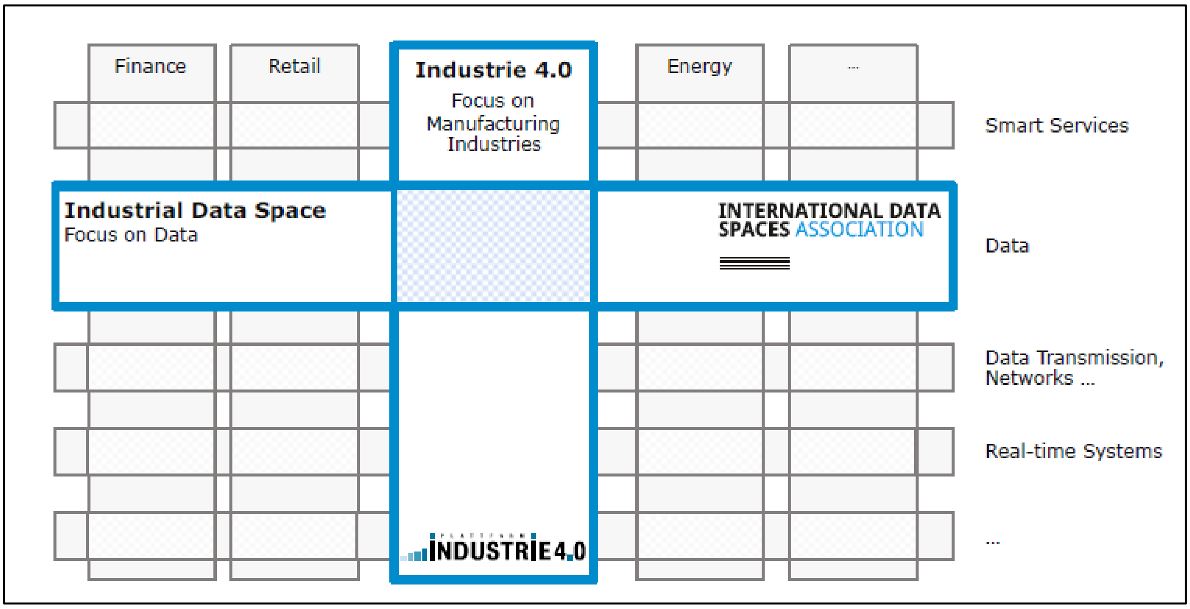


Figure 6 - Relations with Platform Industrie 4.0 (Otto et al., 2018).

The Reference Architecture Model Industry 4.0 (RAMI4.0) is put forward by the platform Industrie 4.0. Achatz. et al. (2018) discusses the alignment of IDS with RAMI4.0. RAMI4.0 is an adaptation of the Smart Grid Architecture Model (SGAM) to fit industrial production (Cimini, Pinto, & Cavalieri, 2017).

Both frameworks have a similar layer structure. However, due to the focus of RAMI4.0 on the integration of physical assets, it presents an additional layer below integration/system to incorporate this. This focus on the integration of physical assets results in more divergencies between the frameworks (Cimini, Pinto, & Cavalieri, 2017). Such as more prevalent data processing, analytics and transformation aspects. Also, the IDS presents a vocabulary of formally defined terms, which is missing in RAMI4.0.

Both framework have some kind of gateway, in IDS this is the connector, in RAMI4.0 this is the administration shell. These are similar in function, however where the administration shell is required to be an origin source of information shared, the IDS connector doesn't have to be.

The differences between IDS and RAMI4.0 can be describes the first enabling the sharing of data as an asset while RAMI4.0 is focussed on enabling information sharing and the integration of data associated with physical assets. IDS is therefore applied between companies and even across domains, RAMI4.0 is more suitable for application within company borders or other inherently trusted ecosystems.

4.2.2 FIWARE

In the core statements of IDS the IDSA states to have formal cooperation with FIWARE (IDSA, 2019a). FIWARE is a platform of open source software aimed at providing smart services (FIWARE, 2015). It provides components which can be combined to implement software solutions. It is therefore not a reference architecture, but it provides the building blocks needed to implement a reference architecture. It origin lays in the EU, however it aims to accepted and adapted on a global scale. The IDSA position paper (Achatz et al., 2018) states that the FIWARE initiative has a high technical readiness level. IDS aligns with FIWARE by providing new insight in trust, interoperability and governance of data usage.

Two implementations of IDS using FIWARE components have been found in the research body. Sarabia-Jacome et al. describe an IDS architecture implementation using FIWARE in the port of Valencia (Sarabia-Jacome et al., 2019). One use case is implemented in which three datasets are connected to the data space. This data space is then used in an application applying big data to improve decision making. The second implementation of the IDS reference architecture using FIWARE components is presented by Alonso et al. (2018). They developed an IDS implementation in which factory information is connected to the data space. Then both a system for predictive maintenance and a system for quality control is connected to the dataspace, consuming the factory data via the IDS.

4.2.3 IShare

IShare provides a scheme for identification, authentication and authorisation in the context of data exchange. It provides the data owner with control of the data shared, when it is shared, with whom it is shared and for how long. Also, it is designed to be easy in use, meaning that little to no effort is needed to set up integration, even with previously unknown parties. The IDSA and IShare have both declared cooperation (IDSA, n.d.-d, 2019a; IShare, 2018). IShare is stated to be well aligned with IDS as it can be applied in the implementation of the trust mechanic in IDS implementations.

4.2.4 Responsible research and innovation

Responsible research and innovation (RRI) is a science policy framework supported by the European Union (RRI-Practice, n.d.). It is concerned with guiding research and innovation with respects to ethics, sustainability, and social impact. It recognizes the potential impact of new technologies and impacts on society. The framework aims to better connect societal stakeholders during design. The IDSA has stated to have formal cooperation with this initiative (IDSA, 2019a). This is reflected IDS development as in all phases of the development stakeholders were heavily involved.

4.2.5 IIC – IIRA Reference architecture

The Industrial Internet Consortium (IIC) is an organisation which aims to guide the industrial internet by promoting the development and adoption of standards, best practices and reference frameworks. It is a program of the Object Management Group (OMG) and its members include some leading industrial companies such as Dell, Microsoft, and BOSCH. The IIC is one of the organisations the IDSA is in formal cooperation with (IDSA, 2019a). The initiative is mainly an US based initiative.

One of the initiatives of the IIC is the development of the Industrial Internet of things Reference architecture (IIRA)(Ishiguro et al., 2017). The viewpoints of which are shown in Figure 7. The IIRA is focussed on overcoming IIoT challenges, mainly concerning integration and operability (Cimini, Pinto, & Cavalieri, 2017). Achatz et al. (2018) compares IDS to the IIRA and found the frameworks to be aligned even though there's difference in perspectives and focus. IDS can mapped to mainly the functional viewpoint of IIRA with some aspects of IDS correspondent with the usage and implementation viewpoints. The concepts of the IIRA are more conceptual in nature whereas IDS describes these in a more detailed and machine readable format where possible. The IIRA and IDS are investigating the application of the IDS connector architecture as a possible implementation gateways in IIRA.

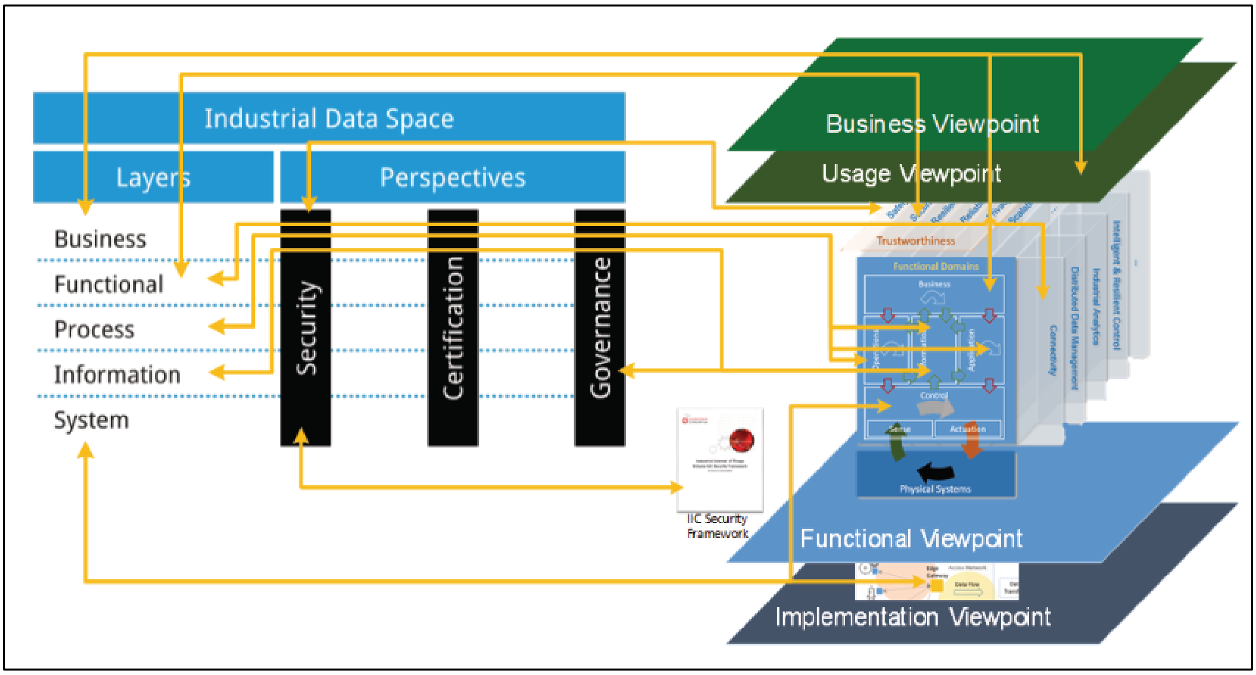


Figure 7 – A mapping of the IDS reference architecture to Industrial Internet Reference Architecture as provided by Achatz. et al. (2018).

4.2.6 IOT-A Architecture reference model

The Internet of Things – Architecture (IoT-A) is an EU project which delivered an reference architecture model in relation to IoT, more specifically the integration of physical devices and isolated solutions. According to Achatz et al. (2018) the presented architecture reference model provided insights and a list of requirement that could be very relevant to IDS. Achatz et al. (2018) also state that IDS can be related to IoT-A by applied IDS as the architecture connecting platforms and networks such IoT, Cloud, and for instance Big data Analytics.

4.2.7 IVI

The Industrial Value Chain Initiative (IVI) an Japanese initiative regarding data sharing between Smart Manufacturing Units (SMU). The IVI has presented a reference architecture to support this. The position paper of Achatz et al. (2018) describes IDS to be containing more detailed descriptions. Also, IDS has a different focus than the reference architecture of the IVI. While IDS is focused on data privacy and security, the IVI reference architecture is more focussed on the business related aspects such as organisational considerations and business processes. The IDSA and the IVI are working on the alignment of their two frameworks and have stated formal cooperation (IDSA, 2019a).

4.3 Digitization and Digitalization

It is first important to note the difference between the terms digitization and digitalization. The term digitization is closely related to digitalization. Queiroz et al. (2019) notes for instance confusion regarding the difference between these terms within the domain of digital supply chains. The terms are often used interchangeably, however they do differ in meaning.

Digitisation describes the process of fitting physical attributes and activities into a digital world (Legner et al., 2017). Digitisation will however also impact the organisation and its environment. This impact is related to the term digitalization (Legner et al., 2017).

The terms digitalization and Industry 4.0 are often used together. Schuh et al. (2020) mention it as part of the development path towards Industry 4.0. Figure 8 shows that digitalisation is comprises one of early steps towards Industry 4.0, encompassing computerisation and connectivity.

Schuh et al. (2020) also state that both digitalisation and Industry 4.0 require an holistic approach. Not only the technology component can be addressed. It is required that the company or companies involved also transform in terms of organisation and culture, becoming more flexible and adaptable to new production and production techniques.

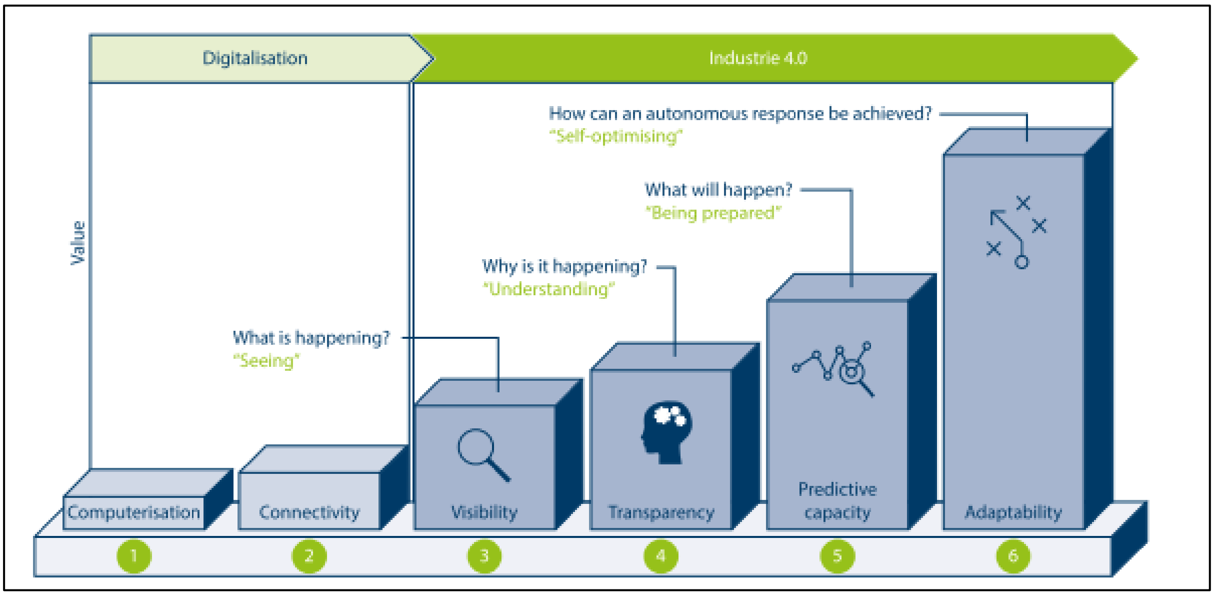


Figure 8 – Digitalisation as part of the stages in the Industry 4.0 development path as presented by Schuh et al. (2020).

4.4 Discussion

When looking at the stages of the Industry 4.0 development path (Figure 8) by Schuh et al. (2020) it becomes clear that IDS can also be related to digitization and digitalization. This because of one the main capabilities of IDS is to enable data sharing, or in other words: help establish connectivity. IDS is however not solely related to connectivity as it also helps enabling visibility of data.

Industry 4.0 is probably in general most closely related to the concepts of IDS. In such that IDS is mainly an enabler of other Industry 4.0 concepts fulfilling the aspect of data and information sharing of Industry 4.0. IDS as being an enabler of this aspects also is concerned with the crosscutting demands that are related to this aspect. Data and information is for instance connected several other layers such as the business processes layer.

5 First stages of maturity model development based on Becker et al. (2009)

This chapter will discuss the approach for developing the maturity model and the components it should encompass. Components are the separate parts that can be distinguished of which a maturity model or approach typically consists of. For example, O'Donovan et al. (2016) states that maturity models typically contain dimensions describing specific capabilities and maturity levels describing stages of maturity.

In order to structure the maturity model development process the procedure model by Becker et al. (2009) is applied. This procedure model distinguishes 8 steps which can be found below. In this chapter steps one to 3 are developed and discussed. The next chapters will focus on step in which the actual model is iteratively designed and tested.

The 8 step procedure model by Becker et al. (2009) for the development of maturity models:

1. Problem definition
2. Comparison of existing maturity models
3. Determination of development strategy
4. Iterative maturity model development
   a. Selecting the design level
   b. Selecting the approach
   c. Designing the model section
   d. Testing the results
5. Conception of transfer and evaluation
6. Implementation of transfer media
7. Evaluation
8. Rejection of maturity model

This chapter will discuss steps one, two and three of this procedure model as applied to the development of the IDS maturity model. In the following chapters also two iterations of maturity model developments are presented which is related to step 4. A transfer model is established which is related to step 5. Finally the model is applied in a single use case which is also related to step 5. But first some general topics are discussed that help provide context to the design choices made in the development of the IDS maturity model.

5.1.1 Stages of adoption

During a typical adoption process several stages of adoption can be identified. Kim and Crowston (2011) define three main stages: pre-adoption, adoption stage, post-adoption. During pre-adoption the technology is examined and the company will make a consideration whether to adopt the technology. After this, during the adoption stage, company can develop an intention to adopt the technology and will consequently develop or buy, adopt and start to use the new technology in the company. The final stage is post-adoption in which the company will continue to use the technology (Kim & Crowston, 2011).

In terms of the IDS maturity model to be developed: the goal of the IDS model to be developed in this research is to support a company to make the adoption decision. Following the adoption stages this means that the model should help the company examine the IDS technology and help the company determine their intention to adopt IDS during the pre-adoption stage.

One can also view adoption stages from the perspective of the innovation life cycle by Rogers (2010). The innovation life cycle describes a bell curve showing the adoption of a new product or innovation divided into five groups: innovators, early adopters, early majority, late majority and finally laggards. IDS as an innovation is in chapter 3.7 identified to be showing some first commercial applications but mostly use cases in the pilot or proof of concept phase. This could suggest most companies to be in the innovators or early adopters phase. The development of an IDS maturity model for IDS adoption could help enable IDS adoption to also be started by the early majority.

5.1.2 UTAUT and supporting the adoption decision

The Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) presents an universally accepted model describing user acceptance of information systems. UTAUT is in this research applied in the discussion on which components the maturity model approach should contain in order to support the adoption decision of IDS.

The model poses four direct determinants of user acceptance and usage behaviour. Figure 9 shows graphical overview of the model. The model shows performance expectancy, effort expectancy and social influence as predictors of behavioural intention. Behavioural intention is a predictor of use behaviour, together with the facilitating conditions determinant. These determinants are defined by Venkatesh et al. (2003) as follows:

- Performance expectancy is defined as “the degree to which an individual believes that using the system will help him or her to attain gains in job performance”.
- Effort expectancy is defined as “the degree of ease associated with the use of the system”.
- Social influence is defined as “the degree to which an individual perceives that important others believe he or she should use the new system”.
- Facilitating conditions is defined as “the degree to which an individual believes that an organizational and technical infrastructure exists to support use of the system”.

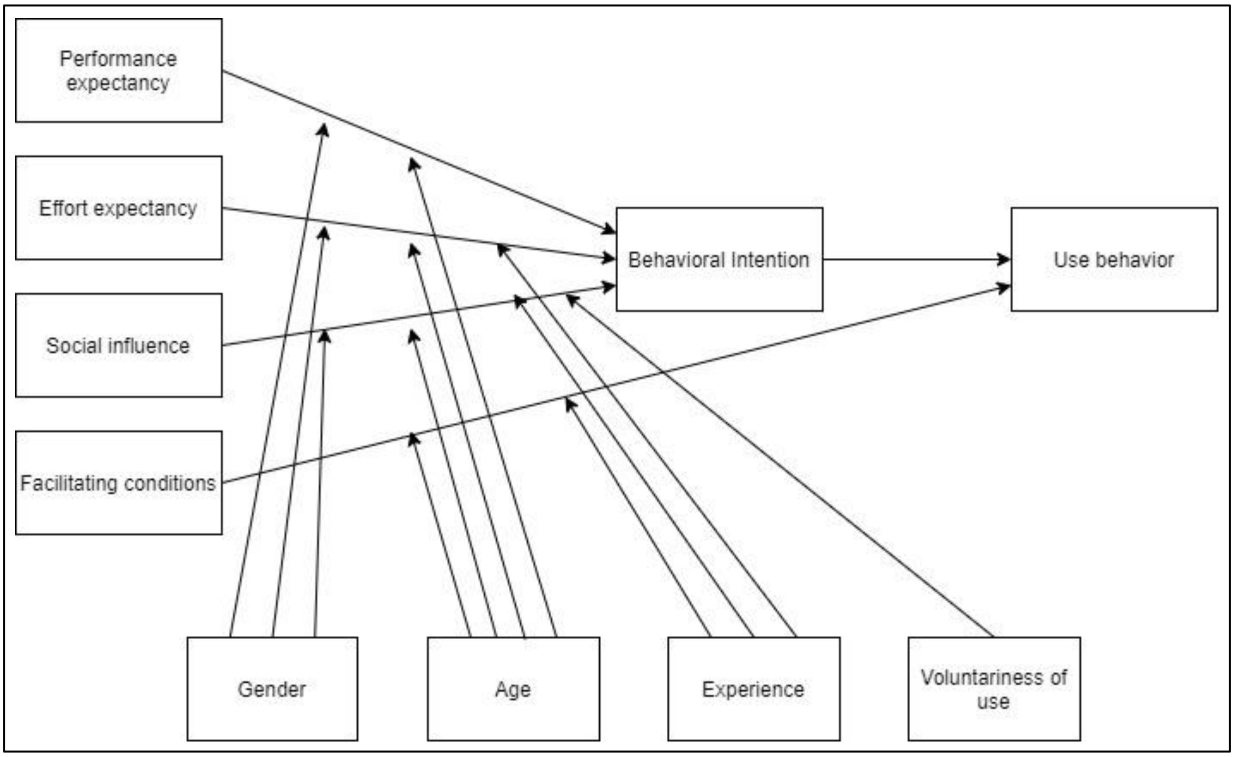


Figure 9 – Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003)

Of performance expectance, effort expectancy and social influence the determinant performance expectancy is considered the strongest predictor of behavioural intention. Each of the four determinants is subject to moderation. For this the gender, age, experience and voluntariness of use variables are distinguished.

This research poses that the IDS adoption decision is congruent with behavioural intention within this model. While actual adoption and use of IDS is congruent with use behaviour. The maturity model to be developed is aimed at supporting the adoption decision. This means that supporting the adoption decision of IDS can be done best by supporting decision making regarding the performance expectancy, effort expectancy and social influence indicators and their moderating variables.

The moderating variables of age and gender of decision makers facing the decision to adopt IDS cannot be affected as these are characteristics of the organisation facing the decision. The effect of the effort expectancy determinant is stronger in cases of limited experience. The effect of the social influence determinant is stronger in cases of limited experience and in case in which use is mandated.

It is not the purpose of the model to bias decision making of companies towards or against choosing to adopt IDS. The purpose of the model is to make sure that a company will choose to adopt, or not to adopt, IDS based on false perceptions and expectations. The model to be developed should focus on supporting the companies' ability to have a correct valuation of the expected effort involved in IDS adoption and the expected performance and impact of IDS adoption on the organisation. This will also help reduce the chance of biased social influence affecting the IDS adoption decision. Mainly because a lack of experience is substitutes by the knowledge contained in the model.

5.1.3 Maturity vs readiness

So far in this research the term maturity has been used to describe the kind of model that is to be developed. Maturity models are models with the main focus to support organisations in reaching an higher level of maturity and capabilities regarding the items or dimensions they describe (Mittal, Khan, et al., 2018). This is normally a step-by-step continuous improvement process (Mettler, 2011).

The term readiness and readiness assessments are closely related to maturity models but have a slightly different purpose. Readiness assessments describe the level of preparedness regarding the purpose of the model (Benedict et al., 2017). This is different to maturity models which describe level of progress towards a goal for which progress is most often already started. In terms of adoption stages: readiness assessments are related to pre-adoption and maturity models are related to adoption and post-adoption.

During this research the term maturity is mainly used where sometimes the term readiness would also fit or might even describe the purpose of the model better. This is decided as the term maturity describes is associated to more stages of the adoption process. The IDS model will aim to provide insight in the minimum maturity required to start IDS adoption, which would fit the term readiness assessment. It will however also provide insight in establishing a strategy to support IDS adoption by the organisation and the impact to be expected by the organisation of adopting IDS. This would fit the term maturity more. In general in order to not confuse the readers it was chosen to use one term of which the term maturity was considered to be most fitting.

5.2 Problem definition

This section discusses the problem definition stage of both the maturity model development procedure by Becker et al. (2009) and the design cycle by Wieringa (2014).

5.2.1 Stakeholders

As discussed before IDS enables companies to take several distinct roles in an ecosystem. The model will only be primarily focused on manufacturing and logistics organisations aiming to take the role of data consumer or data provider in an existing IDS ecosystem. This will help focus development of the maturity model. Manufacturing and logistics organisations make up the most common types of organisation in the supply chain. This role is selected as it is the most common role for an organisation to join IDS. Other roles can be third party organisations such as software providers, governmental bodies or governance bodies. The IDS maturity model will not be developed with these roles in mind as these are more of a specialised nature. The same reasoning can be posed for the aspect of joining an existing IDS ecosystem.

Some maturity models make a distinction between SMEs and big enterprises, focussing on the specific needs of SMEs. The IDS maturity model will not be focussed on a specific size of company.

5.2.2 Goals

A company is required to adapt to changes in the environment in order to remain competitive. Part of these changes are innovation in the IT domain. As discussed in the previous chapters IDS and Industry 4.0 are current innovations which companies are faced with. As each company is faced with a technology such as IDS it is required to investigate this possible opportunity resulting in the decision to adopt or not to adopt the technology. SMEs, for example, are often aware of the need to investigate something but also do not know how this can be done (Maier & Student, 2015 as cited by (Mittal, Khan, et al., 2018).

During this early pre-adoption phase the company typically does not yet have much knowledge regarding the new technology, which in this case is IDS. The UTAUT model as discussed earlier provides insight in determinants of user acceptance and usage behaviour. Having not much knowledge regarding a new technology will create uncertainty which can be the performance expectancy or effort expectancy determinants of behavioural intention. Possibly in a similar way as to how experience influences these.

Also it is not the intention of this research to bias decision making towards or against IDS adoption. The purpose of the research is only to improve the process of decision making. This can be done by removing bias in the decision making process and by improving the efficiency of the decision making process. This could also result in companies to be less likely to adopt IDS when using this model. It is most important for the model to be developed decrease uncertainty regarding IDS adoption.

As for supporting the IDS adoption decision process, it would make most sense to help organisations make an unbiased assessment of their readiness towards IDS. Readiness is related to the pre-adoption stage of the adoption process. Such an readiness assessment will mainly impact the effort expectancy determinant of UTAUT. This because it will enable an organisation in identifying those aspects of the organisation in which the company is required to invest in before and during IDS adoption.

Bias in effort expectancy can be further reduced by also helping the organisation identify the factors that can positively or negatively affect the required effort in adoption IDS. Or in other words, some kind of approach which supports the development of maturity growth strategies.

Secondly it would also make sense to help organisations make an unbiased assessment of the impact of IDS adoption in their organisation in regards to post-adoption capabilities and maturity. This would mainly impact the performance expectancy determinant of UTAUT.

By providing insight in both the expected effort and the expected impact of IDS adoption on the organisation the organisation will be better able to establish a cost-benefit assessment for adopting IDS. Helping companies in establishing a business case for IDS adoption and making a go or no-go decision regarding IDS adoption.

Summarised in terms used by Becker et al. (2009): the maturity model is to be developed for use in a partial discipline. Also, the maturity model is targeted externally as it is aimed to be used by any company interested and will not be focussed on use by a specific company.

5.2.3 Design problem and requirements

Wieringa (2014) defines a summary template called the 'design problem'. By now this can be filled in resulting in the following summary of this maturity model to be developed:

- Improve *IDS adoption decision making of organisations facing the decision to join an existing* IDS ecosystem as an data provider or data consumer
- By *designing a maturity model based approach specific for IDS*
- That *companies can use to determine expected required effort and expected impact of IDS adoption*
- In order to *reduce bias and uncertainty in the decision making process*

The requirement of the model allowing the company to determine the expected required effort and expected impact of IDS adoption are not the only requirements of the model. They are however the main requirements as they are directly related to the goal of the model. The main list of requirements include:

- Determine expected required effort and expected impact of IDS adoption: these functionalities directly support the main goals of the model.
- Holistic approach: the model should describe the organisation or company as a whole. Even though IDS is mainly focussed on data sharing, its impact should be considered across a complete spectrum of aspects as not to overlook any.
- Apply best practices: By applying best practices and aligning with 'bigger' more researched fields existing processes/knowledge can be used by the organisation in assessing IDS readiness and impact. This will ease the use of and the understanding of the model. It will also allow for the model to be more easily integrated in existing strategy processes which the company is involved in.
- Quantified measurements: The more quantified the results are, the more trust a manager can place in the results. Having only suggestions will limit the impact of the model as uncertainty still exists.

5.3 Comparison of existing maturity models

This section will present the findings related to step 2 of the maturity development procedure by Becker et al. (2009). In this section existing maturity models for IDS and similar initiatives such as Industry 4.0 are retrieved and analysed. This will provide insight in the current state of art of maturity model development related to these initiatives, the components these models consist of and will provide the foundation on which the development approach for the IDS maturity model can be based.

In order to provide an exhaustive and correct view of existing models a systematic literature review is performed. First the approach to and the result of this systematic literature review are discussed. Secondly the literature found is analysed. Lastly, a discussion is made regarding the state of art of maturity models and how these model can be used to develop the IDS maturity model, if possible.

5.3.1 Systematic literature review

The systematic literature review is performed following the approach as applied by Wolfswinkel et al. (2011). This approach is already discussed in chapter 2.4 (Systematic literature review).

This systematic literature review uses the Scopus search engine to search and retrieve literature. In addition, Google Scholar is used to retrieve literature that is not available through Scopus.

The search queries are based on several groups of keywords. The first group relates to the distinction between “maturity model” and “readiness assessment”. The second group relates “data exchange”, “data sharing”, “industry 4.0”, “industrie 4.0” and “International Data Spaces”. These keywords are applied in two different queries. The first of which retrieved 273 results, the second of which retrieved 151. An overview of the queries used and the results retrieved can be found in Table 10.

The following exclusion criteria are applied in order to narrow down the amount of results:

- Year or publishing < 2019, and number of times cited < 3
- Year of publishing >= 2019, and number of times cited < 1
- Subject area is in: Business, Management and Accounting, Computer Science, Engineering, Social Sciences, Decision Sciences
- Full text is not accessible
- Not writing in English or German

After applying the exclusion criteria a selection is made based on title. This selection is than further refined by also reading the abstract and removing any duplicate results. The resulting set of literature contained 42 results. After analysing backwards and forwards citations 34 more results were selected to be of interest. The resulting body of literature thus contains 76 results. After reading all pieces of literature fully, another 16 results were removed leaving a total set of 59 results.

Table 10 – Resulting sets of literature when applying the established search queries to the search engine.

Keywords	Search query	Results
“maturity model” or “readiness assessment”, “data exchange”, “data sharing”, “industry 4.0”, “Industrie 4.0” or “industrial data spaces”	(TITLE-ABS-KEY (maturity AND model) OR TITLE-ABS-KEY (readiness AND assessment)) AND TITLE-ABS-KEY ("Industry 4.0" OR "Industrie 4.0" OR "data sharing" OR "data exchange") AND (LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "COMP") OR LIMIT-TO (SUBJAREA , "BUSI") OR LIMIT-TO (SUBJAREA , "DECI") OR LIMIT-TO (SUBJAREA , "SOCI"))	273
“maturity model” and “readiness assessment”	(TITLE-ABS-KEY (maturity AND model) AND TITLE-ABS-KEY (readiness AND assessment)) AND (LIMIT-TO (SUBJAREA , "ENGI") OR LIMIT-TO (SUBJAREA , "COMP") OR LIMIT-TO (SUBJAREA , "BUSI") OR LIMIT-TO (SUBJAREA , "DECI") OR LIMIT-TO (SUBJAREA , "SOCI"))	151

5.3.2 Concepts

In order to analyse the retrieved result concept mapping is applied. An approach which is also applied by Wolfswinkel et al. (2011) and which is based on Webster & Watson (2002). Concept mapping entails the labelling of any insight or findings relevant to the questions posed. By grouping these labels in an iterative approach sets of labels are created which relate different sets of literature to each other. These concepts can be shown in a concepts matrix (Wolfswinkel et al., 2011).

In this research several levels of concepts have been identified. The concepts identified could be group further creating a multi-level hierarchy of concepts. Table 11 displays the amount of articles found to be related to each of the highest level of concepts consists of. A complete overview of the found publications and the concepts related to each of the publications can be found in appendix chapter 12.1. These high level concepts can be described as:

- maturity models: this grouping of concepts consists of literature presenting fully developed maturity models and readiness assessments. Sub-concepts include amongst others, dimensions, maturity stages and domain of application.
- maturity models literature review: this grouping of concepts consists of literature presenting literature reviews.
- factors influencing adoption: this grouping of concepts consists of literature presenting factors that influence the success or failure of adoption. Sub-concepts include amongst others, enablers, barriers, drivers, requirements and success factors.
- adoption (decision) process: this grouping of concepts consists of literature presenting insight in the adoption process in which maturity models and readiness assessments are applied.

Table 11 – Number of articles found related to each of the highest level concepts.

	Maturity models	**Maturity models Literature reviews**	**Factors influencing adoption**	**Adoption (decision) process**
Number of articles	32	10	19	3

5.3.3 Comparison of existing maturity models

This section will discuss the existing maturity models as found by the systematic literature review. These are all related to the high level concept of maturity models. Table 12 presents an overview of the maturity models found. The rest of this section will analyse these maturity models from different perspectives. It is important to note that this analysis will mostly be on a component level and will not discuss the specific differences between how these components are operationalised by the different models. This more in depth analysis will be part of chapter **Error! Reference source not found.** in which the IDS model is developed.

Table 12 – Existing Maturity Models as discovered from the systematic literature study.

#	**Article**	**Dimensions (items)**	**Maturity levels**	**Domain(s)** A = I4.0 B = Manufacturing C = L4.0/SC4.0 * = SME	**Name**
1	(Schumacher et al., 2019)	6 (30)	4	A	
2	(Weber et al., 2017)	0	6	B	M2DDM
3	(Gökalp et al., 2017)	5 (5)	6	A B	
4	(Bibby & Dehe, 2018)	3 (13)	4	A	
5	(Santos & Martinho, 2019)	5 (34)	6	A	
6	(Facchini et al., 2019)	7 (16)	5	A C	
7	(Pacchini et al., 2019)	8 (48)	5	A	
8	(Frederico et al., 2019)	4 (41)	4	A C	

9	(Oleśków-Szłapka & Stachowiak, 2019)	3 (5)	5	A C	
10	(Akdil et al., 2018)	3 (13)	4	A	
11	(Canetta et al., 2018)	5 (36)	4	A	
12	(Stefan et al., 2018)	3 (44)	unknown	A B *	
13	(Asdecker & Felch, 2018)	3 (15)	5	A C	DPMM4.0
14	(A. De Carolis et al., 2018; Anna De Carolis et al., 2017)	4 (18)	5	A B	DREAMY
15	(Lin et al., 2020)	3 (16)	6	A B	
16	(Mittal et al., 2020; Mittal, Romero, et al., 2018)	5 (23)	5	A B *	SM3E
17	(Pirola et al., 2019)	5 (24)	5	A *	
18	(Rauch et al., 2020)	4 (42)	5	A *	
19	(Schumacher et al., 2016)	9 (62)	5	A B	
20	(Chonsawat & Sopadang, 2019)	5 (43)	5	A *	
21	(Leyh et al., 2017)	4	5	A	SIMMI 4.0
22	(Günther Schuh et al., 2020)	4	6	A	ACATECH
23	(Jung & Kulvatunyou, 2016)	4 (6)	6	B	SMSRL
24	(Jodlbauer & Schagerl, 2016)	3 (24)	11	A B	
25	(Colli et al., 2018, 2019)	5 (25)	6	A	360DMA
26	(Ganzarain & Errasti, 2016)	0	5	A *	
27	(Trotta & Garengo, 2019)	5 (11)	5	A *	
28	(Wagire et al., 2020)	7 (38)	4	A	
29	(Vrchota & Pech, 2019)	0	3	A	
30	(Sjödin et al., 2018)	3	4	B	

Even though maturity models are often similar, each is designed for a specific application of domain. Of the 30 maturity models found 27 are related to Industry 4.0 maturity, 10 are related specifically to manufacturing companies, and 4 are related to logistics or supply chain 4.0. No maturity models where found relating to IDS. 7 of the maturity models were specifically tailored for use by small and medium enterprises (SMEs).

27 of the 30 maturity models identified define one or more dimensions, see Figure 10. Only 3 maturity models define no dimensions. The number of dimensions range between 0 and 9. However, two thirds of the maturity models have 3 to 5 dimensions. Some maturity models contain zero dimensions, these models only defined maturity levels. Maturity models containing only a limited number of dimensions offer an easy to interpret results, however are not capable of making a distinction between several aspects. As such, these models are either offer a very generalized overview of the organisation as a whole, or can only measure a single specific perspective of an organisation. Maturity models defining several dimensions can independently score each dimension and thus provide insight and discussing regarding specific aspects of an organisation.

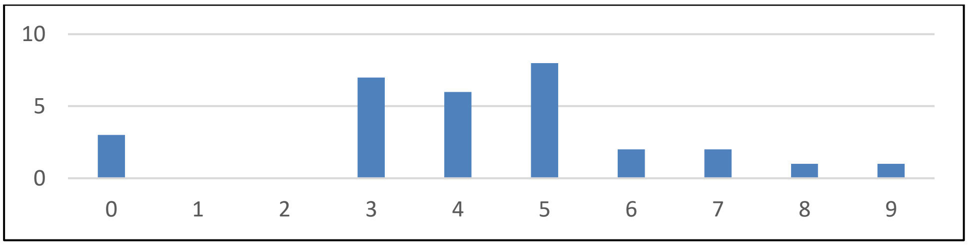


Figure 10 – Number of dimensions per model

Of the 27 maturity models containing dimensions, 21 also define items. Items are describe more specific aspects of a dimension. In Figure 11, the average number of items per dimension is shown per article containing dimensions and items. As can be seen when items are present the number of items per dimension range from on average from 1 to 11 with an outlier at 15. On average, a maturity model defining items defines 27 items, with 62 items being the highest number of items defined by one model.

