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Intelligent ERP:

The general concept and a system assessment

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Master Thesis presented as partial requirement for obtaining
the Master's degree in Information Management

NOVA Information Management School
Instituto Superior de Estatística e Gestão de Informação

Universidade Nova de Lisboa

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INTELLIGENT ERP:
THE GENERAL CONCEPT AND A SYSTEM ASSESSMENT

by

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Master Thesis presented as a partial requirement of the degree of Master of Information Management,
with a specialization in Information Systems and Technologies Management

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ABSTRACT

Enterprise Resource Planning (ERP) systems have been developing gradually. A recent development are intelligent ERP systems (i-ERP). The interest in companies is increasing, whilst the offer is low and the path towards a more intelligent ERP is unclear. The problem is that there is no clear concept in academic research. This qualitative study uses Design Science Research Methodology to answer the questions of what an i-ERP is, how it could look like and how to differentiate, assess, and advance system development towards i-ERP.

It became clear that i-ERP can be explained with four dimensions (Prerequisite, Data, Process, and User Experience) achieved through the application of intelligent (Artificial Intelligence, Machine Learning, Robotic Process Automation, Data Analytics) and prerequisite technology concepts (Cloud Computing, Big Data, Internet of the Things). A concept of i-ERP could be built, indicating the main features, goals, and role of technologies and the components of i-ERP and their relations could be visualized in a model. To show a possible development path, development steps from traditional towards intelligent ERP were proposed. Taking these as a fundament, a system assessment, and targeted recommendations to advance towards an i-ERP could be created.

The proposals were validated through interviews with experts. The usability was demonstrated with a fictional example. Academic value is added by providing a fundamental, conceptual understanding of i-ERP and a path to reach it, opening new research opportunities with and around i-ERP. Practical value is added for system users to comprehend i-ERP and make decisions about use or benefits and for system providers to see what system developments should be considered to staying competitive.

KEYWORDS

ERP, i-ERP, intelligent ERP, Artificial Intelligence, RPA, Machine Learning, Data Analytics

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LIST OF ABBREVIATIONS AND ACRONYMS

| | | |
|---------------|---|--|
| AI | – | Artificial Intelligence |
| BD | – | Big Data |
| CRM | – | Customer Relationship Management |
| DA | – | Data Analytics |
| DL | – | Deep Learning |
| DSR | – | Design Science Research |
| ERP | – | Enterprise Resource Planning System |
| e.g. | – | exempli gratia (for example) |
| et al. | – | et alii (and others) |
| i-ERP | – | Intelligent Enterprise Resource Planning |
| i-RPA | – | intelligent Robotic Process Automation |
| IS | – | Information System |
| KPI | – | Key Performance Indicator |
| ML | – | Machine Learning |
| NN | – | Neural Network |
| n.p. | – | no page |
| RPA | – | Robotic Process Automation |
| SCM | – | Supply Chain Management |
| SME | – | Small and medium-sized enterprise |
| UX | – | User Experience |

1. INTRODUCTION

The background of this thesis is presented, which leads to the formulation of the problem and, subsequently, the presentation of the research questions and objectives. The study's relevance and target groups are outlined, and the structure of the work is introduced.

1.1. BACKGROUND

In today's dynamic world, many technological and societal transformations are impacting businesses. Trends include automation, a deluge of data, and intelligent technologies exploiting data enabling learning from and reaction to environments (Cohen, 2017). Organizations use Information Systems (IS) to cope with valuable information. Access to right information in the right time enables organizations to compete and sustain (Camarinha-Matos et al., 2017). Enterprises must be able to sense their environment, act smart based on the data gathered, to make faster and better decisions, enhancing competitiveness and sustainability. The system used in many organizations to integrate business processes, applications, and data from various departments and sources are Enterprise Resource Planning systems (ERP) (William & Tjhin, 2021).

In today's organizations, ERP systems are no longer only back-office transactional systems but core engines, generating and using a high amount of data (Accenture, 2020a; Elragal, 2014). ERP systems are fully integrated and backbone for digital transformation. Recent market research shows that the ERP market was valued 39.340 million USD in 2019, and is expected to reach more than double, 86.303 million USD, by 2027, showing a huge potential (Gaikwad & Rachita, 2021). ERP software is offered by ERP vendors. The dominators in the market are SAP, Oracle, and Microsoft, but there are many niche players offering systems specialized on industries or organization sizes (Bahssas et al., 2015). In 2017, the world ERP sales market share of SAP (22.5%) and Oracle (12.2%) together was more than one third. Sage (6.1%), Workway (5.8%), and Infor (5.1%) had small shares, but 51% of the market was occupied by other vendors. This shows a dominance of the large players but a diversity in the market (Statista, 2017).

Technical and organizational opportunities led to an evolutionary development of ERPs. It started in the 1960ies as a simple inventory management system, now it is a digital supporting system for almost all organization processes (Goldston, 2020; Jacobs & Weston, 2007). There will continue to be developments and new opportunities with strong impacts on ERPs of the future. The implementation of such developments is an ongoing task and poses challenges to ERP providers and users (Brodzik et al., 2020). One of these developments is the increasing use of new technologies. Terms like Artificial Intelligence (AI), automation, Machine Learning (ML), Big Data Analytics, are omnipresent in business discussions about digital transformation and regarding ERPs.

One of the biggest trends in business, according to several consulting firms, is the use of AI and associated technologies (e.g. Accenture, 2020b; Brodzik et al., 2020). Huge developments in use cases have been made and are expected for the upcoming years (Bughin et al., 2017). However, a survey in German organizations showed that in 2019 only 4% actively used AI and related technologies, although over 50% classify affine. This means there is still a huge potential (PricewaterhouseCoopers, 2019).

1.2. MOTIVATION AND PROBLEM IDENTIFICATION

New ERP requirements evolve as result of digitization, the change of existing and new products and services, and problems with current systems (Bender et al., 2021). Deloitte (2018) discovered that enterprise software, such as ERP systems, is seen as easiest and most popular path towards more intelligence in organizations. The 2020 Gartner Hype Cycle for ERP (Torii & Nguyen, 2020) categorizes ML on the rise and Embedded AI at the peak of the cycle, confirming their relevance for ERP.

ERP systems incorporating AI and related technologies are called intelligent ERP (i-ERP) and are seen as new backbone of digital transformation (Morris et al., 2016). They get smarter and support organizations in information recording and use, leading to better decisions and generation of innovation (Jenab et al., 2019). The ERP landscape will significantly change (Bingler et al., 2018; Gold, 2020). SAP released an ERP system introducing intelligent features, including ML and analytics, making a big step towards i-ERP. Oracle provides intelligent apps for ERP. The development of AI and related technologies, along with the evolutionary development of ERP systems, shows that i-ERP seems to be the next big step. The i-ERP is expected to replace or extend the traditional ERP motivating to find out more about this topic (Gold, 2020; Goundar et al., 2021; Morris et al., 2016).

A recent bibliographical study (Figure 1) conducted by Aktürk (2021) shows that scientific publications relating AI and ERP increased in recent years, with a peak between 2017 and 2019. The decrease in 2021 can be explained by the publication in early 2021 before many studies were released.

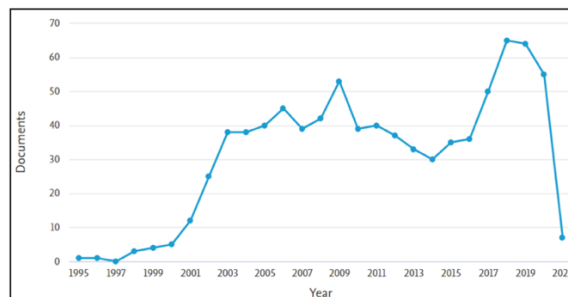


Figure 1 - Number of scientific studies of AI and ERP (Aktürk, 2021, p.73)

However, a closer look at the studies shows that most of them have a very specific and often technical approach and do not relate to the general concept of i-ERP. Consulting the literature about the specific topic of i-ERP one can conclude that the number of publications is very low. Most publications come from large consulting firms and international organizations, only very few from academics.

Although there are similarities in the concepts used in different studies about i-ERP, none of the studies found proposed a defined idea of i-ERP. It becomes obvious that the problem is that it is barely defined what an i-ERP is. There is no clear understanding of how an i-ERP looks and how it differentiates from other types of ERP. The availability of such systems is low, while the demand seems to increase (Bingler, 2020). A clear understanding if a common denominator is needed to do further studies using the emerging concept of i-ERPs. The identified research gap motivates for further research solving the problem defined and to shed more light on i-ERPs and its features in an academic study. The dominance of corporate research means that additional academic research on these this topic is needed. These gaps are the major motivating factors behind objectives and research questions of this thesis.

1.3. OBJECTIVES

The goal of the thesis is to conduct research towards i-ERP. The work has a high-level business perspective and concentrates on the understanding of functions and features. No technical feasibility or details should be examined. The work is conducted independently from any ERP vendor or specific product and has a high-level general approach.