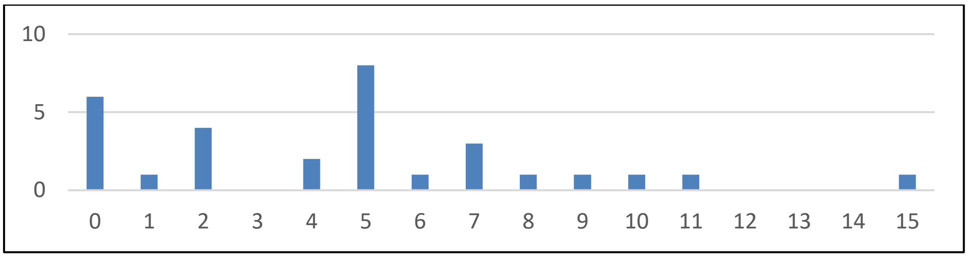


Figure 11 – Average number of items per dimension per model

Of the 30 maturity models found, 29 define a single range of maturity levels or stages. Meaning that these models apply the same range of maturity levels for each of the dimensions of items measured. The only exception to this is the model DPMM4.0 model by Asdecker and Felch (2018), which has related and order characteristics of each item. These ordered characteristics form the 'maturity levels' of this item and can thus vary based on the number of characteristics related. The paper does not provide the 40 items and related characteristics on which the model is based.

By far most models define 4 to 6 maturity levels as can be seen in Figure 12. The most striking exception to this is the model by Jodlbauer and Schagerl (2016) in which each dimensions is rated by a number ranging from 0 to 10.

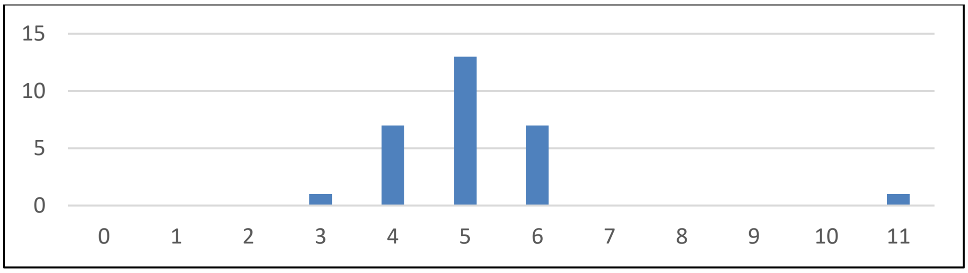


Figure 12 – Number of maturity levels defined per model

As each model is to applied in a context some models also provide a process, methodology or approach for the application of the model. Guiding users in the use and application of the model. Of the 30 models examined, 11 also provided a description of the process. A complete overview of the concepts related to maturity model components related to each maturity model identified in the literature review can be found in appendix chapter 12.2.

In addition to defining a maturity some models also help in developing a strategy, roadmap or realization paths for improving maturity. Of the 30 models examined 8 models have made efforts to provide such a strategy components as part of the model.

Items can be grouped in dimensions. However, it is also possible that a dependency exists between maturity items and dimensions. There's two ways in which this relation can take form in a maturity model. The first is by adding weight to the items and dimensions established. This method is applied by at least 6 of the 27 maturity models that contains dimensions and items. The other method is to explicitly define relationships between the items and maturity levels of each of the items. Of the maturity models identified only one model applied this approach, namely Stefan et al. (2018).

Only three of the 30 models encompassed concepts related to the impact and levers of impact of increasing maturity. This could be a result of the goals defined by the maturity models as most are aimed at providing insight in a state of art and the pathway an organisation can follow to increase maturity. The reasoning for increasing maturity is often only mentioned in the problem statement as a general concept.

A relation might be distinguished between the process and strategy concepts. Seven out of eight models defining a strategy also define a process for applying the maturity model. The other way around, seven out of 11 of the models defining a process also define a strategy for improving maturity.

A similar relation can be found relating dimensions and items with maturity levels. Of the 27 defining dimensions and or items, 26 also define maturity levels. The other way around, of the 29 models defining maturity levels 27 also defined dimensions and or items. It would thus be safe to say, and also in line with maturity research that most maturity models are based on a combination of maturity levels and dimensions and items. This can will be further be named the maturity matrix.

5.4 Development approach and treatment design for the IDS maturity model

This section will provide a discussion regarding step 3 of the maturity development procedure by Becker et al. (2009) and the treatment design phase of the Design cycle by Wieringa (2014).

5.4.1 Determination of development approach

The third step of the maturity model development procedure by Becker et al. (2009) establishes a development strategy for the maturity model to be developed. Some of the option are: development of a completely new design, enhancement of an existing model, combination of several models into a new one and transfer of structures or contents from existing models to new application domains (Becker et al., 2009).

In the previous chapter a comparison is made of existing maturity models. The systematic literature study has found 32 maturity models however none of these models are related to IDS. This means that it is not possible to enhance an existing model or combine several models into a new one. The option are to either develop a completely new design or to transfer structures or contents from existing models to the IDS domain.

Many maturity models were found to exist for Industry 4.0 in the previous section. Also, a relationship exists between IDS and Industry 4.0 as discussed in chapter 4. It would thus seem logical to start development of an IDS maturity model by using structures or contents of the Industry 4.0 maturity models.

The first iteration of the model to be developed will be based on Industry 4.0 maturity models and other related literature. After which through iterative development the model will directly be improved upon in the second iteration of the model. These improvements will be based on a qualitive study due to the lack of scholarly literature available. This approach is elaborated upon in chapter 6.

To be clear, normally the approach by Becker et al. defines a testing phase after each iteration of the model to be developed. However as the first iteration is mainly based on literature from a related field a second iteration was known to be required beforehand. It was chosen not to combine these two iterations of the model development in this report to be only one iteration as this would make it hard or even nearly impossible for other researchers to track the reasoning behind and the support of the model that is developed. By splitting the development in two iterations it becomes more easy to identify what statements are introduced in what stage and what source.

5.4.2 Treatment design

This stage of the maturity model development is also related to the treatment design phase of the design cycle by Wieringa (2014). For this phase requirements are to be established. These have already been defined in chapter 5.2.3. Also, existing approaches are to be investigated, which is done in chapter 5.3.3 and a development approach which is already developed in chapter 5.4.1.

The requirement of determining expected required effort and expected impact of IDS adoption can now be further elaborated upon as the analysis of existing maturity models has been completed. During this analysis several components have been identified to exist in currently existing maturity models.

For the purpose of this research all components identified in chapter 5.3.3 will provide additional value in supporting the adoption decision for IDS. As discussed before the maturity model to be developed should provide help determine expected effort required (pre-adoption) and expected benefits of IDS adoption (post-adoption). In addition the model should help an organisation establish a development strategy helping assess the effort required in adopting IDS. And finally the model should define the process to follow in apply the model and its components properly. The maturity model to be developed thus has to encompass the following components:

- Pre-adoption maturity model: Dimensions and or items, maturity levels for each
- Post-adoption impact mapping
- Process definition
- Strategy guide

6 Iterative development of the IDS maturity model

This chapter will present the design level and design approach to development of the first and second iteration of the IDS maturity model. Last chapter the first three steps of the process defined by Becker et al. (2009) have been discussed. This chapter will discuss the development approach to the first and second iteration of step 4. Chapter 7 presents the first iteration of the IDS maturity model while chapter 8 presents the second iteration of the IDS maturity model.

6.1 Selecting the design level

The model to be developed will encompass a maturity matrix, process definition, strategy guide and impact mapping, as suggested by chapter 5.3.3. The maturity model will be multidimensional of nature, as the IDS maturity model should be capable of providing a holistic overview of the organisation.

In order make sure the model is focussed enough to be of use in practice the model scope has to be defined. The model will focus on the most occurring use case of a company joining an existing IDS Ecosystem in the data provider or data consumer role. The model will be developed to fit the perspective of a single company. It could be that concepts put forward by the model could also be applicable to helping groups of companies make the decision to adopt IDS, however the model is not designed and tested with this in mind. Lastly it is important to note that IDS adoption means that a company has implemented the technical components into its system architecture and that is has integrated the system in one or more core business processes. Thus for this research a company implementing IDS in a singly use case meant for research purposes and on which the company has not made any of its' core processes dependent is not considered to have adopted IDS.

6.2 Approach to the first iteration of the IDS maturity model

During the first iteration model design is mainly based on the literature gathered from the systematic literature review performed in chapter 5 and the discussion on IDS from chapter 3. First an analysis is performed concerning the models found in chapter 5.3.3. This analysis has the goal of selecting one maturity model which the IDS maturity model can be based upon. Secondly this model is discussed based on literature available and adjusted, if needed, to fit the requirements of IDS.

6.2.1 Selecting one existing maturity model on which to base the IDS maturity model

This section will discuss which model is selected from the previously found maturity models, see Table 12 – Existing Maturity Models as discovered from the systematic literature study. Table 12. This model is to be used as the foundation for the IDS maturity model. First the selection process is discussed, secondly the findings are presented.

A selection process is carried out in order to be able to select a single maturity model to base the IDS maturity model on. As discussed no maturity model is found to exist specifically tailored for IDS, as such a model is to be found from other related domains. The results from the maturity can be linked to the domains Industry 4.0 or Industrie 4.0, Logistics 4.0 or Supply chain 4.0, or Manufacturing. All these domains are related to IDS. There's no reason to exclude any of the maturity models based on the domain it is related to.

The selection procedure further compares the available maturity models based on several aspects. The fit aspects evaluates maturity models whether the model contains the components as required for the IDS model. Secondly the representativeness aspect compares the operationalisation of the maturity dimensions and maturity levels. This is done in order to determine which model best reflects the set of maturity models as a whole and can thus be used best as a foundation for the new model. The last aspects is that of quality, models will be compared regarding citations. As one of the exclusion criteria in the systematic literature review is that al results have at least 1 or 3 citations, all models will be show at least some citations. Some models are cited in a lot of other maturity models which suggest that they are ‘more important’ to the field and are considered better models to base the IDS model of.

6.2.2 Fit

The maturity model to be designed will encompass several components. This has been previously discussed in chapter 5.3.3. The first of which is the maturity matrix consisting of dimensions and items on axis and maturity levels on the other axis. A process definition describes how this maturity model is to be applied. A strategy guide will elaborate on how an organisation can become more mature. Lastly an impact mapping will elaborate on the impact of becoming more mature on the organisation.

The maturity model is expected to provide a holistic overview of the of the organisation, as such the maturity matrix will need to consist of several distinct dimensions and or items. Maturity models containing only one type of dimensions will be excluded from consideration.

The following maturity model are excluded from the results of the systematic literature review as presented in Table 12. The concept mapping of all of the dimensions in the maturity models of the systematic literature review can be found in Appendix – Mapping maturity model dimensions to concepts.12.3

Table 12 – Existing Maturity Models as discovered from the systematic literature study. Based on the concept mapping of dimensions in the maturity models the maturity model by Asdecker and Felch (2018) will be excluded as it only contains dimensions related to the concept of processes. The maturity model by Pacchini et al. (2019) will be excluded as it only contains dimensions related to the concept of technology. As well as the models by Weber et al. (2017), Ganzarain and Errasti (2016) and Vrchota & Pech (2019) as these all define no dimensions. This results in a set of 25 maturity models.

Each of these 25 models show a combination of dimension, items and maturity levels as desired from a maturity matrix. Of these 10 also provide a process definition, 8 a strategy guide and 3 impact mapping. Only the maturity model by Rauch (2020) contains all components. Five other models contain all components except for the impact mapping, namely: Jodlbauer and Schagerl (2016), Jung and Kulvatunyou (2016), Mittal et al. (2020) and Mittal, Rommero et al. (2018), Schuh et al. (2020), and Schumacher et al. (2019).

These six maturity models thus seem to fit best to the maturity model and approach to be developed for IDS from a component perspective.

6.2.3 Representativeness

The maturity matrix is the central component of each maturity model. The maturity model to be selected to be the best basis for developing the IDS maturity model should encompass the ideas and concepts put forwards by the field. The selection of maturity models of the systematic literature review, see Table 12, is thus also analysed for their representativeness regarding the concepts of the domain.

The concept mapping of all the dimensions in the maturity models of the systematic literature review can be found in Appendix – Mapping maturity model dimensions to concepts. Table 13 presents the number of models having at least one dimensions related to each of the concepts. In this only models having defined at least one dimension are considered. A complete overview of the dimensions of the found maturity model grouped for each concept can be found in appendix chapter 12.3.

The five main concepts of technology, strategy, processes, organization and products all seem be valid as they are all mentioned by at least one third of the models. The miscellaneous concepts contains three dimensions which do not fit one of the other concepts: customers (Schumacher et al., 2016), customers and partners (Schumacher et al., 2019) and supply chain (Lin et al., 2020). These dimensions all seems concerned with the stakeholders present in de domain the organisation is operating in.

When the miscellaneous concept is disregard, five models contain all concepts identified in the concept mapping. These are the models by Schumacher et al. (2016), Canetta et al. (2018), Santos and Martinho (2019), Schumacher et al. (2019), Trotta and Garengo (2019). Both models by Schumacher et al. also encompass the dimensions related to the miscellaneous concept, namely customers and customers and partners respectively.

The specific dimensions related to each of the concepts and the items they contain are not further investigated in this section. In the next chapter the selected model will be discussed based on the other models derived from the systematic literature search and the IDS characteristics discussed in chapter 3 of this research.

Table 13 - Number of models having at least one dimension related to each of the concepts.

	Technology	**Strategy**	**Processes**	**Organization**	**Products**	**Miscellaneous**
Number of Models (of 27)	24	12	21	24	9	3

6.2.4 Quality

The final aspect considered in comparing the maturity models is that of quality. With this aspect maturity models are compared regarding their status in the domain. Literature that has not been cited by others are considered of less 'quality' then others. This is of course not a foul proof method of quantifying the 'quality' of a maturity model, however it should suffice for the intent of selecting a single maturity to base the IDS model of. In next chapter the selected model is further elaborated on, this discussion also includes papers of 'lesser quality' that haven been rejected.

Two maturity model publications stand out in relation to the number of citations. The first is the maturity model by Schumacher et al. (2016), this publications has been cited 717 times. The second is the maturity model by Schuh et al. (2017), this publication has been cited 334 times. It is important to note that the model found in the systematic literature review is the 2020 version of this maturity model by Schuh et al. However, no citation count could be found for that version as it is 'completely' replaced. All links directed to 2017 version now redirect to the 2020 version.

The rest of the found maturity models are plotted based on year of publication and number of citations. This graph can be found in Figure 13. This found the eight publications to be above the trendline added to the scatter plot, and are thus considered to be more relatively more cited than the other results, these are:

- Gökalp et al. (2017): 117 citations
- De Carolis et al (2018): 107 citations
- Bibby et al (2018): 100 citations
- Sjödin et al (2018): 89 citations
- Akdil et al. (2018): 85 citations

- Schumacher et al (2019): 55 citations
- Olesków-Szlapka et al. (2019): 35 citations
- Mittal et al. (2020): 23 citations

The maturity model by Schumacher et al. (2019) is the second iteration of the maturity model by Schumacher et al. (2016). Both iterations have been cited often.

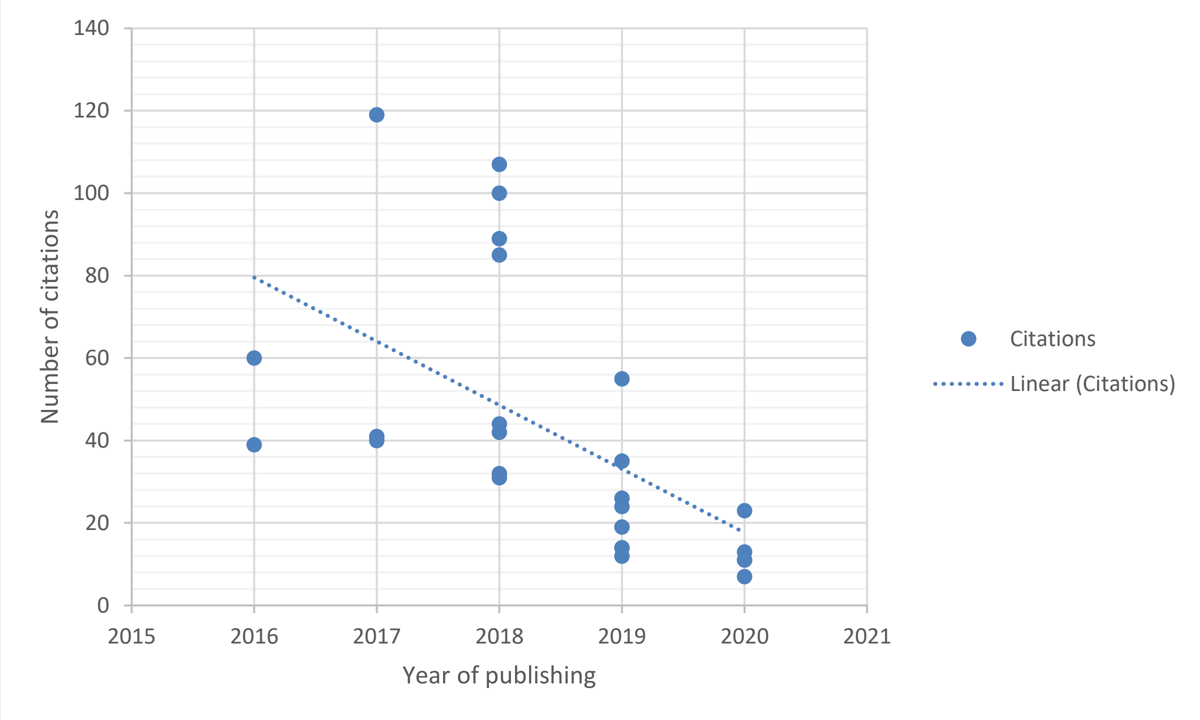


Figure 13 – Number of citations of each paper

6.2.5 Selecting the Schumacher et al. (2019) maturity model as the bases for the IDS maturity model.

This sections' purpose is to select a single maturity model that can be used as the foundation for the IDS maturity model to be developed. As such the maturity models identified in the systematic literature review have been compared in regards to the fit, representativeness and quality aspects. Based on this comparison the maturity model by Schumacher et al. (2019) is selected as the foundation of the IDS maturity model.

The maturity model is the second iteration of the by far most cited maturity model identified in the systematic literature review. It contains most components identified to be demanded of the IDS maturity model to be developed, only the impact mapping components is not part of the maturity model by Schumacher et al. (2019). Finally, it encompasses all dimension concepts identified in the concept mapping, as well as an additional customers & partners dimension.

6.3 Approach to the second iteration of the IDS maturity model

The second iteration of the model is based on expert interviews which in terms of Becker et al. (2009) can be classified as applying a creative technique. The purpose of these interviews is threefold. The first is to provide for a new source of data on which to base the IDS maturity model on.

The first iteration of the model is based on literature from a related field. As such the existing model by Schumacher et al. (2019) is adapted to fit IDS. This adaption is based on found literature and the opinion of the researcher. It is of value to uncover a new source of information on which to base the IDS maturity model on. By combining several sources of information triangulation of data sources is achieved. This will help reduce bias in developing the model.

Secondly, this new information can be used to find additional motivation and explanations for expected behaviour. As expert are knowledgeable about IDS they are better able to predict the factors influencing IDS adoption and how IDS adoption affects an organisation. They should also be able to elaborate this by providing an explanation.

The third and final purpose of the expert interviews is to test the IDS maturity model. As discussed before the maturity model is based on several sources however non of these offer are based on quantitative data. By gathering structured data some testing can be applied to the model. Providing some first insight in the validity, weaknesses and strengths of the model that is developed.

6.3.1 Design of the expect interviews

This section will discuss the design of the expert interviews conducted in this research. This will be a mainly qualitative approach. This is mainly because only limited experts exists in the field of IDS. As discussed before the expert interviews will have a several purposes.

In order to quantify the expert opinions structured responses are required to be gathered. As such this research applies a mixed approach in which interviews are preceded by questionnaires. The results of these questionnaires are then gathered and shared during the interviews. The questionnaires are structured and consists mostly of closed questions, allowing the respondents to only select a single option from a range of pre-determined options.

The semi-structured interviews are the main part of the expert interviews. Semi-structured interviews follow a predetermined line of questioning, but allow the interviewer and interviewee to further elaborate on answers provided. Meaning that an interesting topic can be explored. These kind of interviews fit the purpose of being better able to predict how factors affect IDS adoption and how IDS adoption affects an organisation. Also, it allows this research to discover new explanations and elaborations related to the concepts put forwards by the maturity model.

The questionnaire that is send to the experts can be found in appendix chapter 12.5. Appendix chapter 12.6 shows the interview guide that is followed during the expert interviews.

The design of the questionnaire is based on the Industry 4.0 maturity model by Schumacher et al. (2019). The respondent is asked to rate each of the dimensions and items of the maturity model following the maturity levels determined by the Schumacher et al. model. The respondent will do this from two different perspectives: required maturity before starting IDS adoption and expected maturity after IDS adoption.

The interview guide also follows the structure of the maturity model by Schumacher et al. (2019). This means that the questions are based on the dimensions identified in the maturity model. Also the interview will present the results of the questionnaire as submitted by the respondent. The respondent is asked to validate the results and to explain the reasoning behind the answers provided.

6.3.2 Finding experts

IDS is a relatively new area of research. Is indicated before only little scholarly research has been found. As such it can be expected that only little experts exists. However, IDS is currently in development by the IDSA. Also the IDS reference architecture model is already in version three. In chapter 3.7 the current state of art of the IDS use cases has been investigated. The results of which suggested IDS to be on the brink of commercial implementation. This suggest the presence of experts that have already applied IDS in practice, commercially or in a testbed.

For this research expert are required that are familiar with IDS. Mainly from the perspective of applying IDS in a use case and the impact of adopting the use case into an organisation. Also, it would be helpful but not necessary if the expert that are willing to cooperate with the research are also familiar with Industry 4.0 and its' related concepts.

In order to find experts willing to help in this research an open call was shared with several members of the IDSA, TNO which is the Dutch IDS Hub and researchers at the University of Twente. These experts are then also asked to share the call in their network.

6.3.3 Analysing the results

In order to derive meaningful results from the research the data that is gathered will need to be processed and analysed.

The information collected by the questionnaire will be of a structured nature. It will contain some general questions which will be used in identification, validation and determination of inclusion of the experts. Experts not familiar with IDS concepts and or IDS in practice will be excluded.

For each item and dimension of the Schumacher et al. (2019) maturity model an average maturity level is determined as well as the standard deviation. However this standard deviation is expected to be high due to a low number of expected respondents and the interpretability of definitions.

The information collected by the interview will be of a more quantitative nature and will also follow the structure of the dimensions of the maturity model by Schumacher et al. (2019). The results of the questionnaire as filled in by the expert is shared during the interview. The expert is than asked to explain and elaborate on these results.

The interviews are transcribed then summarized. Statements are related via coding to the individual Schumacher et al. (2019) maturity model dimensions. Finally, the coded results are grouped by dimension for all the statements made by the interviewees. Allowing for a discussion for each concepts improving and elaborating the first iteration of the IDS maturity model.

6.3.4 Results

Five respondents were found to be willing to take part in an interview. Questions asked in the questionnaire and during the interview indicated that all five are familiar with IDS. Four of the respondents also filled in the questionnaire in advance. The function the respondents hold are CIO, scientist (3x) and modeller. All consider themselves either familiar with IDS and or have been involved in a project or implementation involving IDS. The respondents came from four different companies, amongst which were the Dutch IDS hub TNO and a participant from Fraunhofer Institute for Software and System Engineering ISST. The third company is active as logistics provider and the fourth company offers software solutions and consultancy services.

As can be seen in Figure 14, the most occurring standard deviation calculated for the items measured by the questionnaire is between 0.5 up to including 1.0 and 1.0 up to including 1.5. This in a range of maturity levels from 1 up to including 4. This indicates that the average results can generally not be used as a definitive maturity level value for the item. This was expected during the research approach design, as such these numbers are mainly used as a basis for the interviews conducted. The average maturity levels for the dimensions and items will be shared in chapter 8 after which a discussion is made based on the interview results.

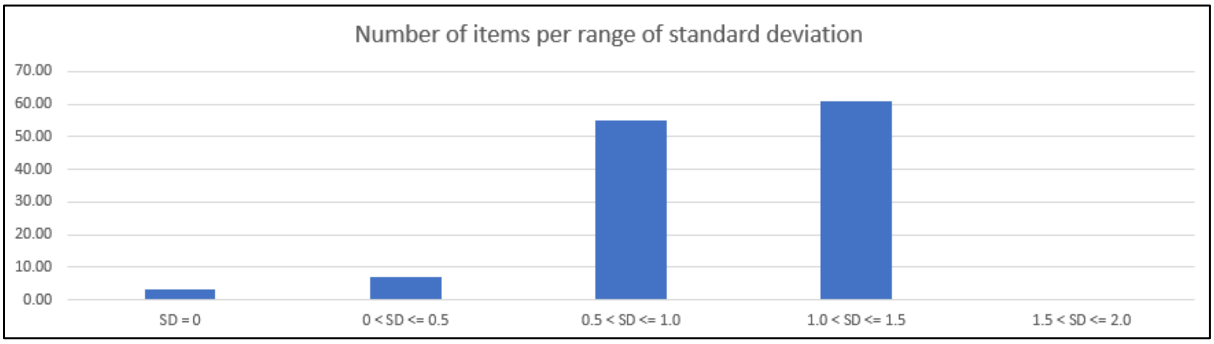


Figure 14 – Spread of Standard deviation as calculated for each of the items measured in the questionnaire concerning expected pre- and postadoption maturity for IDS.

7 IDS maturity model – First iteration

This chapter will discuss present an component of the discusses the first iteration of the IDS maturity model. This first iteration is based on the maturity model by Schumacher et al. (2019) as selected in the previous chapter. First the process definition is presented. Secondly the maturity matrix contain the dimensions, items and maturity levels of the IDS model. Thirdly, the impact mapping and finally the strategy guide.

For this, an attempt is made to discussed each component in three ways: firstly, by discussing in more detailed how the components is presented by Schumacher et al. (2019). Secondly as discussion is provided in regards to what can be learnt from the literature found in the literature study. Lastly a discussion is made for how these aspects can be applied to IDS.

7.1 Process definition

This section discusses the process definition component of the IDS Maturity model and maturity matrix. The maturity model by Schumacher et al. (2019) defines a process consisting of ten separate steps:

1. Industry 4.0 introduction and creation of participant's alignment and commitment
2. Collection of company's Industry 4.0 activities to align for as-it-is maturity assessment.
3. Moderated Industry 4.0 as-it-is self-assessment + collection of highly relevant maturity items
4. Data collection, statistical analysis and creation of company specific maturity report
5. Determination of companies goals in Industry 4.0 to align for target-state assessment
6. Moderated Industry 4.0 target state self-assessment + collection of highly relevant items
7. Analysis of maturity gaps (difference as-it-is to target state) among items and isolation of items with gap > 0.5
8. Development of company-specific realization paths and clustering of related maturity items with gaps > 0,5 into action fields
9. Specification of action fields during workshops and definition of concrete realization-projects based on relevance rating from step 3 and 6.
10. Integration of defined action-fields and realization project into a company-specific realization roadmap towards Industry 4.0.

The maturity models identified in the literature review all apply a process similar to this. Take for instance the maturity model by Schuh et al. (2020) which defines only three steps: identify the current maturity stage, identification of capabilities requiring development, establish measures. This process is similar to the process of the maturity model by Schumacher et al. (2019), even though the process of Schumacher et al. consists of more steps. Steps 1 to 4 are together similar to step one of the Schuh et al. process. Steps 5 to 7 relate to step two and steps 9 to 10 relate to step three.

Another example of a similar approach is the process by Mittal et al. (2020) is also similar to these steps: identify data present, readiness assessment of data-hierarchy steps, develop a tailored vision, identify tools and practices to realize the vision. The same goes for the process by Jodlbauer and Schagerl. (2016).

A pattern emerges in which the company is first introduced to the subject. Secondly the as-is maturity state is established after which also the desired to-be state is established. A gap analysis can then be performed indicating the effort required to reach the target state.

The insight in which areas are to be improved provided by these processes in maturity models can be helpful in the early phases of a business transformation (Cimini, Pinto, & Cavalieri, 2017).

Cimini, Pinto, Pezzotta et al. (2017) defines the following approach for business transformation. This approach, again, is very similar to the other models discussed in this chapter.

- Envision: get a deep understanding of I4.0 and goals. Management is mainly involved, but also possibly customers, suppliers and technology partners. Results in estimation of the investment required.
- Formulation of specific roadmaps to translate long-term strategies into practical areas of development. Readiness assessments and maturity models play an important role in this. Taking into account organisation specific strengths and weaknesses and drivers existing in the environment of the organisation.
- Enact: the implementation of a pilot project. This requires clear objectives and wide collaboration of all stakeholders involved. Only by identifying real advantages the project can be scaled up.

In order to determine the approach to be followed by the IDS maturity model the approach is defined by Schumacher et al. (2019) is used. This because this approach fits the approach used by other similar models. The approach is however specified for assessing Industry 4.0 maturity while our model aims to assess IDS readiness and also provide insight in IDS impact.

The main steps will remain the same, however the operationalisations of the IDS maturity matrix will provide target state of Industry 4.0 maturity. Secondly a step is added which will provide management insight in the expected impact of adopting IDS. This supports the adoption decision to be made by management. Lastly, developing realization paths based on identified items of development is not possible in the way Schumacher et al. (2019) envisioned. This because it will be hard to determine maturity levels exact enough to identify maturity gaps > 0.5.

The adjusted model will be as follows:

1. As-is Industry 4.0 maturity assessment using the Schumacher (2019).
    a. Industry 4.0 and IDS introduction and creation of participant’s alignment and commitment
    b. Collection of company’s Industry 4.0 activities to align for as-it-is maturity assessment.
    c. Moderated Industry 4.0 as-it-is self-assessment based on the model by Schumacher et al.
    d. Data collection, statistical analysis and creation of company specific maturity report
2. Maturity gap analysis
    a. Analysis of minimum maturity gaps. In this the maturity assessment of step 1 is compared with the minimum required maturity items (maturity matrix) in order to identify which items have to become more mature before IDS adoption is started.
    b. Analysis of impact maturity gaps. In this the maturity assessment of step 1 is compared with the impact mapping as established in this report (impact mapping) in order to find item which would benefit from IDS adoption.
3. Perform a cost-benefit analysis based on the maturity gaps identified in step 2a and the impact mapping identified in step 2b.
4. Development of company-specific realization paths and clustering of related maturity items to be developed into action fields.
5. Specification of action fields and definition of concrete realization-projects.

In order to make it more easy for companies to understand the process and thus reduce the threshold to start using the model. As such a visual representation of the process is developed, also displaying how the other components are related. This visual presentation is shown in **Error! Reference source not found.**.

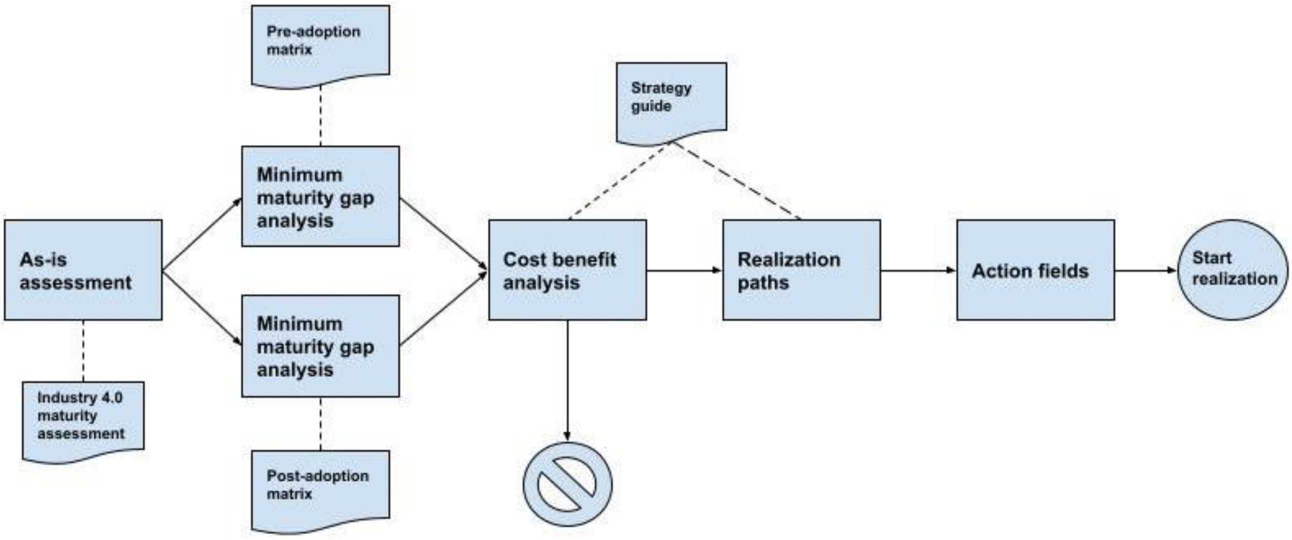


Figure 15 - Schematic overview of the IDS maturity model process.

7.2 Maturity matrix: maturity levels

This section discusses the maturity levels component of the IDS Maturity model and maturity matrix. These are also called maturity stages or maturity phases. They are most often related to maturity items. Allowing for assigning a maturity level to each of the items which later allows for the computation of a maturity level for each of the dimensions of the model. Thus creating the 'maturity matrix'.

The maturity model by Schumacher et al. (2019) defines four maturity levels, namely: level 1: Not, Level 2: Little bit, Level 3: common/often, Level 4: a lot/fully. Each item in the maturity model can be scored on this range. Results are also aggregated on dimension level by determining the weighted average of the items in the dimension. These weight are sadly not published.

As can be seen in Figure 12 of chapter 5.3.3, by far most of the maturity models defined 4 to 6 maturity levels. Vrchota and Pech (2019) is one of the exceptions to this as they only define three maturity levels. Their maturity model does not define any dimensions or items and can thus be described as a single stack of maturity levels.

Another exception is the maturity model by Jodlbauer and Schagerl (2016) which scores maturity on a range from 0 to 10. This model also defines four dimensions but does not define any sub-dimensions or items.

The last clear exception identified in the systematic literature study is the maturity model by Stefan et al. (2018) which does not define clear maturity stages. Instead it has related list of characteristics per item which are ordered to project a development or maturity path. In addition this creates relationships between different domains and items when characteristics are linked to multiple items.

Two different types of maturity ranges can be distinguished based on the starting point. There are maturity models which define the lowest maturity level as level 1, or another way to signify 'some maturity'. Others consciously define the range to start at level 0 or use another way to also include a 'no maturity' stage in the model.

Including a level 0 maturity levels helps use the maturity model in SMEs as it indicates the significant mindset change that is required in the transition between no maturity and a little bit of maturity (Mittal, Khan, et al., 2018).

Basl and Doucek (2019) suggest in their literature review of Industry 4.0 maturity models that some items can only be in binary states regarding maturity. They present the example of adhering to legislative recommendations such as the GDPR. This concept of binary maturity was not identified in any of the maturity models found in the systematic literature study.

In relation to the maturity range definition it is also possible for a maturity model to not define a single range. For instance the maturity model by Facchini et al. (2019) defines a multiple definitions of maturity stages. One for each separate domain it is applied in, which in the case of Facchini (2019) is several different types of logistics. Even though Facchini (2019) defines separate definitions for different types of logistics, the number of maturity levels in each definition remains the same.

Maturity ranges can also be defined on the enterprise level. This can be used to easily classify the stage the company is in regarding overall maturity. An example of this is found in Sjödin et al. (2018). The maturity model states four levels defining overall smart factory maturity:

- Level 1: connected technologies
- Level 2: structured data gathering and sharing
- Level 3: real-time process analytics and optimization
- Level 4: smart and predictable manufacturing

Most maturity models apply some sort of questionnaire to generate a scoring of each maturity item for a specific companies. Some also apply interviews to further investigate findings and adjust were needed. The maturity model by Schumacher applies a questionnaire in which a respondent is asked to rate each item on the maturity scale. In addition when a respondent rates an item with maturity level three or four, which are the two highest levels in this models, the respondent is asked to illustrate the answer with an example. This example can be used by the researcher to better analyse and interpret the results of the questionnaire.

Some maturity models do not let the company fill in a questionnaire as this is a form of self-assessment. They instead often opt to conduct interviews after which the researcher, an external expert, rate the company on each of the items. Reasoning for this is that most companies will not be familiar enough with the Industry 4.0 concepts to be able to reliably perform a self-assessment.

In respect to IDS, the four maturity levels as defined by Schumacher et al. (2019) seem to suffice. No reason is found to alter these. It is however hard to quantify the precise maturity levels related to IDS adoption and IDS impact.

A very generalised and imprecise attempt can be made by relating the expected minimum maturity level for each item to the role of the item in IDS adoption as identified in chapter 7.1. This could for example be functionalized by assigning a minimum maturity level of 3 (common/often) to items with the 'required' classification. Items with the 'helpful' and 'unrelated' classification would require a minimum maturity level of 1 (not). This would warrant further investigation as these rangers are arbitrarily chosen and not supported by any kind of data other than the opinion of the researcher. Also probably differences could exists in the minimum maturity of different items.

7.3 Pre-adoption maturity matrix

This section discusses the dimensions and items component of the IDS Maturity model and maturity matrix. Dimensions are also called areas or categories and are, in short, groupings of items. Items are also called components, capabilities and aspects.

The maturity model by Schumacher et al. (2019) defines 8 dimensions and 65 items, which can be found in Table 58, which can be found as an appendix in chapter 12.4. These dimensions are of an holistic nature, aiming to describe Industry 4.0 from all possible angles (Schumacher et al., 2019).

A distinction can be made between holistic maturity models that describe many dimensions for measuring Industry 4.0 maturity and specific models that encompass less dimension with a more narrow scope (Brozzi et al., 2018; as cite by Hizam-Hanafiah et al., 2020). Basl and Doucek (2019) define a spectrum of range. This range includes: A complete society, an area of society, a sector within an area of society, an enterprise as a whole, an area within the enterprise, a dimension within the enterprise area, or a sub-dimension within the dimensions within the enterprise area.

In the case of the IDS maturity model the model should be developed fitting the 'an enterprise as a whole' range, which is similar to the term 'holistic'. This different from the a more specific approach such as the maturity model by Pacchini et al. (2019) which only encompasses eight enabling technologies of Industry 4.0 as dimensions and items. Basl and Doucek (2019) have found most Industry 4.0 maturity models to be very comprehensive and focussed on an holistic overview, lacking a detailed view.

As discussed in chapter 6.2.3 and Table 13, the individual dimensions in the maturity models found in the systematic literature review can be mapped to dimensions of the maturity model by Schumacher et al. (2019). In the case of Schumacher et al. this means that both the Technology and the Data and Information dimension of the model are related to the technology concept. Corporate standards and Employees are related to the organization concept while Strategy and Leadership is related to both the Strategy and the Organization concepts.

In order to assess an organisations Industry 4.0 readiness 6 aspects should be included (Sony & Naik, 2019). Each of these aspects can be mapped to one or more of the dimensions of the maturity model by Schumacher et al. (2019):

1. Top management involvement and commitment: Strategy and Leadership
2. Employee adaptability with Industry 4.0: Employees
3. Smart product and services: Products
4. Extent of digitization of supply chain: Customers and Partners
5. Level of digitization of the organization: Technology
6. Readiness of organizational strategy: Strategy

Hizam-Hanafiah et al. (2020) identified six most important dimensions in Industry 4.0 maturity models: Technology, People, Strategy, Leadership, Process, Innovation. Most of which can be on directly related to associated dimensions in the Schumacher et al. (2019) maturity model and the concept mapping. The dimension of innovation is less obviously related. However a closer look at the items defined in the Schumacher et al. (2019) maturity model reveals that even though the innovation dimension is not defined separately, that is part of all other dimensions defined.

Aspects such as security, maintenance, connectivity and data and processes can possibly be cross-sectional dimensions (Basl & Doucek, 2019). Cross-cutting dimensions are dimensions which can in by definition not be distinct. They 'cut across' the other dimensions, meaning that the aspect they describe is related to all the other dimensions. If for instance security is considered in a model one or more items regarding security will then by identified in each of the dimensions of the model, as it is affected by all aspects of an organisation, from technology to culture. Grouping these items into one cross-cutting dimensions makes the implicit relation between different dimensions explicit and thus more clear. This relation between dimensions is recognized in the literature review by Sony and Naik (2019).

In Industry 4.0 such crosscutting dimensions can be integration and interoperability. As they are key factors of Industry 4.0 (Chen et al., 2008; Lu, 2016; Romero & Vernadat, 2016). Interoperability describes the ability of two systems to understand and use each other. Integration is related to enabling seamless operations across organizational borders and in doing so create networks. The Industry 4.0 maturity model by Schumacher et al. (2019) does not define any crosscutting dimensions.

The items as put forward by Schumacher et al. (2019) are weighted in the Industry 4.0 maturity model. This weighting is not made part of the IDS maturity model for two reasons. The first of which is that the weighting was not published in the publication by Schumacher et al. (2019) and could also not be found using different methods. Secondly, the weightings are describe the weighting of the items in relation to Industry 4.0 maturity. As the model to be developed will be describing maturity in relation to IDS the weightings would not be of use anyway.

Items as proposed by Schumacher et al. (2019) are in the model also related to three different groupings: enable, implement and formalize. The enable grouping relates to items that are the foundation of realizing I4.0. The implement grouping relates to items that help incorporating Industry 4.0 into an organisation. The formalize grouping relates to items that help sustain Industry 4.0 in an organisation.

The following sections discuss how IDS adoption is related to maturity in each of the dimensions and items of the Industry 4.0 maturity model by Schumacher et al. (2019). Only a discussion is provided as it is not possible to quantify this relation based on literature sources alone.

Each of the items in the maturity model is classified regarding its role in relation to enabling IDS adoption. So regarding the role during the pre-adoption phase. Relating each of the items to one of the following groupings will provide some structure to the results of the discussion.

- Required: When IDS adoption is only possible when this item is mature the item will be classified as ‘required’.
- Helpful: An item that is not directly related to enabling IDS adoption but that does indirectly help in IDS adoption.
- Unrelated: Describing items of which increased maturity does not or only very little impact IDS adoption.

7.3.1 Technology:

Most dimensions extracted from the maturity models found in the systematic literature study relate to the Technology dimension. As can be seen in the appendix in chapter 12.3. This is similar to the finding of the literature review by Hizam-Hanafiah et al. (2020) that found that most dimensions in found literature pertain to the technology dimension, suggesting a need to focus on this aspect. The technology aspect is thus import in Industry 4.0 maturity models.

For the IDS maturity model this might also be the case. As IDS has a strong technology component it is expected that the IDS maturity model will also need to encompass a technology dimension in order to support this aspect of IDS.

The items in the technology dimension defined by the maturity model by Schumacher et al. (2019) are part of the key technologies for Industry 4.0. One of which is ‘technology for information exchange’. This item is closely related to IDS, as IDS states that enabling information exchange is the main purpose of IDS. Thus it is probably not required to have an high maturity as this could actually diminish the added value of IDS. Some maturity could be helpful to use as the foundation for designing and implementing IDS.

Items that are also expected to be relevant for IDS are utilization of cloud technology, mobile devices on shop floor, decentral information storage. These items all fit use cases for IDS. However, as IDS it the enabling technology for these items the minimum industry 4.0 maturity level for each of these items that is required for a company to start adopting IDS is expected to be very low. It could however help if these use case are already in place. As then the ‘end-goal’ of IDS adoption is already present. These items are thus classified as ‘helpful’.

The final set of items, namely Integrated computers in machines, Integrated computers in tools, Utilization of robots, Sensors for data collection and Additive manufacturing are all not directly related to IDS. It can be stated that IDS requires data and information in order to be able to provide value. These items are related to creating or using this data. Even though the items could be of influence it is not expected that a minimum maturity is needed to start adopting IDS and no real benefits are gained from being mature in these items. As such these items are classified as ‘unrelated’.

7.3.2 Products:

The products dimensions is also mentioned by nine of the 27 other maturity model identified in the systematic literature search. Most of these models defined it as the product dimensions, while some also add services or the ‘smart’ classification.

The products dimensions encompasses six items. Of which internet connection of products, collection of product-use information, digital compatibility and interoperability of products, and data-processing components in products are indirectly related to IDS as they involve the data collection and data sharing components of products. However, no maturity is required for IDS as it not required for IDS to have ‘smart’ products to be implemented. These items are all classified as ‘helpful’ as their presence could indirectly help in IDS adoption as they make sure data exists to be shared by using IDS.

The items product individualization, data processing components in products and flexibility of product characteristics are considered ‘unrelated’ to IDS. Their maturity does not provide any tangible benefit in adopting IDS and are certainly not a requirement.

IT-services related to physical products is related to IDS in the sense that IDS can be an enabler of this. As such this item is also considered ‘unrelated’.

7.3.3 Customers and Partners:

The Customers and Partners dimensions is special as it Schumacher et al. (2019) is the only maturity model found to distinguish this aspect as a dimension. Only Lin et al. (2020) defines a similar dimension: supply chain. This dimensions is involved with the state of art of customers and partner organisations, and thus investigates to domain the company is operating in.

Customers and Partners maturity will be of great influence on IDS adoption. As IDS is specifically tailored for sharing data across company borders, sharing data with customers and partners. IDS adoption is not possible when partnering organisations are not mature. Even when the organisation is in all aspects ready for IDS implementation themselves.

The items of openness to new technology, digital contact with company partners and company partner's degree of digitalization directly relate to IDS adoption readiness. When these items are not mature IDS implementation is impossible. No other data consumer, data provider or other role will be present in the IDS Ecosystem making any use case impossible to adopt in the business process of the company. These items are thus classified as 'required'.

Competence with modern ICT, digitalization of customer contact, utilization of customer related data and IT-collaboration for product development all support adopting IDS use cases but are not required. Thus they are classified as 'helpful'.

The only item which is not required for IDS adoption and does not influence the adoption process is that of Customer integration in product development. This item is thus classified as 'not related'.

7.3.4 Value creation processes:

Most of the maturity models identified in the systematic literature review identify some sort of processes dimensions. Most define this as processes or operations however some mention specific types of processes. Such as Asdecker and Felch (2018) which make a distinction between processing, warehousing and shipping. The product lifecycle is mentioned by Lin et al. (2020), Jung and Kulvatunyou (2016) mention performance management and Schuh et al. (2020) mention efficient communication as part of the resources dimension. Only Schumacher et al. (2019), Wagire et al. (2020) and Colli et al. (2018, 2019) associate the term value or value creation with the processes dimension.

This dimensions is related to IDS as it claims that one of its mains strength is that is enables the development of new business processes. However, by stating that it enables the development of new processes it seems to indicate that no such business processes need to exist before IDS is adopted.

The items of databased machine maintenance and information exchange between machines are indirectly related to IDS as it is involved with having data available for IDS to share. These items are classified as 'helpful' as they are not necessary for IDS adoption.

The items of value creation process automation, automated object handling, collaboration of humans and robots, automated quality control and autonomy of machine park might be impacted or even enabled by IDS adoption. However they are not related to the readiness of adopting IDS and are thus classified as 'unrelated'.

7.3.5 Data & Information:

Most of the other models analysed in the systematic literature review did not specify a data and information dimensions. Most of the models encompassed this concept in the technology dimension.

This dimension is also directly related to IDS, in the sense that the whole purpose of IDS is to exchange data and information. This seems to suggest that some data should be available to be shared before IDS can be adopted.

The items of digital information processes, databased decision making and automated information provisioning are directly related to IDS adoption and some maturity is required in these items to start adopting IDS. There items are classified as ‘required’.

Automated data collection and individualization of provided information also seem to closely related to enabling IDS. However maturity is not specifically required to start IDS adoption, however it would probably be of great help if a company is mature in these items. However, as they are not required they are classified as ‘helpful’.

The final category of items is classified as ‘unrelated’. These items are related to data and information and could possibly benefit from IDS adoption. However are not required for adoption and will not help or will only help a little in IDS adoption. These items are: digital process visualization, data-driven software-simulation of future scenarios and analysis of collected data.

7.3.6 Corporate standards:

This dimension is not specified by other maturity models found in the systematic literature study, However it is similar to the governance, organizational culture and monitoring and control dimensions commonly specified by other models. These dimensions are grouping in the organization concept during the concept mapping of the maturity model dimensions.

For IDS adoption this dimensions is expected to be less relevant as it has not stated any need for existing corporate standards to exist in an organisation adopting IDS. In the contrary, IDS is greatly comprised of tools and measured enabling the ability to define and monitor corporate standards such as usage control, authentication mechanisms and cyber security.

A lot of items in this dimension are of benefit to IDS adoption but are not enablers of IDS adoption. The following items are thus classified as ‘helpful’: technical standards, employee trainings of digital competences, legal protection for digital products and services, increased cyber security, rules for employees in digital work environment. As IDS is heavily involved with defining, configuring and monitoring policies and standards it would be of great benefit when a company is already familiar with this. However, it is not required as IDS can also be adopted without previous knowledge by implementing a default type of IDS Connector.

The monitoring of Industry 4.0 realization, adjustments of works arrangements and recruitment for Industry 4.0 items do not influence IDS adoption and are thus classified as ‘unrelated’.

7.3.6.1.1 Employees:

This dimensions was defined by a lot of the models found in the systematic literature study. These models also referred to the dimension as personnel, workforce, people or competences. Another dimension which is defined by other models is the culture dimension. The culture dimension is not defined specifically by Schumacher et al. (2019) specifically but is scattered among the dimensions, especially the employee dimension.

This dimension is not linked to IDS. The only link between IDS and employees is that they are the ones who have to use it on a daily basis. Even though this relationship could influence the impact of adopting IDS, it in general does not directly enable the adoption of IDS.

The openness to new technology, competences with modern ICT and knowledge about employee competences are considered to be required for successful IDS adoption and thus classified as ‘required’. This is because it is directly related to the competences and willingness of employees to adopt this new technology. As they are the one configuring and using the system on a daily basis these items are required.

Items of which maturity would benefit IDS adoption are: awareness of non-IT-employees for data, awareness of non-IT-employees for cyber security and experience with interdisciplinary work. These items are classified as ‘helpful’.

The final set of items do not influence IDS adoption and are classified as ‘unrelated’: willingness to flexibilize work arrangements, autonomy of shop floor workers and willingness for continuous training on the job.

7.3.7 Strategy and leadership:

The strategy and leadership dimension as defined by Schumacher et al. (2019) is defined separately by most other models investigated. The dimension defines items related to both defining and monitoring strategic development as well as the leadership aspects required to support this.

This is directly related to IDS as IDS as an innovation requires investment to implement use cases. IDS can become part of an organisations long term strategy towards Industry 4.0 or can be taken up independently of Industry 4.0, minimising the industry 4.0 strategy requirement. In both cases leadership is required to guide the organisation towards IDS adoption.

In order to start adopting IDS leadership is required to have a clear vision of what IDS could bring and what it takes to adopt IDS as only then management is willing to realize IDS. The risk assessment for Industry 4.0, willingness of managers to realize Industry 4.0 and manager trainings for Industry 4.0 items are classified as ‘required’.

Even though maturity regarding roadmap for Industry 4.0 realization, central coordination of Industry 4.0 and employee objectives to realize Industry 4.0 would help in IDS adoption they are not required. They are classified as ‘helpful’.

One item is not considered to be required for IDS adoption as well as not having an influence on IDS adoption. This item is communication of Industry 4.0 activities and is classified as ‘not related’.

7.3.8 Summary of Industry 4.0 maturity influencing IDS adoption

The previous sections discussed each of the items of the Schumacher et al. (2019) maturity model in relation to their potential role in the IDS adoption process. A suggestion for classifying each item based on three possible options is made: enable, improve and unrelated. A summary of which can be found in Table 14.

Table 14 – Pre-adoption maturity items classified based on their role in IDS adoption

Technology Required (0): Helpful (4): Technology for information exchange, Utilization of cloud technology, Mobile devices on shop floor, Decentral information storage Unrelated (5): Integrated computers in machines, Integrated computers in tools, Utilization of robots, Sensors for data collection, Additive manufacturing	**Data & Information** Required (3): Digital information processes, Databased decision making, Automated information provision Helpful (2): Automated data collection, Individualization of provided information Unrelated (3): Analysis of collected data, Digital process visualization, Data-driven software-simulation of future scenarios
Products Required (0): Helpful (3): Collection of product-use-information, Internet connection of products, Digital compatibility and interoperability of products	**Corporate standards** Required (0): Helpful (5): Technological standards, Employee trainings of digital competences, Legal protection for digital products and services, Increased cyber security, Rules for employees in digital work environment

Unrelated (4): Product individualization, Flexibility of product characteristics, Data processing components in products, IT-services related to physical products	Unrelated (3): Monitoring of Industry 4.0 realization, Recruitment for Industry 4.0, Adjustments of works arrangements
Customers and Partners Required (3): Openness to new technology, Digital contact with company partners, Company partner's degree of digitalization Helpful (4): Competence with modern ICT, Digitalization of customer contact, Utilization of customer related data, IT-collaboration for product development Unrelated (1): Customer integration in product development	**Employees** Required (3): Openness to new technology, Competences with modern ICT, Knowledge about employee competences Helpful (3): Awareness of non-IT-employees for data, Awareness of non-IT-employees for cyber security, Experience with interdisciplinary work Unrelated (3): Willingness to flexibilize work arrangements, Autonomy of shop floor workers, Willingness for continuous training on the job
Value Creation Processes Required (0): Helpful (2): Databased machine maintenance, Information exchange between machines Unrelated (6): Value Creation Process automation, Autonomy of machine park, Automated quality control, Automation object handling, Collaboration of humans and robots, remote control of machine park	**Strategy and Leadership** Required (4): Risk assessment for Industry 4.0, Willingness of managers to realize Industry 4.0, Manager trainings for Industry 4.0, Financial resources to realize Industry 4.0 activities Helpful (3): Roadmap for Industry 4.0 realization, Central coordination of Industry 4.0, Employee objectives to realize Industry 4.0 Unrelated (1): Communication of Industry 4.0 activities

7.4 Post-adoption maturity matrix

This section discusses the post-adoption maturity matrix component of the IDS Maturity model. This components provides insight in the impact of adopting IDS in an organisation, this means the increase in Industry 4.0 maturity and possible benefits relating to this increase.

The following sections discuss how IDS adoption is related to maturity in each of the dimensions and items of the Industry 4.0 maturity model by Schumacher et al. (2019). Only a discussion is provided as it is not possible to quantify this relation based on literature sources alone.

Each of the items in the maturity model is classified regarding how IDS adoption affects the post-adoption maturity of an organisation regarding this item. Relating each of the items to a grouping will provide some structure to the results of the discussion.

- Maturing: When IDS directly increased maturity concerning this item.
- Enabling: When IDS adoption does not directly makes this item more maturity but when IDS does makes it possible for other technologies or changes to increase maturity.
- Not affected: Describing items of which IDS adoption does not or very remotely relate to an increase in maturity.

7.4.1 Technology

The technology dimension is one of the most important dimensions of Industry 4.0. As discussed in chapter 7.3.1.

The Technology for information exchange and Decentral information storage items are considered to become more mature during IDS adoption. This is a direct effect of the key attributes of IDS and thus these items are considered to be 'maturing'.

IDS is considered to be 'enabling' in regards to the items Utilization of cloud technology, sensors for data collection, mobile devices on shop floor and utilization of robots. This because IDS can provide the platform for these technologies to receive and share data.

Finally, the items of additive manufacturing, integrated computers in machines and integrated computers in tools are considered to be ‘not affected’ by IDS adoption.

7.4.2 Products

One of key goals of IDS is to enable new business models. This already describes some key insights in regard to the product dimension. As IDS is mainly an enabler of new business models most items are expected to not directly be affect by IDS adoption but are becoming more ready to become more mature by adopting other technologies and processes. In all cases, increasing maturity in regards to products items will be dependent on the business model of the company adopting IDS. It is easy to see how a company offering digital services can benefit from IDS technologies while the value of IDS in a company providing more physical or labour products can be less obvious.

In adopting IDS a company is expected to directly become more mature regarding the Data processing components in products and Digital compatibility and interoperability of products items.

A company that has adopted IDS will be more ready to become maturity regarding the Collection of product-use-information, Product individualization, Flexibility of product characteristics, Internet connection of products and IT-services related to physical products items of products.

7.4.3 Customers and Partners

IDS is mainly to designed to be applied across company borders. As such it is to be expected that an increase in maturity is seen regarding the customers and partners dimension following IDS adoption.

Of the items in the customers and partners dimension the Digitalization of customer contact, digital contact with company partners and company partner’s degree of digitalization items are directly becoming mature following IDS adoption.

In addition, IDS will allow customers and partners to be ready to become more mature regarding Competences with modern ICT, customer integration in product development, utilization of customer related data and IT-collaboration for product development. However some specific effort is probably still required for these items to become more mature.

It is not expected that IDS adoption has any effect regarding the Openness to new technology displayed by the customers and partners of the organisation. It could be that an organisation has had a positive experience in adopting IDS and can conclude that it thus should be more open to similar innovations in the future. This research considers such an affect however too indirect and remote to be prescribed to IDS specifically.

7.4.4 Value creation processes

The value creation processes of an organisation depend a lot on the characteristics of that organisation. IDS is not directly involved as with value creation but it does offer some functionality that enables new value creation processes. These can be used by any interested organisation. A company can for instance ask for a payment before allowing another company access to its data.

IDS can be directly applied in establishing information exchange between machines. As such this item is considered to be ‘maturing’ following IDS adoption.

Value creation process automation and databased machine maintenance are thus items that are enabled by IDS adoption. IDS provided a lot of the necessary tool to increase maturity regarding these items. However it is expected that other technologies are needed in addition to truly benefit and gain maturity regarding these items.

The items of autonomy of machine park, automated quality control, automation object handling, remote control of machine park and collaboration of humans and robots are not directly affected by IDS adoption.

7.4.5 Data & information

The Data and Information dimension is closely related to IDS key functionalities, IDS will probably thus have a great direct or indirect impact on maturity regarding this dimension.

Items such as digital information processes, automated data collection, analysis of collected data, automated information provision and individualization of provided information are directly impacted and will show maturity after adoption of IDS.

While IDS directly impacts the above mentioned items, the item of databased decision making is not directly impacted. For this additional solutions will need to be implemented. IDS does however could support these solutions in filling the database with the data required.

The items digital process visualization and data-driven software-simulation of future scenarios are not considered to be affected by IDS implementation.

7.4.6 Corporate standards

By adopting IDS the company will be required to adopt the way of working as prescribed by IDS, at least withing the scope of IDS. This way of working probably also trickles down into the rest of the organisation.

IDS adoption will directly help organisations become more mature regarding technological standards, legal protection for digital products and services, increased cyber security and rules for employees in digital work environment

While IDS does not affect the monitoring of Industry 4.0 realization, recruitment for Industry 4.0, adjustments of works arrangements and employee trainings of digital competences items of Industry 4.0 maturity.

7.4.7 Employees

Processes in the whole of the organisation will change in order to support the adoption of IDS. As employees are key in any organisation and organisational process an impact is expected on employee maturity as they are faced with the new capabilities of the system.

This impact is however mainly indirect, as IDS itself does not influence these items but the processes and applications that are changes due to IDS adoption will. IDS thus enables growth in maturity in the awareness of non-IT-employees for data, awareness of non-IT-employees for cyber security and autonomy shop floor works items of Industry 4.0.

The items of openness to new technology, competences with modern ICT, willingness to flexibilize fork arrangements, experience with interdisciplinary work, willingness for continuous training on the job and knowledge about employee competences are all not impacted by IDS adoption.

7.4.8 Strategy and Leadership

The final dimension of the maturity model by Schumacher et al. (2019) is the strategy and leadership dimension. This dimension is expected to only indirectly be impacted by IDS adoption as none of the items in this dimension are directly impacted by the adoption of IDS.

Some items are however indirectly impacted by IDS and IDS adoption can enable maturity growth in these items when the right additional actions are taken. These items are the roadmap for Industry

4.0 realization, risk assessment for Industry 4.0, Financial resources for Industry 4.0 and willingness of managers to realize Industry 4.0.

The central coordination of Industry 4.0, communication of Industry 4.0 activities, employee objectives to realize Industry 4.0 and managers trainings for Industry 4.0 items are not directly or indirectly affected by IDS adoption.

7.4.9 Summary of how IDS adoption influences Industry 4.0 maturity items

The previous sections discussed each of the items of the Schumacher et al. (2019) maturity model in relation to their potential role in the IDS adoption process. A suggestion for classifying each item based on three possible options is made: enable, improve and unrelated. A summary of which can be found in Table 15.

Table 15 – Post-adoption maturity items classified based on the effect of IDS adoption on each of the items

Technology Maturing (2): Technology for information exchange, Decentral information storage Enabling (4): Utilization of cloud technology, Sensors for data collection, Mobile devices on shop floor, Utilization of robots Not affected (3):, Integrated computers in machines, Integrated computers in tools, Additive manufacturing	**Data & Information** Maturing (5): Digital information processes, Automated data collection, Analysis of collected data, Automated information provision, Individualization of provided information Enabling (1): Databased decision making Not affected (2): Digital process visualization, Data-driven software-simulation of future scenarios
Products Maturing (2): Data processing components in products, Digital compatibility and interoperability of products Enabling (4): Product individualization, Flexibility of product characteristics, Collection of product-use-information, IT-services related to physical products Not affected (1): Internet connection of products	**Corporate standards** Maturing (4): Technological standards, Legal protection for digital products and services, Increased cyber security, Rules for employees in digital work environment Enabling (0): Not affected (4): Monitoring of Industry 4.0 realization, Recruitment for Industry 4.0, Adjustments of works arrangements, Employee trainings of digital competences
Customers and Partners Maturing (3): Digitalization of customer contact, Digital contact with company partners, Company partner's degree of digitalization Enabling (4): Competence with modern ICT, Customer integration in product development, Utilization of customer related data, IT-collaboration for product development Not affected (1): Openness to new technology	**Employees** Maturing (0): Enabling (3): Awareness of non-IT-employees for data, Awareness of non-IT-employees for cyber security, Autonomy of shop floor workers Not affected (6): Openness to new technology, Competences with modern ICT, Willingness to flexibilize work arrangements, Experience with interdisciplinary work, Willingness for continuous training on the job, Knowledge about employee competences
Value Creation Processes Maturing (1): Information exchange between machines Enabling (2): Value Creation Process automation, Databased machine maintenance Not affected (5): Autonomy of machine park, Automated quality control, Automation	**Strategy and Leadership** Maturing (0): Enabling (4): Roadmap for Industry 4.0 realization, Risk assessment for Industry 4.0, Willingness of managers to realize Industry 4.0, Financial resources for Industry 4.0 Not affected (4): Central coordination of Industry 4.0, Communication of Industry 4.0 activities, Employee objectives to realize Industry 4.0, Manager trainings for Industry 4.0

object handling, Remote control of machine park, Collaboration of humans and robots	

7.5 Strategy guide

This section discusses the strategy guide component of the IDS Maturity model. This component is sometimes also called the roadmap, improvement plan, realization paths, or action plan.

Garcia and Bray (1997) define roadmaps as “plans that match short-term and long-term goals with specific technology solutions to help to meet those goals”. It is easy to see how IDS can be part of the roadmap to Industry 4.0. Or a single development item can be part of the roadmap to IDS adoption. Such a step-wise approach is needed to manage large scale transformation of people processes and technology (Sjödin et al., 2018).

Organisations should not ‘just’ implementing new innovative technologies without due consideration (Cimini, Pinto, & Cavalieri, 2017). It is important that potential benefits are investigated (Morgan et al., 2008 as cited by Cimini, Pinto, & Cavalieri, 2017). SMEs need to develop an own Industry 4.0 vision and roadmap (Mittal, Khan, et al., 2018).

Different types of strategy guides exist. Frederico et al. (2019) relate several aspects to each its four maturity levels. These are strategic outcomes, processes performance requirements, technology levers and managerial and capability supporters. Combined they form what they call a ‘Supply chain 4.0 strategy path’. Such a multi aspect support of strategy allows for a great understanding of the relationship between different aspects. In this case for instance the relationship between certain technology levers on the one end and strategic outcomes on the other.

Other strategy guides provide complete packages or toolkits for helping increase maturity (Mittal, Khan, et al., 2018). These toolkits combine methods, tools, and practices to reach a certain goal (Mittal, Romero, et al., 2018). Qin et al. (2016) suggest the use of ‘building’ blocks of modular units to create integrated smart manufacturing systems.

Another approach is to define readymade transition paths. The paths can be used by organisations to determine current progress and next developments. Ghobakhloo (2018) defines such readymade transitions parts for each of the following fields of I4.0 strategy:

- Strategic management
- Marketing strategy
- Human resources strategy
- IT maturity strategy
- Smart manufacturing strategy
- Smart supply chain management strategy

Looking more in depth in these strategies results in the following conclusions the integration and connectivity aspects of IDS are part of the first steps in the smart supply chain management strategy and the smart manufacturing strategy. In addition IDS as a possible enabler of key steps in the IT maturity and marketing strategies by supporting integration of existing networks and making data accessible for advanced technologies.

7.5.1 Schumacher et al. (2019)

The strategy guide component of the maturity model by Schumacher et al. (2019) is mainly described in steps 7 to 10 of the process definition. It describes how a gap-analysis is performed using the current, as-is, maturity state and the target state, to-be. Items derived from this gap analysis are then clustered and prioritized to generate company specific realization paths.

Schumacher et al. defines three types of maturity items: enable, implement and formalize. During the creation of realization paths each of the items is related to such a type. Enable relates to items that are the basis for Industry 4.0 realization. Implement relates to items that levy Industry 4.0 concepts into practices. The formalize type relates to items that help sustain target state.

During the as-is and target state maturity assessments respondents can mark as being important. These markings are used during the creation of realization paths as prioritisation can be based on these markings.

The maturity model by Schumacher et al. (2019) does not provide any additional tools to help the user in establishing the realization paths. The IDS maturity model aims to help the user by identifying which factors positively of negatively affect IDS adoption. Also, the IDS model will help the user in determining what potential advantages or disadvantages IDS adoption provides.

7.5.2 Factors influencing strategies and approaches

As discussed some publications try to define ready-made realizations paths or modular toolkits. However these are often difficult to convert to tangible roadmaps. The first reason for this is that each organisation is different. This makes that a generic roadmap such as proposed by Ghobakhloo (2018) will need to be adapted to the organisation that is attempting to apply it. Challenges differ for instance based on size, culture, (regulatory) domain, and so forth. Also the position of the company in the supply chain affects the strategy to be adopted (Cimini, Pinto, Pezzotta, et al., 2017).

SMEs show for instance distinct differences and requirements when compared to big companies (Mittal, Khan, et al., 2018). Problem oriented learning approach can be applied to create company specific solutions (Lee et al., 2015; Schumacher et al., 2019).

Strategies can also be implemented at different levels. Hizam-Hanafiah (2020) defines three main levels in organisations in which Industry 4.0 can be adopted: Operations level, Organization level, Customers level. Each require different measures.

The environment the organisation is part of also influences Industry 4.0 adoption. More specifically, the relationship between the organisation and other parties present in the environment and value chain (Sony & Naik, 2019).

7.5.3 Enabling technologies of Industry 4.0

For industry 4.0 a lot of research has been performed in determining the enabling technologies of Industry 4.0. Enabling technologies are those technologies which presence help make other functionality possible. Based on the literature discovered in the systematic literature study the concepts are grouped and presented in Table 16. Concepts mentioned by only one publication are left out.

When this list of enabling technologies it becomes clear that IDS is not being enabled by these technologies. Rather, IDS is part of these concepts, sometimes combining them. As such these enabling technologies of Industry 4.0 cannot be considered to also be the enabling technologies of IDS. The relationship between each technology and IDS thus has to be established in order to determine whether this technology is also an enabler of IDS, part of IDS, or enabled by IDS. This will provide insight in the role of IDS in relation to these technologies and possible provide the basis for a roadmap.

Table 16 – Enabling technologies of Industry 4.0

Concept	Related terms	Publications
Cyber physical systems	Digital twin	(Oztemel & Gursev, 2020), (Vijaya Kumar et al., 2020), (Alcácer & Cruz-Machado, 2019), (Ghobakhloo, 2018), (Queiroz et al., 2019)
Cloud computing		(Oztemel & Gursev, 2020), (Vijaya Kumar et al., 2020), (Alcácer & Cruz-Machado, 2019), (Hamidi et al., 2018), (Ghobakhloo, 2018), (Havle & Üçler, 2018), (Queiroz et al., 2019), (Cimini, Pinto, Pezzotta, et al., 2017)
Simulation	Augmented reality	(Oztemel & Gursev, 2020), (Vijaya Kumar et al., 2020), (Alcácer & Cruz-Machado, 2019), (Ghobakhloo, 2018), (Havle & Üçler, 2018), (Queiroz et al., 2019), (Cimini, Pinto, Pezzotta, et al., 2017)
Internet of things	Internet of people, internet of data, internet of services, industrial internet of things	(Oztemel & Gursev, 2020), (Vijaya Kumar et al., 2020), (Alcácer & Cruz-Machado, 2019), (Hamidi et al., 2018), (Ghobakhloo, 2018), (Havle & Üçler, 2018), (Queiroz et al., 2019), (Cimini, Pinto, Pezzotta, et al., 2017), (Calabrese et al., 2020)
Big data	Data mining, Artificial intelligence, computing	(Oztemel & Gursev, 2020), (Vijaya Kumar et al., 2020), (Alcácer & Cruz-Machado, 2019), (Hamidi et al., 2018), (Ghobakhloo, 2018), (Havle & Üçler, 2018), (Queiroz et al., 2019). (Cimini, Pinto, Pezzotta, et al., 2017), (Calabrese et al., 2020)
Smart factories	Additive manufacturing, Autonomous robots, automation, autonomous system, Advanced 'hardware' technologies based on innovative devices, Transport system, sensors and robots	(Oztemel & Gursev, 2020), (Vijaya Kumar et al., 2020), (Alcácer & Cruz-Machado, 2019), (Hamidi et al., 2018), (Ghobakhloo, 2018), (Queiroz et al., 2019), (Cimini, Pinto, Pezzotta, et al., 2017), (Havle & Üçler, 2018), (Calabrese et al., 2020)
Horizontal and vertical integration	Semantic technologies, sharing	(Alcácer & Cruz-Machado, 2019), (Ghobakhloo, 2018), (Havle & Üçler, 2018), (Cimini, Pinto, Pezzotta, et al., 2017), (Calabrese et al., 2020)
Cyber security	Blockchain	(Alcácer & Cruz-Machado, 2019), (Ghobakhloo, 2018), (Havle & Üçler, 2018), (Queiroz et al., 2019), (Kache and Seuring 2017), (Calabrese et al., 2020)
Production control	ERP and business intelligence, Supply chain MRP	(Oztemel & Gursev, 2020), (Havle & Üçler, 2018), (Cimini, Pinto, Pezzotta, et al., 2017)
Mobile computing	Mobile access	(Hamidi et al., 2018), (Havle & Üçler, 2018)

Some of the concepts identified are directly related to IDS. This means that the key functionalities of IDS are related to (part of) the key functionalities of this concept. This is the case for the cloud computing, internet of things, horizontal and vertical integration, cyber security and mobile computing concepts. These concepts are related to IDS by being used to setup a secure and trusted platform for sharing data, both internally as crossing company boundaries. In doing so IDS can be applied to connect existing platform such as cloud platforms, mobile devices and devices such as used in internet of things. In doing so horizontal and vertical integration is achieved.

Some concepts are enabled by IDS. This means that IDS helps in implementing these concept in the organisation. This is the case for cyber-physical systems, big data and smart factories concepts. IDS can be an enabling technology for these concepts by providing the platform via which data can be made available. Alternatives also exist, mainly in the cases for internally run systems which is probably most often the in the smart factories concepts. The cross-discipline aspect of IDS is very powerful for big data and big data analysis as it enables companies to get access to previously inaccessible or unusable sets of data.

Lastly, some concepts are simply not directly or very remotely related to IDS. These concepts are simulation and production control.

7.5.4 Mapping Industry 4.0 success factors and barriers to IDS adoption

This section will provide a discussion on how IDS adoption can be supported based on known Industry 4.0 factors. This because Industry 4.0 has been investigated more extensively than the concept of IDS. In addition, IDS sees itself as part of the Industry 4.0 roadmap. As such it is expected that some of the factors influencing Industry 4.0 adoption also influence IDS adoption.

Several publications identify success factors and barriers of Industry 4.0 adoption. These positively (success factor) or negatively (barrier) affect the capability of an organisation to adopt Industry 4.0. In this research the term driving forces is associated with success factor, the term challenges is associated with barriers.

Each of the success factors and barriers identified in the literature study are grouped by related Industry 4.0 dimensions following the maturity model by Schumacher et al. (2019).

This section will discuss whether the identified success factors and barriers also relate to IDS adoption. In doing so it becomes more clear what can be done to help organisations achieve IDS adoption.

This section will also discuss how IDS affects the SWOT elements identified for each of the Industry 4.0 maturity dimensions. In doing so it becomes more visible how IDS adoption affects Industry 4.0 adoption and thus why companies on the way to Industry 4.0 should or should not decide to adopt IDS.

A SWOT analysis is comprised of four elements, namely: Strengths, Weaknesses, Opportunities and Threats. A lot of publications have been identified to discuss these elements in relation to Industry 4.0. These are also identified and grouped for each Industry 4.0 dimension. Other related terms in Industry 4.0 literature are benefits and advantages, which can be related to either strengths or opportunities, and disadvantages which can be related to weaknesses or threats. For each of these terms are related to one of the SWOT elements based on the closest fit.

IDS adoption can have three types of effects for each of the elements: positive influence, negative influence or no influence. Positive influence increases the effect of strengths or opportunities of

Industry 4.0 or mitigates weaknesses or threats. In contrast, negative effect will mitigate strength and opportunities while it strengthens weaknesses and threats of Industry 4.0.

The concepts related to the elements of the SWOT analysis might overlap due publications using differing terminology. In this the terminology used in the original publication is considered leading, otherwise an attempt is made to map the item to one of the four SWOT elements. Nevertheless, the groupings should provide insight in the factors influencing Industry 4.0 adoption.

7.5.4.1 Technology

In Table 17 an overview is provided of the success factors and barriers mentioned in found literature related to this dimension. These success factors of Industry 4.0 suggest that having a proper IT infrastructure and digitization of the organization in place with capabilities related to supporting physical processes such as transportation, warehousing, tracking, and so on is helpful during the adoption. These technologies should be modular and easy to use. In contrast, the aspect of technical resource availability could be posing a barrier for Industry 4.0 adoption related to the technology dimension.

IDS does not require an extensive IT infrastructure to be in place as it is capable of providing the main technical components itself. Some integration capabilities are helpful however as IDS is to be connected to the existing systems.

The barrier of technical resource availability is also relevant for IDS. IDS does not require much technical resources in implementing the system, however some resources are required in configuring, maintaining and utilizing.