The research should answer the following research questions:

RQ1: *What is an i-ERP and how is it composed?*

RQ2: *How does an i-ERP differentiate from stages of ERP development and how can it be achieved?*

An i-ERP concept and model should be created. The concept should show the main features and characteristics and role of different, selected technologies in a structured way. The model should visualise the features, components, and interrelationships of an i-ERP in general to understand how an i-ERP can be composed and how the functions are achieved. Subsequently, different development stages of an ERP towards an i-ERP should be examined). Building on this, a tool should be developed to classify an existing or planned system into those levels and to give targeted recommendations on how the system can be advanced towards an i-ERP. This results in the following sub-objectives:

- i. Explain the concept, history, and development of ERP towards i-ERP
- ii. Show the state of the art of i-ERP
- iii. Identify research in subtopics of intelligent technologies that could comprise an i-ERP
- iv. Propose a concept of an i-ERP based on the literature review
- v. Propose a model of an i-ERP based on the literature review and the i-ERP concept
- vi. Propose a taxonomy of an i-ERP based on the literature review and the i-ERP concept
- vii. Propose a tool to categorize an ERP system into the taxonomy and give recommendations on how to grow towards an i-ERP based on the assessment
- viii. Validate and evaluate the artifacts

The data gathered in the evaluation step should be used in the final discussion to describe the validity of the artifacts and to derive recommendations for future research, for example a new research iteration. The future research is mentioned as an objective as this is a new and emerging topic and a foundation for future research is very important.

1.4. STUDY RELEVANCE, IMPORTANCE, AND TARGET GROUP

It is important to clearly communicate the use of the work to the right target group(s) and to explain the value (Hevner et al., 2004). The problem was described as a lack of scientific concept, model, or definition of i-ERP. This study aims to add to ERP research, having theoretical and practical implications.

Scientific Researchers in Information Systems and Management: This study starts with presenting the state of the art of ERP, i-ERP, and i-ERP technologies as well as their relation. AI technologies have just recently begun to emerge in ERP, posing new opportunities and the need for further development of ERPs, but missing a scientific fundament (Brodzik et al., 2020; Goundar et al., 2021). The contribution of the proposed study in research is that it frames and delimits i-ERP. The proposed artifacts can help to conduct future research based on a common fundament.

Teaching in ERP and intelligent Technologies: Related to the research implications parts of this study can also be used in teaching. Especially In higher education, ERP systems are included in study programs (Hepner & Dickson, 2013). With this study it is possible to give students an outlook in how a future ERP could look like. In addition, this study gives an opportunity for practical use cases of AI.

Enterprises: CIOs, IT Managers, ERP Consultants, and Manufacturers: There is a large interest towards more intelligent ERPs in practice. In 2020 9% (4% in 2019) of participants of the Accenture ERP study stated that intelligence related technologies are already core part of their ERP, 32% are actively working on it, and 44% are interested (Accenture, 2019, 2020a). On contrary, according to Gold (2020) the offer of such features is low. The proposed study can help managers, e.g., CIOs, IT Managers to understand what features an i-ERP can have and how it could support their organization. The i-ERP assessment can help to categorize the intelligence level of a current or planned system and gives insights in how to evolve further towards an i-ERP. This knowledge can support selection of a system and benefits for improving the existent ERP or implementing a new one. It can support ERP consultants to help organizations defining the future ERP, whilst it can help ERP vendors to understand which areas, they can explore to build and i-ERP and what functions it should have, to stay competitive on the market.

Table 1 is a summary of the relevance of this work in science, practice, and teaching.

| Discipline | Relevance of the work presented |
|---|---|
| <p style="text-align: center;">Science <i>(IS, Management)</i></p> | <ul style="list-style-type: none"> • State of the art of ERP, i-ERP, and i-ERP technologies • Concept: Structure of i-ERP functions and characteristics • Model: Visualization of components and interrelationships • Taxonomy: Delimit i-ERP from ERP development stages • Assessment: Classification and recommendation • Open and propose future i-ERP research opportunities • Present use case of “intelligent” technologies in organizations |
| <p style="text-align: center;">Teaching <i>(Teachers, Students)</i></p> | <ul style="list-style-type: none"> • Outlook how a future ERP could look like • Present use case of AI and other “intelligent” technologies |
| <p style="text-align: center;">Practice <i>(Users, Providers, Consultants)</i></p> | <ul style="list-style-type: none"> • Understand functions and use cases of i-ERP • Assessment and Taxonomy: Tool for the system evaluation and derivation of recommendations based on levels • Present ideas for an organization in creation and use of i-ERP |

Table 1 - Summary: Relevance of the work presented

1.5. STRUCTURE OF THE WORK

- **Chapter 2:** The literature review is presented and includes the state of the art around ERP, i-ERP, and intelligent technologies.
- **Chapter 3:** Introduces Design Science Research as Methodology used and describes the artifacts as well as the research methods and process.
- **Chapter 4:** In this chapter the thesis artifacts (i-ERP Concept, i-ERP Model, i-ERP Taxonomy, and i-ERP Assessment) are presented, an example is shown, the results are validated, and discussed based on what was learned in literature work and the validation step.
- **Chapter 5:** In the final chapter conclusions of the work conducted are drawn, limitations of the study are explained, and an outlook on future research opportunities is given.

2. METHODOLOGY

The research methodology is the strategy, process, and techniques used to uncover new knowledge. It gives validity to the work and shows how the research was planned and developed (Cruz & Cruz, 2020).

In IS research one can differentiate two complementary research paradigms: Design science and behavioural science (March & Smith, 1995). Behavioural science focusses on development and verification of theories, the focus of design science is to extend organizational and human capabilities through the creation and evaluation of artifacts (Hevner et al., 2004; Hevner & Chatterjee, 2010).

The methodology that seems suitable for the objectives of the proposed work is (qualitative) Design Science Research (DSR) for IS. The goal is the creation of four artifacts that solve the defined research problem (section 1.2) of the lack in academic i-ERP studies and the loosely defined concept of i-ERP and expand and improve the current knowledge. In the DSR knowledge contribution framework this research adds value through improvement of the knowledge and the invention of new ideas around i-ERP (Gregor & Hevner, 2013). The proposed artifacts should help in practical problems and in the improvement of business performance (March & Smith, 1995; March & Storey, 2008).

2.1. DESIGN SCIENCE RESEARCH

The roots of DSR date back to Simon (1969, 1996) and his research about “The sciences of the artificial” and the creation of artifacts to solve new but identified problems. In recent years DSR became a well-accepted and used in IS (Gregor & Hevner, 2013; Peffers et al., 2018).

According to Hevner (2004) DSR is a problem-solving paradigm with the goal to create and evaluate new and innovative artifacts to extend capabilities. In DSR focus is put on the importance of the problem identified, the novelty of the artifact(s), and the utility of the artifact(s) (Hevner & Chatterjee, 2010). Creation and evaluation of artifacts are the two main activities of DSR (March & Smith, 1995).

Artifacts is everything that humans create to achieve a better situation for life (Simon, 1996). An artifact is transformable into a real or artificial object or a process (March & Smith, 1995). An artifact in DSR should solve a defined research problem (Hevner et al., 2004; March & Smith, 1995). In cases of this work, the goal is the creation of four artifacts to solve the research gap defined in section 1.2. One can differentiate four general types of artifacts: constructs, models, methods, and instantiations (March & Smith, 1995). In case of this work the artifacts can be categorized as follows:

- **i-ERP Concept:** It can be classified as a model, because it describes how the i-ERP concept (thing) is (March & Smith, 1995).
- **i-ERP Model:** It can be classified as a model, because it shows how the i-ERP (thing) could look (March & Smith, 1995).
- **i-ERP Taxonomy:** It can be classified as a model, because it shows how the i-ERP levels (thing) could look (March & Smith, 1995).
- **i-ERP Assessment:** It can be classified as a method, because it describes actions and steps on how to perform the assessment (task) (March & Smith, 1995).

The goal of DSR is to create an artifact with utility. It does not need to be complete or fully true. Often a subset or starting point is presented. The goal is a satisfactory outcome that might not be completely realistic but adds progress to the knowledge base. An artifact can be further refined in later DSR iterations (Hevner et al., 2004; Simon, 1996).

A defined process as mental model should be followed to conduct DSR. It makes the research comprehensible and verifiable. The most known approaches are from Peffers (2007a) and Hevner (2004). For this work the six steps by Peffers et al. (2007a) (Figure 2) were chosen as it is a generally accepted approach for implementation and presentation of DSR (Deng & Ji, 2018).

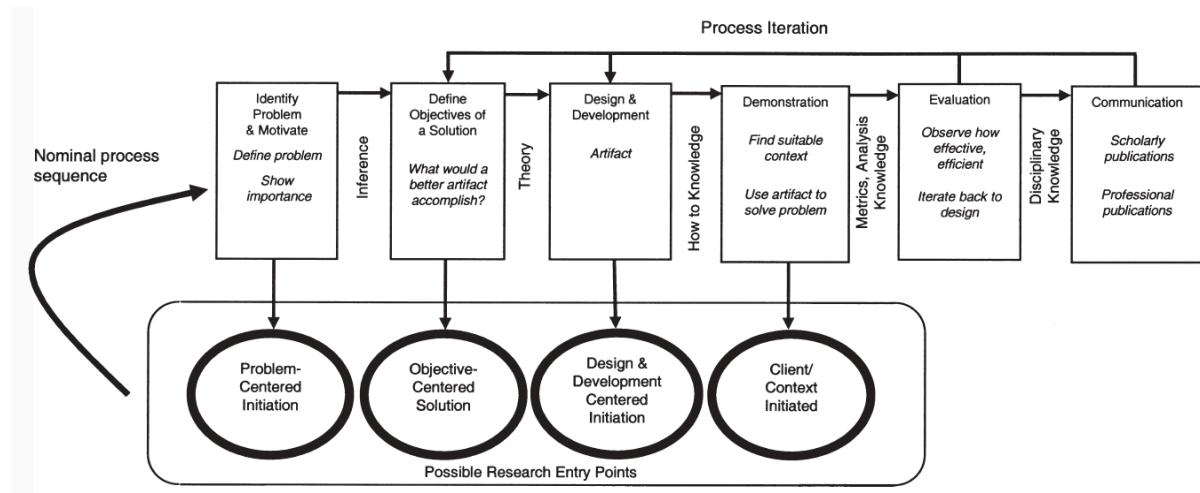


Figure 2 - Design Science Research process model (Peffers et al., 2007b, p. 54)

The six steps are explained and in the next chapter those steps are adopted to this work. The steps do not need to be in sequential order, but all steps should be conducted in the research process. Peffers (2007a) differentiates four possible research entry points to start and DSR iteration: defined problem, objective for a solution, design or development, and from a client or context.

1. Identify Problem and Motivate

The first phase entails defining the research problem and justifying the importance of the desired outcome. This step establishes the foundation for the investigation and the outcome. The significance of the situation must be demonstrated. A solid knowledge base of the subject is required. The problem for the study should be explained, framed, and the value demonstrated (Peffers et al., 2007a).

2. Define Objectives of a Solution

The second step generates possible objectives of a solution to improve the state of the art based on the previous step. Major requirements for the proposed artifact(s) are described and justified to ensure availability of all necessary information to proceed. The goals are derived from the problem identified. They can be qualitative and explain how the solution is supported (Peffers et al., 2007a).

3. Design Development

The third step is the development of the artifact(s). The artifact(s) are based on the data gathered in the first two steps from different knowledge bases and theory and aligned to the objectives (Peffers

et al., 2007a). The design process rigour is weighted lower as in other methodologies and it is not required to base the design on formal theory (Peffer et al., 2018).

4. Demonstration

This step aims to use the artifact(s) created to solve instances of a problem. This can be done with any kind of proof that the artifact(s) work to solve the problem described (Peffer et al., 2007a).

5. Evaluation

This step evaluates how the artifacts support the solution of the problem. The evaluation can be done with any appropriate empirical qualitative or quantitative method or type of logical proof (Hevner et al., 2004; Peffer et al., 2007a). The evaluation process does not only provide information on the artifact(s), but it also input for future enhancements (March & Smith, 1995; vom Brocke et al., 2020).

6. Communication

The knowledge gathered should be communicated to all relevant interest groups, with a focus the communication of utility, novelty, rigor, and effectiveness (Peffer et al., 2007a). A strict formal process is not needed (Peffer et al., 2018). This step is crucial to gather additional feedback about the artifact(s) (Hevner et al., 2004).

The last two steps can be the trigger for a new iteration of the DSR process according to the new insights, opinions, feedback etc. received (Cruz & Cruz, 2020; Peffer et al., 2007a). This information can serve as a recommendation for future work or lead to a new iteration (Peffer et al., 2007a).

DSR requires a scientific approach. In his widely accepted paper Hevner (2004) published a set of guidelines for DSR. Those guidelines should be applied in a DSR process for the best possible outcome and must be adopted to the individual research problem. Figure 3 summarizes the rules. In the next chapter the rules are adopted to this research.

| Table 1. Design-Science Research Guidelines | |
|---|---|
| Guideline | Description |
| Guideline 1: Design as an Artifact | Design-science research must produce a viable artifact in the form of a construct, a model, a method, or an instantiation. |
| Guideline 2: Problem Relevance | The objective of design-science research is to develop technology-based solutions to important and relevant business problems. |
| Guideline 3: Design Evaluation | The utility, quality, and efficacy of a design artifact must be rigorously demonstrated via well-executed evaluation methods. |
| Guideline 4: Research Contributions | Effective design-science research must provide clear and verifiable contributions in the areas of the design artifact, design foundations, and/or design methodologies. |
| Guideline 5: Research Rigor | Design-science research relies upon the application of rigorous methods in both the construction and evaluation of the design artifact. |
| Guideline 6: Design as a Search Process | The search for an effective artifact requires utilizing available means to reach desired ends while satisfying laws in the problem environment. |
| Guideline 7: Communication of Research | Design-science research must be presented effectively both to technology-oriented as well as management-oriented audiences. |

Figure 3 - DSR guidelines (Hevner et al., 2004, p. 84)

2.2. RESEARCH STRATEGY

In the previous chapter the DSR steps from Peffers (2007a) were presented. In figure 4 it is summarized how those steps are adopted to this work.

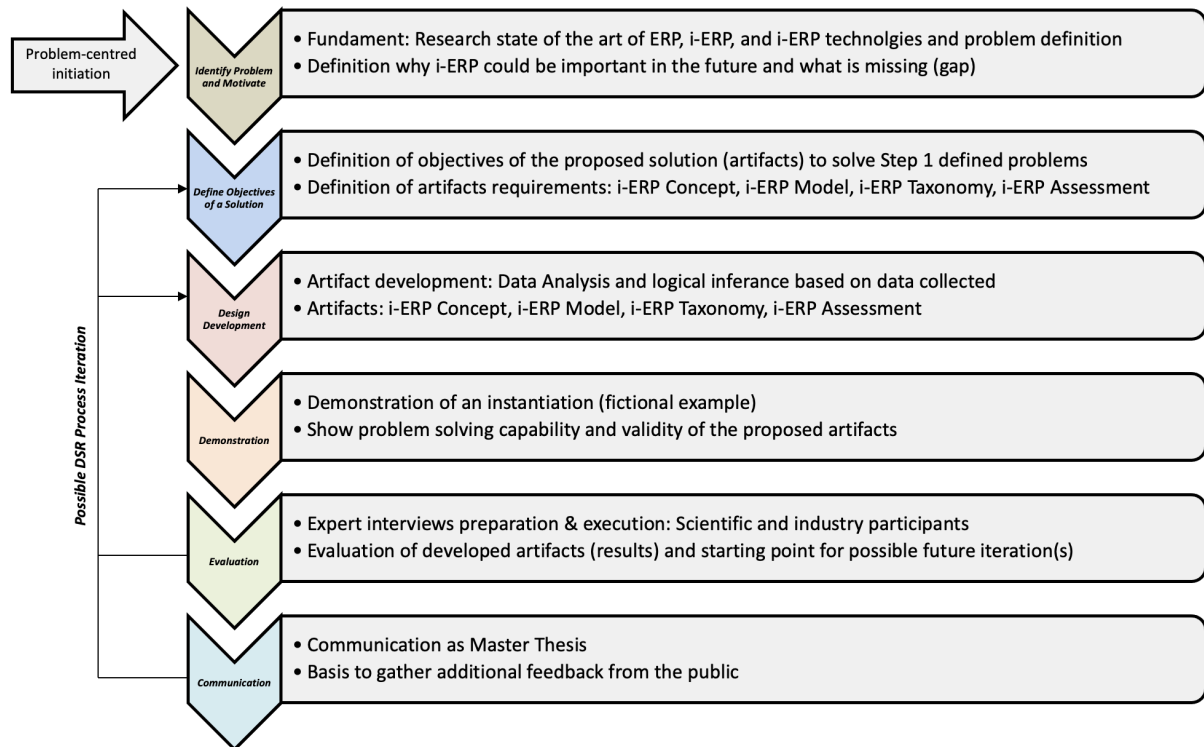


Figure 4 - DSR process of this thesis

The entry point in this research is based on a problem (Problem - Centred initiation), which was described in chapter 1.2 (Peffers et al., 2007a). The lack of a clear definition and delimitation of i-ERP and its features causes a lot of unclearness in this topic in science. The need of a more flexible, adoptable, and creative ERP solution in organizations to drive digital transformation triggers the development research around i-ERP.

1. Identify Problem and Motivate

The aim of this step is to present the starting point and problem definition of (i-)ERP systems in organizations in the context of new developments. In chapter 1.2, the theoretical and practical problem situation is presented, and a research need is derived. The main problem focus of this work is the lack of a clear academic concept of i-ERP as a gap in ERP literature and the aspiration of companies for more intelligent technologies in ERP to gain competitive advantage.

In chapter 3, the state of the art is discussed. This step builds the transition between Peffers step 1 and step 2. The topic around i-ERP is deeply investigated to understand the paradigms included as well as the current solutions, proposals, problems, and opportunities. The analysis of different documents is conducted (qualitative methods) (Gill et al., 2008). Documents are scientific literature (papers, scientific journals, conferences, etc.) and reliable papers of international consulting agencies, governmental, and non-governmental institutions. The topic is covered by research of non-academic

institutions adding a vital fundament and knowledge source in addition to traditional scientific literature.

The state of the art of the development of ERP, i-ERP and advanced technologies are researched and the problem for the study could be framed, explained, and the value shown.

2. Define Objectives of a Solution

The goals are derived from the problem definition and literature review. This knowledge base allows the derivation of the possible solution i-ERP. In this case the work aims qualitative artifacts (solutions) for this reason, as recommended by Cruz and Cruz (2020). The objective, sub-objectives, and research questions are clearly defined in chapter 1.3.

3. Design Development

The artifacts are based on the qualitative data gathered in the first two steps, aligned to the objectives, and extended by additional research in literature. The artifacts developed in the proposed work are:

- i-ERP Concept
- i-ERP Model
- i-ERP Taxonomy
- i-ERP Assessment

4. Demonstration

i-ERP Concept and i-ERP Model: In the scope of the proposed study, it is not possible to build an i-ERP for demonstration. For a demonstration a prototype in a real-world organization would be needed. This topic is in a too early stage and will need several DSR iterations. This study is conceptual, and the artifacts should serve as a starting point for future research.

i-ERP Taxonomy and i-ERP Assessment: A theoretical, fictional example is applied and described. It can be demonstrated that the proposed solution is valid and works.