In short:

- IDS success factors regarding technology: IT infrastructure regarding connecting IDS systems to existing systems
- IDS barriers regarding technology: technical resource availability

Table 17 – Success factors and Barriers of Industry 4.0 related to the Technology dimension

	Related terms	**Publications**
Success factors	IT infrastructure, digitize the organization, configure modular technology, real-time status, ease of use, transportation, automation, tracking, PPC and WMS, warehouse capabilities, transportation	(Frederico et al., 2019), (Sjödin et al., 2018), (Dallasega et al., 2020), (Mittal, Khan, et al., 2018), (Queiroz et al. 2019)
Barriers	Technical resource availability	(Vijaya Kumar et al., 2020)

The systematic literature review has discovered SWOT elements related to the technology dimension of Industry 4.0 which is presented in Table 18. IDS will have the effect the following items:

- Positively (1): Strict requirements concerning advance IT hardware implementation (weakness)
- Negatively (1): Network infrastructure (threat)
- Unaffected (9)

Table 18 – SWOT elements of Industry 4.0 related to the Technology dimension

	Items	**Publications**
Strengths	Easy monitoring and diagnosis of system malfunction (unaffected), Increased self-awareness and maintenance capabilities of systems	(Oztemel & Gursev, 2020), (Oleśków-

	(unaffected), Unbiased real-time knowledge based decision making (unaffected), Smart cities \buildings \factories in distance control (unaffected), Full integration of reality and virtual world (unaffected)	Szłapka & Stachowiak, 2019)
Opportunities	Smart maintenance and service (unaffected), Real-time communication between users (unaffected), Machines and other systems (unaffected)	(Cimini, Pinto, Pezzotta, et al., 2017), (Oleśków-Szłapka & Stachowiak, 2019)
Weaknesses	Factory reorganisation (unaffected), Strict requirements concerning advanced IT hardware implementation (lowered)	(Calabrese et al., 2020), (Oleśków-Szłapka & Stachowiak, 2019)
Threats	Network infrastructure (increased)	(Calabrese et al., 2020)

7.5.4.2 Product

In Table 19 an overview is provided of the success factors and barriers mentioned in found literature related to this dimension. These success factors of Industry 4.0 suggest that developing smart products adapted to the changing customers' needs helps successfully adopting Industry 4.0. In addition a company should be capable of increasing competitiveness by innovating its business models.

IDS contains some capabilities enabling new business models. As such the companies aiming to use IDS should be capable of using these capabilities in order for IDS to be successful. Having smart products is not required for this as it would only allow a company more options to apply IDS. However, IDS can also be successfully implemented and used by companies not offering smart products. The capability of changing a company's business models and products to fit customers' needs is a key success factor for the success of any company or technology use case, IDS is no exception.

In short:

- IDS success factors regarding product: enabling new business models that fit customers' needs

Table 19 – Success factors and Barriers of Industry 4.0 related to the Product dimension

	Related terms	**Publications**
Success factors	Smart products, Competitiveness and business model innovation, adapting to changing customer needs	(Sony & Naik, 2020), (Vuksanović Herceg et al., 2020)
Barriers		

The systematic literature review has discovered SWOT elements related to the product dimension of Industry 4.0 which is presented in Table 20. IDS will have the effect the following items:

- Positively (5): more customized products (strength), services directly responding to customers' needs (opportunities), product personalisation (weakness), more demand on 7/24 running services (weakness), Investment in integrated digital tools/services (threat)
- Negatively (0)
- Unaffected (7)

Table 20 – SWOT elements of Industry 4.0 related to the Product dimension

	Items	**Publications**
Strength	Output quality (unaffected), Improved product quality (unaffected), Production line flexibility (unaffected), More customized products (increased), Production time reduction (unaffected), Penetrated products and service increasing life quality (unaffected)	(Oztemel & Gursev, 2020), (Lu, 2017), (Sjödin et al., 2018), (Oleśków-Szłapka & Stachowiak, 2019)
Opportunities	Digital engineering (unaffected), Lead-time decreasing for products (unaffected), Services directly responding to customers' needs (increased)	(Cimini, Pinto, Pezzotta, et al., 2017), (Oleśków-Szłapka & Stachowiak, 2019), (Cimini, Pinto, Pezzotta, et al., 2017)
Weaknesses	Product personalisation (lowered), More demand on 7/24 running services (lowered)	(Oztemel & Gursev, 2020), (Calabrese et al., 2020)
Threats	Investment in integrated digital tools/services (lowered)	(Cimini, Pinto, Pezzotta, et al., 2017)

7.5.4.3 Customers and Partners

In Table 21 an overview is provided of the success factors and barriers mentioned in found literature related to this dimension. These success factors of Industry 4.0 suggest that effort in the digitization and integration of suppliers, partners and customers will help in successfully adopting Industry 4.0. In addition coordination and collaboration of the efforts helps, as well as enabling connectivity and applying lean and agile processes.

IDS is completely focussed on integrating data exchange between the company and its customers, partners and suppliers. As such efforts flexible processes regarding coordinating and collaboration between organisations will certainly help in the successful adoption of IDS. Any existing integration could help guide the integration to be instantiated by IDS. This however could also be a source of resistance due to reduced willingness by of the organisations to be integrated as it requires new investments for something that is already established. Connectivity of systems in the customers, suppliers and partners organisation will help connecting IDS to the existing systems.

In short:

- IDS success factors regarding Customers and Partners: Coordination and collaboration of organisations, Connectivity of existing systems in both the original as collaborating companies.

Table 21 – Success factors and Barriers of Industry 4.0 related to the Customers and Partners dimension

	Related terms	**Publications**
Success factors	Coordination, Efforts to digitize the supply chain, Digitization, connectivity and network, lean and agility, collaboration, supplier integration, customer integration	(Frederico et al., 2019), (Sony & Naik, 2020), (Dallasega et al., 2020), (Mittal, Khan, et al., 2018), (Queiroz et al. 2019)
Barriers		

The systematic literature review has discovered SWOT elements related to the technology dimension of Industry 4.0 which is presented in Table 22. IDS will have the effect the following items:

- Positively (10): Increased e-business with more spread markets and access to global markets (strength), nationwide participation for contributing to the economy (strength), more easy access to public services (strength), increased visibility and flexibility of supply chains (strength), improvement of all the processes performed in supply chain (strength), vertical integration and horizontal integration (opportunity), digital sales and marketing (opportunities), competitiveness outside sector (opportunities), requirements concerning integration of systems and supply chain elements (weakness), business partners not able to collaborate around digital solutions (threat).

- Negatively (0)
- Unaffected (4)

Table 22 – SWOT elements of Industry 4.0 related to the Customers and Partners dimension

	Items	**Publications**
Strength	Increased e-business with more spread markets and access to global markets (increased), Nationwide participation for contributing to the economy (increased), More easy access to public services (increased), Increased visibility and flexibility of supply chains (increased), Improvement of all the processes performed in supply chain (increased)	(Oztemel & Gursev, 2020), (Oleśków-Szłapka & Stachowiak, 2019)
Opportunities	Competitiveness outside sector (increased), Vertical integration and Horizontal integration (increased), Customer sensing (unaffected), Digital sales and marketing (increased), Better adjusting to customer needs (unaffected)	(Calabrese et al., 2020), (Cimini, Pinto, Pezzotta, et al., 2017), (Hamidi et al., 2018)
Weaknesses	Changing customer orientation (unaffected), Requirements concerning integration of systems and supply chain elements (lowered), Low awareness among companies due to novelty of the approach (unaffected)	(Calabrese et al., 2020), (Oleśków-Szłapka & Stachowiak, 2019)
Threats	Business partners not able to collaborate around digital solutions (lowered)	(Cimini, Pinto, Pezzotta, et al., 2017)

7.5.4.4 Value Creation Processes

In Table 23 an overview is provided of the success factors and barriers mentioned in found literature related to this dimension. These success factors of Industry 4.0 suggest that cost reduction, performance improvements and smart production help in the successful adoption of Industry 4.0.

IDS is not directly involved with reducing cost, performance improvements or smart production. These do no help in adopting IDS. Thus no success factors regarding Value Creation Processes are identified.

Table 23 – Success factors and Barriers of Industry 4.0 related to the Value Creation Processes dimension

	Related terms	**Publications**
Success factors	cost reduction and performance improvements, smart production	(Vuksanović Herceg et al., 2020), (Queiroz et al. 2019)
Barriers		

The systematic literature review has discovered SWOT elements related to the technology dimension of Industry 4.0 which is presented in Table 24. IDS will have the effect the following items:

- Positively (3): new digital business models (opportunities), information monetisation (weakness), increased plagiarism and difficulty to keep intellectual properties (weakness)
- Negatively (0)
- Unaffected (12)

Table 24 – SWOT elements of Industry 4.0 related to the Value Creation Processes dimension

	Items	Publications
Strength	Cost reduction (unaffected), Profitability (unaffected), High productivity (unaffected), Cost- and time-efficiency (unaffected), Power operational cost (unaffected), Faster production process (unaffected), Improved innovation capability (unaffected), New business and service models (unaffected), Increased availability of machines and operators (unaffected), Decrease in risk of structural or organizational mistakes in processes formed (unaffected)	(Calabrese et al., 2020), (Lu, 2017), (Sjödin et al., 2018), (Oztemel & Gursev, 2020), (Oleśków-Szłapka & Stachowiak, 2019)
Opportunities	New digital business models (increased)	(Cimini, Pinto, Pezzotta, et al., 2017)
Weaknesses	Information monetisation (lowered), Complex systems management (unaffected), Increased plagiarism and difficulty to keep intellectual properties (lowered), Requirements concerning implementation of process-oriented management methods (unaffected)	(Calabrese et al., 2020), (Oztemel & Gursev, 2020), (Oleśków-Szłapka & Stachowiak, 2019)
Threats		

7.5.4.5 Strategy and Leadership

In Table 25 an overview is provided of the success factors and barriers mentioned in found literature related to this dimension. These success factors of Industry 4.0 suggest that strong leadership and management support that acknowledge the financial constraints related to Industry 4.0 adoption. In the case of SMEs it is important that the owner understands the concepts of Industry 4.0. This does however also apply to top management of bigger organisations.

A lack of managerial competences and financial resources, for instance due to the high early investment costs will impede Industry 4.0 adoption.

IDS requires the same success factors and barriers as Industry 4.0.

In addition, relating to strategy, a vision aligning initiatives with strategy will help in the successful adoption of Industry 4.0. Strategy aspects related to organizational culture and improving competitiveness by cost reduction and performance improvements are also important.

The uncertainty of the Industry 4.0 business case, a lack of a common vision among staff and perceived costs can impede Industry 4.0 adoption.

Organisational culture and improving competitiveness is less important in the success of IDS adoption while a strategic and aligned vision will probably positively affect IDS adoption success. Just like Industry 4.0, an uncertain business case, the lacking of a common vision among staff and perceived costs will also be a barrier for IDS adoption.

Finally, related to change management and organisational leadership, strong project and change management applying organizational skills, agile processes, culture and alliances and increasing awareness will help in successful adopting Industry 4.0. This can be hampered by resistance of the organisation due to attachment to legacy concepts, perceived threats to established competences and difficulties in adaption existing processes. Or it could simply be that the organisation is overwhelmed with decision to be made or the organisation is lacking a systematic approach.

In regards to IDS, change management will also be important as it supports the changes that need to be made to existing processes and systems. The same items hampering Industry 4.0 change management can be hampering IDS related change managements and thus need to be monitored.

In short:

- IDS success factors regarding Strategy and Leadership: strong leadership and management support acknowledging the financial constraints, understanding of Industry 4.0 by owner/leadership, strategic and aligned vision, change management
- IDS barriers regarding Strategy and Leadership: Lack of managerial competences, lack of common vision among staff, lack of financial resources, perceived costs, resistance of the organisation to change.

Table 25 – Success factors and Barriers of Industry 4.0 related to the Strategy and Leadership dimension

Concept		**Related terms**	**Publications**
Leadership	Success factors	Leadership support, Management support, acknowledge financial constraints, understanding by owner (SMEs),	(Frederico et al., 2019), (Sony & Naik, 2020), (Mittal, Khan, et al., 2018)
	Barriers	Lack of managerial competences, lack of financial resources (SMEs), high early investment cost	(Vuksanović Herceg et al., 2020), (Vijaya Kumar et al., 2020), (Sjödin et al., 2018)
Strategy	Success factors	Strategic vision, align initiatives with organizational strategy, organization culture, competitiveness and business model innovation, cost reduction and performance improvements	(Frederico et al., 2019), (Sony & Naik, 2020), (Mittal, Khan, et al., 2018), (Cimini, Pinto, Pezzotta, et al., 2017), (Vuksanović Herceg et al., 2020)
	Barriers	Uncertain business case, staff lack a common vision, perceived costs	(Sjödin et al., 2018), (Ghobakhloo, 2018)
Organizational leadership	Success factors	Change management, organizational skills, awareness, project management, introduce agile processes, culture and implementation, alliances with knowledge institutes	(Frederico et al., 2019), (Sony & Naik, 2020), (Sjödin et al., 2018), (Dallasega et al., 2020), (Mittal, Khan, et al., 2018)
	Barriers	Resistance, attachment to legacy, perceived threat to established competences, lacking systematic approach, difficulties changing existing processes, overwhelmed with decision (SMEs)	(Vuksanović Herceg et al., 2020), (Sjödin et al., 2018), (Mittal, Khan, et al., 2018)

The systematic literature review has discovered SWOT elements related to the technology dimension of Industry 4.0 which is presented in Table 26. IDS will have the effect the following items:

- Positively (2): increase competitiveness by overcoming technological constraints (opportunities), investment in infrastructures for machines' connections (threats)
- Negatively (0)
- Unaffected (5)

Table 26 – SWOT elements of Industry 4.0 related to the Strategy and Leadership dimension

	Items	Publications
Strength	Competitiveness (unaffected)	(Calabrese et al., 2020)
Opportunities	Increase competitiveness by overcoming technological constraints (increase)	(Hamidi et al., 2018)
Weaknesses	High investments cost (unaffected), High implementation costs (unaffected), Requirements concerning implementation of Industry 4.0 technologies (unaffected)	(Calabrese et al., 2020), (Oleśków-Szłapka & Stachowiak, 2019)
Threats	Economic benefits and return on investment more difficult to estimate (unaffected), Investment in infrastructures for machines' connections (lowered)	(Cimini, Pinto, Pezzotta, et al., 2017)

7.5.4.6 Data & Information

In Table 27 an overview is provided of the success factors and barriers mentioned in found literature related to this dimension. These success factors of Industry 4.0 suggest that having ICT policies in place have an positive effect on Industry 4.0 adoption. In contrast, the requirements for increased data security will be a barrier for successful Industry 4.0 adoption.

IDS adoption will also be supported by having ICT policies in place as these are also needed to be put in place during IDS adoption. This required effort is lessened. Data security will be less of a barrier in IDS adoption as IDS will be mainly responsible for data security or otherwise help enforce it.

In short:

- IDS success factors regarding Data & Information: Having ICT policies in place.

Table 27 – Success factors and Barriers of Industry 4.0 related to the Data & Information dimension

	Related terms	Publications
Success factors	ICT policies	(Queiroz et al. 2019)
Barriers	Data security	(Vijaya Kumar et al., 2020)

The systematic literature review has discovered SWOT elements related to the technology dimension of Industry 4.0 which is presented in Table 28. IDS will have the effect the following items:

- Positively (9): information sharing (strength), ease of access to personal information (strength), information management (weakness), restricting access to knowledge (weakness), not being able to remove or hide unwanted information flow (weakness), not much privacy to be sustained (weakness), increased cyber-attacks and reduced information security (weakness), data security (threat), privacy issues in sharing data with external stakeholders (threat)
- Negatively (0)
- Unaffected (2)

Table 28 – SWOT elements of Industry 4.0 related to the Data and Information dimension

	Items	**Publications**
Strength	Information sharing (increased), Ease of access to personal information (increased), Availability of advanced technologies for analysis of unlimited amount of data (unaffected)	(Calabrese et al., 2020), (Oztemel & Gursev, 2020), (Oleśków-Szłapka & Stachowiak, 2019)
Opportunities		
Weaknesses	Information management (lowered), Restricting access to knowledge (lowered), Not being able to remove or hide unwanted information flow (lowered), Not much privacy to be sustained (lowered), Increased cyber-attacks and reduced information security (lowered), Problems with availability of data with no methods to process them with (unaffected)	(Oztemel & Gursev, 2020), (Calabrese et al., 2020), (Oleśków-Szłapka & Stachowiak, 2019)
Threats	Data security (lowered), Privacy issues in sharing data with external stakeholders (lowered)	(Calabrese et al., 2020), (Cimini, Pinto, Pezzotta, et al., 2017)

7.5.4.7 Corporate standards

In Table 29 an overview is provided of the success factors and barriers mentioned in found literature related to this dimension. These success factors of Industry 4.0 suggest that having standards in place regarding compliance, sustainability and managing and cyber security and safety will help in the successful adoption of Industry 4.0. In addition these standards need to be maintained.

In contrast, a lack of standards and standardization or a lack of conscious planning can impede successful Industry 4.0 adoption.

In successful adopting IDS it is less important to have these standards in place. However these have to be developed and adopting during implementation of IDS and thus it will be beneficial when a company has already defined these practices. A lack of standards and standardization will not directly impede IDS adoption as IDS will provide the tools for users adjust to the specific standard demanded by the other party. Conscious planning is always important in any adoption process, also in IDS.

In short:

- IDS success factors regarding Corporate standards: Having standards in place for compliance, cyber security, safety and sustainability
- IDS barriers regarding Corporate standards: lack of conscious planning

Table 29 – Success factors and Barriers of Industry 4.0 related to the Corporate standards dimension

	Related terms	**Publications**
Success factors	Compliance, managing cyber security, security and safety, maintaining standards, Sustainability	(Frederico et al., 2019), (Sony & Naik, 2020), (Dallasega et al., 2020), (Mittal, Khan, et al., 2018), (Sony & Naik, 2020)
Barriers	Lack of standards and conscious planning, lack of standardization	(Vuksanović Herceg et al., 2020), (Vijaya Kumar et al., 2020)

The systematic literature review has discovered SWOT elements related to the technology dimension of Industry 4.0 which is presented in Table 30. IDS will have the effect the following items:

- Positively (2): communication standards (threat), legal framework (threat)
- Negatively (0)
- Unaffected (4)

Table 30 – SWOT elements of Industry 4.0 related to the Corporate standards dimension

	Items	**Publications**
Strength	Increased safety and sustainability (unaffected), Environmental friendly products (unaffected)	(Sjödin et al., 2018), (Oztemel & Gursev, 2020)
Opportunities		
Weaknesses	More distractions leading to hazardous accidents (unaffected)	(Oztemel & Gursev, 2020)
Threats	Communication standards (lowered), Legal framework (lowered), Cultural transformation to manage operations using digital technologies (unaffected)	(Calabrese et al., 2020), (Cimini, Pinto, Pezzotta, et al., 2017)

7.5.4.8 Employees

In Table 31 an overview is provided of the success factors and barriers mentioned in found literature related to this dimension. These success factors of Industry 4.0 suggest that cultivating digitally capable people will help in successfully adopting Industry 4.0. Generating employee participation, adapting to labour market changes and establishing right worker policies are also enablers of successful Industry 4.0 adoption.

In contrast a lack of skilled people or an unclear communication of transformation and capabilities development can be a barrier of Industry 4.0 adoption.

In short:

- IDS success factors regarding Employees: cultivating digitally capable people, employee participation, adapting labour market changes, establishing right worker policies.
- IDS barriers regarding Employees: lack of skilled people, unclear communications regarding employee capabilities transformation

Table 31 – Success factors and Barriers of Industry 4.0 related to the Employees dimension

	Related terms	**Publications**
Success factors	HR, cultivate digital people, people, employee participation, labour market changes, worker policies	(Frederico et al., 2019), (Sony & Naik, 2020), (Sjödin et al., 2018), (Dallasega et al., 2020), (Mittal, Khan, et al., 2018), (Vuksanović Herceg et al., 2020), (Queiroz et al. 2019)
Barriers	Lack of skilled workforce, skills gap, communication of transformation and capabilities development	(Vuksanović Herceg et al., 2020), (Vijaya Kumar et al., 2020), (Sjödin et al., 2018)

The systematic literature review has discovered SWOT elements related to the technology dimension of Industry 4.0 which is presented in Table 32. IDS will have the effect the following items:

- Positively (4): Digital workplace (opportunity), autonomous decision by all systems users (opportunity), skills (threat), lack of digital skills in the workforce (threat)
- Negatively (0)
- Unaffected (3)

Table 32 – SWOT elements of Industry 4.0 related to the Employees dimension

	Items	Publications
Strength		
Opportunities	Digital workplace (increased), Development of new skills (unaffected), Autonomous decision by all system users (increased)	(Cimini, Pinto, Pezzotta, et al., 2017), (Hamidi et al., 2018), (Oleśków-Szłapka & Stachowiak, 2019)
Weaknesses	Employee reorganisation (unaffected), Dissemination of work knowledge and improved manipulations (unaffected)	(Oztemel & Gursev, 2020), (Calabrese et al., 2020)
Threats	Skills (lowered), Lack of digital skills in the workforce (lowered)	(Calabrese et al., 2020), (Cimini, Pinto, Pezzotta, et al., 2017)

7.6 Discussion

This chapter a first iteration of the IDS maturity model is developed. This iteration is mainly based on literature found in an extensive systematic literature search. This search retrieved mainly publications related to Industry 4.0. No publications directly related to IDS were found.

The first iteration of the IDS maturity model is thus based on the existing maturity model for Industry 4.0 by Schumacher et al. (2019). This model was then adapted and elaborated upon to fit IDS.

In chapter 5.3.3 it was identified that the IDS maturity model should be comprised of several components in order to provide an holistic approach to supporting the IDS adoption decision:

- Process definition describing how the components of the maturity model should be applied.
- Maturity matrix describing the minimum required pre-adoption maturity for IDS adoption.
- Impact mapping describing the expected impact of IDS adoption on each of the post-adoption maturity items.
- Strategy guide describing what factors could influence the maturity matrix and impact mapping results and should thus be kept in mind during IDS adoption.

The model by Schumacher et al (2019) provided a solid foundation but contained only limited description of the strategy guide component, only describing the process that can be used in establishing realization paths. The model did not provide any support for management to understand the context of the items and the factors possibly affecting the strategy and realization paths.

Future iterations should aim to find more support for the IDS model designed. As it is currently based on literature from a related field it can not be stated with certainty what items are related to IDS adoption and in what manner. Finding ways to further validate or invalidate the current design of the IDS model would make it much more reliable. A method that can be applied is that of ensuring triangulation, meaning that different types of input are used to base statements on. An example of which could be to conduct expert interviews.

Secondly, fitting no real effort is made to support the creation of a transfer medium based on this first iteration of the model. This it is expected following the maturity model development approach by Becker et al. (2009) as the design of the transfer medium is the next step, after having concluded more iterations of the model. However, it also means that it will probably hard for a company to use the designed model as-is. The next iteration of the IDS model could provide a more elaborate and 'readable' description of for instance the strategy guide. This would help in testing and validating the model, without needing to completely develop the transfer medium as the transfer medium is mainly used in the widespread use of the model. Testing can be done in the scope of control of the researcher and thus requires a less extensively developed transfer medium.

8 IDS maturity model – Second iteration

This chapter will discuss the second iteration of the IDS maturity model. In chapter 7, the first iteration of the IDS maturity model is developed in which a maturity matrix, an impact mapping, strategy guide and process definition.

This version of the model will discuss the same components in a separate section each. The only difference is that the maturity matrix and impact mapping are combined as they follow the same structure.

This chapter follows the following structure: first changes to the process definition are discussed, secondly the maturity matrix and impact mapping are redefined and third the strategy guide is elaborated upon. The chapter is concluded with a discussion and conclusions sections.

8.1 Process definition

The process definition as developed in the first iteration is maintained. This is because no real indication was found in the questionnaires and interviews that the process would not be suitable. Mainly this could be as the questionnaires and interviews were not designed to retrieve specific feedback regarding this component. The process for applying the IDS maturity model in a company will thus remains the same, summarized by the following points and figure Figure 16.

1. As-is Industry 4.0 maturity assessment using the Schumacher (2019) maturity model.
    a. Industry 4.0 and IDS introduction and creation of participant's alignment and commitment
    b. Collection of company's Industry 4.0 activities to align for as-it-is maturity assessment.
    c. Moderated Industry 4.0 as-it-is self-assessment based on the model by Schumacher et al.
    d. Data collection, statistical analysis and creation of company specific maturity report
2. Maturity gap analysis
    a. Analysis of pre-adoption maturity gaps. In this the maturity assessment of step 1 is compared with the pre-adoption maturity matrix in order to identify which items have to become more mature before IDS adoption is started.
    b. Analysis of post-adoption maturity gaps. In this the maturity assessment of step 1 is compared with the post adoption maturity matrix in order to find item which would benefit from IDS adoption.
3. Perform a cost-benefit analysis based on the maturity gaps identified in step 2a and the impact mapping identified in step 2b. This could result in the decision to not yet start IDS adoption.
4. Development of company-specific realization paths and clustering of related maturity items to be developed into action fields.
5. Specification of action fields and definition of concrete realization-projects.

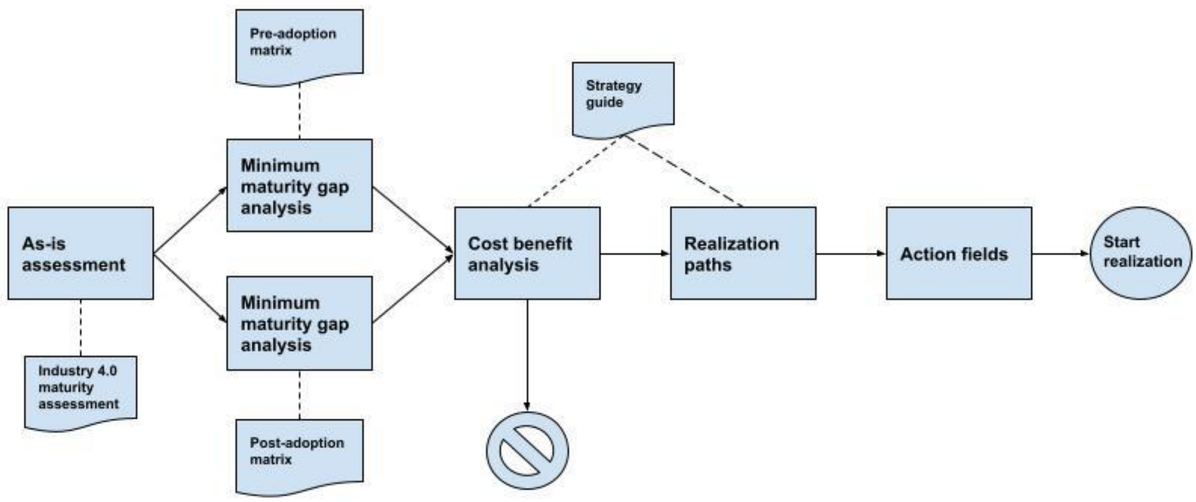


Figure 16 - Schematic overview of the IDS maturity model process (again).

8.2 Redefining the pre-adoption maturity matrix and post-adoption maturity matrix

This section will discuss how the results of the questionnaires and interviews affected the maturity dimensions and items of the previously established IDS maturity model. For each dimension the results of the questionnaire are shown. Also a discussion is provided to define for each item in the dimension how maturity regarding the item affects IDS adoption and how IDS adoption impacts maturity of the item. Finally the section provides a summary of the new model and a summary of remarks made during interview regarding the completeness of the model.

8.2.1 Overview of dimension level maturity

As a result from the questionnaire a ranking can be established for the maturity dimensions. This can be done for pre-adoption minimum required maturity for IDS adoption as well as post adoption resulting maturity after IDS adoption. These results can be found in Table 33. The minimum maturity level in the questionnaire was level 1, the maximum maturity level was 4.

As can be seen, it is expected that IDS adoption will incur the most growth in maturity regarding the corporate standards dimension. The customers and partners dimension is required to have the highest maturity level pre-adoption of all dimensions but will also show the highest maturity post-adoption.

These values can however not be considered very reliable due to the limited number of responses gathered. They can however be used to provide an indication to the how these dimensions are related to each other.

Table 33 – Comparing the results of the questionnaire on a dimension level.

Pre-adoption		**Post adoption**		**Difference**
Customers and Partners	2.8	Customers and Partners	3.2	0.4
Employees	2.7	Employees	3.2	0.5
Strategy and Leadership	2.5	Corporate standards	3.1	0.9
Data and Information	2.4	Strategy and Leadership	3.1	0.5
Corporate standards	2.3	Data and Information	3.0	0.6
Technology	2.2	Technology	2.6	0.4
Products	2.1	Value creation processes	2.5	0.6
Value creation processes	2.0	Products	2.3	0.2

8.2.2 Technology

Results of the questionnaire

In Table 34 a summary is shown of the questionnaire results. Based on these results the interviews were conducted, asking for explanations for the results received. The table shows the minimum required maturity for IDS adoption from high to low (pre-adoption). In addition it shows the expected maturity after adopting IDS (post-adoption) as well as how much this differs from the required maturity, only in case there's a significant change.

Table 34 – Results of the questionnaire regarding the Technology dimension

Pre-adoption	**2.2**	**Post-adoption**	**2.6**	**Difference**
Technology for information exchange	3.0	Technology for information exchange	3.5	0.5
Integrated computers in machines	2.5	Utilization of cloud technologies	2.75	0.5
Utilization of cloud technologies	2.25	Decentral information storage	2.75	**0.75**
Sensors for data collection	2.25	Additive manufacturing	2.75	0.5
Additive manufacturing	2.25	Sensors for data collection	2.5	-
Decentral information storage	2.0	Integrated computers in machines	2.5	-
Integrated computers in tools	2.0	Integrated computers in tools	2.25	0.5
Utilization of robots	2.0	Utilization of robots	2.25	-
Mobile devices on shop floor	1.5	Mobile devices on shop floor	2.0	0.5

Minimum maturity required for IDS adoption

The first iteration of the model was mainly based on literature and the researchers' opinion. As can be found in Table 35, this resulted in no items classified as being required for IDS adoption. Four items were considered helpful for IDS adoption and five items were not helpful to be mature in regards to IDS adoption.

IDS is based only on existing technologies. In order to successfully apply these technologies the company should thus have some understanding of these readily available technologies (1)(2).

Based on the opinion of interviewee (5) a company currently adopting IDS will require high maturity regarding technology. This is because the technical aspects of IDS are complex and still being developed, such as the IDS Connector. The learning-curve associated with IDS is therefore quite high. Getting involved with IDS now probably also requires the company to also contribute to this technical development. When IDS is further along, a company is not required to have in depth knowledge of how the IDS technology works and thus a lower maturity is required.

The previous iteration posed technology for information exchange as the item most closely related to IDS, which is also explicitly mentioned by interviewee (3). The interviews supported the notion that some maturity regarding data exchange is needed. The presence of already existing data sharing will help in adopting IDS (3)(5). This is supported by feedback received from market, as the concept of sharing data in platforms is already well known and that related technical capabilities are already in place (2). Additionally, interviewee (2) states that even though IDS is based on existing technologies, the connectivity aspect will be the hardest to establish. Thus more maturity regarding data exchange would be helpful.

IDS does not provide value for companies which are mainly focussed in for instance additive manufacturing, utilization of robots or sensors for data collection items (4). Extending the notion

According to interviewee (4) required maturity is depending on the use case. Some maturity is needed when a company is aiming to make more structural and long term choices regarding technology for information exchange, utilization of cloud technology and decentral information storage. Structural choices are mainly needed after first stages of integration when a connection to more than a few companies is required. The company can also decide to just 'use' IDS for a establishing a few connections and not be concerned with long term implications then less maturity is required.

No comments are made regarding Mobile devices on shop floor. This item is dubious as in a sense it is directly related to IDS as the IDSA specifically states the capability of IDS to run on mobile devices. This is mostly related to the impact of IDS however, which discussed in next section. As such this item in the context of IDS is considered not to be related to IDS adoption.

Expected growth in maturity resulting from IDS adoption
As can be found in Table 35, the first iteration of the model resulted in two items classified to increase in maturity directly related to the act of adopting IDS. For four items IDS adoption is considered to help enable maturity growth. Three items are not impacted in regards to maturity by adopting IDS.

A distinction can be made to how the company approach the adoption of IDS (4). A company can just implement the help, possibly by outsourcing the work, in order to set up a connection with another company. This will result in little growth. The company can also decide to take a more structural approach, applying IDS not only for a current demand but also for a multitude of future connections. This approach will require the company to put in more effort, gain more expertise and thus will result in more growth in maturity.

Growth is already achieved by 'just doing' anything with technology (2). This however not recognised by interviewee (1) who points to the fact that the technologies IDS is comprised of already exists. This it is not expected that IDS adoption will not force the company to encounter and develop new capabilities. This would suggest that direct growth is only achieved when these technologies were not present in the company beforehand.

A similar argument is made for the technology for information exchange item (3). However, interviewee (2) points out that growth regarding this item might be mainly dependent on whether you were already mature but that growth regarding the specific aspect of semantics will most likely occur.

The very act of adopting IDS will make a company more mature regarding decentralised information storage (3). It is also important to note that IDS can be applied to this affect internally (3), even though the main aim of IDS is to be applied across company boundaries.

According to interviewee (4), IDS will mostly enable new opportunities for which the data that is made available can be used for. Examples given are: sensing, artificial intelligence and preventative maintenance.

Finally, interviewee (3) states that utilization of robots is an example of the many items that are not affected by IDS adoption. The integrated computers in machines and tools, sensors for data collection and additive manufacturing items are deemed to be similar to the utilization of robots items in this regard.

Again, no comments are made regarding Mobile devices on shop floor. This item is dubious as in a sense it is directly related to IDS as the IDSA specifically states the capability of IDS to run on mobile devices. As such this item in the context of IDS is considered to be enabled by IDS, similar as to how utilization of cloud technology is enabled by IDS.

Table 35 – Summary of the first and second iteration of the Technology dimension of the IDS maturity model

First iteration	Second iteration
Pre-adoption Required (0): Helpful (4): Technology for information exchange, Utilization of cloud technology, Mobile devices on shop floor, Decentral information storage Unrelated (5): Integrated computers in machines, Integrated computers in tools, Utilization of robots, Sensors for data collection, Additive manufacturing	**Pre-adoption – Some maturity required*** Required (1): Technology for information exchange ** Helpful (2): Utilization of cloud technology **, Decentral information storage** Unrelated (6): Integrated computers in machines, Integrated computers in tools, Mobile devices on shop floor, Utilization of robots, Sensors for data collection, Additive manufacturing
Post-adoption Maturing (2): Technology for information exchange, Decentral information storage Enabling (4): Utilization of cloud technology, Sensors for data collection, Mobile devices on shop floor, Utilization of robots Not affected (3): Integrated computers in machines, Integrated computers in tools, Additive manufacturing	**Post-adoption – Maturing**** Maturing (2): Technology for information exchange, Decentral information storage Enabling (2): Utilization of cloud technology, Mobile devices on shop floor Not affected (5): Integrated computers in machines, Integrated computers in tools, Sensors for data collection, Additive manufacturing, Utilization of robots
	* Higher in current state of IDS Connector development ** depending on the use case

8.2.3 Products

Results of the questionnaire

In Table 36 a summary is shown of the questionnaire results. Based on these results the interviews were conducted, asking for explanations for the results received. The table shows the minimum required maturity for IDS adoption from high to low (pre-adoption). In addition it shows the expected maturity after adopting IDS (post-adoption) as well as how much this differs from the required maturity, only in case there's a significant change.

Table 36 – Results of the questionnaire regarding the Products dimension

Pre-adoption	2.1	Post-adoption	2.3	Difference
IT-services related to physical products	2.5	IT-services related to physical products	2.5	-
Collection of product-use-information	2.0	Collection of product-use-information	2.5	**0.5**
Product individualization	2.0	Product individualization	2.25	-
Flexibility of product characteristics	2.0	Flexibility of product characteristics	2.25	-
Data processing components in products	2.0	Data processing components in products	2.25	-
Digital compatibility and interoperability of products	2.0	Digital compatibility and interoperability of products	2.25	-
Internet connection of products	2.0	Internet connection of products	0	-

Minimum maturity required for IDS adoption

The first iteration of the model was mainly based on literature and the researchers' opinion. As can be seen in Table 37Table 35, this resulted in no items classified as being required for IDS adoption. Three items were considered helpful for IDS adoption and four items were not helpful to be mature in regards to IDS adoption.

Most interviewees reported that it is not required for companies to be mature regarding Industry 4.0 types of products, or smart products (1)(3)(4). In contrast to the way they are produced and for whom, which is more important (4). This is in line with the discussion provided in the first iteration of the model.

It is however important to note that the use case for which IDS is adopted might be of influence to this (1)(3). Having products that generate data to be collected or used can help establish a business case for IDS (3)(4). Internet connection of products can therefore be helpful, if only fitting the use case.

Interviewee (4) for instance points that most smaller manufacturing organisations would not benefit from IDS when they do not first start doing sales and related processes digitally. This is supported by statements made by interviewee (2), indicating that a fit is required between the products offered by IDS and the use case implemented. Thus the item of IT-services related to physical products is considered helpful to be mature, if only this fits the use case to be implemented.

Expected growth in maturity resulting from IDS adoption
As can be found in Table 37, the first iteration of the model resulted in two items classified to increase in maturity directly related to the act of adopting IDS. For four items IDS adoption is considered to help enable maturity growth. Three items are not impacted in regards to maturity by adopting IDS.

Growth is expected as IDS enables quicker time to market in regards to products, more control over products that are sent out into the world and more control over the data associated with these products (5).

However most interviewees stress a dependence on the use cases being implemented (1)(3)(4)(5). This was also recognized during the first iteration of the model. An example of such a factor is for instance the type products offered by the company. First, even though it is not required for a company to offer smart products, companies offering simple goods will benefit less from IDS adoption (1).

Secondly, some use cases do not require the company to change its products offering, and thus no growth is expected in such IDS use cases (3)(4).

Interviewee (4) recognizes however that the current Dutch manufacturing philosophy is aimed at enabling the Industry 4.0 capabilities of manufacturing unique products at low cost and with high quality. Being able to quickly adapt to changings customer demands. IDS is creates a smart factory which offers opportunities, these opportunities also need to be cashed in requiring growth in maturity (5). During the first iteration of the model it was discussed that IDS could enable new business models.

Also the type of company with which to collaborate is of influence to the expected growth in maturity regarding the products dimension. A small company might not be able to directly handle a product offering based on IDS. In this case additional effort is required to develop additional compatibility or connectiveness, for instance by also implementing an app for the company to install and use IDS with (4).

Even though the first iteration of the model expected a direct impact of IDS on the data processing components in products, no reviewer made any mention of this relationship existing.