5. Evaluation

The verification of the correctness of the findings is done by interviews with experts from the ERP/i-ERP area from science and practice. The goal is to give appropriate empirical evidence and logical proof for the artifacts' validity. Because of the flaws in the Demonstration stage, this step is crucial. The knowledge base and the with information gathered from the interviews is used to build informed arguments for utility and validity (Hevner et al., 2004).

6. Communication

This work serves as a starting point to the topic of i-ERP making the communication vital. New DSR iterations can follow based on information gathered from the feedback on the communication. The knowledge gathered in this research should be communicated especially to researchers and interested organizations in the areas of ERP and AI (Peffer et al., 2007a).

In the previous chapter the seven guidelines for DSR according to Hevner (2004) were introduced. They are applied to this research. In some points there are parallels to the above-described research process, therefore this section is kept short.

1. Design as an Artifact

This research aims to create four related artifacts: i-ERP Concept, i-ERP Model, i-ERP Taxonomy, i-ERP Assessment.

2. Problem Relevance

The relevance of the work is stated in chapter 1.2 (problem statement) and 1.4 (Study relevance and target group). The relevance can be justified from theory and from practice.

3. Design Evaluation

The design evaluation is presented in chapter 4.5. The evaluation is reached with the demonstration of a fictional example (Peppers step 4) and expert interviews (Peppers step 5), showing utility and validity of the artifacts developed.

4. Research Contributions

The contribution of this work are the artifacts. The artifacts are a starting point for future studies as not much research is available yet. In this topic many developments are expected in the next years.

5. Research Rigor

This requirement is by the structured literature review, demonstration, and expert interviews. The demonstration should be further improved in a larger, practical study through and with real life case studies to obtain better and more accurate data and insights.

6. Design as a Search process

A literature review on the current state of research is carried out. It describes existing models, constructs, methods, and theory which, however, is still very limited due to the novelty of the topic.

7. Communication of Research

Chapter 1.4 shows the scientific and practical addressees of this study. The communication is done as a master thesis at NOVA IMS, Lisbon, Portugal (available online).

3. LITERATURE REVIEW

This chapter presents a literature review as theoretical fundament for all (sub-) topics around i-ERP that are relevant for the work and for the creation of artifacts. This literature review serves as introduction and helps to understand the background. The importance of the research and the literature gap become clearer.

For all parts of this work, various scientific databases were used to obtain best insight into the topic, namely NOVA Discovery (EBSCOHOST), Scopus, Google Scholar, IEEE Xplore, Springer Link, and Research Gate.

The literature review is divided into in three parts which are linked logically (Figure 5) and show what an ERP is and how it has evolved towards i-ERP. Then the idea of i-ERP is deeply explained, and the technologies used as well as their possible roles can be learned. The contents of the respective parts and the strategy to find and analyse literature are explained below.

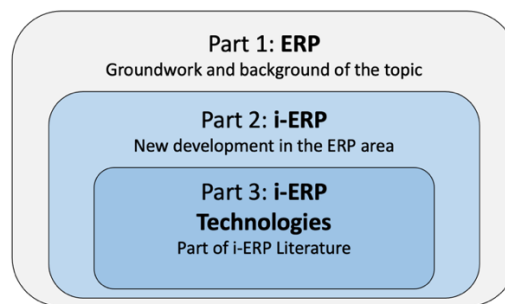


Figure 5 - Structure of the literature review and relation of sub-topics

ERP

It is clarified what ERPs are, what they are used for, and what benefits and challenges they have. It is shown that there are different types of ERP systems to derive similarities and differences. The chapter ends with an overview how ERPs evolved over time and what new trends are.

This part of the review serves as groundwork, to understand and categorize the topic and derive main ideas and concepts. To clarify the basic concepts, fundamental literature is searched and consulted, which is then supplemented with current studies and other publications. In this part, no particular method is used. The aim is to ensure that the topic is introduced in a simple and comprehensive way, based on highly cited works, to build the groundwork for the following.

i-ERP

A comprehensive insight into the topic of i-ERP is given based on a holistic literature review. The idea of i-ERP and main functions and use cases are presented. The technology concepts that could comprise an i-ERP are summarized, and the chapter ends with a collection of expected benefits and drawbacks.

This chapter represents the main topic of the work. A broad literature review is carried out to get a holistic insight into i-ERP. The integration of findings from different studies helps to address the research question from multiple perspectives. The review of literature helps to synthesize research

findings. It is an essential concept in the creation of new concepts or frameworks. Due to the explorative type of the study, this literature review is designed rather open, like an integrative review. This method is most suitable when creating something new in an emerging topic (Snyder, 2019). The goal of this thesis is the creation artifacts in the emerging topic of i-ERP, which makes this approach suitable. This research is structured in a way to have an extensive to get all relevant inputs to enable the best possible, creative creation of the artifacts which are mainly based on this review. The literature was iteratively revised during the work (September 2021 – January 2022) to incorporate any new relevant findings. The search and selection strategy are explained.

General Search Strings: The search strings used have the goal to holistically grasp the topic. To find i-ERP literature the following keywords were used in different combinations: i-ERP, AI-ERP, ERP 4.0, intelligent ERP (ERP is also replaced with the full expression “Enterprise Resource Planning System”).

Type of topic: The thesis has a qualitative approach. Qualitative and quantitative studies are consulted, but the focus is put on qualitative results as the suit best the outcomes of the thesis.

Viewpoint: The work has a business-oriented view with resulting in the exclusion of technical studies as they do not correspond to the aim of this work of a high-level business understanding.

Dates: The fundamentals of the study and to understand basic topics have no time limitation. However, care is taken to prioritise, recent studies from the last 5 years (2016+) to provide a modern perspective.

Types of Sources: As this is a scientific master thesis, priority is given to academic publications. However, it is very important to also use papers from large tech and consultancy companies, as this is a practice driven topic, and the number of publications is higher. The reliability of the source is always considered in the specific case and context and can lead to the exclusion of some works, for example if they are composed like marketing reports of vendors or consultancies.

i-ERP Technologies

The main i-ERP technology concepts are explained in a non-technical way and the (possible) use cases for i-ERP are shown with a short literature summary of related studies.

A general approach is taken to explain the technology concepts used. Like in the ERP chapter, basic concepts are clarified using fundamental literature, supplemented with current studies. In the second part of each sub-chapter the role of the respective technology concept in relation to (i-) ERP is shown. Therefore, ERP and i-ERP were combined with the respective technology concepts and searched in the above databases. The described delimitation criteria are considered.

3.1. ENTERPRISE RESOURCE PLANNING (ERP) SYSTEM

The number of studies in ERP is extensive. This makes a prioritization of the studies and authors essential. There are many traditional sources that have a high number of citations and were published around the 2000s, when ERPs first existed. These studies explain very well the basic concept of ERP. The sources mostly agree on the concepts and trends.

The composition of ERP systems is explained, and differences of ERP types are shown, and the benefits and drawbacks are presented. The chapter concludes with an overview over the evolution of ERP systems over time.

3.1.1. Concept of i-ERP

The ERP research community is diverse, comprehensive, multi-disciplinary, and inter-disciplinary (Moon, 2007). Nazemi et al. (2012) point out that one has to differentiate the concept and the system view on ERP. The concept behind ERP is the integration of business processes, to improve the workflow and information exchange. The ERP system on the other hand side describes the technical system supporting a company to realize the ERP concept. This work focusses on the system view. According to Akkermans et al. (2003) one can differentiate three perspectives, the functional (what can it do), technical (how does it do), and business perspective (outcome for the business). This work focusses on a combination of functional and business view. There are several approaches to define ERP and there is no agreed definition (Klaus et al., 2000).

- Davenport (1998) defines ERP system as a collection of software modules, helping enterprises in automation and integration of business functions. ERP is characterized by sharing an accessing information, data, and practices.
- ERPs are *“comprehensive, packaged software solutions [that] seek to integrate the complete range of a business's processes and functions in order to present a holistic view of the business from a single information and IT architecture”* (Klaus et al., 2000, p. 141).
- Al-Mashari (2003) describes ERP as a software used to integrate processes from different functional silos in a company.
- Laudon and Laudon (2019) define a system for the integration of business processes in a software system and of information in a centralized repository.

Studies show that ERP implementation is not only a technical change but an organizational change, affecting how people and the organization work and its strategy and culture (Davenport, 1998). ERP contains different modules running various business processes and activities, in and across different company functions (Bahssas et al., 2015; Davenport, 1998). The integration of the modules allows cross organizational information sharing and embedded, optimized business processes (Beric et al., 2018; Nazemi et al., 2012). The system can have interfaces cross geographical location and company borders (Abd Elmonem et al., 2016; Wortmann, 1998).

In their literature-based works, Rashid et al. (2002) and Bytniewski et al. (2020) define main characteristics and features of ERP. Main points are similar, although one of the works dates from the beginning of the ERP period and the other from the present. The main characteristics are:

- Modular design comprising multiple business functions and open for new modules
- Centralized, integrated database
- Integration and seamless information flow between modules
- Contain best business practices
- Process orientation and integration

3.1.2. ERP Composition and Types

ERP systems have different modules integrated by a central database. The modules can differ between organizations, aligned to the respective needs. Traditional ERP is a client server architecture, with the layers database, application, and presentation (Klaus et al., 2000). A widely cited model is the ERP anatomy shown in figure 6 (Davenport, 1998).