Table 37 - Summary of the first and second iteration of the Product dimension of the IDS maturity model

First iteration	Second iteration
Pre-adoption Required (0): Helpful (3): Collection of product-use-information, Internet connection of products, Digital compatibility and interoperability of products Unrelated (4): Product individualization, Flexibility of product characteristics, Data processing components in products, IT-services related to physical products	**Pre-adoption – No maturity required*** Required (0): Helpful (3): IT-services related to physical products*, Internet connection of products*, Digital compatibility and interoperability of products* Unrelated (4): Product individualization, Collection of product-use-information, Flexibility of product characteristics, Data processing components in products
Post-adoption Maturing (2): Data processing components in products, Digital compatibility and interoperability of products Enabling (4): Product individualization, Flexibility of product characteristics, Collection of product-use-information, IT-services related to physical products Not affected (1): Internet connection of products	**Post-adoption – Enabling*** Maturing (0): Enabling (5): Product individualization*, Flexibility of product characteristics*, Collection of product-use-information*, IT-services related to physical products*, Digital compatibility and interoperability of products* Not affected (2): Internet connection of products, Data processing components in products
	* Depending on the use case

8.2.4 Customers and Partners

Results of the questionnaire

In Table 38 a summary is shown of the questionnaire results. Based on these results the interviews were conducted, asking for explanations for the results received. The table shows the minimum required maturity for IDS adoption from high to low (pre-adoption). In addition it shows the expected maturity after adopting IDS (post-adoption) as well as how much this differs from the required maturity, only in case there's a significant change.

Table 38 – Results of the questionnaire regarding the Customers and Partners dimension

Pre-adoption	2.8	Post-adoption	3.2	Difference
Openness to new technology	3.5	Openness to new technology	3.75	-
Competence with modern ICT	3.25	Competence with modern ICT	3.5	-
Company partner's degree of digitalization	3.25	Company partner's degree of digitalization	3.5	-
Customer integration in product development	2.75	Digitalization of customer contact	3.25	0.75
Digitalization of customer contact	2.5	Digital contact with company partners	3.25	**1.0**
Utilization of customer related data	2.5	Utilization of customer related data	3.0	0.5
IT-collaboration for product development	2.5	Customer integration in product development	2.75	-
Digital contact with company partners	2.25	IT-collaboration for product development	2.75	-

Minimum maturity required for IDS adoption
The first iteration of the model was mainly based on literature and the researchers' opinion. As can be seen in Table 39, this resulted in three items classified as being required for IDS adoption. Four items were considered helpful for IDS adoption and one item was not helpful to be mature in regards to IDS adoption.

Customers and Partners requires at least some maturity. This dimensions focusses one of the biggest barriers of IDS: collaboration and trust (2). IDS is aimed sharing data across company borders, this it is to be expected that this dimensions is directly related to IDS (1).

Existing relationships will be required for successful IDS adoption as the adoption process requires investment, trust and cooperation from both parties (1). Strengthening the discussion made in this regard in the first iteration.

Such relationships would also be comprised of agreements regarding sales and delivery processes, product codes to be used, capabilities expected to be present and the use of standards (4). As these all also need to be established in digital form and configured it will be helpful if these already exist.

Furthermore, it is required that Customers and Partners are at all willing and able to communicate digitally (1). As stated clearly by interviewee (5): two-to-tango. A point which was also made in the first iteration of the model.

Lastly, it is important that the company and its' partners and customers are able to create value from the collaboration (2), for this it is helpful when the company is establishing more connections (1). This could reflected by the Customer integration in product development (5) and IT-collaboration for product development items. It is thus considered helpful for these items to be present. Interviewee (3) adds that maturity regarding these items is only helpful depending on the use case to be implemented. The item of customer integration in product development has been classified as 'not related' in the first iteration of the model.

The use case to be implemented can also be related to the data which is to be shared. When data is to be shared in the use case then some pre-existing maturity is helpful (3). Following this logic, maturity regarding the utilization of customer related data (5) is considered helpful depending on the use case.

In regards to specific items: some maturity is required regarding openness to new technology (3)(4)(5), however even the fact of considering IDS adoption already shows openness (3). Some maturity regarding competence with modern ICT (3)(5) and digitalization of customer contact (5) will also be required, otherwise it would be hard to start collaboration (3). In contrast to these two items being classified as helpful in the first iteration of the model.

Expected growth in maturity resulting from IDS adoption
As can be seen in Table 39, the first iteration of the model resulted in three items classified to increase in maturity directly related to the act of adopting IDS. For four items IDS adoption is considered to help enable maturity growth. One item is not impacted in regards to maturity by adopting IDS.

It is expected that the company as well as the related customers and partners will grow in maturity together following successful IDS adoption (2)(4). Similar to the technology dimension, applying IDS, in itself, will contribute to growth in the organisation. Interviewee (1) however does not agree with this notion, stating that growth is possible but not necessarily expected.

Knowing and investigating the concepts of IDS will possibly improve the external and internal processes. Even without fully implementing IDS (3). Enabling new opportunities previously not possible or viable (4). This seems to suggest IDS to be enabling maturity relating to items such as utilization of customer related data or IT-collaboration for product development. In contrast, interviewee (3) states that the IT-collaboration for product development item is not related to IDS.

When IDS is implemented in an organisation and the organisation shares this achievement with its' partnering organisation then collaboration is improved. Customers and partners could improve their processes. An example would be a big company forcing other companies to use IDS (3). Digitalization of customer contact would grow (3) as well as possibly customer integration in product development and IT-collaboration for product development.

Growth related to these items is also encouraged by the need of companies to seize the new opportunities made available by IDS (2). However, interviewee (3) does not agree that items concerning product offerings are related to IDS and will this not grow more mature after IDS adoption. It seems that growth regarding the customer integration in product development and IT-collaboration for product development items cannot just be expected, suggesting a dependency on the use case being implemented.

Table 39 - Summary of the first and second iteration of the Customers and Partners dimension of the IDS maturity model

First iteration	Second iteration
Pre-adoption <u>Required (3):</u> Openness to new technology, Digital contact with company partners, Company partner's degree of digitalization <u>Helpful (4):</u> Competence with modern ICT, Digitalization of customer contact, Utilization of customer related data, IT-collaboration for product development <u>Unrelated (1):</u> Customer integration in product development	**Pre-adoption – Maturity required** <u>Required (5):</u> Openness to new technology, Competence with modern ICT, Digitalization of customer contact, Digital contact with company partners, Company partner's degree of digitalization <u>Helpful (3):</u> Customer integration in product development*, IT-collaboration for product development*, Utilization of customer related data* <u>Unrelated (0):</u>
Post-adoption <u>Maturing (3):</u> Digitalization of customer contact, Digital contact with company partners, Company partner's degree of digitalization <u>Enabling (4):</u> Competence with modern ICT, Customer integration in product development, Utilization of customer related data, IT-collaboration for product development <u>Not affected (1):</u> Openness to new technology	**Post-adoption - Maturing** <u>Maturing (4):</u> Digitalization of customer contact, Digital contact with company partners, Company partner's degree of digitalization, Competence with modern ICT <u>Enabling (3):</u> Utilization of customer related data, Customer integration in product development*, IT-collaboration for product development* <u>Not affected (1):</u> Openness to new technology
	* Depending on the use case

8.2.5 Value creation processes

Results of the questionnaire

In Table 40Table 34 a summary is shown of the questionnaire results. Based on these results the interviews were conducted, asking for explanations for the results received. The table shows the minimum required maturity for IDS adoption from high to low (pre-adoption). In addition it shows the expected maturity after adopting IDS (post-adoption) as well as how much this differs from the required maturity, only in case there's a significant change.

Table 40 – Results of the questionnaire regarding the Value Creation Processes dimension

Pre-adoption	**2.0**	**Post-adoption**	**2.5**	**Difference**
Value Creation Process automation	2.0	Value Creation Process automation	3.0	**1.0**
Information exchange between machines	2.0	Information exchange between machines	2.75	0.75
Databased machine maintenance	2.0	Databased machine maintenance	2.75	0.75
Remote control of machine park	2.0	Remote control of machine park	2.5	0.5
Automated quality control	2.0	Automated quality control	2.5	0.5
Autonomy of machine park	2.0	Autonomy of machine park	2.25	-
Automation object handling	2.0	Automation object handling	2.25	-
Collaboration of humans and robots	1.75	Collaboration of humans and robots	2.25	0.5

Minimum maturity required for IDS adoption
The first iteration of the model was mainly based on literature and the researchers' opinion. As can be seen in Table 41, this resulted in no items classified as being required for IDS adoption. One item was considered helpful for IDS adoption and five item was not helpful to be mature in regards to IDS adoption.

It is not the purpose of IDS to create value (5). It is difficult to relate value creation processes maturity to IDS as it is very dependent on the existing value creation processes and the use case to be adopted whether or not any maturity is required (1).

Companies should put effort in two things. Firstly, some form of control of the business processes (4), which is often lacking in smaller companies (4).

Secondly companies should determine the value of the data present in the organisations and the machines (4). This requires machines in the company to be capable of generating and sharing information (3). This could be required for certain business cases in which such data is used. However it cannot be stated that these capabilities are required in any way.

It is important to note that IDS cannot be considered a silver bullet. With this it is meant that IDS is not capable of filling in all the gaps of missing maturity in an item (5). For this IDS is to be used in conjunction with other technologies.

No real statements have been made concerning specific items. Interviewee (3) states that the hardware in organisations is not required to be mature regarding Industry 4.0 for IDS to be of use. Which is supported by interviewee (4) who mentions collaboration of humans and robots as an example items which is not of importance.

Expected growth in maturity resulting from IDS adoption
As can be seen in Table 41, the first iteration of the model resulted in no items classified to increase in maturity directly related to the act of adopting IDS. For two items IDS adoption is considered to help enable maturity growth. Four item are not impacted in regards to maturity by adopting IDS.

The main aspect resulting in growth is whether or not a use case for IDS fitting your company is found (1). It could be that existing value creation process fit IDS in their current state, it could also be that new value creation processes can be established based on capabilities enabled by IDS (1). In both cases it IDS would be an enabler (3)(5).

Value creation process automation maturity will possibly grow as a results of begin able to share data but only when a company is able to use the data (3). Preferred by partners which also use IDS and share data with you. This will increase opportunities for more value. Improving the whole chain instead just locally (3).

Table 41 - Summary of the first and second iteration of the Value Creation Processes dimension of the IDS maturity model

First iteration	**Second iteration**
Pre-adoption Required (0): Helpful (2): Databased machine maintenance, Information exchange between machines Unrelated (6): Value Creation Process automation, Autonomy of machine park, Automated quality control, Automation object handling, Remote control of machine park, Collaboration of humans and robots	**Pre-adoption – No maturity required** Required (0): Helpful (3): Databased machine maintenance, Value Creation Process automation, Information exchange between machines Unrelated (5): Autonomy of machine park, Automated quality control, Automation object handling, Remote control of machine park, Collaboration of humans and robots
Post-adoption Maturing (1): Information exchange between machines Enabling (2): Value Creation Process automation, Databased machine maintenance Not affected (5): Autonomy of machine park, Automated quality control, Automation object handling, Remote control of machine park, Collaboration of humans and robots	**Post-adoption – Mostly Unaffected** Maturing (2): Value Creation Process automation*, Information exchange between machines Enabling (1): Databased machine maintenance Not affected (5): Autonomy of machine park, Automated quality control, Automation object handling, Remote control of machine park, Collaboration of humans and robots
	* Depending on use case

8.2.6 Data & Information

Results of the questionnaire

In Table 42 a summary is shown of the questionnaire results. Based on these results the interviews were conducted, asking for explanations for the results received. The table shows the minimum required maturity for IDS adoption from high to low (pre-adoption). In addition it shows the expected maturity after adopting IDS (post-adoption) as well as how much this differs from the required maturity, only in case there's a significant change.

Table 42 – Results of the questionnaire regarding the Data & Information dimension

Pre-adoption	**2.4**	**Post-adoption**	**3.0**	**Difference**
Digital information processes	3.25	Digital information processes	4.0	0.75
Analysis of collected data	2.75	Analysis of collected data	3.25	0.5
Automated data collection	2.5	Automated data collection	3.25	0.75
Automated information provision	2.25	Automated information provision	3.0	0.75
Digital process visualization	2.25	Databased decision making	2.75	0.75
Data-driven software simulation of future scenarios	2.25	Individualization of provided information	2.75	0.75
Databased decision making	2.0	Digital process visualization	2.5	-
Individualization of provided information	2.0	Data-driven software simulation of future scenarios	2.5	-

Minimum maturity required for IDS adoption

The first iteration of the model was mainly based on literature and the researchers' opinion. As can be seen in Table 43, this resulted in three items classified as being required for IDS adoption. Two items were considered helpful for IDS adoption and three item are not helpful to be mature in regards to IDS adoption.

Infrastructure is needed to prepare and offer data for IDS to use in a structured manner (1)(2)(3). Digital information processes and automated data collection are both directly related to these processes (4), maturity is thus expected regarding these items before starting IDS adoption. This is in contrast to interviewee (5) which states that no maturity is required for any item in this dimension in order to start IDS adoption, however it recognizes the need then for a company to develop the capabilities alongside the adoption of IDS.

It is not needed to be mature regarding automated information provisioning or individualisation of provided information. As a company can very well decide to start IDS adoption without these items (3). Having these in place already would however help in establishing a more extensive IDS use case.

The other items are not required (4), such as database decision making and data-driven software-simulation of future scenarios as items that are not required.

Expected growth in maturity resulting from IDS adoption

As can be seen in Table 43, the first iteration of the model resulted in five items classified to increase in maturity directly related to the act of adopting IDS. For one item IDS adoption is considered to help enable maturity growth. Two item are not impacted in regards to maturity by adopting IDS.

It is expected that IDS adoption will increase maturity in general regarding this dimension (5).

By adopting IDS a company will have improved its capability to transfer data through a central entity which is also capable of handling the semantics aspect of data transfer (1). This directly increases maturity regarding digital information processes, automated information provisioning and individualization of provided information (3).

After IDS it is not hard to adopt additional technology making automated data collection possible. IDS is thus an enabler for this.

IDS forces a company to consider the aspects related to data usage. This will help in establishing insight in what information is available in the organisation, the value it could have and how it should be made available (3). This means that IDS is an enabler of the analysis of collected data item. This way of thinking can also be applied in regards to customers, resulting in possibly increased maturity towards individualisation of provided information (3).

Table 43 - Summary of the first and second iteration of the Data & Information dimension of the IDS maturity model

First iteration	Second iteration
Pre-adoption Required (3): Digital information processes, Databased decision making, Automated information provision Helpful (2): Automated data collection, Individualization of provided information	**Pre-adoption – Some maturity required** Required (2): Digital information processes, Automated information provision Helpful (1): Automated data collection Unrelated (5): Individualization of provided information, Analysis of collected data, Digital process visualization, Data-driven software-simulation of future scenarios, Databased decision making

Unrelated (3): Analysis of collected data, Digital process visualization, Data-driven software-simulation of future scenarios	
Post-adoption Maturing (5): Digital information processes, Automated data collection, Analysis of collected data, Automated information provision, Individualization of provided information Enabling (1): Databased decision making Not affected (2): Digital process visualization, Data-driven software-simulation of future scenarios	**Post-adoption - Maturing** Maturing (3): Digital information processes, Automated information provision, Individualization of provided information Enabling (2): Analysis of collected data, Automated data collection Not affected (3): Databased decision making, Digital process visualization, Data-driven software-simulation of future scenarios

8.2.7 Corporate standards

Results of the questionnaire

In Table 44 a summary is shown of the questionnaire results. Based on these results the interviews were conducted, asking for explanations for the results received. The table shows the minimum required maturity for IDS adoption from high to low (pre-adoption). In addition it shows the expected maturity after adopting IDS (post-adoption) as well as how much this differs from the required maturity, only in case there's a significant change.

Table 44 – Results of the questionnaire regarding the Corporate standards dimension

Pre-adoption	2.3	Post-adoption	3.1	Difference
Technological standards	2.75	Legal protection for digital products and services	4.0	**1.75**
Legal protection for digital products and services	2.25	Increased cyber security	4.0	**1.75**
Increased cyber security	2.25	Technological standards	3.5	0.75
Adjustments of work arrangements	2.25	Adjustments of work arrangements	3.0	0.75
Rules for employees in digital work environment	2.25	Rules for employees in digital work environment	3.0	0.75
Monitoring of Industry 4.0 realization	2.25	Employee training for digital competences	2.75	0.75
Employee training for digital competences	2.0	Monitoring of Industry 4.0 realization	2.5	-
Recruitment for Industry 4.0	2.0	Recruitment for Industry 4.0	2.25	-

Minimum maturity required for IDS adoption

The first iteration of the model was mainly based on literature and the researchers' opinion. As can be seen in Table 45Table 35, this resulted in no items classified as being required for IDS adoption. Five items were considered helpful for IDS adoption and three item as not helpful to be mature in regards to IDS adoption.

At least some maturity is required for the adoption of IDS (1)(2)(3)(5). This in order for a company to be capable of understanding the 'package' of existing standard of which IDS consists of (1).

This means for example that a pre-existing culture and processes have to be present for enabling cyber security (2)(5). Implementing authentication mechanisms will not be possible when a company does not have proper user management as otherwise the system cannot be adopted or will fail as a result from any change or irregularity (2). In the context of the IDS maturity model: this would indicate a required maturity in regards to cyber security

The culture components of the reasoning above suggest it would be helpful for a company to be a least somewhat mature regarding employee trainings of digital competences and rules for employees in the digital work environment.

No statements have been made specifically related to the legal protection for digital products and services item. As it is very related to what IDS does it is considered helpful to be at least somewhat mature regarding this item. This is also what was concluded during the first iteration of the model.

Regarding technological standards: some maturity is required to be capable of determining what data is in your possession (3), an example of which is the need to have established some standards regarding the semantics of data (3).

(5) states that the monitoring of Industry 4.0 will help but that it is not the only factor having influence on IDS adoption, no reasoning for this provided. Interviewee (3) does not think any maturity is required regarding this item as it is not related to IDS adoption or data sharing. Similarly, the recruitment for industry 4.0 is also not considered related to IDS adoption (3).

Expected growth in maturity resulting from IDS adoption
As can be seen in Table 45, the first iteration of the model resulted in four items classified to increase in maturity directly related to the act of adopting IDS. For no items IDS adoption is considered to help enable maturity growth. Four item are not impacted in regards to maturity by adopting IDS.

Growth in maturity is expected as a result of adopting IDS (1)(2)(5). Interviewee (5) adds that IDS is not the sole contributor to improve this maturity. Effort by the company is required in conjunction to adopting IDS. However, it is expected that the concepts enforced within IDS will trickle down in to the companies' corporate standards (2).

This because a company cannot be operating sloppy internally and expect to be able to work meticulous externally (2).

IDS forces you to think better about your data (3), so growth expected in all items with the exception of monitoring of Industry 4.0 realization and recruitment for Industry 4.0 as these items are not related to IDS or data sharing (3). This does not only apply to the company as a whole but also for the employees, as such growth is expected in the awareness among employees in regards of data sharing (5).

Interviewee (4) Posed that growth is mainly related to technological standards, and more specifically 'semantic standards'. This because IDS makes it more easy to share data in a controlled manner, but to be able to use the data also the semantics of the data should be understood. This is an aspect that has previously often been neglected.

This increase in growth is also interrelated. For instance, thinking about the legal aspect of your data will also force you to think about the security of the data or what regulations are should be put in place regarding data sharing by employees (3).

Table 45 – Summary of the first and second iteration of the Corporate standards dimension of the IDS maturity model

First iteration	**Second iteration**
Pre-adoption	**Pre-adoption – Some maturity required**

Required (0): Helpful (5): Technological standards, Employee trainings of digital competences, Legal protection for digital products and services, Increased cyber security, Rules for employees in digital work environment Unrelated (3): Monitoring of Industry 4.0 realization, Recruitment for Industry 4.0, Adjustments of works arrangements	Required (2): Technological standards, Increased cyber security Helpful (3): Employee trainings of digital competences, Legal protection for digital products and services, Rules for employees in digital work environment Unrelated (3): Monitoring of Industry 4.0 realization, Recruitment for Industry 4.0, Adjustments of works arrangements
Post-adoption Maturing (4): Technological standards, Legal protection for digital products and services, Increased cyber security, Rules for employees in digital work environment Enabling (0): Not affected (4): Monitoring of Industry 4.0 realization, Recruitment for Industry 4.0, Adjustments of works arrangements, Employee trainings of digital competences	**Post-adoption - Maturing** Maturing (6): Technological standards, Legal protection for digital products and services, Increased cyber security, Rules for employees in digital work environment, Adjustments of works arrangements, Employee trainings of digital competences Enabling (0): Not affected (2): Monitoring of Industry 4.0 realization, Recruitment for Industry 4.0

8.2.8 Employees

Results of the questionnaire

In Table 46Table 34 a summary is shown of the questionnaire results. Based on these results the interviews were conducted, asking for explanations for the results received. The table shows the minimum required maturity for IDS adoption from high to low (pre-adoption). In addition it shows the expected maturity after adopting IDS (post-adoption) as well as how much this differs from the required maturity, only in case there's a significant change.

Table 46 – Results of the questionnaire regarding the Employees dimension

Pre-adoption	**2.7**	**Post-adoption**	**3.2**	**Difference**
Openness to new technology	3.25	Openness to new technology	3.75	0.5
Awareness of non-IT-Employees for data	3.0	Awareness of non-IT-Employees for data	3.75	0.75
Competences with modern ICT	3.0	Awareness of non-IT-Employees for cyber security	3.75	**1.25**
Awareness of non-IT-Employees for cyber security	2.5	Competences with modern ICT	3.5	0.5
Willingness for continuous training on the job	2.5	Willingness for continuous training on the job	3.0	0.5
Willingness to flexibilize work arrangements	2.5	Willingness to flexibilize work arrangements	2.75	-
Experience with interdisciplinary work	2.5	Experience with interdisciplinary work	2.75	-
Knowledge about employee competences	2.5	Knowledge about employee competences	2.75	-
Autonomy of shop floor workers	2.25	Autonomy of shop floor workers	2.5	-

Minimum maturity required for IDS adoption

The first iteration of the model was mainly based on literature and the researchers' opinion. As can be seen in Table 47, this resulted in three items classified as being required for IDS adoption. Three items were considered helpful for IDS adoption and three item as not helpful to be mature in regards to IDS adoption.

It is important that an organisation shows maturity regarding the employees dimensions before adopting IDS (1)(2)(4). Interviewees (1) and (2) state specifically that some maturity to be required, while interviewee (4) even mentions a need for high maturity.

Maturity is required as it is important that employees are capable to understand, value, use and integrate IDS correctly (1)(3)(4). A structural approach is required, similar to how HRM and accounting have become structural components of any company, as it is necessary but also because it provides sanity (4).

A distinction can be made between capabilities required by employees involved in the adoption of IDS and capabilities required by people who are going to use the final system. Interviewee (2) indicated that this distinction might possibly explain the differing opinions on the required maturity levels: the development and implementation of IDS can be complex however the use of IDS in practice should not be (2).

Interviewee (2) points to the fact that platform-like systems are commonplace now, for instance in social media. Employees should this be capable of adjusting to the concept quickly, requiring less maturity before adoption for non-it-employees that are going to use the system. In contrast, non-it-employees are also required to use the system, deciding on whether and how to share data (2). These decisions should not only be made by the IT department of a company (3).

Some companies already have people with expertise to support IDS adoption (5). Some companies however do not, these companies are discouraged to start IDS adoption (5).

Either way, employees are required to be open to new technology and competent with ICT for IDS adoption to be successful (3). In addition a company should be knowledgeable about employee competences. This is in line with the items posed to be required during the first iteration of the model. In this iteration also awareness of non-IT-employees for data and cyber security is required, not 'just' helpful.

Interviewee (3) adds that employees can also be a driving factor in initiating IDS adoption. When employees are capable with (modern) IT then they will probably themselves push for and implement IDS adoption.

Other items such as experience with interdisciplinary work and willingness for continuous training are not related to IDS and data sharing (3)(5). When an employee is not willing to train access can be denied. Also training doesn't have to be continuous (3).

No statements are made about willingness to flexibilize work arrangements and autonomy of shop floor workers. Therefore these are also in this iteration of the IDS maturity model classified as unrelated to IDS adoption.

Expected growth in maturity resulting from IDS adoption
As can be seen in Table 47, the first iteration of the model resulted in no items classified to increase in maturity directly related to the act of adopting IDS. For three items IDS adoption is considered to help enable maturity growth. Six item are not impacted in regards to maturity by adopting IDS.

Growth is expected (1)(2)(3)(5), as by implementing IDS the understanding and application of value data sharing is increased (1). Interviewee (4) recognizes this too, but also notes that growth would be very dependent on the use case implemented. Increasing capabilities will only occur when the company takes a structural approach towards IDS adoption. Otherwise this adoption work can be outsourced.

New competences are asked of employees as IDS demands a much broader vision of the environment in which the company is to operate in (2)(3)(5). This in turn demands growth by the non-IT-employees as well as IT-employees(3). As well as possibly growth of the IT department (2). Interviewee (3) notes that that this increase is probable, but cannot be expected.

This discussion is mostly related to the awareness of non-IT-employees for data and cyber security items (3)(5). But also the autonomy of shop floor workers item as interviewee (2) states that it is important that also non-it-employees are allowed to make decisions regarding data and data sharing during use, without consulting other departments such as the IT department first. These three items are all considered to be maturing following IDS adoption unlike the first iteration in which the items were considered to be enabled or even unrelated.

Items such as and willingness for continuous training are not related to IDS and data sharing. When an employee is not willing to train access can be denied. Also training doesn't have to be continuous (3).

No remarks could be related to the competences with modern ICT, willingness to flexibilize work arrangements and knowledge about employee competences items. As such it is chosen to also classify these items are unrelated, in accordance with the first iteration of the IDS model.

Table 47 – Summary of the first and second iteration of the Employees dimension of the IDS maturity model

First iteration	**Second iteration**
Pre-adoption Required (3): Openness to new technology, Competences with modern ICT, Knowledge about employee competences Helpful (3):, Experience with interdisciplinary work Unrelated (3): Willingness to flexibilize work arrangements, Autonomy of shop floor workers, Willingness for continuous training on the job	**Pre-adoption – Maturity required*** Required (5): Openness to new technology, Competences with modern ICT, Knowledge about employee competences, Awareness of non-IT-employees for data, Awareness of non-IT-employees for cyber security Helpful (0): Unrelated (4): Experience with interdisciplinary work, Autonomy of shop floor workers, Willingness for continuous training on the job, Willingness to flexibilize work
Post-adoption Maturing (0): Enabling (3): Not affected (6):, Competences with modern ICT, Willingness to flexibilize work arrangements, Experience with interdisciplinary work, Willingness for continuous training on the job, Knowledge about employee competences	**Post-adoption – Maturing*** Maturing (3): Awareness of non-IT-employees for data, Awareness of non-IT-employees for cyber security, Autonomy of shop floor workers Enabling (0): Not affected (6): Openness to new technology, competences with modern ICT, Willingness for continuous training on the job, Experience with interdisciplinary work, Willingness to flexibilize work arrangements, Knowledge about employee competences
	* Depending on the use case

8.2.9 Strategy and Leadership

Results of the questionnaire

In Table 48 a summary is shown of the questionnaire results. Based on these results the interviews were conducted, asking for explanations for the results received. The table shows the minimum required maturity for IDS adoption from high to low (pre-adoption). In addition it shows the expected maturity after adopting IDS (post-adoption) as well as how much this differs from the required maturity, only in case there's a significant change.

Table 48 – Results of the questionnaire regarding the Strategy and Leadership dimension

Pre-adoption	**2.5**	**Post-adoption**	**3.0**	**Difference**
Willingness of managers to realize Industry 4.0	2.75	Willingness of managers to realize Industry 4.0	3.25	0.5
Risk assessment for Industry 4.0	2.5	Risk assessment for Industry 4.0	3.25	0.75
Central coordination of Industry 4.0 activities	2.5	Central coordination of Industry 4.0 activities	3.0	0.5
Financial resources to realize Industry 4.0	2.5	Financial resources to realize Industry 4.0	3.0	0.5
Manager training for Industry 4.0	2.5	Manager training for Industry 4.0	3.0	0.5
Roadmap for Industry 4.0 realization	2.5	Roadmap for Industry 4.0 realization	2.75	-

Minimum maturity required for IDS adoption
The first iteration of the model was mainly based on literature and the researchers' opinion. As can be seen in Table 49, this resulted in three items classified as being required for IDS adoption. Three items were considered helpful for IDS adoption and one item as not helpful to be mature in regards to IDS adoption.

Similarly to employees, an high maturity is required in regards for leadership to be able to understand, value and apply IDS correctly (1)(2). Management could form a barriers as the IDS adoption process might not even be started when management if not open for new technologies (2). When a company is not very mature regarding use of data and does not have a clear strategy than it will become hard to adopt IDS (3)(5).

Interviewee (3) states that whether central coordination is required to be mature depends how IDS adoption is carried out. Interviewee (3) expects IDS adoption not to be initiated from high level in the company but from a lower level. "someone just has to propose the idea and pull the organisation"(3), this can also be a single lower level employee. Initiating adoption from this lower level requires less central coordination maturity then IDS adoption initiated at an higher level (3). In addition, starting IDS adoption, centrally, at an high level in the organisation will probably result in internal resistance (3).

It is however recognised by interviewee (3) that the company needs strategy and leadership, but this is just a necessity as required by all companies that are to thrive.

Another barrier can be the lacking of a long-term strategic vision of the company (2). This is because it helps a company to be aware beforehand of the investment needed and the opportunities for value creation which can be realised (2)(5). Focussing and investing in those aspects that create the most benefit, data sharing is probably one of those (4). This will be harder for first adopters (5). It is important for a company to be able to assess the business case correctly, which requires a company to gain access to the right knowledge and competences (4). Also it is required for a company to perform risk assessments and to think before doing to prevent accidents such as accidentally sharing data with the wrong parties (3)(4).

Interviewee (2) Indicated a need for maturity regarding strategy and leadership. However, interviewee (2) also added that, strictly, no maturity regarding strategy and leadership is required to start IDS adoption. For instance in the case that a big organisation demands the use of a certain technology by a smaller organisation, which requires minimal strategy and leadership maturity (2). This does not fit the IDS concept in which ecosystem members act are equals, adopting IDS in such a manner requires the company to have a vision and strategy of their own (2).

The above discussion would support classifying the following items as required: the willingness for managers to realize Industry 4.0, risk assessment for Industry 4.0, roadmap for Industry 4.0 realization, Manager trainings for Industry 4.0 and central coordination of Industry 4.0. In which the central coordination manager trainings for Industry 4.0, and willingness of managers to realize Industry 4.0 items are dependent on the level on which IDS adoption is initiated.

Interviewee (3) does not completely agree with this assessment as it stated that the company does not need to be mature regarding roadmap, central coordination, financial resources and risk assessments. A company involved in these activities will probably be a better performing company, but it is not required. However, based on the discussion provided above and in the first iteration of the model, and the fact that interviewee (3) recognizes the necessity for maturity regarding this dimensions it is decided to still classify these items as required in the maturity model.

The communication of Industry 4.0 activities items is only required after adoption (3).

Also, it is hard to determine the relationship between the employee objectives items and IDS (3).

Expected growth in maturity resulting from IDS adoption
As can be seen in Table 49 , the first iteration of the model resulted in no items classified to increase in maturity directly related to the act of adopting IDS. For three items IDS adoption is considered to help enable maturity growth. Four item are not impacted in regards to maturity by adopting IDS.

IDS enables many opportunities for a company (5) as by implementing IDS the understanding and application of value data sharing is increased (1). It is however not clear how this is related to the strategy and maturity items defined in by Schumacher et al. (2019).

As IDS is focussed on enabling data sharing across company borders it is expected that IDS adoption will mainly increase maturity regarding central coordination and communication of Industry 4.0 activities (3).

Also, it is hard to determine the relationship between the employee objectives items and IDS (3).

Overall, growth is expected by interviewee (5). However the interviews in general did not state many points to support a discussion related to what items this is to be expected in. The classification of items not discussed above is thus not changed in this second iteration of the model.

Table 49 – Summary of the first and second iteration of the Strategy and Leadership dimension of the IDS maturity model

First iteration	Second iteration
Pre-adoption Required (4): Risk assessment for Industry 4.0, Willingness of managers to realize Industry 4.0, Manager trainings for Industry 4.0, Financial resources to realize Industry 4.0 Helpful (3): Roadmap for Industry 4.0 realization, Central coordination of Industry	**Pre-adoption – Maturity required** Required (6): Willingness of managers to realize Industry 4.0*, Risk assessment for Industry 4.0, Roadmap for Industry 4.0 realization, Manager trainings for Industry 4.0, Central coordination of Industry 4.0*, Financial resources to realize Industry 4.0 activities Helpful (0): Unrelated (2):

4.0, Employee objectives to realize Industry 4.0 Unrelated (1): Communication of Industry 4.0 activities	Employee objectives to realize Industry 4.0, Communication of Industry 4.0 activities
Post-adoption Maturing (0): Enabling (4): Roadmap for Industry 4.0 realization, Risk assessment for Industry 4.0, Willingness of managers to realize Industry 4.0, Financial resources to realize Industry 4.0 activities Not affected (4): Central coordination of Industry 4.0, Communication of Industry 4.0 activities, Employee objectives to realize Industry 4.0, Manager trainings for Industry 4.0	**Post-adoption - Enabling** Maturing (2): Central coordination of Industry 4.0, Communication of Industry 4.0 activities Enabling (4): Roadmap for Industry 4.0 realization, Risk assessment for Industry 4.0, Willingness of managers to realize Industry 4.0, Financial resources to realize Industry 4.0 Not affected (2): Employee objectives to realize Industry 4.0, Manager trainings for Industry 4.0
	* Depending on source of IDS adoption initiation

8.2.10 Summary

Similar to the overview developed in chapter 7.3.8 an overview can be developed summarizing the results of the second iteration of the IDS maturity model regarding pre-adoption and post-adoption maturity. This overview can be found in Table 49.

Table 50 – Summary of IDS maturity model iteration two, pre-adoption maturity and post-adoption maturity.

Pre-adoption	Post-adoption
Technology – Some maturity required* Required (1): Technology for information exchange ** Helpful (2): Utilization of cloud technology **, Decentral information storage**	**Technology – Maturing**** Maturing (2): Technology for information exchange, Decentral information storage Enabling (2): Utilization of cloud technology, Mobile devices on shop floor
Products – No maturity required** Required (0): Helpful (3): IT-services related to physical products**, Internet connection of products**, Digital compatibility and interoperability of products**	**Products – Enabling**** Maturing (0): Enabling (5): Product individualization**, Flexibility of product characteristics**, Collection of product-use-information**, IT-services related to physical products**, Digital compatibility and interoperability of products**
Customers and Partners – Maturity required Required (5): Openness to new technology, Competence with modern ICT, Digitalization of customer contact, Digital contact with company partners, Company partner's degree of digitalization Helpful (3): Customer integration in product development**, IT-collaboration for product development**, Utilization of customer related data*	**Customers and Partners – Maturing** Maturing (4): Digitalization of customer contact, Digital contact with company partners, Company partner's degree of digitalization, Competence with modern ICT Enabling (3): Utilization of customer related data, Customer integration in product development**, IT-collaboration for product development**
Value Creation Processes – No maturity required Required (0): Helpful (3): Databased machine maintenance, Value Creation Process automation, Information exchange between machines	**Value Creation Processes – Mostly Unaffected** Maturing (2): Value Creation Process automation**, Information exchange between machines Enabling (1): Databased machine maintenance

Data and Information – Some maturity required Required (2): Digital information processes, Automated information provision Helpful (1): Automated data collection	**Data and Information - Maturing** Maturing (3): Digital information processes, Automated information provision, Individualization of provided information Enabling (2): Analysis of collected data, Automated data collection
Corporate standards – Some maturity required Required (2): Technological standards, Increased cyber security Helpful (3): Employee trainings of digital competences, Legal protection for digital products and services, Rules for employees in digital work environment	**Corporate standards – Maturing** Maturing (6): Technological standards, Legal protection for digital products and services, Increased cyber security, Rules for employees in digital work environment, Adjustments of works arrangements, Employee trainings of digital competences Enabling (0):
Employees – Maturity required** Required (5): Openness to new technology, Competences with modern ICT, Knowledge about employee competences, Awareness of non-IT-employees for data, Awareness of non-IT-employees for cyber security Helpful (0):	**Employees – Maturing**** Maturing (3): Awareness of non-IT-employees for data, Awareness of non-IT-employees for cyber security, Autonomy of shop floor workers Enabling (0):
Strategy and Leadership – Maturity required Required (6): Willingness of managers to realize Industry 4.0***, Risk assessment for Industry 4.0, Roadmap for Industry 4.0 realization, Manager trainings for Industry 4.0, Central coordination of Industry 4.0***, Financial resources to realize Industry 4.0 activities Helpful (0):	**Strategy and Leadership - Enabling** Maturing (2): Central coordination of Industry 4.0, Communication of Industry 4.0 activities Enabling (4): Roadmap for Industry 4.0 realization, Risk assessment for Industry 4.0, Willingness of managers to realize Industry 4.0, Financial resources to realize Industry 4.0 activities
* Higher in current state of IDS Connector development ** depending on the use case *** Depending on source of IDS adoption initiation	

8.3 Redefining the Strategy guide

This section discusses how the strategy guide established in the first iteration of the IDS maturity model is expanded upon. In this iteration the previously discussed impact of IDS on SWOT elements is combined with statements made during the interviews.

Similar items are grouped together and for each grouping a more easy to read description is written as opposed to the listing of only single items in the first iteration of the model. This makes the suggestions made by the guide more easy to read and interpret and this the model more easy to use.

Two categories of items are distinguished: items which influence the effort required to adopt IDS (pre-adoption) and items which are influenced by IDS adoption (post-adoption). Each of these items can have a positive or negative impact on IDS adoption or these items can be affected, positively or negatively by IDS adoption in the organisation.

Statements made by the experts during the interview or in the questionnaire is denoted by '(X)'. The number relates that has made this statement. A summary of the interviews of these experts can be found in appendix chapter 12.7.

8.3.1 Technology

During the first iteration of the maturity model a list of enabling technologies of Industry 4.0 was added to the strategy guide. The statements made by the expert during the interview did not provide an indication whether these are or are not related to IDS adoption. As such this list remains unchanged. A summary can of the enabling technologies of Industry 4.0 identified can be found below:

- Cyber physical systems
- Cloud computing
- Simulation
- Internet of Things
- Big data
- Smart factories
- Horizontal and vertical integration
- Cyber security
- Production control
- Mobile computing

8.3.1.1 Supporting IDS adoption

Existing infrastructure internal connectivity (beneficial)
It helps when the existing infrastructure is already capable of connecting to other systems. For instance when the infrastructure already export data to a separate business intelligence application. This point has come forward from literature as a success factor of Industry 4.0 and is related to statements made by interviewee (2). It is also in line with the items which the IDS maturity model has identified to be required or helpful in IDS adoption.

Existing external digital collaboration (beneficial)
It helps when a company already have technologies in place for digital collaboration. This is a driver for companies to further investigate collaboration technologies and join research initiatives. This has come forward from literature as a success factor of Industry 4.0 and is related to statements made by interviewee (2). It is also in line with the items which the IDS maturity model has identified to be required or helpful in IDS adoption.

Lacking technical resource availability (detrimental)
A lacking of technical resources will hinder IDS adoption. This has come forward from literature as a barrier of Industry 4.0. During the current stage of IDS development a company adopting IDS will be required to also get involved in the technical development of IDS and the IDS Connector. Currently, this will entail a high learning-curve (5), strengthening this drawback of IDS. Even when IDS technology has matured the approach the company takes towards IDS adoption will be of influence to this factor. A company taking a more structural approach will also be faced with the learning-curve required to become knowledgeable of IDS. By then this learning curve will be much lower though.

Not recognizing technology importance (detrimental)
It will be helpful when a company recognizes the role ICT technologies take in the organisation. Disregarding big companies, many manufacturing organisations for instance often do not recognize the fact that their factory is essentially one big ICT system. This way of thinking is much more present in administration focussed domains as banking and government. This has come forward from statements made by interviewee (4).

Structural approach requires more effort (detrimental)
When IDS is adopted in a structural manner the company is expected to be faced with more challenges. This because more requirements are to be met and capabilities to be developed for a company to gain the required understanding of how IDS works. This understanding will enable company to be capable of handling change and be able to easily adopt IDS also in other use cases in the future. This has come forward from statements made by interviewee (4).

8.3.1.2 Impact of IDS adoption

Help implement hardware adhering to strict requirements (beneficial)
A weakness of Industry 4.0 as identified by literature is that it desires adherence of strict hardware requirements during implementation. IDS will help mitigate the effort required in this as these requirements are met and enforced by the IDS reference architecture and related services the IDS validation services. No other hardware related to Internet of Things or similar Industry 4.0 technologies is required in applying IDS (4). Decreasing the need of companies to be concerned with mitigating this weakness of Industry 4.0.

Ease of connecting after initial implementation (beneficial)
One of the main strengths of IDS is that it enables easy set-up of additional connections due to its' peer to peer architecture. After setting up the initial connection to the IDS Ecosystem all members of the ecosystem can start data sharing with the company (4). Of course these companies have to follow the access and usage rules set up by the company.

Increased dependency on network infrastructure (detrimental)
By adopting IDS in the business processes of the organisation the company will be faced with an increased dependency on the network infrastructure. This because the data sharing will require a reliable internet connection capable of handling the demands made by IDS. This adds to risks associated with IDS, mainly for companies which are located in places in which the internet connection cannot be relied on.

8.3.2 Products

8.3.2.1 Supporting IDS adoption

New business model adoption that fit customers' needs (beneficial)
It will help when a company is capable of adopting new business models that fit the customers' needs. This is a success factor of Industry 4.0 which is also considered to be related to IDS. This is also identified during the interviews: as it will help if companies are willing to start using technologies for their product offering. For instance when a company previously relying on physically brokered sales decided to start making use of digital collaboration technologies (4).

Platform-like systems are well known (beneficial)
Interviewee (2) states that the concept of establishing platform-like systems is already well known. Organisations and employees should thus be able to quickly adapt IDS in this regards as it is similar to these kinds of systems.

Part of package (beneficial)
Software suppliers will develop software packages in which IDS is only part of the package (4). The prospective buyer of the package doesn't even necessarily have to be aware that IDS is applied. This will help in IDS adoption as it increases the IDS Ecosystem. Also, it help companies overcome the barrier of needing additional technologies to fully enable the value creation opportunities provided by IDS.

8.3.2.2 Impact of IDS adoption

Improved capability to adapt to customers' needs (beneficial)

Adopting IDS will enable the strength of Industry 4.0 of companies be able to offer more customised products. In addition IDS support Industry 4.0 opportunity to be capable of adapting services so that they respond to customers' need. IDS can define usage policies and use brokers and apps to dynamically adapt the data that is made available to customers' needs.

As IDS is tailored for this customisation the weakness of Industry 4.0 regarding the effort required to enable product personalisation is mitigated. As well as the Industry 4.0 weakness of increased customer demand for services that are available 7/24.

Ease of integrating digital tools and services (beneficial)

IDS can also act as an enabler of other technologies by offering the data this other technology is required to function properly. In doing so IDS adoption can mitigate some of the Industry 4.0 threat related to investments required to integrate new digital tools and services.

An example can be analytics, an existing IDS implementation in a company will provide the to be integrated analytics application with a central access point which can provide all the data the application needs (2). This without needing to invest much effort in setting up this additional connection. This allows for new opportunities.

8.3.3 Customers and Partners

8.3.3.1 Supporting IDS adoption

Existing collaboration between organisations (beneficial)

It helps when a company already are engaged in (digital) collaboration. IDS use cases should be about cross company collaboration thus pre-existing collaboration can then be the foundation for the IDS use case to be implemented. Allowing for both companies to skip several steps during the initial phase of the process in which agreements and trust between organisations is established. This is one of the Industry 4.0 success factors related to IDS, in addition interviewee (2) has made comments in this regard.

Having also digital systems in place allowing for collaboration would even further help in IDS adoption, reducing even more the effort required for adopting IDS as these systems can be used as an example for (part) of the IDS system implementation, configuration and integration with internal systems of both companies.

Resistance (detrimental)

Resistance towards IDS adoption can be triggered for several reasons. One factor can be that IDS adoption by your company is forced upon you by one of your customers or partners (2).

Another can be that you're in a relationship with another party in which the other party is a customer. Companies involved in such a relationship or collaboration cannot directly control the other party which can possibly lead to tension. Customers and partners relationship can thus become a barrier (2).

8.3.3.2 Impact of IDS adoption

Horizontal and vertical Integration (beneficial)

IDS directly enables the Industry 4.0 opportunities related to vertical and horizontal integration. By integrating both vertically as horizontally a dense network is created, turning the economy in a digitally interconnected economy. Supporting the Industry 4.0 strength of nationwide participation for contributing to the economy.

In addition supply chains are supported by this integration, supporting improvement of the processes in supply chain and increase visibility and flexibility of supply chains which have previously been identified as two strengths of Industry 4.0. As the integration is made as easy as possible, especially after the making the initial connection to the ecosystem, IDS also reduces a weakness of industry 4.0: the requirements concerning integration of systems and supply chain elements.

Access to new (global) markets (beneficial)
It is very easy to connect to new and previously unknown parties in an ecosystem after a company has connected to this ecosystem. Enabling one the Industry 4.0 opportunity of digital sales and marketing as well as supporting the strength of industry 4.0 related to increased e-business with more spread markets and access to global markets.

IDs combines ease of connecting to other members of an ecosystem with the cross domain characteristic of these IDS ecosystems. This means that IDS enables competitiveness outside the sector a company is currently operating in.

Make it easy (beneficial)
As IDS is comprised of a whole package it will make collaboration very easy. Most components are developed by software suppliers which means that after initial set-up only knowledge is required regarding use and for maintenance. As such IDS will mitigate the Industry 4.0 tread of business partners not being able to collaborate around digital solutions. Still some effort is probably required to help such partners but the way IDS is designed should lower the amount of effort that should have been expected before adopting IDS.

Focussed on business to business (detrimental)
Interviewee (3) indicates, rightfully, that IDS is mainly aimed at application in the B2B context. Or at least: customers are probably never faced with the direct decision to implement and adopt an IDS Connector. In the case that an IDS Connector is related to a consumer, the IDS Connector will most likely be integrated in another package without the consumer knowing it is powered by IDS. This can be considered a possible weakness of IDS as it limits the amount of parties that can connect to the Ecosystems and thus the value opportunities available.

8.3.4 Value creation processes

8.3.4.1 Supporting IDS adoption

No fitting Value Creation Processes (detrimental)
IDS adoption is influenced by the value creation processes that are in place before IDS adoption is started. It is very dependent on the existing value creation processes whether or not maturity is required (1). However, It could for instance be that implementing IDS makes available new value creation processes that are not related to any pre-existing processes. In that case it depends on which value creation processes IDS is to be applied in to determine whether or not IDS adoption is negatively influenced by not having these processes in place before adoption.

No control of business processes (detrimental)
Interviewee (4) points out that companies should have some form of control regarding their business processes and be thinking about the value of the data present in the organisation. Big companies often have systems such as ERP systems. Smaller companies should at least also have some sort of planning, sales or purchasing systems.

Lacking long tail adoption (detrimental)
As second point made by interviewee (4) is that new IDS value creation opportunities come available when also the long tail adopts IDS. Big companies are often well suited for IDS as for them it could

already be a better alternative than most traditional technologies. This is however not necessarily the case for the long tail. Meaning that most companies adopting IDS also still have to support other more traditional ways of connecting. Lacking long tail adoption is thus a barriers for IDS adoption.

8.3.4.2 Impact of IDS adoption

New business models (beneficial)
IDS will enable a company to make use of new business models which is one of the opportunities of Industry 4.0 identified in the first iteration of the model. IDS will improve value creation process automation if only the company is able to use the data provided by IDS (3). Preferably by sharing data not just internally but within the whole supply chain (3), increasing opportunities for value creating within the whole supply chain.

Interviewee (2) for instance expect a company to move more towards analytics, thus platforms such as IDS will become more central to the organisation. Providing opportunities for optimalisation and changing the way of work.

Information monetisation (beneficial)
IDS can be a solution in handling with a group of weaknesses of Industry 4.0 related to information monetisation: enabling information monetisation, increased plagiarism and difficulty to keep intellectual properties. IDS contains usage policies protecting the usage of data and access to this data. An example of which is to require payment per use of a specific piece of data.

Only enabling value creation (detrimental)
The main weakness of IDS is that it will mainly be an enabler of value creation. In this, IDS is just a technology, in this case for data sharing (4). A company also needs to apply other systems and technologies to be able to use the data (3). IDS is thus not a silver bullet for creating value (5).

Interviewee (5) recognizes this by stating that value creation is not the main purpose of IDS. Of course IDS will help but this will mostly require applying IDS in addition to or part of other systems (5). IDS can be applied to set up the connection, for instance in the Dutch Smart Connected Supplier Network (SCSN) (4).

Value only created after first stages (detrimental)
One of the main threats of IDS is to apply it in the wrong use case. IDS will provide an advantage in comparison to most other tradition technologies when it is applied to set up a multitude of connections (4). IDS will this offer no value or less value than comparable technologies during the setup of the first few connections (4). Thus a threat of IDS is to apply it in use cases which never are expected to evolve from the first stages of IDS adoption in which the first connections are made.

External focus (detrimental)
IDS can be applied in an internal setting but is mainly designed for enabling data exchange across company borders (3). There does not seem to be made a distinction between made between running IDS internally and externally even though such a distinction might be expected. Systems running only within the protected border of a company might have to meet less requirements and can thus be a lighter and more ease to develop and implement system. As IDS does not make such a distinction it might be unnecessary complex and thus costly for use within company borders, also it is not clear what value is provides when internally run (3).

8.3.5 Data & Information

8.3.5.1 Supporting IDS adoption

Pre-existing ICT policies (beneficial)
In regards to IDS adoption it will be beneficial when ICT policies are already in place in the company aiming to adopt IDS. This is also a success factor of Industry 4.0. Interviewee (2) adds that this also entails having already established ontologies and having models available. An example from the domain of logistics would be the OpenTrip model (2). IDS requires establishing these policies during adoption and thus it would be helpful when these are already in place and can be used instead of developing new policies from the ground up. This reduces the complexity of the IDS adoption.

Understand the semantics of data (beneficial)
IDS will make it more easy to share data in a controlled matter. When a company is able to understand the semantics of the data it able to share or can start receiving will be important for the company to properly set up the connection. Usage policies, vocabulary and other data management requires this, as well as to prevent accidentally sharing confidential information that should not be shared externally.

8.3.5.2 Impact of IDS adoption

Sharing data (beneficial)
One of the main contributions of IDS adoption to a company is that it enables the sharing of data. This supports two previously identified strengths of Industry 4.0: information sharing and ease of access to personal information.

Central point of coordination (beneficial)
The way IDS is set up in using the IDS Connector as a gateway, IDS will support another strength of Industry 4.0: central point for coordination. Having such a point of coordination is also a prerequisite for a company to become more their data and information (2). IDS is not possible without aligning data & information (2).

Information management and usage control (beneficial)
IDS encompasses extensive measures to make usage control and information management possible. All congregating in the philosophy data sovereignty. As such it reduces several previously identified weaknesses of Industry 4.0: information management, restricting access to knowledge, sustaining privacy, not being able to remove or hide unwanted information flow. In order to truly foster this qualities IDS can be applied on conjunction with other technologies. An example of which is FAIR which defines proper structuring and use of standards related to data, helping companies in proper data management (5).

Data security and privacy (beneficial)
Another aspect of enabling data sovereignty is data security and privacy. These aspects are also ensured by IDS, mitigating the possibly Industry 4.0 threat of data security. As well as the threat of privacy issues in sharing data with external stakeholders. Another weakness of Industry 4.0 adoption can be an increase in cyber-attacks and reduced information security. Mainly regarding information security IDS can be of benefit for a company willing to counter this weakness effectively.

8.3.6 Corporate standards

8.3.6.1 Supporting IDS adoption

Pre-existing standards in place (beneficial)
Having pre-existing standard in place for compliance, cyber security and safety and sustainability are success factors of Industry 4.0. These are all also considered success factors in IDS adoption. Even

when such standards are own custom structures and architectures will be helpful (3). This will help as IDS enforces the use of such standards, when these are not in place the company is required to develop these during the adoption process, increasing the complexity of the process.

In a similar manner will it help when a company already has existing standards in place regarding user management and cyber security. When you look at for instance IShare, authentication is based on user management. User management thus cannot be faulty, otherwise the system will fail (2). For cyber security a culture and process required to exist. Otherwise a company will be often faced with wrong use of the system or data and every change or irregularity would lead to being disconnected from IDS as the security of the data cannot be guaranteed.

Becoming a standard (beneficial)
IDS is on its way to becoming a standard. This will help in IDS adoption is it increases pull from the government and the domain the company is operating in to start adopting IDS. In addition, becoming a standard will make sure that everyone knows what is talking about the same thing. Finally, it reduces the amount of custom concepts and interpretation of IDS being developed.

The data governance act has just now been published by the European Union. This act is legislation describing how entities operating in Europe should handle data (5). IDS concepts are integrated in this act. IDS is also integrated in GAIA-X and the Dutch Smart Supplier network (5).

8.3.6.2 Impact of IDS adoption

Adopting a package (beneficial)
During the adoption of IDS into an organisation IDS will force the company to become mature regarding quite a bit of aspects of corporate standards. The process of configuring these aspects in IDS is supported by the design of the IDS components. This makes that also a company with little experience with this kind of thinking will be supported in configurating these processes, protocols and structures properly and completely. This is a strength of IDs: it offers usage policies and other standards as part of its complete package (1). Ensuring maturity growth.

The aspects of corporate standards are also interrelated. For instance, thinking about the legal aspect of your data will also force you to think about the security of the data or what regulations are should be put in place regarding data sharing by employees (3). As IDS encompasses and support most of these perspectives it ensures that this process is taken up fully.

Trickle down maturity (beneficial)
When a company is faced with the required choices and way of working as is enforced in IDS it is expected that this way of thinking will trickle down into the corporate standards of the organisation (2). This will help reduce the possible threats of Industry 4.0 related to setting up proper legal frameworks and communication standards.

No complete solution (detrimental)
IDS in itself will enforce a lot of standards and force the company to think about existing and new standards present in the organisation. However, IDS in itself will not be the solution to these aspects, additional effort by the company is required to become more mature (5). A company has to take the requirements enforced within the IDS Ecosystem seriously and possibly in result change the way they handle data internally also.

8.3.7 Employees

8.3.7.1 Supporting IDS adoption

Cultivating digitally capable people (beneficial)

The Industry 4.0 success factors of cultivating digitally capable people and adapting to labour market changes are also considered to be success factors of IDS. When a company has able to ensure that its workforce is capable of those things that are required less of a learning period is required for IDS adoption.

Employee participation and worker policies (beneficial)

Another success factor of Industry 4.0 that is related to IDS adoption is that of employee participation. Employees should be motivated to put in the effort required for adopting IDS. In addition it could be that when employees are capable with IT that they themselves will push for and be more willing to help implement IDS adoption (3). Part of this establishing the right worker policies, which is yet another Industry 4.0 success factors related to IDS.

Lack of skilled people (detrimental)

Employees are vital to a companies' success, but can similarly also be detrimental to the success of a company. It is this a very important that a company takes care of this dimension (4). Most companies are not really yet aware of IDS and integration subjects, disregarding big companies most do not have an IT department (4). Big differences however exist between companies as some have employed dedicated people to support using technologies such as cloud in the company (5).

Companies having little to no specialised people to work with new technologies are discouraged to start IDS adoption in the current state of IDS (5). With the current state it is meant that IDS is still in development and is becoming more mature. When IDS is for example offered 'as-a-service', then IDS would be more accessible for companies lacking skilled people. Lacking skilled employees capable of implementing IDS will not result in successful adoption of the use case.

Unclear communications regarding capabilities (detrimental)

As a consequence of the many-to-many relations in IDS, IDS will require a company and its employees to have a much broader vision of the domain it operates in (2). This will ask new competences from employees. The percentage of employees that will come in contact with ICT will grow or more will be asked of them (2). A related barriers of Industry 4.0 is unclear communications regarding employee capabilities transformation.

Employees not autonomous (detrimental)

The final factor that could have a negative influence on IDS adoption is that of not allowing employees to make decisions of their own. Interviewee (3) points to the fact that also non-IT employees are required to make decisions regarding data sharing and that it should not only be the role of the IT department to make such decision.

8.3.7.2 Impact of IDS adoption

Enables the digital workplace (beneficial)

IDS adoption has a beneficial impact on enabling a digital workplace which is one of the opportunities of Industry 4.0 identified in the first iteration of the model.

Autonomous decision making (beneficial)

IDS adoption has a beneficial impact on enabling autonomous decision making by all system users which is one of the opportunities of Industry 4.0 identified in the first iteration of the model.

Ease of use (beneficial)
IDS is designed to be easy in use. When IDS is past the current phase of development and when IDS has been adopted in an organisation it should be able to be used without having in depth technical knowledge of how IDS works. The company will then mostly focus on configuring the IDS systems in terms of which data to share and what policies and rules to enforce in use. For this UIs are developed and well known industry standards and models are used. Use of IDS in practice is not difficult or complex (2), which is a strength of IDS. Also, this mitigates two previously identified threats of Industry 4.0 regarding skills and a lack of digital skills in the workforce.

Hard to adopt (detrimental)
While IDS is easy in use, IDS adoption is not. Development and implementation of IDS can be complex (2). One reason for this is provided by interviewee (2): IDS is different to other solution in that it forces you to take the role of partners and not that of a costumer. This requires you to not just follow the commands of other companies to use it. You are independent from other companies and thus required to make own choices and thus need to be more knowledgeable. Another reason is that IDS is most valuable when it is taken on as a structural solution and not for a one-of implementation (4). This requires a company to invest more in developing and maintaining knowledge of IDS during adoption in order to also be able to use it in the future. It cannot just be outsourced.

Awareness of data is required (detrimental)
Finally, employees working in a company which want to actively apply IDS are forced to become more aware about sharing data. This required change of thinking could be considered be a weakness of IDS adoption.

8.3.8 Strategy and Leadership

8.3.8.1 Supporting IDS adoption

Acknowledging financial constraints (beneficial)
As discusses before, adoption of IDS can be complex and challenging. This due to the need to comprehend IDS as well as the possible impact of IDS on the whole of the organisation and its value creation processes. As to support this process it is very helpful when a companies' leadership acknowledges the financial constraints involved with IDS adoption. This is also one of the success factors of Industry 4.0.

Aligning strategic vision with activities by knowledgeable management (beneficial)
Having a strategic vision and having activities be in line with this vision is a success factor of Industry 4.0 as well is IDS. In line with this it is a success factor of Industry 4.0 as well as IDS to have a management that understands the concepts at hand. It will be very hard for management to align a solid strategic vision regarding IDS adoption with activities present in the organisation without grasping what is required for IDS adoption. This points is even more important in SMEs in which the owner and leadership can be the same person.

Lastly, it will be helpful in IDS adoption when a company has organised change management properly. This has been identified as a success factor of Industry 4.0 in the first iteration of the model but it is also expected to be a success factor of IDS.

Enabling and recognizing employees push (beneficial)
IDS adoption can be initiated at different levels of the organisation. When employees are capable with IT then they will probably themselves push for and implement IDS adoption (3). IDS implementation is expected to start at smaller divisions of an organisation before it is made part of

the whole company (3). Less maturity is required regarding strategy and leadership during this initial stage as it can be initiated by someone 'just' proposing the idea.

However, to fully adopt IDS into the organisation at some point management will have to be involved. In this it is important for company management to recognize the employee push and support it using their role and associated capabilities within the company.

Lack of management capabilities (detrimental)
A detrimental factor to IDS adoption can be a lack of management capabilities. This is a barriers of Industry 4.0 as well as IDS. IDS adoption can be quite demanding, for leadership as well as it required leadership to overcome uncertainties about gains and the distribution of gains (2). It is important to assess the business case and to do this right, for this you have to have, or hire, the right knowledge and competences (4).

Lack of common vision among staff (detrimental)
Company leadership should have a strategic vision, but when this vision is not shared among other employees and staff the company will face difficulties in IDS adoption. A lack of common vision among staff is a barrier of Industry 4.0 but also of IDS. A lack of a common shared strategic vision makes it hard to overcome the uncertainties about gains and distribution of gains involved with the adoption of IDS (2).

Lack of financial support (detrimental)
IDS adoption is negatively influenced by a lack of financial support. This includes the industry 4.0 barriers of lack of financial resources and perceived costs. But also a lack of focus on those aspect that could provide a potential benefit for a company (4). It can require a lot of investment before something as an IDS implementation can be realised. That is quite demanding, for leadership as well (2).

Resistance to change (detrimental)
A company that shows resistance to change will have a harder time adopting IDS. Resistance of the organisation to change is one of the Industry 4.0 barriers identified in the first iteration of the model. A company can for instance 'just' not be open to adoption of new technologies. Interviewee (1) adds that this also applies to management, as otherwise the IDS adoption process probably won't even be started.

Lacking risk assessment (detrimental)
The final identified aspect that could negatively influence IDS is that of a lacking assessment of risks and a lack of conscious planning in general. A lack of conscious planning has also been previously been identified as a barrier of Industry 4.0.

It is important for a company to think before doing. In the sense that the business case has to be assessed and that this is done right by having the right knowledge and competences involved (4). This also includes for management to think about possible risks involved as to prevent accidents such as the accidental sharing of proprietary information (4). This is strengthened by the current stage of IDS adoption in which the company will most likely be part of the early adopters group and thus be faced with more challenges, but also more opportunities (5).

8.3.8.2 Impact of IDS adoption

Overcoming technical constraints (beneficial)
IDS adoption will enable the opportunity of Industry 4.0 of increased competitiveness by overcoming technological constraints. In addition IDS adoption will mitigate the Industry 4.0 threat of investment

in infrastructure for machines' connection. Due to the fact that an IDS systems present in the organisation will in itself solve a lot of the prerequisites required for these two aspects.

Collaboration required (detrimental)
A possible weakness of IDS adoption is its reliance on the adoption of IDS by company customers and partners also. In this these companies cannot be forced to join IDS as this will not be in line with the collaborative nature of IDS (2). A lacking ability of a company to share the progress and results from IDS adoption will hinder the ability of company partners to recognize the need for IDS adoption, reducing the potential value of IDS adoption for both companies.

It can be that a company forces another company to use IDS for establishing a connection between the companies (2). Which can be a reason for that company to start investigating the value of IDS. However, also in this case it required both companies to be willing to invest in IDS to create value and new value creation opportunities.

Finally, in line with the discussion before: a company that does not have many (prospective) customers and partners will be expected to benefit less from IDS adoption. Just because IDS is mainly aimed at creating new business models aimed at external parties. When these do not exist there are simply now opportunities to be created.

8.3.9 Additional remarks/ missing dimensions
During each of the interviews the interviewee has been asked whether any aspects had not been discussed that in their opinion could also affect IDS adoption or be affected by IDS adoption. This section will discuss what is answered in response.

Differing use case
Use cases can vary a lot and can be very different. Depending on the use case the organisation is intending to adopt the items required to be mature and the impact of IDS adoption can be different (1). This has already in different forms been discussed during the design of the second iteration of the model. For now this has been incorporated by assigning an note to items that are specifically impacted by this aspect.

Ecosystem
The ecosystem in which the company operates in is key in the adoption of IDS, in the questionnaire the closest dimension to this would be customers and partners (1). The model designed in this research is based on the perspective of a single company. In practice in most cases the changes are developed by a group of companies or a sector (4).

It is not clear if and how this remark can be included in the current design of the IDS model which is, as stated, mainly focussed on a single enterprise perspective. Further research is required to investigate if the model can also be applied to help support IDS adoption by a group of companies.

Required management maturity versus IDS as easy to use
It can be considered contradictory that the management and leadership is required to have good insight in the costs, value, risks and opportunities of IDS while IDS is aimed to be easy to adopt without very little previous little knowledge (1). This is one of the reasons for the IDSA to wanting to be involved early in the process, even during the early development of the first use cases. This only further validates the need for a model such as designed in this research.

Existing collaboration agreements
One of the main subjects of IDS is how to collaborate. It is therefore also of importance to know what are agreements have been made or are to be made (2). For instance, what if one company

frustrates the collaboration, what are the consequences and how is it handled? A dimension or item concerning the agreements between companies seems to be missing in the model by Schumacher et al. (2019)(2).

Some items in the current model can be considered to be related to the remark made by (2). However they only cover part of the aspects related to customer collaboration standardisation and corresponding (contract) agreements.

- Corporate standards: Cyber security, Legal protection for digital products and services.
- Customers and Partners: Digitalization of customer contact, Digital contact with company partners.

This could be an aspect which requires an expansion of the IDS model. This should be further investigated.

Adopting only (some of) the concepts of IDS
The concepts of IDS can also be of value for a company, even if a company is not willing or capable of fully adopting IDS (3). This remark can be of interest when the model is possibly adapted in the future to fit differing use cases. One of the use cases for which to develop a fitting model could be that of companies only adapting the concepts of IDS. For now however this is out of scope of the current research.

The distinction between the product, the concept and end-user applications
A distinction can be made between IDS as a concept, IDS as a product offered by software suppliers or part of a bigger package, and the IDS as integrated in the end user-application (4). This is a valid distinction to make as it could very well be the case that IDS is going to be offered as part of another product, with the customer just buying a product which they do not know to contain IDS.

This is also related to the statements made regarding differing use cases. Future research could investigate the effect of different ways in which IDS can be offered to interested organisations. The current model is mainly focussed on adopting IDS in its own but fully. So not as part of a package containing other technologies or in which IDS is an enabler operating in the background. And not as only the concept or parts of the concepts.

Government enforcement
It could very well be that government bodies will decide to enforce the use of IDS in the future (5). The European Union has a data and AI strategies in which IDS concepts are already being incorporated. An example of this is the data governance act which is published recently by the European Union and describes how data should be used.

This remark is very interesting in regards to the position of IDS as part of the long term vision of a company. It would probably strengthen the position of IDS on the roadmap. In addition it could alleviate some of the barriers identified or be empowering strengths of IDS. The precise impact of this would need to be investigated further.

9 Applying the maturity model to a real world use case

This chapter will discuss the validation of the previously developed IDS maturity model. In the previous chapters the IDS maturity model has been developed following the maturity model development procedure by Becker et al. (2009). The next step in the development is the validation of the model developed. This is in line with the 'testing' phase as described in step four of the procedure by Becker et al. (2009).

During the previous chapters this research has discussed also discussed the problem investigation and treatment design phases of the design cycle by Wieringa (2014). This chapter will discuss the next phase namely the treatment validation phase.

The main purpose of this phase is to validate that the IDS maturity model that has been developed is able to meet its goals and requirements. This is different to evaluation in respect that validation is performed before the model is applied into a real world situation (Wieringa, 2014). Evaluation in contrast is performed when the model has already been implemented in a real world use case and the success of this implementation is investigated.

The research questions of this research are defined in chapter 1.4. The fifth research question is concerned with the validation of the model. It was defined as follows:

- Is the developed model expected to support the decision to adopt IDS?

Supporting the adopting decision encompasses several goals and requirements that have established during the development of the IDS maturity model. In order to find an answer to this research questions more questions have been established following the treatment validation research questions template presented by Wieringa (2014). Only the trade-offs questions type of validation research questions has not been posed as part of this research.

1. Does the model result in a complete and holistic overview? (Effect)
2. Does the model align with best practices? (Requirements satisfaction)
3. Does the model offer quantified measurements and results? (Requirements satisfaction)
4. Do company characteristics influence the usability of the model? (Sensitivity)

9.1 Approach

Validation is involved with investigating the interaction of a prototype with a model of the context in which it is to be applied, frequently applied methods are modelling, simulation and testing (Wieringa, 2014).

Several research methods can be applied in validation research of which several have been suggested by the design cycle by Wieringa (2014). These are expert opinions, single-case mechanism experiments, technical action research and statistical difference-making experiments.

A single-case mechanism experiment test the model in relation to a validation model and aims to explain the mechanisms occurring in the model. Such a method is useful in validation research as it allows for control over the case and thus helps identify the relationship between cause and effect within a understood context (2014). It is applied in idealized and realistic conditions.

Technical action research would also fit the goal of this research. Technical action is similar to single-case mechanism experiments but it also produces a results to be used by the client. It is thus applied in conditions of practice (Wieringa, 2014). Technical action research is driven by the desire to validate an artifact opposed to other action research which is typically driven by the desire to solve a problem (Wieringa, 2014).

Both single-case mechanism experiment and technical action research can be used to describe the approach applied in this research as it is not completely clear whether this research operates in realistic conditions or conditions of practice. Of the two, technical action research would probably fit best as a separate reports is developed for the client for the client investigated.

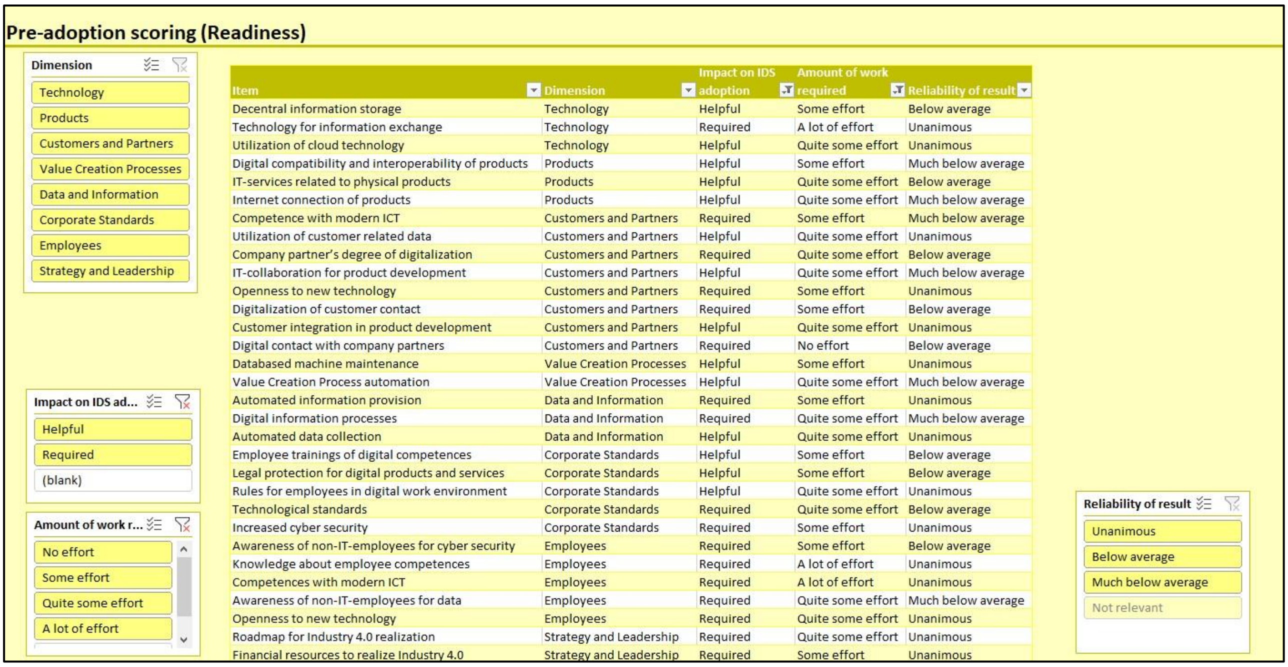
In order to validate the model the process as defined by the model is applied. One of the first steps of this process is to do a maturity assessment based on the Industry 4.0 maturity model by Schumacher et al. (2019). Schumacher et al. suggest this assessment to be carried out collaboration with an expert which in this case will be the researcher. As such a combination of questionnaires and interviews is used. The questionnaires provide a numeric input and baseline for the opinion of the respondent. By also conducting interviews the expert is able to adjust the result of the questionnaires to better fit the intended results, reducing faults. It is favourable to have respondents having different roles in the organisation. This in order to reduce possible bias based on performing the assessment based on only a single perspective.

After assessing the current Industry 4.0 readiness the gap analysis for both pre-adoption and post-adoption maturity is performed. The results of which provide are used to determine realization paths in collaboration with the company. Normally these are established by the company and researcher together with the company in the lead. However, due to constraints related to the COVID-19 epidemic this research was not able to conduct this step as intended.

It is needed to validate the results of the technical action research in order to answer the validation questions posed at the start of this chapter. For this two approaches are applied. First the results of the IDS maturity model are compared with several other studies and projects performed previously at the company. Secondly an interview was conducted with the main decision maker of the company related to IDS. The results are presented after which his perspective on the four previously established validation research questions is asked.

9.2 Transfer medium

The next step in the maturity model development procedure is to develop a transfer medium which can be used to easily share the model with other parties. This research developed an excel file in which the results of the questionnaire performed during an assessment can be added. The file will then calculate the average maturity and standard deviation for each item, presenting the results in a table (see Figure 17) of items and visually by showing a graph (see Figure 18). A similar table and graph is constructed for post-adoption items. This will enable to manager to easily identify areas in which work is still required during the pre-adoption phase and areas in which the company will have the most potential to benefit from IDS adoption. It is important to note that the figures shown are based on random data and do not reflect the data gathered during the use case performed during this validation effort.



Pre-adoption scoring (Readiness)

Item	Dimension	Impact on IDS adoption	Amount of work required	Reliability of result
Decentral information storage	Technology	Helpful	Some effort	Below average
Technology for information exchange	Technology	Required	A lot of effort	Unanimous
Utilization of cloud technology	Technology	Helpful	Quite some effort	Unanimous
Digital compatibility and interoperability of products	Products	Helpful	Some effort	Much below average
IT-services related to physical products	Products	Helpful	Quite some effort	Below average
Internet connection of products	Products	Helpful	Quite some effort	Much below average
Competence with modern ICT	Customers and Partners	Required	Some effort	Much below average
Utilization of customer related data	Customers and Partners	Helpful	Quite some effort	Unanimous
Company partner's degree of digitalization	Customers and Partners	Required	Quite some effort	Below average
IT-collaboration for product development	Customers and Partners	Helpful	Quite some effort	Much below average
Openness to new technology	Customers and Partners	Required	Some effort	Unanimous
Digitalization of customer contact	Customers and Partners	Required	Some effort	Below average
Customer integration in product development	Customers and Partners	Helpful	Quite some effort	Unanimous
Digital contact with company partners	Customers and Partners	Required	No effort	Below average
Databased machine maintenance	Value Creation Processes	Helpful	Some effort	Unanimous
Value Creation Process automation	Value Creation Processes	Helpful	Quite some effort	Much below average
Automated information provision	Data and Information	Required	Some effort	Unanimous
Digital information processes	Data and Information	Required	Quite some effort	Much below average
Automated data collection	Data and Information	Helpful	Quite some effort	Unanimous
Employee trainings of digital competences	Corporate Standards	Helpful	Some effort	Below average
Legal protection for digital products and services	Corporate Standards	Helpful	Some effort	Below average
Rules for employees in digital work environment	Corporate Standards	Helpful	Quite some effort	Unanimous
Technological standards	Corporate Standards	Required	Quite some effort	Below average
Increased cyber security	Corporate Standards	Required	Some effort	Unanimous
Awareness of non-IT-employees for cyber security	Employees	Required	Some effort	Below average
Knowledge about employee competences	Employees	Required	A lot of effort	Unanimous
Competences with modern ICT	Employees	Required	A lot of effort	Unanimous
Awareness of non-IT-employees for data	Employees	Required	Quite some effort	Much below average
Openness to new technology	Employees	Required	Quite some effort	Unanimous
Roadmap for Industry 4.0 realization	Strategy and Leadership	Required	Quite some effort	Unanimous
Financial resources to realize Industry 4.0	Strategy and Leadership	Required	Some effort	Unanimous

Figure 17 – Transfer medium: Pre-adoption gaps per item and dimension.