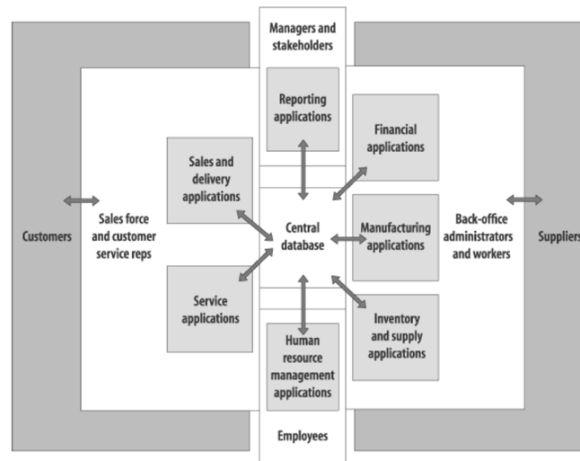


Figure 6 - Anatomy of an enterprise system (Davenport, 1998, p. 5)

The central database is connected to all ERP modules and information is shared between modules. The modules (applications) read and write data. An ERP system faces different stakeholders, such as customers (e.g., Sales and Service Modules), suppliers (e.g., Supply Modules), managers and other stakeholders (e.g., Reporting Modules), and employees (e.g., Human Resource Management Module) (Davenport, 1998).

The anatomy is a traditional view. Rashid (2002) states that ERP vendors offer different modules, but in the core modules are very similar. Modules can work on their own or can be integrated. The consultation of several authors shows that the following modules are mentioned to be core of modern ERP systems (Akyurt et al., 2020; Bradford, 2015; Laudon & Laudon, 2019; Rashid et al., 2002; Shehab et al., 2004; Zabukovšek et al., 2020).

Finance and Accounting: This module handles the in- and outflow of capital and companies' assets. It provides functions such as financial accounting, investment, controlling, and asset management.

Human Resources: This module includes financial functions such as payroll or travel expenses. Workforce Planning, employee scheduling, and training and development are also part of it. Employee information such as applicant data, or performance and attendance data can be managed. It helps in employee's management with skill matrices, job descriptions, and organizational charts.

Sales & Distribution: This module includes functions for order processing, quotations, pricing, promotions, or availability checks. In distribution this module includes transportation management and scheduling, dispatch of products or services, export controls, billing, and invoicing.

Materials Management: This module includes functions for purchasing and production, such as the management and planning of purchasing operations, inventory control and management, supplier

management, or reporting. Regarding production it has production planning, scheduling and execution, bill of materials management, and material requirement planning.

Project Management: This module supports in the controlling of projects phases. It includes quotations to design and approval, resource management, and cost settlement. It can encompass work breakdown planning and activity management.

Quality Management: This module ensures the quality in companies processes. It encompasses the management of supply chain quality, plant maintenance, and customer service.

The functions of Customer Relationship Management (CRM) and Supply Chain Management (SCM) are often described as separate IS (e.g., Laudon & Laudon, 2019). For this thesis and the opinion of other authors consulted (sources above) these are modules of ERP.

Customer Relationship Management: This module tracks and manages the customer relation. A single view of the customer is created through analysing centralized customer data.

Supply Chain Management: This module manages the flow of information, goods, and funds from the supplier, through the company, to the final customer.

ERP systems started as software in large industrial enterprises, the use in additional sectors and differently sized companies increased (Adam et al., 2011; Shehab et al., 2004). The ERP composition above is an understanding of ERP in its traditional role in manufacturing industry. Nowadays, ERP implementation happens in almost all types of organizations (Gronau, 2021). Already in early stages of ERP, Davenport (2000) argued that the name ERP system is no longer the right term, as it does support a variety business activities. Depending on the modules selected, different characteristics and requirements are targeted. Modules with industry specific functions are offered (Klaus et al., 2000). New actors in the ERP market offer specific solutions and traditional vendors expand their offer. SAP or Oracle for example offer solutions for specific industries, such as financial services, wholesale, or retail, public organizations, such as healthcare, education, and many other specializations (Botta-Genoulaz & Millet, 2006). ERP modules highly depend on the requirements of the respective organization. A simple example: An engineering provider (service company) has no production and logistics. This situation would be reflected in the ERP by not using the respective modules. It is possible that certain functions are not available in ERP but needed for a specific industry, so they are covered by a different system which is integrated via an interface. In general, one can distinguish functions that can completely, partially, or cannot be mapped in ERP (Gronau, 2021).

The variety of ERP modules and functions and the different focuses of the providers make it difficult to categorize ERP systems. Among others, Gronau (2021) proposes a classification for ERP (Figure 7).

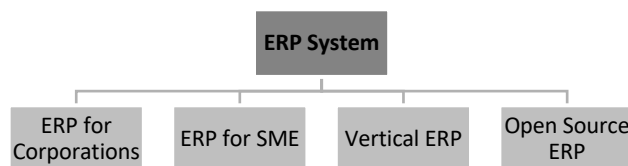


Figure 7 - ERP classification (own figure, adopted from Gronau (2021))

ERP for corporations: Very comprehensive functions in all required core modules, with a focus on finance. The ERP can be distributed, and systems can be integrated via interfaces.

Examples of ERP for corporations are not included, as most of the information presented aims at this type of ERP.

ERP for SMEs: Tasks are less comprehensive, and the number of transactions is lower. The functions focus on few processes, often with a focus on accounting and physical resource management. Functionality and integration level is lower than in ERP for corporations.

The biggest differences between SMEs and large enterprises is the availability of funds in the enterprise and the function range needed from the ERP system (Haddara & Zach, 2011). In general, SMEs have less complex but more individual business processes as large corporations which poses the need for more customization. The modules needed in the respective industry are similar, but their extend differs (Zach et al., 2014). Several specifics need to be considered, summarized by Khadrouf et al. (2020), in categories organization, economic, environmental, and technological.

ERP for specific industries (vertical ERP): ERP systems or modules tailored to requirements of a specific industry, e.g., retail, construction, public administration, or education.

Hospital: A hospital has specific requirements for reporting and processes for services execution or reimbursement and practices can vary between countries and hospitals (Soh et al., 2000). ERP systems for hospitals are developed to collect, store, retrieve, and communicate data about patients, patient care, and administration, resulting in medical support, nursing care, operating theatres, meal supply, finance and administration, logistics, human resource management, medication, appointment scheduling, etc. (Bakker, 1990). Examples can be an Hospital IS (Bakker, 1990) or Hospital Resource Planning (Roth & Dierdonck, 1995).

Public Administration (e-government): In principle, the modules of an ERP for public administration are very similar to those of a service business but often concentrate more on back-office processes. The nature of operations and regulations can differ a lot from the private sector (Ziemba, 2013). Kumar et al. (2002) mention social obligations, higher legislative and public accountability, and unique culture as challenges for public administration ERPs. There is an increased number of adoptions of ERP of governments which also results in an adoption of ERP by the systems vendors themselves according to the specific needs of public administration.

Educational Institutions: ERP systems for education contain multiple modules which focus on the requirements of the education system. Noaman & Ahmed (2015) summarize education ERP functionalities in their work and show that it has many specifics / adoptions from traditional ERP functions. On a high level, an education ERP should contain multiple functions for the management of finances, administration of students, and management of human resources (Noaman & Ahmed, 2015). ERPs in education should support students' information access, academic records, and other education specific data (Davis & Huang, 2007).

Open-Source ERP: This type of ERP is developed by a community based on publicly available code. The functions are often limited. A lot of knowledge is required, since no support of ERP providers is available. It can be for any type of company and can be adopted to specific needs.

Examples of open-source ERP are not included, as this type of ERP is not about specific functions but a different creation approach which is not focus of this work.

The examples show that ERP can be used in a wide variety of organizations and many modules are adopted to specific requirements. The modules, their amount and functions of the individual modules can differ depending on the industry. However, the general idea and functionality of ERP remains. They have a central database, and the aim is to digitalise and automate processes, improve the flow of information, and achieve integration. In short, the ERP characteristics from chapter 3.1.1 apply.

3.1.3. Benefits and Drawbacks of ERP

It is important to understand why companies adopt ERP systems and what prevents them. This chapter gives an overview over the main benefits and drawbacks.

Benefits of ERP

In a case study, Mesicek et al. (2021) found that the expected and real benefits of ERP differentiate. This complies with the findings of other authors stating that benefits depend from factors (Chou & Chang, 2008). Those factors are for example business culture, strategy, organization structure (Al-Mashari et al., 2003; Rashid et al., 2002)

ERP benefits can be categorized in tangible, intangible, and strategic benefits (Rashid et al., 2002). The strategic benefits are hardest to measure and quantify (Murphy & Simon, 2002; Ragowsky & Somers, 2002). There have been several approaches to categorize benefits. The most cited is by Shang and Seddon (2002). Main benefits are categorized in the five dimensions Operational, Managerial, Strategic, IT Infrastructure, Organizational, those contain 21 subdimensions. This framework is not specialized on any specific ERP module or industry. Karimi et al. (2007) uses a business process perspective. Garg and Venkitakrishnan (2008) collected intangible benefits. Mabert et al. (2000) studied the performance improvements trough of ERP implementation. Matolcsy et al. (2005) did an empirical study from an economic perspective. Other main works consulted are recent studies such as Meiryani (2021), Měsíček et al. (2021), or Brahmadeep & Thomassey (2016) and highly cited works from the beginning of ERP such as Ragowsky and Somers (2002), Gupta (2000), Davenport (2000), or Rashid (2002). Table 2 summarizes predominant ERP benefits from the studies consulted.