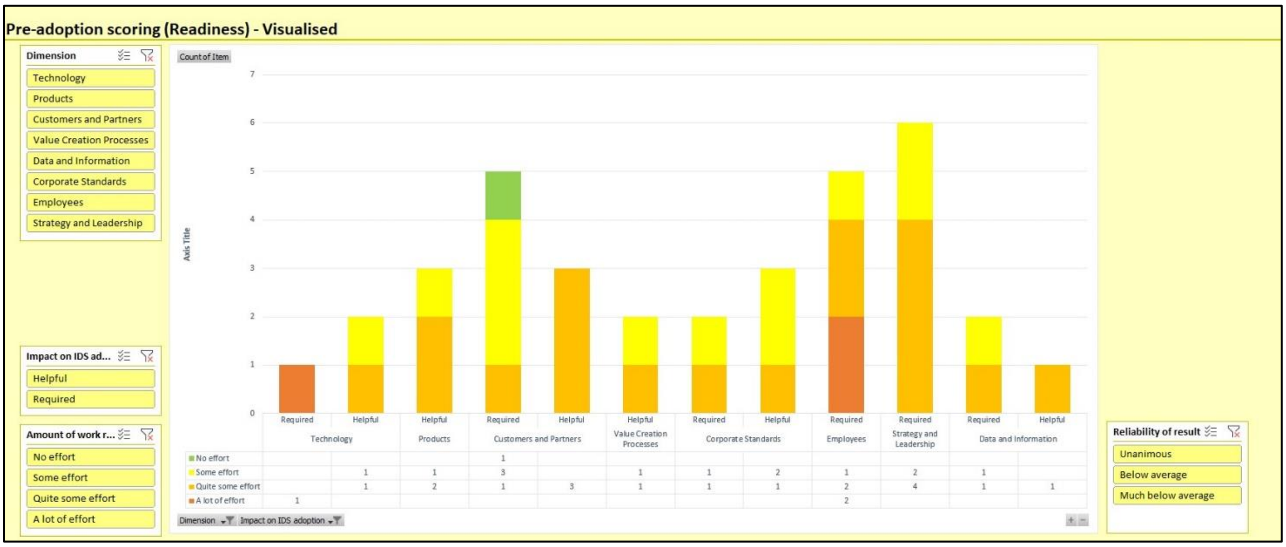


Figure 18 – Transfer medium: Pre-adoption gaps (visual representation).

Also the items identified in the strategy guide were added to the transfer medium. However no automatic links or filtering was added based on the finding of the gap analysis. This is left for the decision makers to do. The items that are of importance to the decision makers will be heavily dependent on the discussion taking place during the working groups and the realization paths envisioned during these working groups. These items will help support this discussion by providing context and inspiration. Two overviews were added to the excel file, both containing a radar graph displaying the current maturity levels per dimension on the left and a table of factors on the right. The first overview displays factors related to factors influencing IDS adoption (see Figure 19) and the second overview displays factor in which IDS influences the organisation and Industry 4.0 strengths and weaknesses (see Figure 20).

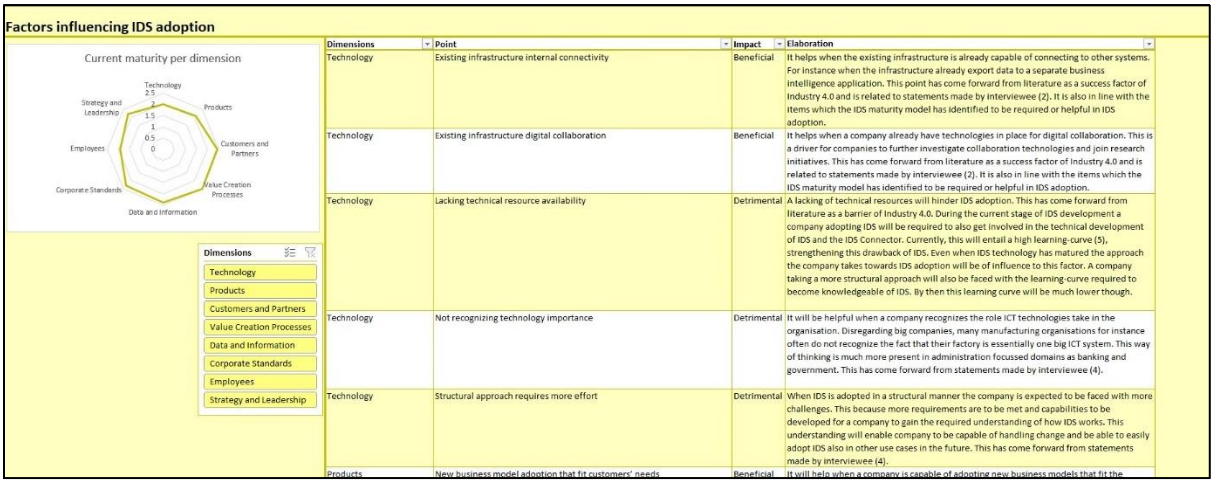


Figure 19 – Transfer medium: Strategy guide, factors influencing IDS adoption.

Figure 20 – Transfer medium: Strategy guide, Influence of IDS adoption.

9.3 Results

Questionnaires and interviews were conducted with three employees who describe their own function as director, CIO, and Business & Process analyst. The goal of basing the maturity assessment on the opinion of employee with different perspectives is thus achieved. However, only three respondent can be considered to be a low amount. More respondents would increase the reliability of the results and thus enable more statistically supported decision making. For now the result will mostly provide an indication that should not be fully trusted upon.

It was possible to follow the process as defined in the process definition of the model and discussed in the previous section. This resulted as expected in several findings, such as a gap analysis of pre- and post-adoption IDS maturity items, suggestions for supporting IDS adoption, expected advantages and disadvantages of adopting IDS. Realizations paths for IDS adoption were not developed, as expected. As it was not possible to meet in working group as the model intended due to the COVID-19 epidemic.

The results of the questionnaires adjusted after the interviews show mostly a standard deviation between 0.5 op to including 1.0, See Figure 21. The number of respondents is limited so no real conclusion can be drawn whether the company employees show agreement regarding the maturity of the company regarding the items. The maturity levels are defined in integers ranging from 1 tot 4.

As such it can be assumed that the results of the questionnaire should generally provide insight in whether the items are at least somewhat mature or not. The questionnaire ratings of only a few items was adjusted for each respondent as a result from the interviews.

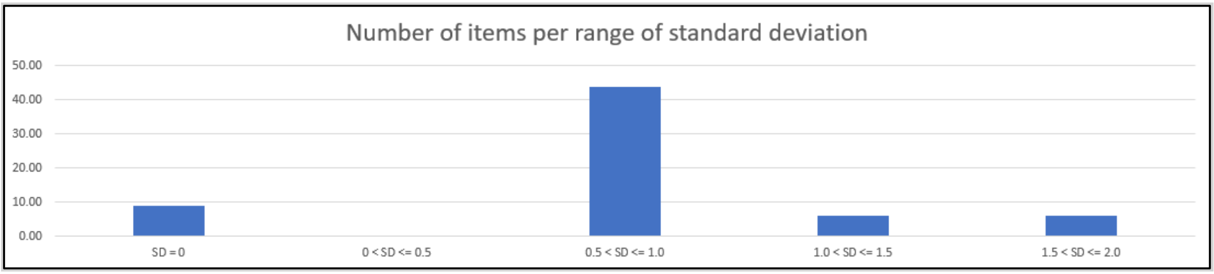


Figure 21 - Spread of Standard deviation as calculated for each of the items in the Industry 4.0 maturity assessment.

9.3.1 Validation questions

In the start of this chapter four validation research questions have been stated. The results of the validation effort performed will now be discussed for each of the questions. This is based on the opinion of the researcher, a comparison to other related studies within the company and the interview in which the assessment results have been presented to the main decision making in the use case company. This is the interview that is referred to whenever the rest of this section discussed feedback from 'the interview'.

1. Does the model result in a complete and holistic overview? (Effect)

The validation process indicated that items brought forward in other studies are also found by the IDS maturity model. This goes for both pre-adoption as for post-adoption items. The IDS maturity model generally produces more items than other studies identified. However it no statements can be made whether these extra items are indeed valid items. All in all, the items found to be needing improvement or which are found to be expecting improvement in maturity related to IDS adoption come from the holistic set of dimensions and items.

In the interview it was added that the main perceived benefit of the model was that it was capable of 'triggering' the manager to further investigate certain aspects of their companies' readiness. It was noted that the approach was trying to measure something that in essence can not be measured, as such it was appreciated that the model compared the numeric value of the Industry 4.0 readiness assessment with the insight of this report.

Gaining insight in the Industry 4.0 items related to IDS was of added value. Items that show little agreement in the answers submitted by respondent should also be further investigated according to the interviewee. This is in line with the following steps of the process definition of the IDS maturity model which have been left out in this use case.

Normally the next step would involve discussing the results in working groups in order to discuss the findings, prioritise items and to establish realization paths. The interviewee recognized the added value of the strategy guide in this but added that the strategy is not considered to be the main value of the model. It would benefit the user most during the establishment of the action to be taken by the company by providing context to the findings. This is in line with the intended purpose of the strategy guide component. The interviewee summarised his opinion as follows: "I see this model as being a tool, not to measure maturity, but to help synchronise the organisation and company wide vision."

2. Does the model align with best practices? (Requirements satisfaction)

This question cannot be conclusively answered by the validation performed in this research. The company investigated was already involved in investigating their own capabilities and trying to determine a strategy for improvement. These were however generally related to single aspect or studied the organisation in relation to a single innovation to be implemented.

The IDS maturity model aimed to align itself with Industry 4.0 literature. Companies that have already performed an Industry 4.0 readiness assessment should be able to skip the first step of the IDS maturity model and directly start performing the gap analysis.

The company investigated in use case did not have previous knowledge directly related to Industry 4.0. However, the company did however show at least some maturity regarding most of the items. Suggesting that the concepts of which Industry 4.0 is comprised are also applied outside the domain. Companies are thus probably likely to have at least some knowledge regarding some items of Industry 4.0, even if they don't know that they do themselves.

3. Does the model offer quantified measurements and results? (Requirements satisfaction)

The model resulted in clearly defined list of items in which either pre-adoption maturity is required to be improved as well as a list of items which are expected to become more mature following IDS adoption. These items are grouped by the simple distinction of being 'required' or 'helpful' (pre-adoption) and 'maturing' or 'enabling' (post-adoption). It is then to the company themselves to prioritize them and develop realization paths. The interviewee recognized this by stating that no direct conclusions could be drawn from an item scoring a '1' versus a '2' as it is not clear what this means.

The maturity assessment can be carried out by a small amount of people, which would not result in reliable results. A company wanting to gather reliable and useable results is this advised to question as many people as possible, of course these are required to have some knowledge of the topics discussed and the company investigated.

In addition, the IDS maturity model does not encompass any weighting of the items and dimensions. Due to the technology being new and the lacking research in the relation between IDS and Industry 4.0. The interviewee stated that this IDS Maturity model could in this perspective provide the basis for further maturing of the IDS maturity model.

4. Does the domain the company operates in influence the usability of the model? (Sensitivity)

As the IDS maturity model is based on Industry 4.0 literature some items in the readiness assessment are related to manufacturing processes. As such it can be hard for a company that is not a manufacturing company to determine maturity regarding these items. An example of such a company is a logistics provider, which is also the type of company in which this validation research has been carried out. However, due to the cross-domain nature of the IDS most, if not all, of the items related to manufacturing only are not directly or indirectly related with IDS adoption, as is established in the IDS maturity model. These items can thus also be excluded from the initial maturity assessment if not fitting the company that is assessed.

The interviewee does not think that the characteristics of a company would influence the model much as it is includes little to no company specific items and components. The only requirement to a company wanting to use the model is that it should fit some form of general representative process in which the company will join IDS in an active role. The IDS model presented in his research has provided some scoping for this model as it states to fit companies in the manufacturing and logistics domain aiming to join IDS as a data provider or data consumer. It could be added that the model thus does not fit a company that is joining IDS only to meet some requirement by a partners and that as such is not investing in gaining knowledge of how to operate and use IDS themselves.

9.4 Discussion

These results where used to perform a pre- and post-adoption gap analysis. The results of which were generally in line with other studies and projects. However, it was hard to draw conclusions in this regard. The other projects and studies performed were often only focussed on single aspects of the company, such as a certain grouping of technologies. The IDS maturity model however provides an holistic overview. As such it is hard to validate whether the IDS maturity model results has resulted in too many items. It can for instance be the case that the IDS maturity model has identified items of concern that have not yet been discovered in previous studies. The interview indicated the results to be 'triggering' the interviewee in it's decision making process as to start investigating other aspects of the company also.

In regards to establishing realization paths: it was hard to prioritize items. For one, items and dimensions in the IDS maturity model have no weighting. As such is it not clear how each should be prioritized. The fact that the IDS model does not offer any means to quantify the gap in the gap analysis of both pre-adoption and post-adoption amplifies this aspect. Normally up to the company to align possible realization paths with current strategy by the company during working groups. However this part of the IDS maturity model process definition could not be validated or tested due to COVID-19 constraints.

The interviewee was pleased with the results, mainly stating that the model serves as a tool supporting the decision making process. Not by offering quantified results but by offering an indication on which items to work on or at least to investigate. Part of this is the synchronisation of the views within the company.

The model was able to support the decision making process of the company by providing insight in the pre-adoption items that require work before IDS adoption, the impact of IDS adoption on the organisation, the factors supporting IDS adoption and the influence of IDS adoption on the organisation. As such the model is considered to be an effective and complete model. However, the model does not offer quantified results, which is a shortcoming.

10 Conclusion

This chapter will present the work done in this research. It will discuss the answers to the research questions, the main contributions of this research to industry and research, limitations of the research and recommendations for future work.

10.1 Research questions

The main research question posed was as follows:

"What maturity model based approach can be developed to support the decision to adopt IDS by an organisation?"

In order to provide an answer to this question five additional research questions were stated. The answers to each of which will be discussed now.

1. What is currently know about IDS adoption and the impact of IDS adoption by an organisation?

This questions is answered by applying explorative research mainly based on IDSA documentation and an interview conducted with a project manager of TNO, the Dutch IDSA Hub.

IDS is discussed in regards to several aspects. The components of which IDS is comprised of are deemed to fit the purpose of the technology. IDS does not only present a reference architecture but also encompasses other components helping to put IDS and IDS concepts into practice, for instance the IDS Connector, the IDS information model and the IDSA. Together they supply a complete platform for the implementation and adoption of IDS commercially.

The use cases investigated were in line with this, as they show IDS to be in a phase just before scaling up to wide scale commercial application. Use cases were found to be in the proof of concept, prototype and product phase. These use cases however only implemented a part of the IDS Ecosystem. No use cases were found to exist that incorporated all roles defined in the IDS reference architecture. Thus no real IDS Ecosystem was found to exist.

Finally IDS was also discussed in relation to it's adoption and expected advantages and disadvantages. Showing the benefits of adopting IDS from the perspective of the IDSA and when IDS should not be adopted, including drivers and barriers present in the current Dutch ecosystem.

2. How does IDS relate to other data sharing technologies and initiatives?

This question is also answered by applying explorative research and is mainly based on IDSA documentation. It was identified that the Industry 4.0 initiative is closely related to Industry 4.0 and that the Industry 4.0 initiative is more mature. Thus possibly providing an alternative source of publications for the lacking amount of scholarly publications for IDS.

IDS is mainly related to the data and information aspect of Industry 4.0, acting as an enabler for many of the technologies in the field.

3. What components should a maturity based model to support the IDS adoption decision contain?

In order to answer this question an extensive systematic literature search was performed identifying 30 maturity models related to IDS, Industry 4.0 and other data sharing technologies. The maturity models were analysed resulting in the identification of four components of maturity models:

- Pre-adoption maturity model: Dimensions and or items, maturity levels for each
- Post-adoption impact mapping
- Process definition
- Strategy guide

Almost all maturity models found contained some form maturity matrix, comprised of dimensions and or items on one axis and maturity levels on the other axis. Some maturity models also presented some form of impact mapping, discussion how changes in maturity is expected to impact the organisation. Also, most maturity models defined some form of process describing how the maturity model is to be applied. Finally, a lot of the models also describes an approach or tooling to help companies establish some form of strategy of how maturity growth can be established.

A distinction is suggested between two types of maturity models: maturity models only defining a maturity matrix and maturity models defining a process definition and strategy or impact guide in a addition to the maturity matrix.

4. How can these components be operationalised in a new maturity based model for supporting the adoption decision of IDS?

Following the maturity model development procedure by Becker et al. (2009) the problem definition, goals, stakeholders, requirements and development approach for the IDS maturity model were established.

The industry 4.0 maturity model by Schumacher et al. (2019) was selected for the IDS maturity model to be based on, an overview of the maturity dimensions and items of this model can be found in appendix chapter 12.4. The model describes 65 items in the grouped in the following eight dimensions:

- Technology
- Products
- Customers and Partners
- Value Creation Processes
- Data and Information
- Employees
- Corporate standards
- Strategy and Leadership

This model is then adapted based on literature found in the systematic literature search and expert interviews. This development is presented in two iteration of the maturity model development stage of the maturity model procedure by Becker et al. (2009).

The resulting model identified 36 items of the 65 Industry 4.0 items presented by Schumacher et al. (2019) to be related to IDS pre-adoption readiness, categorised to be either required or helpful to be mature in. Of the 65 Industry 4.0 items presented by Schumacher et al. (2019), 40 items were found to be expected to be impacted by IDS adoption. These items are categorised to be either directly maturing following IDS adoption or IDS adoption to be enabling maturity growth in the future.

Besides identifying the pre- and postadoption maturity items related to IDS, the IDS maturity model has also defined a process definition and strategy guide. This process definition describes how the IDS maturity model is applied. In short: after performing an as-is maturity assessment a gap analysis can be performed regarding pre- and postadoption maturity. These results of which can then be used to establish strategy based on realization paths. To support the establishment of these realization paths a guide is developed describing factors influencing IDS adoption and how IDS adoption influences the organisation for each dimension of the Schumacher et al. (2019) maturity model.

5. Is this developed model expected to support the decision to adopt IDS?

Them developed model is validated in a single case mechanism experiment for which questionnaires are sent and interviews conducted. Several validation questions were stated, determining whether would be capable of having the desired effect taking into account the requirements put forward.

The IDS maturity model that is developed seems to produce the desired results adhering to the requirements put forward. Some lessons have also been learnt about the use and application of the maturity model. These are discussed in chapter 10.4: recommendation for future work.

10.2 Contribution to research and practice

This research has contributed to research domain of International data spaces. This domain does not include many publications yet and none of the existing publications have discussed any aspect related to maturity, maturity models or readiness assessments. As such this research is the first attempt made to establish such a model.

The model is based on the maturity model for Industry 4.0 by Schumacher et al. (2019). By adapting this model to fit IDS it has become more clear how IDS is related to Industry 4.0, and also how it is not.

In industry companies are faced with many new technologies and innovation in day-to-day practice. The IDS maturity model developed will enable companies to more easily and complete assess their readiness towards IDS, the reasons to adopt or not to adopt IDS and what it can do to influence IDS adoption. By aligning the model with current the related field of Industry 4.0 a company can assess IDS in relation to Industry 4.0 strategy, which the company can already have started with separately.

10.3 Limitations

The main limitation of this research is the availability of peer reviewed publications directly related to IDS. As such this research was required to pioneer in the field, trying to extract knowledge from other domains. The research has tried to reduce bias to a minimum by applying triangulation methods and conducting a truly extensive systematic literature search.

There is however not much known about how Industry 4.0 items are to be operationalised when they are related to IDS. This research for instance did not establish a weighting for the dimensions and items in the IDS model. No statistical research has been carried out proving the importance of the items and their possible relationships to each other. This made it hard to further consolidate the maturity model and strategy guide, for instance at an item level instead of on the dimension level as it is now.

Also the domain of IDS is currently rapidly changing. The IDS reference architecture model is at the of writing in version 3.0 but version 4.0 is already announced. Many use cases and initiatives are started leaving the domain in ‘flux’ resulting in the fact that even during the process of writing this thesis the gathered information can have become old.

10.4 Recommendations for future work

1. The model developed should provide a starting point for an IDS model. It should be further refined by developing further iterations following the iterative approach by Becker et al. (2009). Such further application, refinement and testing of the model based on new and

other sources will allow for the model to become better, meaning that it will be more reliable and that it can be better adapted to fit the context it is applied in.

2. The model developed is specified for a specific use case: namely joining an existing IDS ecosystem as a data consumer or data provider. IDS does however define more roles and as such the IDS model should also be tested and adjusted for use by companies willing to join IDS in one of these other roles.
3. During this research several methods have been applied to identify the dimensions and items related to IDS. However, none of these techniques provide a solid quantitative foundation to draw conclusions upon. Future research should quantify and validate the presence of the items in the model, their weighting and their interrelatedness. This could possible also allow the model to convert from the systematic of using the 'required', 'helpful', 'maturing', and 'enabling' classifications to numeric values.
4. The current model is mainly presented in tables and text. The maturity model development procedure by Becker et al. (2009) describes in steps 5 and 6 the conception and implementation of a transfer medium. Future research can be performed to find the best suitable form, develop and implement such a transfer medium for the IDS model. During the validation of the model an excel file was developed which proved to be useful, helping combine the results of the IDS maturity model in a visual representation. However, this excel file is not considered 'mature' enough to be considered a fully valid transfer medium. It lacks for instance clear descriptions of definitions and explanations on how to use and interpret the file. This is needed to be able to share the model and file with parties that have no intimate knowledge of this research.

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12 Appendices

12.1 Appendix – Systematic literature review results

- MM = Maturity model
- MML = Literature review regarding Maturity Models
- REQ = Literate containing factors influencing adoption, such as enablers, requirements, barriers, success factors
- AD = Literature regarding the adoption process and adoption decision

Table 51 – Domain and content of found literature

#	Article	Domain(s)	MM	MML	REQ	AD
1	(Adrian et al., 2016)	Big data		X		
2	(Agostini & Filippini, 2019)	I4.0			X	
3	(Akdil et al., 2018)	I4.0	X			
4	(Alcácer & Cruz-Machado, 2019)	I4.0, Manufacturing			X	
5	(Asdecker & Felch, 2018)	I4.0, Manufacturing	X			
6	(Basl & Doucek, 2019)	I4.0		X		
7	(Bibby & Dehe, 2018)	I4.0	X			
8	(Calabrese et al., 2020)	I4.0			X	
9	(Canetta et al., 2018)	I4.0	X			
10	(Chonsawat & Sopadang, 2019)	I4.0, SME	X			
11	(Cimini, Pinto, & Cavalieri, 2017)	I4.0, Manufacturing		X		
12	(Cimini, Pinto, Pezzotta, et al., 2017)	I4.0, Manufacturing			X	X
13	(Colli et al., 2018, 2019)	I4.0	X			
14	(Dallasega et al., 2019)	I4.0, L4.0, SME			X	
15	(Dallasega et al., 2020)	I4.0			X	
16	(A. De Carolis et al., 2018; Anna De Carolis et al., 2017)	Manufacturing	X			
17	(Facchini et al., 2019)	L4.0	X			
18	(Frederico et al., 2019)	I4.0	X		X	
19	(Ganzarain & Errasti, 2016)	I4.0, SME	X			
20	(Ghobakhloo, 2018)	I4.0		X		X
21	(Ghobakhloo & Ching, 2019)	I4.0, Manufacturing, SME			X	
22	(Gökalp et al., 2017)	I4.0	X			
23	(Hamada, 2019)	I4.0				X
24	(Hamidi et al., 2018)	I4.0, SME		X	X	
25	(Havle & Üçler, 2018)	I4.0			X	
26	(Hizam-Hanafiah et al., 2020)	I4.0		X		
27	(Hofer et al., 2019)	Manufacturing				X
28	(Jodlbauer & Schagerl, 2016)	I4.0	X			
29	(Jung & Kulvatunyou, 2016)	Manufacturing	X			
30	(Kolla et al., 2019)	I4.0, SME			X	
31	(Leyh et al., 2017)	I4.0	X		X	
32	(Lin et al., 2020)	Manufacturing	X			
33	(Lu, 2017)	I4.0			X	
34	(Mittal et al., 2020; Mittal, Romero, et al., 2018)	Manufacturing, SME	X			
35	(Mittal, Khan, et al., 2018)	I4.0, Manufacturing, SME		X		

36	(Modrak et al., 2019)	I4.0, SME			**X**	
37	(Oleśków-Szłapka & Stachowiak, 2019)	L4.0	**X**		**X**	
38	(Oztemel & Gursev, 2020)	I4.0		**X**		
39	(Pacchini et al., 2019)	I4.0, Manufacturing	**X**			
40	(Pirola et al., 2019)	I4.0, SME	**X**			
41	(Queiroz et al., 2019)	I4.0, SC4.0			**X**	
42	(Rauch et al., 2020)	I4.0, SME	**X**			
43	(Santos & Martinho, 2019)	I4.0, Manufacturing	**X**			
44	(Günther Schuh et al., 2020)	I4.0	**X**			
45	(Schumacher et al., 2016)	I4.0, Manufacturing	**X**			
46	(Schumacher et al., 2019)	I4.0, Manufacturing	**X**			
47	(Sjödin et al., 2018)	Manufacturing	**X**		**X**	
48	(Sony & Naik, 2019)	I4.0		**X**		
49	(Sony & Naik, 2020)	I4.0			**X**	
50	(Stefan et al., 2018)	I4.0, Manufacturing, SME	**X**			
51	(Trotta & Garengo, 2019)	I4.0, SME	**X**			
52	(Vijaya Kumar et al., 2020)	I4.0		**X**	**X**	
53	(Vrchota & Pech, 2019)	I4.0	**X**			
54	(Vuksanović Herceg et al., 2020)	I4.0			**X**	
55	(Wagire et al., 2020)	I4.0	**X**			
56	(Weber et al., 2017)	I4.0, Manufacturing	**X**			

12.2 Appendix – Maturity model components

- D = Dimensions
- I = Items
- MS = Maturity stages
- P = Process definition
- S = Strategy guide
- R = Relation between items
- IM = Impact mapping

#	Article	D	I	MS	P	S	R	IM
1	(Akdil et al., 2018)	X	X	X				
2	(Asdecker & Felch, 2018)	X	X	X				
3	(Bibby & Dehe, 2018)	X	X	X				
4	(Canetta et al., 2018)	X	X	X	X			
5	(Chonsawat & Sopadang, 2019)	X	X	X				
6	(Colli et al., 2018, 2019)	X		X	X			
7	(A. De Carolis et al., 2018; Anna De Carolis et al., 2017)	X		X	X	X		
8	(Facchini et al., 2019)	X		X				
9	(Frederico et al., 2019)	X	X	X				X
10	(Ganzarain & Errasti, 2016)			X	X			
11	(Gökalp et al., 2017)	X		X		X		
12	(Jodlbauer & Schagerl, 2016)	X	X	X	X	X		
13	(Jung & Kulvatunyou, 2016)	X	X	X	X	X		
14	(Leyh et al., 2017)	X		X				
15	(Lin et al., 2020)	X	X	X				
16	(Mittal et al., 2020; Mittal, Romero, et al., 2018)	X	X	X	X	X		
17	(Oleśków-Szłapka & Stachowiak, 2019)	X	X	X				
18	(Pacchini et al., 2019)	X	X					
19	(Pirola et al., 2019)	X	X	X				
20	(Rauch et al., 2020)	X	X	X	X	X		X
21	(Santos & Martinho, 2019)	X	X	X				
22	(Günther Schuh et al., 2020)	X	X	X	X	X		
23	(Schumacher et al., 2016)	X	X	X	X			
24	(Schumacher et al., 2019)	X	X	X	X	X		
25	(Sjödin et al., 2018)	X		X				X
26	(Stefan et al., 2018)	X	X	X			X	
27	(Trotta & Garengo, 2019)	X	X	X				
28	(Vrchota & Pech, 2019)			X				
29	(Wagire et al., 2020)	X	X	X				
30	(Weber et al., 2017)			X				

12.3 Appendix – Mapping maturity model dimensions to concepts

12.3.1 Technology

Table 52 – Dimensions from each model mapped to the concept of 'Technology'

Dimension from model	Articles
Models containing no dimension related to Technology	(Akdil et al., 2018), (Asdecker & Felch, 2018), (Mittal et al., 2020; Mittal, Romero, et al., 2018)
Technology	(Schumacher et al., 2019), (Canetta et al., 2018), (Stefan et al., 2018), (Sjödin et al., 2018), (Frederico et al., 2019), (Schumacher et al., 2019), (Trotta & Garengo, 2019), (Rauch et al., 2020), (A. De Carolis et al., 2018; Anna De Carolis et al., 2017), (Colli et al., 2018, 2019)
Enabler technologies	(Pacchini et al., 2019)
Industry 4.0 base technology	(Wagire et al., 2020)
Smart manufacturing technology	(Wagire et al., 2020)
Cross-sectional technology criteria	(Leyh et al., 2017)
Automation	(Lin et al., 2020)
IT	(Jung & Kulvatunyou, 2016)
Information systems	(Günther Schuh et al., 2020)
Application management	(Gökalp et al., 2017)
Intelligence	(Lin et al., 2020), (Jodlbauer & Schagerl, 2016)
Technology integration	(Pirola et al., 2019)
Asset management	(Gökalp et al., 2017)
Flow of material and information (4)	(Facchini et al., 2019)
Flow of material	(Oleśków-Szłapka & Stachowiak, 2019)
Resources	(Günther Schuh et al., 2020)
Factory of the future (8)	(Bibby & Dehe, 2018)
Smart factories	(Santos & Martinho, 2019)
Data & Information	(Schumacher et al., 2019)
Data	(Jodlbauer & Schagerl, 2016)
Technology driven process	(Chonsawat & Sopadang, 2019)
Vertical integration	(Leyh et al., 2017)
Horizontal integration	(Leyh et al., 2017)
Information connectivity	(Jung & Kulvatunyou, 2016)
Connectivity	(Lin et al., 2020), (Colli et al., 2018, 2019)
Flow of information	(Oleśków-Szłapka & Stachowiak, 2019)

12.3.2 Strategy

Table 53 - Dimensions from each model mapped to the concept of 'Strategy'

Dimension from model	Article
Models containing no dimension related to Technology	(Jung & Kulvatunyou, 2016), (Jodlbauer & Schagerl, 2016), (Gökalp et al., 2017), (Leyh et al., 2017), (Günther Schuh et al., 2020), (Stefan et al., 2018), (Asdecker & Felch, 2018), (Facchini et al., 2019), (Oleśków-Szłapka & Stachowiak, 2019), (Pacchini et al., 2019), (Lin et al., 2020), (Rauch et al., 2020), (A. De Carolis et al., 2018; Anna De Carolis et al., 2017), (Colli et al., 2018, 2019)
Strategy	(Schumacher et al., 2016), (Bibby & Dehe, 2018), (Canetta et al., 2018), (Mittal et al., 2020; Mittal,

	Romero, et al., 2018), (Pirola et al., 2019), (Trotta & Garengo, 2019)
Strategy (& leadership)	(Akdil et al., 2018), (Schumacher et al., 2019)
Finance	(Mittal et al., 2020; Mittal, Romero, et al., 2018)
Organizational strategy, structure and culture	(Santos & Martinho, 2019)
Strategic outcomes	(Frederico et al., 2019)
Business organization strategy	(Chonsawat & Sopadang, 2019)
Organisational strategy	(Wagire et al., 2020)

12.3.3 Processes

Table 54 - Dimensions from each model mapped to the concept of 'Processes'

Dimension from model	Article
Models containing no dimension related to Technology	(Bibby & Dehe, 2018), (Facchini et al., 2019), (Oleśków-Szłapka & Stachowiak, 2019), (Pirola et al., 2019), (Pacchini et al., 2019)
Process	(Canetta et al., 2018), (Mittal et al., 2020; Mittal, Romero, et al., 2018), (Sjödin et al., 2018), (A. De Carolis et al., 2018; Anna De Carolis et al., 2017)
Operations	(Schumacher et al., 2016)
Performance management	(Jung & Kulvatunyou, 2016)
Digital transformation	(Jodlbauer & Schagerl, 2016)
Process transformation	(Gökalp et al., 2017)
Digital product development	(Leyh et al., 2017)
Resources (efficient communication)	(Günther Schuh et al., 2020)
Organizational culture (social collaboration)	(Günther Schuh et al., 2020)
smart business processes	(Akdil et al., 2018)
Processing	(Asdecker & Felch, 2018)
Warehousing	(Asdecker & Felch, 2018)
Shipping	(Asdecker & Felch, 2018)
Smart processes	(Santos & Martinho, 2019)
Processes performance requirements	(Frederico et al., 2019)
Value creation processes	(Schumacher et al., 2019), (Colli et al., 2018, 2019)
Manufacturing and operations	(Chonsawat & Sopadang, 2019)
Digital support	(Chonsawat & Sopadang, 2019)
Production	(Trotta & Garengo, 2019)
Operation	(Lin et al., 2020), (Rauch et al., 2020)
Product lifecycle	(Lin et al., 2020)
Value chain and processes	(Wagire et al., 2020)

12.3.4 Organisation

Table 55 - Dimensions from each model mapped to the concept of 'Organisation

Dimension from model	Article
Models containing no dimension related to Technology	(Leyh et al., 2017), (Asdecker & Felch, 2018), (Pacchini et al., 2019)
Organization	(Jung & Kulvatunyou, 2016), (Stefan et al., 2018), (Rauch et al., 2020), (A. De Carolis et al., 2018; Anna De Carolis et al., 2017)

Leadership	(Schumacher et al., 2016),
Culture	(Schumacher et al., 2016)
People	(Schumacher et al., 2016), (Mittal et al., 2020; Mittal, Romero, et al., 2018), (Sjödin et al., 2018), (Pirola et al., 2019), (Trotta & Garengo, 2019)
Governance	(Schumacher et al., 2016), (Colli et al., 2018, 2019)
Digital transformation	(Jodlbauer & Schagerl, 2016)
Organizational alignment	(Gökalp et al., 2017)
Data governance	(Gökalp et al., 2017)
Organizational structure	(Günther Schuh et al., 2020)
Organizational culture	(Günther Schuh et al., 2020)
Resources	(Günther Schuh et al., 2020)
People and culture	(Bibby & Dehe, 2018), (Wagire et al., 2020)
(strategy) and organization	(Akdil et al., 2018)
Personnel	(Canetta et al., 2018), (Stefan et al., 2018)
Workforce	(Santos & Martinho, 2019)
Management	(Facchini et al., 2019), (Oleśków-Szłapka & Stachowiak, 2019)
Managerial & capability	(Frederico et al., 2019)
Structure and management	(Lin et al., 2020)
Corporate standards	(Schumacher et al., 2019)
Employee	(Schumacher et al., 2019)
(strategy and) leadership	(Schumacher et al., 2019)
People capability	(Chonsawat & Sopadang, 2019)
Talent readiness	(Lin et al., 2020)
Socio-culture	(Rauch et al., 2020)
Industry 4.0 awareness	(Wagire et al., 2020)
Monitoring and control	(A. De Carolis et al., 2018; Anna De Carolis et al., 2017)
Competence	(Colli et al., 2018, 2019)

12.3.5 Product

Table 56 - Dimensions from each model mapped to the concept of 'Product'

Dimension from model	**Article**
Models containing no dimension related to Technology	(Jung & Kulvatunyou, 2016), (Jodlbauer & Schagerl, 2016), (Gökalp et al., 2017), (Leyh et al., 2017), (Günther Schuh et al., 2020), (Bibby & Dehe, 2018), (Stefan et al., 2018), (Asdecker & Felch, 2018), (Sjödin et al., 2018), (Facchini et al., 2019), (Frederico et al., 2019), (Oleśków-Szłapka & Stachowiak, 2019), (Pirola et al., 2019), (Chonsawat & Sopadang, 2019), (Pacchini et al., 2019), (Lin et al., 2020), (Rauch et al., 2020), (A. De Carolis et al., 2018; Anna De Carolis et al., 2017), (Colli et al., 2018, 2019)
Products	(Schumacher et al., 2016), (Mittal et al., 2020; Mittal, Romero, et al., 2018), (Trotta & Garengo, 2019)

Smart products and services	(Akdil et al., 2018)
Products and services	(Canetta et al., 2018)
Products and services oriented technology	(Wagire et al., 2020)

12.3.6 Miscellaneous

Table 57 - Dimensions from each model mapped to the concept of 'Miscellaneous'

Dimension from model	**Article**
Customers	(Schumacher et al., 2016)
Customers and partners	(Schumacher et al., 2019)
Supply chain	(Lin et al., 2020)

12.4 Appendix – Maturity model by Schumacher et al. (2019)

Table 58 – Dimensions and items as operationalized by Schumacher et al. (2019).