| Benefit | Description | Authors |
|---------------------|---|---|
| Quality improvement | Quality of the processes and the products is improved: less errors and a better information exchange. | (Karimi et al., 2007), (Garg & Venkitakrishnan, 2008), (Meiryani et al., 2021) |
| Cost reduction | Costs of processes can be reduced: More efficient processes, less staff needed, or better quality. | (Karimi et al., 2007), (Ragowsky & Somers, 2002), (Meiryani et al., 2021), (V. A. Mabert et al., 2001), (Rashid et al., 2002) |
| Time reduction | Time reduction: shorter lead, delivery, transactions cycle, or repose times. | (Karimi et al., 2007), (Davenport, 2000), (Ragowsky & Somers, 2002), (Gupta, 2000), (Brahmadeep & Thomassey, 2016), (V. A. Mabert et al., 2001) |

| | | |
|--|---|--|
| Increased productivity | Increasing output with same input: Better utilization of resources. | (Karimi et al., 2007), (Ragowsky & Somers, 2002), (Meiryani et al., 2021), (Gupta, 2000) |
| Decision making improvement | Data availability and access: Faster, and better decisions based on holistic information. | (Karimi et al., 2007), (Garg & Venkitakrishnan, 2008), (Meiryani et al., 2021), (Gupta, 2000) |
| Information accuracy and uncovering | Uncovering of new, accurate information for analysis, and allows access. Transfer tacit information to explicit. | (Garg & Venkitakrishnan, 2008), (Meiryani et al., 2021), (Rashid et al., 2002), (Meiryani et al., 2021), (Beheshti, 2006), (Brahmadeep & Thomassey, 2016), (Davenport, 2000), (Měsíček et al., 2021) |
| Information centralization | Data are integrated from multiple business functions/ERP modules in one central database serving as centralized information repository. | (Měsíček et al., 2021), (Rashid et al., 2002), (Meiryani et al., 2021), (Beheshti, 2006), (Brahmadeep & Thomassey, 2016), (Ragowsky & Somers, 2002) |
| Efficiency improvement | Processes get more efficient: Less resources needed to archive the same outcomes as before. | (Meiryani et al., 2021), (Beheshti, 2006), (Gupta, 2000) |
| Communication improvement | The common system and centralized database enable communication and synchronization internally and externally. | (Beheshti, 2006), (Brahmadeep & Thomassey, 2016) |
| Process improvement and automation | ERP enables redesign of processes based on best practices and enhances automation aspirations. | (Meiryani et al., 2021), (Beheshti, 2006), (V. A. Mabert et al., 2001), (Karimi et al., 2007) |

Table 2 - ERP benefits summary

Drawbacks of ERP

Many studies refer to implementation challenges, which is not the focus. The main disadvantage mentioned is the scope of customization needed (Al-Fawaz et al., 2008; e.g., Bin Ye et al., 2005; Davenport, 1998; Shehab et al., 2004). Organizations must adopt to ERP by changing exiting practices and processes (Sheik & Sulphey, 2020). Bin Ye at al. (2005) argue that ERP is not flexible, dynamic, and intelligent. It blocks the enterprise evolution, as adoption to requirement changes is complicated.

A second main point is cost. Mabert (2001) found that the cost of ERP software itself is only 10-20% of the actual costs. Main cost drivers are changes in the way employees and the business work and the customization of ERP or the adoption of business processes (Al-Fawaz et al., 2008; Beheshti, 2006).

Authors Zare Mehrjerdi (2010) and Brahmadeep & Thomassey (2016) created literature based collections of ERP drawbacks resulting in very similar points. Shehab et al. (2004) categorized drawbacks in a model in four areas cost and implementation, functional, technical, and usability. Traditional highly cited studies (Beheshti, 2006; Davenport, 1998; Gupta, 2000; Rashid et al., 2002; Shang & Seddon, 2002) are extended by recent opinions (Sheik & Sulphey, 2020) to summarize possible ERP drawbacks. Table 3 summarizes predominant ERP risks from the studies consulted.

| Drawback | Description | Authors |
|---|---|--|
| Missing flexibility | The systems are inflexible and often do not exactly match the company's needs. Companies invest a lot of money and/or time to customize the system. In some cases, the adoption is not possible and process change is required. | (Beheshti, 2006), (Brahmadeep & Thomassey, 2016), (Shehab et al., 2004), (Davenport, 1998), (Zare Mehrjerdi, 2010), (Al-Fawaz et al., 2008), (Bin Ye et al., 2005) |
| Process change | The inflexible and rigid nature of ERP systems results in process adoption. This can result in a loss of competitive advantage via processes. | (Shang & Seddon, 2002), (Sheik & Sulphey, 2020), (Beheshti, 2006), (Brahmadeep & Thomassey, 2016), (Shehab et al., 2004) |
| Investment costs | The initial investment and choice of and switching costs to a (new) an ERP system are very high. | (Beheshti, 2006), (Rashid et al., 2002), (Al-Fawaz et al., 2008), (Zare Mehrjerdi, 2010), (Brahmadeep & Thomassey, 2016), (Sheik & Sulphey, 2020) |
| Maintenance costs | Companies face high costs for updates, training, IT infrastructure, etc. post implementation. | (Gupta, 2000), (Zare Mehrjerdi, 2010), (Bin Ye et al., 2005) |
| Time consumption | The time needed for choice, preparation, implementation, and post implementation issues. | (Rashid et al., 2002), (Shehab et al., 2004), (Al-Fawaz et al., 2008), (Brahmadeep & Thomassey, 2016) |
| System complexity | ERP systems are complex software systems, needing good technical and organizational understanding. | (Rashid et al., 2002), (Shehab et al., 2004), (Al-Fawaz et al., 2008) (Brahmadeep & Thomassey, 2016) |
| Implementation issues | The implementation of ERPs is often long and reveals a lot of issues, such as user resistance, cost overruns, missing support, or different functional interests. | (Shehab et al., 2004), (Brahmadeep & Thomassey, 2016), (Gupta, 2000) |
| Missing integration | The integration with already existing / other new systems in can be challenging. | (Shehab et al., 2004), (Rashid et al., 2002), (Zare Mehrjerdi, 2010) |
| Need of skilled workforce | The ERP systems need skilled workforce to have the most successful outcome, this results in the need for user and technical staff training. | (Brahmadeep & Thomassey, 2016), (Shehab et al., 2004), (Zare Mehrjerdi, 2010), (Al-Fawaz et al., 2008), (Shang & Seddon, 2002) |
| Supplier dependency | A supplier can only be changed with high cost and time resources. | (Shang & Seddon, 2002), (Rashid et al., 2002) |
| Data errors, integrity, and security | Errors in data are accessible from all modules. Data quality and regulations of data integrity or security, or the resistance to share data lead to issues. | (Brahmadeep & Thomassey, 2016), (Gupta, 2000) |

Table 3 - ERP drawbacks summary

3.1.4. Evolution of ERP

It is important to understand the evolution of ERP to comprehend how they might develop in the future. ERP systems are industry driven concepts (Moon, 2007). The roots of the ERP system lay in manufacturing. The stronger need for integration of different functions in the company led to the

evolution of ERP systems (Jacobs & Weston, 2007). ERP started as back office system and is now an important backbone for organizations (Davenport, 2000). ERP systems must keep up with changes in business models and new technological developments in hardware and software. This leads to an ongoing, gradual development (Bahssas et al., 2015; Majstorovic et al., 2020; Rashid et al., 2002).

In the 1960s Inventory control packages, an IS to check, monitor, and manage inventory, were the roots of ERP (Majstorovic et al., 2020; Rashid et al., 2002). Those basic systems could calculate reorder points, lot sizes, or safety stocks, to optimize inventory (Jacobs & Weston, 2007; Wortmann, 1998). In the 1970s Material Requirements Planning (MRP I) systems made planning of manufacturing processes and purchases of materials more efficient (Klaus et al., 2000; Majstorovic et al., 2020; Rashid et al., 2002). In the 1980s Manufacturing Resource Planning (MRP II) software optimized the production planning and execution process, synchronizing materials with production requirements. It could support production, purchasing, inventory, and distribution. This was a move towards an enterprise-wide system for resource management (Shehab et al., 2004). In the early 1990s the term ERP was first used by the Gartner Group (Wylie, 1990). First, operational parts of the firm were integrated with accounting (Goldston, 2020). Shortly after, ERP systems enabled the integration of business activities (planning, purchasing and distribution) across functional departments (marketing, design, accounting, HR). This led to inter-functional integration (Majstorovic et al., 2020; Rashid et al., 2002). The ERP had a client – server architecture with a central database (Jacobs & Weston, 2007).

After the 1990s, the understanding of ERP development became more complex. While before there was agreement between most mainstream authors on the timing and naming of ERP developments, authors are now proposing different developments to represent the next levels of ERP.

In the 2000s developments improved existing functions making them more efficient and advanced and added functions such as CRM and SCM (Rashid et al., 2002). Other developments were the use of internet, Service Oriented Architecture, and mobile access (Bahssas et al., 2015; Beleş & Purcărea, 2017; Majstorovic et al., 2020). This type of ERP is mainly referred to as extended ERP or ERP II (e.g., Bahssas et al., 2015; Beleş & Purcărea, 2017; Majstorovic et al., 2020). The main ERP trend in the 2010s was ERP cloud computing (CC) as software as a service model (SaaS) (Goldston, 2020; Majstorovic et al., 2020). ERP reached some state of maturity and functional developments slowed down (Beleş & Purcărea, 2017; Goldston, 2020). In the late 2010s and early 2020s new developments such as BD, AI, or IoT started merging into ERP (Bytniewski et al., 2020). Authors use different names for such ERPs, such as ERP 4.0, ERP III, i-ERP, etc. (Basl & Novakova, 2019; Morris et al., 2016). This new type of ERP system is discussed in the following sections of this literature review. To sum up, figure 8 summarizes the evolution of ERPs. The focus of the following work is highlighted in blue.