Technology • Technology for information exchange; • Utilization of cloud technology; • Mobile devices on shop floor; • Decentral information storage; • Sensors for data collection; • Integrated computers in machines; • Integrated computers in tools; • Additive manufacturing; • Utilization of robots	**Data & Information** • Digital information processes; • Automated data collection; • Analysis of collected data; • Databased decision making; • Automated information provision; • Individualization of provided information; • Digital process visualization; • Data-driven software-simulation of future scenarios
Products • Product individualization; • Flexibility of product characteristics; • Collection of product-use-information; • Data processing components in products; • Internet connection of products; • Digital compatibility and interoperability of products; • IT-services related to physical products	**Corporate standards** • Monitoring of Industry 4.0 realization; • Technological standards; • Recruitment for Industry 4.0; • Adjustments of works arrangements; • Employee trainings of digital competences; • Legal protection for digital products and services; • Increased cyber security; • Rules for employees in digital work environment
Customers and Partners • Openness to new technology; • Competence with modern ICT; • Digitalization of customer contact; • Customer integration in product development; • Utilization of customer related data; • IT-collaboration for product development; • Digital contact with company partners; • Company partner's degree of digitalization	**Employees** • Openness to new technology; • Competences with modern ICT; • Awareness of non-IT-employees for data; • Awareness of non-IT-employees for cyber security; • Willingness to flexibilize work arrangements; • Autonomy of shop floor workers; • Experience with interdisciplinary work; • Willingness for continuous training on the job; • Knowledge about employee competences
Value Creation Processes • Value Creation Process automation; • Autonomy of machine park; • Information exchange between machines; • Remote control of machine park; • Automated quality control; • Databased machine maintenance; • Automation object handling; • Collaboration of humans and robots	**Strategy and Leadership** • Roadmap for Industry 4.0 realization; • Central coordination of Industry 4.0; • Financial resources to realize Industry 4.0; • Communication of Industry 4.0 activities; • Employee objectives to realize Industry 4.0; • Risk assessment for Industry 4.0; • Willingness of managers to realize Industry 4.0; • Manager trainings for Industry 4.0

12.5 Appendix – Questionnaire design

- Please indicate your consent to the conditions described above. (Yes or No)
- General information - What is your name? (only compulsory when also taking part in an interview)(Text)
- General information - What is the name of your company? (Text)
- General information - What is your role at this company? (Text)
- How would you describe your relationship with International Data spaces? (Multiple choices available)
    - I'm member of the IDSA.
    - I'm doing research in IDS or related fields.
    - I'm interested in starting a project or implementation of IDS into my organisation.
    - I've previously or currently been involved in a project or implementation of IDS into my organisation.
    - I have no relationship with IDS.
    - Other... - Text
- Do you consider yourself to be familiar with IDS? (Yes or No)
    - How would you describe your relationship with Industry 4.0? (Multiple choices available)
    - I'm doing research in Industry 4.0 or related fields.
    - I'm interested in starting a project or implementation of Industry 4.0 into my organisation
    - I've previously or currently been involved in a project or implementation of Industry 4.0 into my organisation.
    - I've no relationship with Industry 4.0
    - Other... - Text
- Do you consider yourself to be familiar with Industry 4.0? (Yes or No)
- What capabilities should be present in an organisation that is deciding to adopt IDS into its main business processes?
- What capabilities are expected to be present by an organisation having adopted IDS into its main business processes?
- For each item of the Schumacher et al. (2019) maturity model, grouped by dimension:
    - Q1: For item … an organisation should have reached a minimum maturity level of … before starting adoption of an IDS use case (matrix, maturity items vs maturity levels: options={1,2,3,4, scoring not possible})
      Example provided:
      Technology for information exchange should receive score 2 "little bit" when you think IDS adoption can start in an organisation displaying only little maturity regarding technology for information exchange. Meaning that these technologies are only sometimes applied in key business processes. When an organisation is required to be fully dependant on technologies for information exchange in its key processes before starting IDS adoption a score of 4 "a lot/fully" would be most appropriate. -
        - Please explain why scoring was not possible. (Only shown when one or more items was scored 'scoring not possible')
    - Q2: For item … an organisation is expected to have reached a maturity level of … after adoption of an IDS use case. (matrix, maturity items vs maturity levels: options={1,2,3,4, scoring not possible})
        - Please explain why scoring was not possible. (Only shown when one or more items was scored 'scoring not possible')

12.6 Appendix – Interview guide template

0-5 Minutes – Introduction

- Ask for consent for recording the interview, only for use by me. Statements can be made part of the paper but will not be linked to a name.
- Introduce myself shortly: Ewout Gort. Master Student Business and IT, University of Twente, Faculty of Electrical Engineering Mathematics and Computer Science. Connected to Emons Group, University of Twente.
- Can you introduce yourself?
- How was the questionnaire? Do you have any remarks or observations to discuss before proceeding to the rest of the interview?

5-25 Minutes – Maturity dimensions

- Are you familiar with the terms IDS and Industry 4.0.

Per dimension:

- 1m: You have scored the following regarding minimal maturity of these Industry 4.0 items. *Show scoring per item*. Can you elaborate?
- 1m: Do you expect impact of adopting IDS on this maturity in terms of growth? Can you elaborate?

1. Technology
2. Products
3. Customers and Partners
4. Value Creation Processes
5. Data & Information
6. Corporate standards
7. Employees
8. Strategy and leadership

- Are there any other dimensions which could be of importance to this study?

25-30 Minutes – Final remarks

- Do you know of any other people interested in taking part in this study?
- If I have any follow up questions, can I then contact you again?
- Would you like to receive a copy of my findings?

12.7 Appendix – Interview summaries

12.7.1 Interview 1

Interviewer: Ewout Gort Date: 21-01-2021

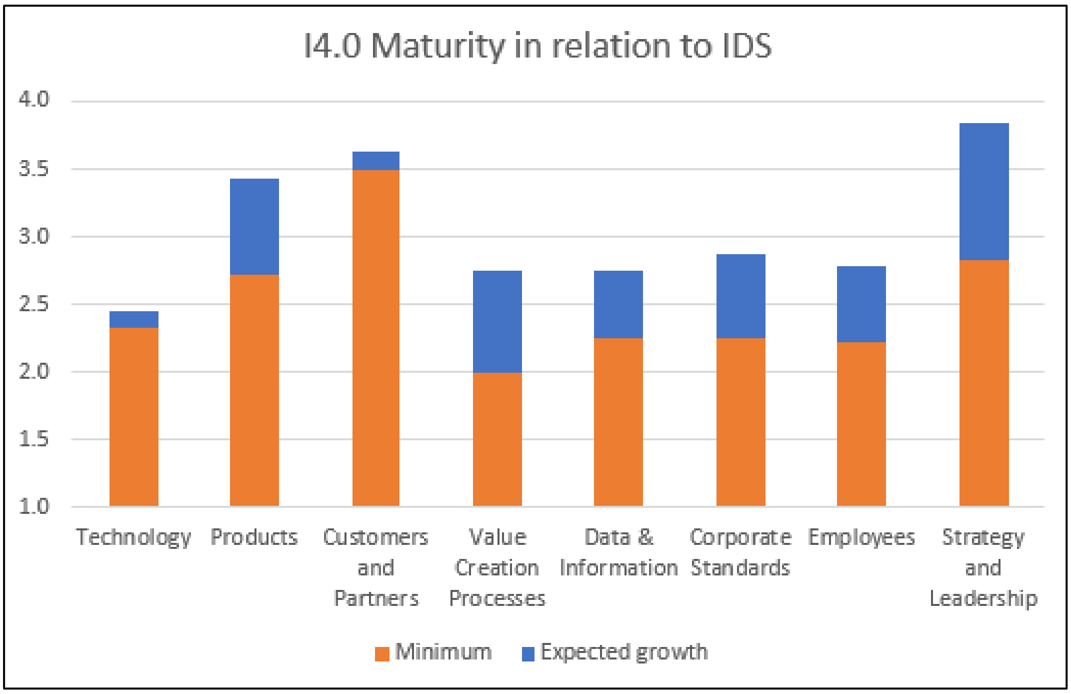

Figure 22 – Questionnaire results respondend 1

Technology

A company should have decent maturity regarding technology in order to start adoption of IDS. However little growth in maturity is expected. This is because the technologies which are applied in IDS already exist. IDS mostly adds value by combining these existing technologies in a package. The company should off course be able to use these, however no new technology capabilities are developed during adoption.

Products

It is difficult to relate the products dimension to IDS as it is very dependent on the use case. However, it is to be expected that companies offering more simple goods would benefit less from IDS.

Customers and Partners

A company should have an high minimum maturity concerning the Customers and Partners dimension. This is because of what IDS does: enabling data sharing across company borders. For this there need to be customers and partners willing and able to exchange the data with. True value is created when there are many connected organisations. Existing close relationships is key as the IDS requires investment, trust and cooperation.

Only little growth is expected concerning the customers and partners dimension. Even though IDS builds upon existing mature relationships it is not expected to require these relationships to become more mature.

Value Creation Processes

It is also difficult to relate value creation processes maturity to IDS. As it is very dependent on the existing value creation processes whether or not maturity is required. For instance when VCP processes that become available by implementing IDS are not related to your now core VCP.

If you find a use case for IDS fitting to your company than growth is expected.

Data & Information
In order for implementation of IDS to be successful the company needs have some maturity regarding data & information. There's need for existing infrastructure to prepare and offer the data for IDS to use. In reconsideration an higher minimum maturity for Data & information is expected than is reflected by my questionnaire.

Corporate standards
Corporate standards follows the same argumentation as the technology dimension. As IDS offers a package companies are not required to know a lot regarding corporate standards. It is part of IDS. However it is expected that a company will grow in maturity concerning corporate standards during the adoption of IDS and that some pre-existing maturity is required to successfully implement IDS

Employees and Strategy and leadership
Employees and Strategy and leadership maturity should be high for employees and management to understand, value and use IDS correctly. Growth in maturity is expected as by implementing IDS understanding and application of value data sharing is increased.

Concerning management: otherwise the IDS adoption process will not be started. This can thus also be a big hurdle for the adoption of IDS, when management is not open for these kind of technologies.

Are there any other dimensions which could be of importance to this study?
As stated before: use cases can vary a lot and be very different. Depending on the use case in mind the questionnaire could show different results.

The ecosystem in which the company operates in is key in the adoption of IDS, in the questionnaire the closest dimension to this would be customers and partners.

During discussion it became clear that: It is contra dictionary that management requires high maturity and understanding of IDS like technologies while IDS aims offers a 'simple to use' almost 'plug and play' package.

That is one of the reasons why every adoption process starts with the use case. This enables Fraunhofer and IDSA to help investigate what is required.

12.7.2 Interview 2

Interviewer: Ewout Gort Date: 27-01-2021

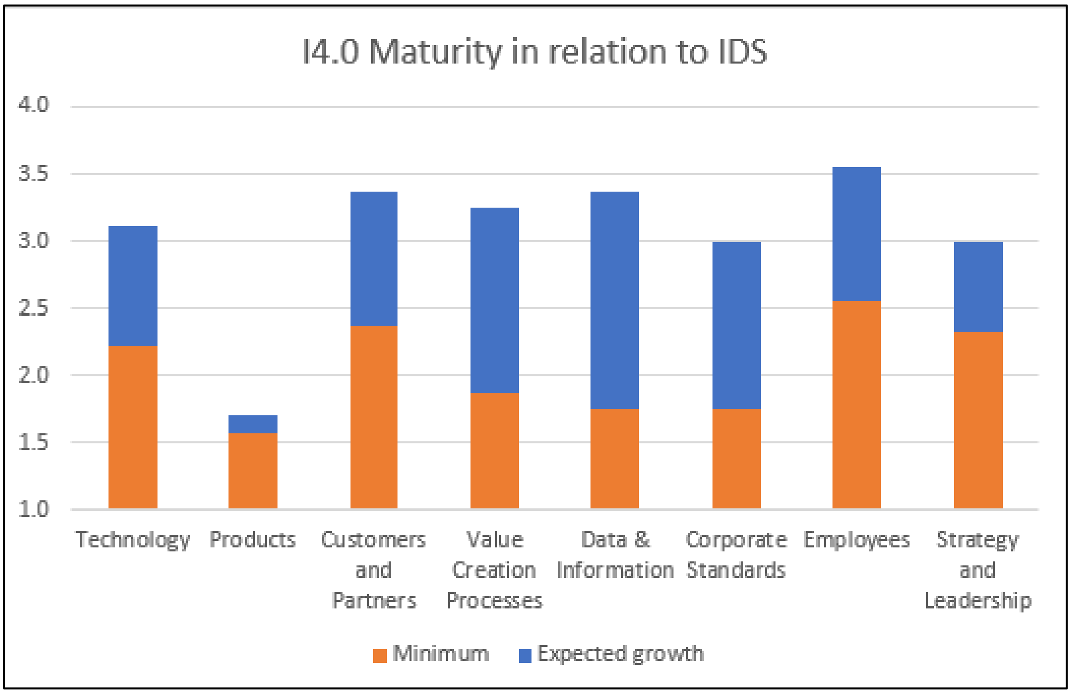

Figure 23 – Questionnaire results respondend 2

Technology

Minimum maturity is in accordance with the expectation. It corresponds to feedback from the market, in which most organisations already have technological solutions. It's one of the reasons for companies to become join collaboration and investigation of such innovations. Following joining this collaboration, growth is expected in several aspects the coming year, of which in technology albeit not the biggest of the aspects. Mostly in the field of semantics.

Technology is mostly about 'just doing'. Which is supported by our technology partner which indicated that all 'building blocks' of IDS already exist in practice. The main reason why the expected minimum maturity level isn't very low is because of the aspect of connectivity. The aspect of creating a platform is not really that big of a deal.

Products

The logistics products offered by the company are already fitting an IDS environment, so little effort is required. Low maturity is required concerning Industry 4.0 maturity for IDS adoption. This strict context of logistics.

The technology of IDS is in this responsible for the data sharing. Connections between companies already exist, trucks and drivers are already tracked. That data can without much effort be shared with a platform.

Customers and Partners

A lower maturity level was expected concerning than what was the result of the questionnaire (2.3). Expected growth was however expected to be higher.

This resolves around the biggest problem which is collaboration and trust. And besides this the value creation processes having the capabilities to see and seize the value in this.

There's a distinction between customers and partners. We can tell partners to do something, such as by hiring charters. This is not really exiting, also not from an IDS perspective. Especially because we can be in control. The main tension is in the relationship with customers.

I do expect growth during implementation of IDS because customers will be involved during the good implementation and development of an IDS Ecosystem. Together growing in maturity.

Value Creation Processes
In the long term a lot of things we do now will not be necessary anymore. For example when you look at self-driving cars in which IDS may take a part in the control process. That would be a great value creation process for me as a company.

Growth during IDS adoption is expected. Is becoming more mature requires you to find a central point, a point of coordination, which can be fulfilled by IDS.

Data & Information
In this dimension the OpenTrip model and similar models are important. When IDS has been implemented you will be speaking in a similar language and translating to a language you know. In realising an IDS you've certainly experienced growth which is enforced by IDS.

An IDS is not possible without aligning data & information. It is a similar to a printerdriver, the driver will be able to translate commands from the pc and be able to translate these commands to a specific printer. Effectively coordinating data & information through that central entity.

Corporate standards
When you look at for instance IShare, authentication is based on user management. User management thus cannot be faulty, otherwise the system will fail. Enforcement of standards by IDS should trickle down to your own corporate standards. You cannot be operating sloppy internally and expect to be able to work meticulous externally. Adopting IDS thus an immense impact on corporate standards maturity.

You have to be started implementing corporate standards in your organisation before starting the adoption of IDS otherwise it would not work. There has to be a culture and an existing process involving security. Otherwise would every change or irregularity lead to being disconnected from IDS. That will be frustrating.

Employees
The minimum security as resulting from the questionnaire is too high.

Platform-like systems are commonplace by now. So many exists that everyone in transport should by now know of them. Looking for instance to Facebook and Instragram, these are in fact also platforms. (company) specific solutions can off course be new but even then employees should be able to get up to speeds with the concept quite easily.

When you're talking about analytics and follow-up for instance, there will be growth but it won't be new for employees.

As possible explanation for the too high maturity assessment could be this: the development and implementation of an IDS can be complex however the use of IDS in practice is not.

IDS is different in that you are not a customer of the dataspace but a partner. This difference changes your role and the opportunities in the dataspace.

There are different ways to be conscious about data. One's from the perspective of understanding the concept which is quite hard. The other perspective is of being conscious about entering the right data in the system and is also required for IDS. That could maybe also be described as data discipline. I might have interpreted the questionnaire keeping a different perspective in mind.

My expectation is that a company will move more towards analysis. The platform will become more central to the organisation and it will allow for opportunities for optimalisation. This will change the way of work.

IDS is also much more broader. When you look at IDS as many-to-many you'll get a much broader vision of which to operate in as an organisation. That will ask new competences from employees. The percentage of employees that will come in contact with ICT will grow or more will be asked of them.

Strategy and leadership
Strategy and leadership can be a barrier. That's also the case with customers and partners.

Strategy and leadership is about the strategic vision of customers but also the strategic vision of your own company. It can require a lot of investment and giving before something can be realised. That is quite demanding, for leadership as well. This is in the sense of being able to overcome the uncertainties about gains and the distribution of gains. This requires starting from an own long term vision of possibilities. That is a barrier, if not a challenge, regarding strategic insight and customers.

A company can start looking into IDS and similar initiatives from a position of being a customer, being forced by outside influence to keep up. Forces in the logistics domain forces organisation into connecting to platforms. Which can be IDS.

But also without strategy and leadership one can take part in such a platform without strategy and leadership. This however does not fit IDS as it is much more about collaboration. IDS is an environment in which companies are involved as they see value in sharing data, improving common results. IDS is not about sharing data because another organisation requires it from you.

Being a 'partner' instead of a 'customer' in the IDS Ecosystem thus results in a higher required strategy and leadership maturity level.

Are there any other dimensions which could be of importance to this study?
One of the main subjects of IDS is how to collaborate. What are the common agreements to be made. For instance, what if one company frustrates the collaboration, what are the consequences and how is it handled? A dimension concerning the agreements between companies is thus missing.

12.7.3 Interview 3

Interviewer: Ewout Gort Date: 10-02-2021

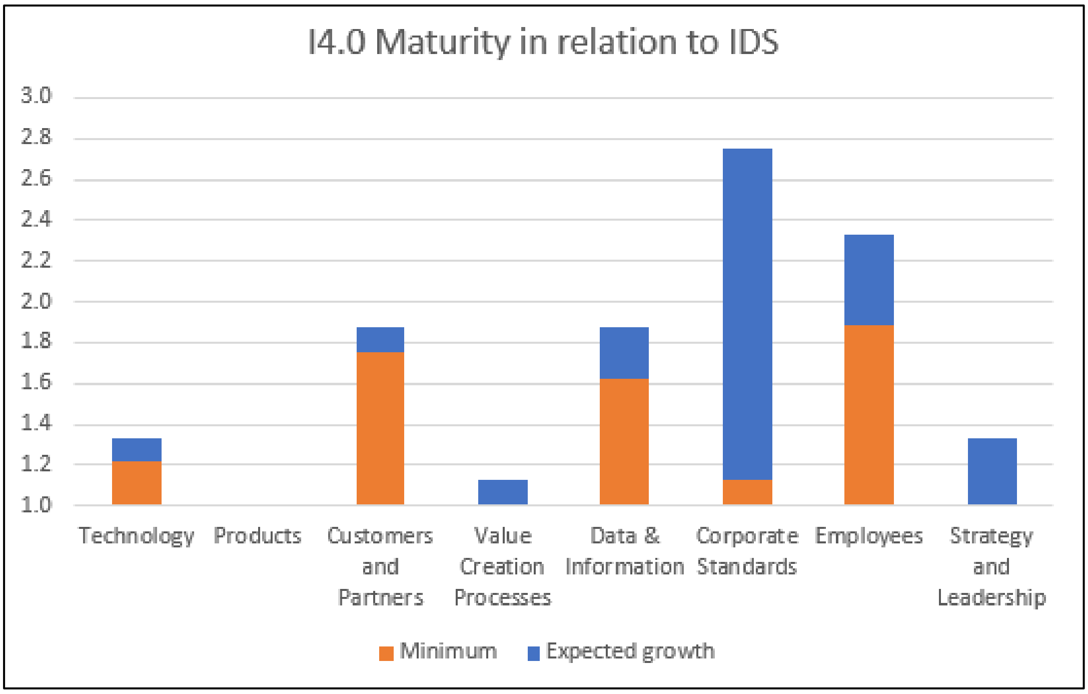

Figure 24 – Questionnaire results respondend 3

Technology
IDS and I4.0 come together in the data exchange aspect.

If, you as a company, are not mature in data exchange then it will be hard to start exchanging data with other parties. So you need some minimum maturity. Just applying IDS while you are not mature in data exchange will not make you more mature.

IDS is mainly about data exchange between external parties. You can try applying IDS within your own company borders but it is not clear what value this will provide.

Growth can be seen in the decentral information storage item. This is because the very fact of starting exchanging data externally will make it more mature. But you could also apply IDS internally to distribute data. It is not necessary but I do expect it to.

The Technology dimension contains a lot of items that do not relate to IDS, for example the 'Utilization of robots item'. You don't need to be using robots in order to apply IDS.

Products
Products scored very low as was expected. These items are all not required for applying IDS. You can very successfully apply IDS in your organisation without offering any smart products.

It can depend on the use case for which IDS is implemented.

Customers and Partners
The fact that you are thinking of adopting IDS already indicates towards your openness to new technologies. You have to be capable to apply IT. Also some maturity is required for company partner's degree of digitalization, because it is hard to start collaboration otherwise.

The other items in this dimension are mostly customers related. IDS is not really meant to be applied in B2C context. If that is the intention of an use case, then an higher maturity regarding these aspects should be required.

Would you fill in the questionnaire the same if you would also allow for B2B 'Customers'?

The questionnaire was probably answered with the 'consumers' interpretation of the term 'customers' in mind. If the questionnaire is answered with B2B 'Customers' in mind then answers would more like the final item: maturity level 2. For example item three, digitalization of customer contact would score higher.

Item 4, customer integration in product developments would not be affected, as again, it relates to the products offered which is not related to IDS. As well as item 6, IT-collaboration for product development. These items can be of course be required to have reached a minimum maturity, but then these items should be part of a specific use case.

It is mainly dependent on which data is to be shared.

Regarding growth:

When IDS, which is a nice way of sharing data, is implemented in an organisation and the organisation announces this to its partnering organisation then collaboration is improved and these partners will grow improve their processes. Mainly when a big company forces other companies to use IDS.

Applying IDS, in itself, will contribute to growth. Knowing and investigating the concepts of IDS will maybe improve the processes. Even maybe without fully implementing IDS.

Value Creation Processes
The low minimum required maturity items are all related to 'hardware'. This hardware does not need to related to Internet of Things or other similar I4.0 technologies to apply IDS. If the goal of the IDS use case is to share data coming from you machines then of course it is important for your machines to be capable of sharing this information. However, without this information IDS might very well be suited for your organisations.

The first item, value creation process automation will grow as a result from being able to share data, if only you are capable of using the data. Preferred by partners which also use IDS and share data with you. This will increase opportunities for more value. Improving the whole chain instead just locally.

IDS in itself will not add value. Value is in the use of data. IDS is an enabler in this.

Data & Information
This dimension is most closely related to IDS. IDS will be impossible in an organisation which is not mature in regards to digitalisation of its data. Otherwise data sharing is enabled while you there is not any data to share.

Item three, analysis of collected data is expected to show some growth. In IDS it is important to govern your data from the perspective of use. This perspective is currently applied too little and IDS forces you to. You'll automatically analyse data better and when new data is generated you'll have to decide how it will be made available externally.

IDS mainly forces you to think about all the aspects which are part of its data use policies. Who can do what with which data. This way thinking is often not applied when data is only kept for internal use while it often results in new insights. For instance, why is a company willing to share a piece of data with one company and not with the other. Could this say anything about the importance of this specific piece of data?

Automated information provisioning is expected to grow as this is what IDS does. Also, a company is expected to invest in automation of sharing and obtaining data when IDS is implemented.

Individualisation of provided information is also expected to grow. This is related to the fact IDS forces you to think about data usage management, which will also be the level of individual parties.

It is not required to be mature regarding automated information provisioning or individualisation of provided information. This because it is very well possible to start using IDS by sharing a certain set of data without extensive usage control.

Corporate standards
Some maturity is required regarding technological standards as it is important to be capable to determine what data is in your possession. Even when you've setup your own custom structure and architecture you will show some maturity regarding this item, as even a standard developed by yourself is a standard.

For many things it is important to have established semantics of data. Otherwise it cannot be interpreted.

No maturity is required regarding Items 1 and 3, monitoring of I4.0 realization and recruitment for I4.0. These items are not related to IDS and data sharing.

Growth is expected in the other items as IDS forces you to better think about your data. You are forced to better capture your processes regarding these items. The legal aspect for instance. Because you are thinking about the legal aspect your security will improve. Up until regulations are developed regarding what data can be shared by which employees, or what aspects they should at least consider before sharing data.

Employees
This is closely related to the corporate standards dimension and the answer provided. Employees are forced to be more aware about sharing data. Non-IT employees should be able to make the decision of sharing data as it should not be the decision of IT department.

This argument is also related to Autonomy of shop floor workers. IDS can improve maturity regarding this item, but cannot be expected to do so.

Other items such as experience with interdisciplinary work and willingness for continuous training are not related to IDS and data sharing. When an employee is not willing to train access can be denied. Also training doesn't have to be continuous.

Growth in maturity is mainly expected for item 3 and 4, awareness of non-IT-employees for data and awareness of non-IT-employees for cyber security. This because employees are introduced with IDS and will thus be faced with new concerns and thinking.

Strategy and leadership
No maturity is required regarding strategy and leadership.

Growth is only expected in item 2 and 4, central coordination of I4.0 activities and communication of I4.0 activities. This because IDS is focussed externally, so external communication will be required.

It is required for someone to propose the idea of implementing IDS and pull the organisation. However this doesn't require leadership. Someone just has to state that it will be done. When a company does not have strategy and leadership already it will already be facing troubles. IDS does not require any special leadership.

The individual items are mostly not strictly required for IDS to be implemented. Most would be helpful but are not required. For instance a roadmap, central coordination, financial resources and risk assessments. A company involved in these activities will probably be a better performing company, but it is not required.

IDS implementation is expected to start at smaller divisions of an organisation before it is made part of the whole company.

Communication is required after implementation so that will induce growth. But does not require maturity before implementing IDS.

It is expected that a company that is starting IDS adoption is thinking about the data to be shared, from this perspective strategy and leadership might be rated higher than the results of the questionnaire indicate.

Central coordination can be required to be mature in the case that a company is aiming to adopt IDS centrally. But as stated, I expect IDS adoption to start at a lower level in the company. Starting IDS adoption at an high level of the organisation, centrally, will probably result in internal resistance.

It is hard to relate to employee objectives.

You can be very mature regarding strategy and leadership but if employees are not capable of implementing IDS the use case will not be successful. While when employees are capable with IT then they will probably themselves push for and implement IDS adoption.

Are there any other dimensions which could be of importance to this study?
I don’t think so, mainly because your questionnaire and interview were founded on an academic model.

I think mainly the IDS concepts are interesting, the requirements on which IDS is based. Also without the full implementation of for instance the connector and broker IDS can be valuable.

You could also investigate what IDS requirements are related to what specific I4.0 aspects.

12.7.4 Interview 4

Interviewer: Ewout Gort   Date: 26-02-2021

<questionnaire was not available at time of interview>

Technology
It depends. The main question is: what does a company need IDS for? IDS is just a technology just like XML, in this case for data sharing. A company should this not just invest in IDS.

When discussing an use case a conversation is started as to ascertain what data is shared, with whom and how many. In this case IDS can be used as the technology to set up this connection. For instance in the Supply chain, such as in the Dutch Smart Connected Supplier Network (SCSN).

In a company which is mainly only involved in items such as h, i, and e, IDS is not really of added value. But IDS becomes more important to be considered as soon as you enter a stage involving more fundamental thinking about for instance items a and b, and possibly d. So when a more structural choices have to be made concerning these items.

Most manufacturing company are not used to thinking about their factory as one big ICT system, disregarding big companies. This way of thinking is already more adopted by other domains such as banking, insurance, government. They think more about their current enterprise architecture, whether they require a service bus, gateway or connector to enable digital collaboration with a supplier. So this way of thinking is more common in administratively focussed companies.

Only when adoption of IT is past the first stages of IT integration then the more structural questions are asked. So when the company has overcome it first challenges in small and first use cases and further scaling is required to not only connect so several individual parties but instead also connect to multiples of other companies. Only then the questions regarding a, b, d are asked.

There are two considerations regarding IDS adoption by a company that already has data sharing solutions in place. First, just connect to IDS. The company will retreive IDS specifictions and then select a software supplier to implement the system. And that's it.

The second is when more connections are expected in the future also. In this case a more fundamental approach is required and the business case for IDS will increase.

Such a fundamental approach requires, for now, more effort. But will provide advantages to a company especially when a connection is made to a group of company versus the traditional single company by using traditional approaches. No value, or even less value, is achieved by using IDS in setting up the first few connections in comparison to traditional approaches. However after IDS offers many benefits compared to traditional technologies. One of which is that making additional connections using IDS is much more easy as it does not requires a company to connect to the ecosystem only once after which data can be shared with all other ecosystem members.

Big companies are well suited to adopt IDS as it can be a better alternative to traditional technologies. However this is not the case for the long tail, consisting mostly of SMEs. When these are also connected using IDS new opportunities become available.

Growth is expected in the sense that after IDS adoption new opportunities become available for the data to be used for. For instance regarding sensing, artificial intelligence, preventative maintenance etc. In other words: growth is expected after IDS adoption as it acts as an enabler.

Products
The product that is produced does not really matter in contrast to the production facility and environment. This is often the case in manufacturing: products can be uncomplicated while the manufacturing is very complex, this in order to reduce costs and increase quality of manufacturing these uncomplicated products.

Small companies often do not even have systems like ERP or planning software or any smart tools or machines. In these cases supply chain digitalisation requires additional solutions such as the creation of an easy to use app.

Therefore, some knowledge or maturity regarding technology is required to enable supply chain digitalisation. It is for instance required to have some data which to be shared. This can change for instance when a company decided to start using these technologies to make sales in contrast to relying on physical sales traditionally.

Product do not necessarily become more smart when IDS is adopted, it could but this is not required. However the current manufacturing philosophy is that the Dutch manufacturing should be capable of manufacturing low volumes, unique products (n=1) competitively to China's bulk volume production cost.

This requires easy reconfiguration of production lines to adapt quickly and competitively adapt to changing customers needs.

In summary, it is not required for your product to be smart but your production facility does have to me. This in order to enable customisation, low cost and high quality.

Germany has a higher focus on robots and also more volume production. The Netherland only has some really big production facilities related to food production as these are hard to move.

Many projects start by asking for a robot, however this is most often not the solution. As the robots needs to be programmed. When this has to be done often, such as in low volume production then the added value of the robot in terms of labour cost saved is diminished.

More in place would then be to have a system supervision labour. This to reduce faults or to reduce the amount of expertise required to do a job, this can help in labour shortages. Several forms of this are possible, for instance by using a robotic arm to support the worker, a camera and or some form of projections.

Customers and Partners
Some things have to be in place. For instance agreements regarding sales and delivery processes, product codes to be used, capabilities expected to be present, use of standards.

In addition the customers has to be open for new technologies.

Growth is expected generally. For instance by enabling new opportunities note possible or viable before.

Value Creation Processes
Yes, some maturity should be present regarding most items. Some items are not required such as items h.

Companies should put effort in two things namely some form of control of the business processes and thinking about the value of the data present in the organisation and machines. Big companies often have an ERP, but small companies should at least have some sort of planning and sales or purchasing systems.

This is the basis to do many other things such as quality control and automated object handling, and so forth. Many opportunities require access to data and data in your machines.

Data & Information
It is not necessary to be doing most of these things already. These items are mainly related to the collection and analysis of data. You need to be doing some things, such as items a and b, you should be collecting some data in some structured manner.

Items such as d and h are not required before starting IDS adoption.

And anyway, IDS is usually part of a bigger product of package. So either you are thinking more strategic about data sharing and thus adopt IDS or it is part of another system you bought.

Corporate standards
I expect growth mostly related to item b, and more specifically ‘semantic standards’. This because IDS makes it more easy to share data in a controlled manner, but to be able to use it also the semantics of the data should be understood. This aspect has previously been neglected.

Employees
This dimensions is really required to be taken care of. Simply because most companies are really not yet aware of IDS and integration subjects. Most do not have an IT department. These companies do need to think more structurally about this.

Every company needs to be a bit mature. It is similar to HRM and accounting. Nobody wants to do it but it is necessary. It is a sanity aspect.

It depends on the role of the company whether growth is expected. It is not expected if you do it once. Some companies are however developing more new use cases after IDS adoption and these do require growth in maturity. For instance by hiring an IT-employee instead of outsourcings all IT related affairs.

For software suppliers IDS can be an interesting technology to increase the market. When developing a proprietary solution it is much more easy to place it in companies.

Strategy and leadership
This depends. My personal vision is this companies should only focus on those aspects that provide potential benefit for your company. One of these aspects is data sharing which has many potential benefits.

As for leadership it is required to think before doing to prevent accidents and mistakes such as accidentally sharing data with the wrong parties. This might be considered part of item f.

It is important to assess the business case. In addition it is important to do it right, so make sure you hire of have the right knowledge and competences.

Are there any other dimensions which could be of importance to this study?
The distinction between the product, the concept and the end-users application in which IDS is included in. In all cases it should be interesting for the company to know about the technology which is used.

In addition: this questionnaire and interview are based on the perspective of a single company. In most cases these changes are developed by a whole community, a group of companies which can be one big company with a lot of smaller suppliers and customers or a sector.

12.7.5 Interview 5

Interviewer: Ewout Gort Date: 26-02-2021

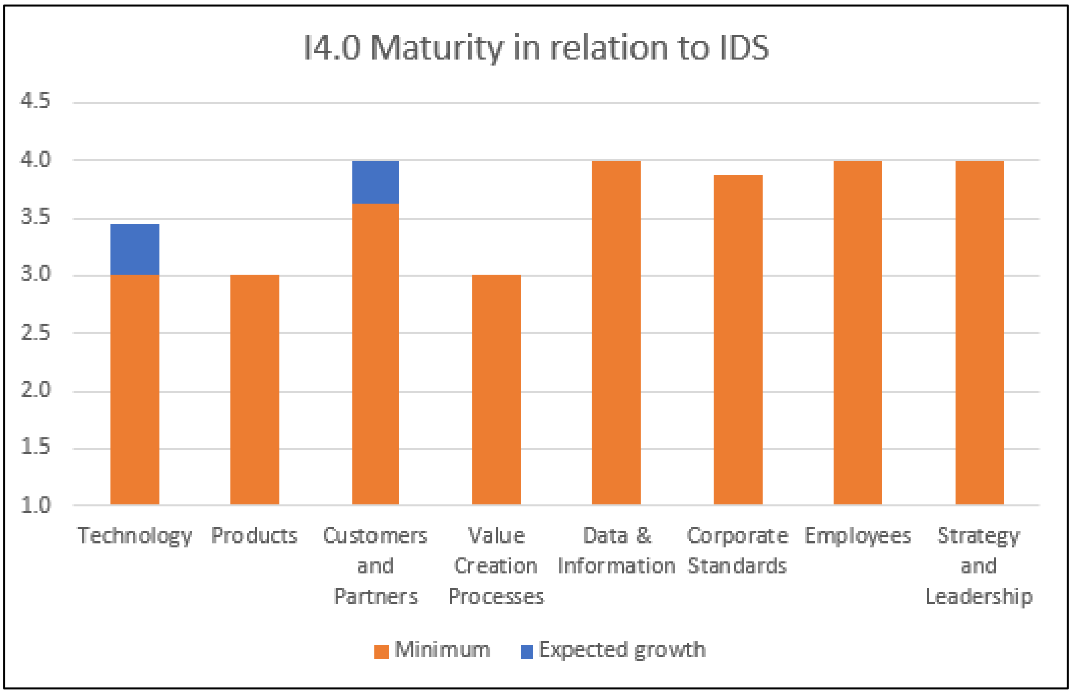

Figure 25 – Questionnaire results respondend 5

Technology
High maturity is required, for now. IDS is still in a phase in which it can be quite complex and it has a steep learning curve. Mainly when one is involved with the development of the IDS Connectors. Customers are however less involved with this and thus require less learning, especially when the customer already knows technical aspects such as cloud, Kubernetes and deployment strategies.

The IDS Connector is very technical. Certain companies will however not be faced with the internal workings of the IDS Connector, they will just provide some swagger API which to connect to. Our IDS Connector will load in the required standards and can then be easily configured to connect.

Products
Adoption of IDS and Industry 4.0 creates a digital or smart factory which offers opportunities. However these opportunities need to be cashed in which requires knowledge of technologies and such. So change is expected in the future.

When only looking at IDS, IDS enabled you to be live with new products much more quickly. You have more control over the products you send out and the data associated with them. So growth is expected.

Customers and Partners
Your customers and partners also need be grow. You need two-to-tango.

Items a, b, c, d are considered more important. E is an outcome of having adopted IDS.

The data governance act has recently been published by the European Union which is legislation regarding public data and government institutions. Change is happening in Europe in regards to how we should handle our data, mostly to combat Chinese and American dangers.

TNO is also one of the founding fathers of GAIA-X, in which IDS is probably going to fill in the sovereign data sharing aspect.

Also the Smart Connected Supplier Network (SCSN) is of interest to your research.

Value Creation Processes
This is not the purpose of IDS. IDS will help but IDS will not be the silver bullet. More things are needed such as the rest of Industry 4.0, which IDS only a part of. IDS adoption as is will for instance not result in an autonomous machine park. The term 'enabler' would fit here.

Data & Information
IDS will also be an enabler regarding data and information. But also initiatives like FAIR which defines proper structuring and use of standards related to data. Applying FAIR in conjunction with IDS will result in a win-win. Some overlap exists between these two, but FAIR helps organisations in establishing proper data management.

Growth is expected and a company start IDS adoption without being mature in this. When you just want to use IDS then you can start even without begin mature in this regards. However IDS will not fix all problems so a company will need to develop this in addition to adoption of IDS.

Corporate standards
Maturity in resulting from the questionnaire is a bit high as growth is expected during IDS adoption. This because, amongst others, it is expected that employees will become more aware of the dangers of data sharing.

IDS is not the solution as is and will require additional effort of a company to become more mature. Monitoring of Industry 4.0 for instance will help but is also not the only factors having influence. IDS contains a lot of technical standards and IDS enforces these but that will does not mean everything.

Cyber security is of importance also.

Employees
It is not directly required to hire new people when adopting IDS but you see big differences between companies. Some companies are already working in the cloud and have hired specialised people to work with these technologies. Others are still very manual and use only little technology. I would discourage these kind of companies to start IDS adoption in the current state of IDS.

When a company is not very mature regarding use of data and does not have a clear strategy than it will become hard to adopt IDS.

Items g and h are of less importance.

Strategy and leadership
IDS can contribute to this. Adoption IDS enables many opportunities for you as a company.

It is not required but it helps to be aware of these opportunities before starting IDS adoption. When you are one the first adopters of IDS you'll be faced with more challenges but IDS can also offer a lot.

Growth is expected.

Are there any other dimensions which could be of importance to this study?
It is possible that government bodies will enforce use of IDS in the future. The European Union has a data and AI strategy in which the IDS concepts are incorporated. The beforementioned data governance act is a result of this.