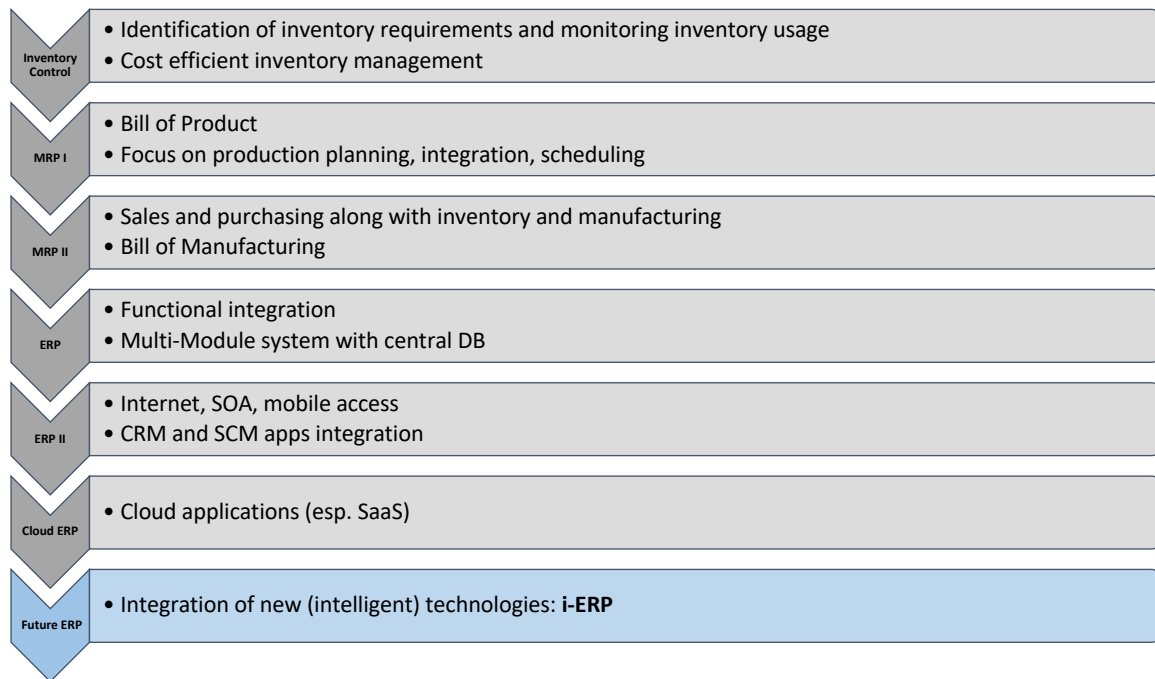


Figure 8 - The evolution of ERP systems (own figure based on Bahssas et al., 2015; Beleş & Purcărea, 2017; Goldston, 2020; Jacobs & Weston, 2007; Klaus et al., 2000; Majstorovic et al., 2020; Rashid et al., 2002)

3.2. INTELLIGENT ERP SYSTEMS (i-ERP)

It was found that the number of studies in the field of i-ERP is small. Academic studies are very limited. It is a practice-driven concept with several non-academic publications from international consultancies and organisations. Most studies date from the past five years. Studies are mostly qualitative, general ideas and proposals or very specific studies on a use case. However, the topic is loosely defined and conceptualised.

According to the findings, the term i-ERP was first used by the author Morris et. al. (2016). A confirmation of the trend towards i-ERP can be found in the ERP trend studies of the renowned IT consultancy Accenture (2019, 2020a) or the German organization BITKOM (Becker et al., 2021).

Bergdahl (2018) researched the business value and application of AI in an ERP on a very high level organizational context and found that only few processes yet are supported by AI and in the future a more AI driven approach is needed to gain the best possible value for the organization. Insights into i-ERP, possible advantages and comparisons to a traditional ERP are provided by Rizza and Lava (2021).

There is some information on the related concept of ERP 4.0. It is focused on the manufacturing industry and the challenges of Industry 4.0, while i-ERP has a more general approach to all application areas of ERP. The studies on ERP 4.0 can provide important indications for the i-ERP idea and composition. Of particular note are a study by Majstorovic (2020) where a framework model of an ERP 4.0 is presented, Basl and Novakova (2019) where a maturity model is created based on Industry 4.0 factors, and Bytniewski et al. (2020) presenting a functional and technological basis for ERP 4.0.

Studies were found in which very specific i-ERP systems were created, for example an intelligent sales management ERP (Liu et al., 2020) or an i-ERP for active SCM (Jayender & Kundu, 2021). The focus is more on intelligent functions and not on a full system, which is the focus of this work. Bouchemal and Bouchemal (2019) propose a kind of i-ERP based on agents and cloud. Jenab et al. (2019) could prove that intelligent technology can be merged with ERP, and it can be used in company operations. They also outline the possible scope of i-ERP and show advantages. Meidina (2017) integrated intelligent chatbots in ERP and found that they can improve ERP in making processes efficient and automated. None of the studies found have a general, holistic, high-level approach.

Particularly noteworthy are general studies that provide insights into technologies or use cases in i-ERP (Bauer & Bingler, 2020; Gold, 2020; Goundar, 2021; Gronau, 2021). The most important points of the above studies, supplemented by other sources, are presented in a structured way.

3.2.1. Idea of i-ERP

I-ERP is in an early stage of development. In an Accenture (2020a) study it was found that only a minority of organizations use a system comparable to i-ERP. The challenge for ERP vendors is the development of a real time, self-controlling and self-learning system (Bauer & Bingler, 2020). There is no agreed definition of what an i-ERP is.

- Jenab et al. (2019) describe an i-ERP as a smart system to help the company innovate and make better decisions. An i-ERP supports digital transformation and embeds new technologies to work autonomic and predictive.
- Goundar (2021) states that the use of AI makes an i-ERP system.

- Morris et al. (2016) define an i-ERP as a cloud based ERP system to enable innovative products and services, enhance employee productivity, and to maximize the return on information assets, supporting digital transformation.
- Bouchemal and Bouchemal (2019) state that an i-ERP is comprised by several advanced technologies and is characterized by its intelligence, autonomy, and real-time behaviour, generating results from the data it collects.
- Accenture (2019) see new automation and prediction capabilities, while retaining traditional recording capabilities. Intelligent technologies are integrated in the core of the platform comprising an i-ERP.
- SAP (2018) state that i-ERP is characterized by multiple intelligent technologies that allow automation and process efficiency.
- Rizza and Lava (2021) describe i-ERP as system that can provide actionable insights for employees based on a huge data repository to automate tasks.

Accenture (2019) make clear that i-ERP do not lose the core ERP functionality of transaction recording and processing. In the same publication they present five fundamental trends for i-ERP. CC is the key, and it should be partnered with innovative cloud experts, not traditional vendors. The customer experience and customization must be seamless. Data must be treated as an asset, and it should be accessible and centralized, and the ERP must be intelligent (automation and intelligence capabilities) the core, not just as add-on. Morris et al. (2016) describe the effects on the three main dimensions of a digital transformation: People, Process, Technology. In the people dimension i-ERP is expected to change roles, responsibilities, and tasks, leading to a change of jobs. In the process dimension i-ERP will lead to increasing automation of tasks. In the technology dimension, i-ERP brings cognitive technologies in companies resulting in a competitive advantage.

The i-ERP changes the role of the system user since, in a traditional ERP system, manual tasks had to be completed, but in an i-ERP, steps can be automated and learned. ERP acts as a storage for transactional data, but the i-ERP manages the business using data (Table 4) (Rizza & Lava, 2021).

| Traditional ERP | Intelligent ERP |
|---|---|
| <ul style="list-style-type: none"> • Reactive • Manual Centric, semi-automated • Periodic or batch updated • Historical view on data • Internal focus with little consideration of external data | <ul style="list-style-type: none"> • Proactive • Automated, self-healing • Real time • Insights, situational intelligence • Synthesizes and analyses many internal and external data sources |

Table 4 - Differences: traditional ERP and intelligent ERP (Rizza & Lava, 2021, p. 2)

Multiple authors (e.g., Gold, 2020; Morris et al., 2016) point out the importance of data quality and quantity. With no data one cannot build an i-ERP, wrong data leads to wrong results. Large companies can generate more data which simplifies the use of i-ERP (Gold, 2020). Morris et al. (2016) point out that the right data for the process are need (value) and they must cover all the needed parts of the business process (completeness). The i-ERP can rapidly process complex data (Kenge & Khan, 2020). Intelligence of i-ERP systems comes from learnings from data and the application of the learning to

achieve business outcomes (Slowik & Burian, 2020). The workflow of an i-ERP is explained using an AI model adopted to i-ERP (Figure 9) (Gold, 2020).

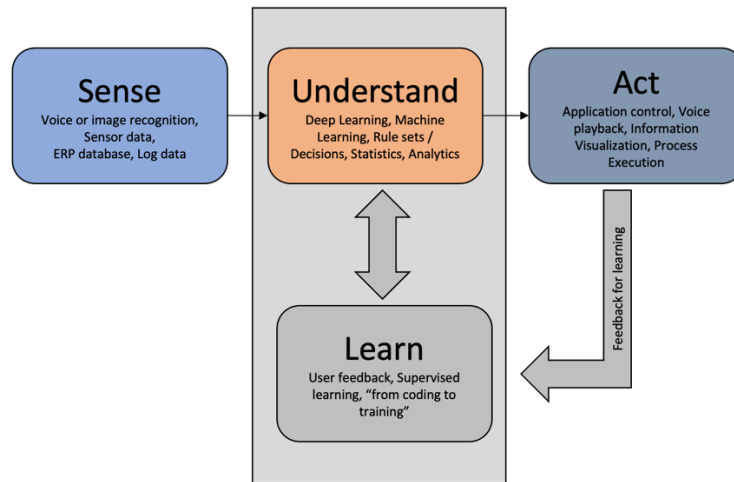


Figure 9 - General components of i-ERP workflow (own figure, adopted from (Gold, 2020))

I-ERP can “Sense” data from the ERP database, IoT, log files, and other structured and unstructured data sources. Various approaches, such as ML, rule-based reasoning, or decision trees, allow understanding the data (“Understand”) and enables the system to “Act” autonomously and, for example, control applications or processes, display information, or produce speech or graphics. To enable understanding and action, the system must learn (“Learn”), based on technologies, inputs, and feedback from the “Act” step. Learning can happen through training and with feedback, which can for example be processed, through cause/effect comparisons or true/false messages and improve the i-ERP (Becker et al., 2021; Gold, 2020).

It was introduced that an ERP has three layers: Presentation, Application, Database (Klaus et al., 2000). Gronau (2021) explains that an AI driven ERP has specific features in the layers (Table 5).

| | |
|---------------------------|--------------------------------------|
| Presentation Layer | AI Assistants |
| Application Layer | AI Planning Component, AI Algorithms |
| Database Layer | NoSQL database, In-Memory database |

Table 5 – AI-ERP characteristics in stack model (Gronau, 2021)

In course of the work on ERP 4.0 Majastorovic (2020) created a general model (Figure 10). The model has three parts Virtual (virtual model of the ERP, with the intelligent functions), Portals (interfaces to provide and exchange information), and ERP model of modules (business-technological and managerial functions). The model is very general, and the functions of an ERP 4.0 do not become clear explicitly, it rather shows the structural composition. No other i-ERP model could be found in course of this research.

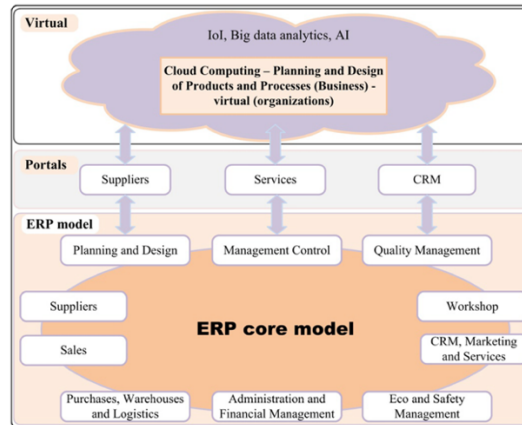


Figure 10 - ERP 4.0 model (Majstorovic et al., 2020, p. 291)

Two models were proposed to separate i-ERP from other levels of ERP development and to assess how intelligent an ERP system is. The first one is for the idea of the concept of ERP 4.0 developed by Basl and Novakova (2019) and the second one a Master Thesis at NOVA IMS, Lisbon proposing a taxonomy and guide for the incorporation of AI in ERP by de Carvalho Silva (2020). Both approaches start with the idea of a traditional ERP system and end with a proposal of i-ERP / ERP 4.0. They help to better understand the concept of i-ERP and to differentiate it from other systems and development steps. Basl and Novakova (2019) use four dimensions, Business Model, Technology, Data, and Processes, on six levels of maturity. This model is derived from Industry 4.0 trends. In general, it is not clear in this model whether the focus is on technologies or functions, as both are mixed. De Carvalho Silva (2020) presents his taxonomy with six levels and takes a very general approach with no specific structure or focus, also mixing technologies, functions, and roles. He also proposes ideas how to move forward to next higher levels with a very general approach.

3.2.2. Technologies in i-ERP

I-ERP functionalities are enabled by multiple technologies (Bouchemal & Bouchemal, 2019). Several trends and developments in ERP have driven the development of i-ERP. Key driver are according to Goundar (2021) IoT sensors, the ability to handle Big Data (BD), and the data storage in the cloud. The integration of people and devices in the organization using IoT, the use of BD to have a fundament for AI algorithms, and CC to host system and data are required for i-ERP (Cognizant, 2019). Multiple authors agree that i-ERPs are based on CC for application hosting and data storage, allowing flexibility, updates, and upgrades with new technologies and functions (e.g., Basl & Novakova, 2019; Majstorovic et al., 2020; Morris et al., 2016).

In their ERP 4.0 idea, Basl and Novakova (2019) combine CC, IoT, and AI. CC can operate the ERP, IoT improves real time data availability and accuracy, building the foundation for AI and ML. Similarly, Majstorovic et al. (2020) include CC, gathering data with IoT, and storing it in BD databases. The analysis and use of data is driven by AI and ML technologies.

In i-ERP literature, Accenture (2020a) see predictive analytics, AI, ML and automation in i-ERP based on their ERP trend report. In the 2019 report AI, ML, and analytics are mentioned (Accenture, 2019). Jenab et al. (2019) describes i-ERP as a combination of Business Intelligence (BI) and ERP and the use of ML and advanced analytics (AA) technologies. According to Morris et al. (2016) i-ERP relies on BD

datasets and uses cognitive technologies such as ML, AA, and Natural Language Processing (NLP). Rizza (2020) sees ML, Deep Learning (DL), and Robotic Process Automation (RPA) in ERP. Slowik and Burian (2020) propose cloud computing, IoT, DA, ML, and AI. AI, ML, analytics, Blockchain, BD, and IoT are the main technologies mentioned by Bouchemal and Bouchemal (2019). Donatelli et al. (2020) propose the use of RPA and AI. AI, RPA, ML, BD, and Predictive analytics are used by Rizza and Lava (2021). Wang (2021) found that companies desire analytics, automation, and AI in i-ERPs.

Summing up, the main trends mentioned are CC (for infrastructure and data storage), IoT (for the data collection and monitoring), and BD (for the processing and storing of huge number of different types of data). Those trends are seen as key enablers for an i-ERP, but those do not make up an i-ERP. The trends that make an ERP intelligent are RPA, different types of DA, AI, and ML to archive intelligent functionalities.

3.2.3. Functions and Use Cases of i-ERP

The functions of i-ERPs are diverse, but the main functions are described similarly by most authors. There are different categorisation approaches. Gronau (2021) categorizes in five types.

- **Administration:** Transaction data collection, pattern recognition and classification
- **Disposition:** Automation of routine tasks and workflows, automated proposals
- **Information:** Key Performance Indicator (KPI) creation, advice, and warning functionality
- **Analysis:** Evaluations, real-time trend, error analysis
- **Prediction:** Maintenance, customer behaviour, etc.

Morris et al. (2016) uses three dimensions to describe i-ERP core functionalities and characteristics. This approach is on a higher level than the one proposed by Gronau (2021) above.

- **User Experience Dimension:** The User Experience (UX) should be assistive for the user and be in conversational style making it easier to navigate and leading to a more effective work.
- **Process Dimension:** I-ERP supports automation of tasks, can recognize patterns in processes, and works intelligent to redefine processes.
- **Data Dimension:** The i-ERP should have data management ability and it should be able to enable access to relevant data in real time.

An overview of the functions mentioned by various authors is given.

The data quality can be improved and the management of data simplified (Deloitte, 2021). An i-ERP can create reliable data and learn and improve from data (Gronau, 2021). I-ERP is a source of data and real time information (Rizza & Lava, 2021). Gold (2020) points out that i-ERP allows individualized data insights according to the context of the process or task. Morris et al. (2016) add that i-ERP can learn how humans request data in respective contexts.

The system can automate routine tasks and take decisions (Morris et al., 2016; Rizza & Lava, 2021). Accordingly, Goundar (2021) explains that i-ERPs can automate processes based on learnings and predictions. I-ERP can automate and improve processes and suggest problem solutions (Accenture, 2019; Jenab et al., 2019). A study by Gold (2020) confirms that companies see automation as one of the biggest opportunities. Bingler (2020) adds that an i-ERP can adopt processes in real time to a changing internal or external situation (Morris et al., 2016). The i-ERP allows optimization of processes

(Deloitte, 2021; Donatelli et al., 2020). Processes in i-ERP can automatically be refined (Morris et al., 2016). Slowik and Burian (2020) describe this as an ongoing self-configuration of i-ERP. I-ERP algorithms evolve and proactively suggest improvements (Gold, 2020). I-ERP can adapt processes to changes in the environment in real time (Gronau, 2021).

Accenture (2019) names UX and personalization as one of the i-ERP fundamentals. Slowik and Burian (2020) name an adoptive UX as key part. Morris et al. (2016) describe the UX to be assistive and conversational. The understanding of contexts and individual workflows allows a customized user interface (UI). Examples of an i-ERP UX can be, simple to use and customizable UI, different access ways, or automation (Rizza & Lava, 2021). A better UX can be achieved through a individualization of data and functions shown (SAP SE, 2017a). Intelligent assistants that understand how users work and communicate can support the work (Bauer & Bingler, 2020). The assistants can be used to contextualize information and to predict next steps or needs (SAP SE, 2017b). Examples are prediction of next steps or actions or identification and notification of weak signals (Morris et al., 2016).

The implementation of i-ERP leads to different use cases. There are studies about some functions and what organizations expect. A selection is presented to understand i-ERP use from a practical view. In an i-ERP multiple intelligent functions should be included in the i-ERP core. The selection gives an idea of the direction in which such functions can go and what is possible and imaginable today.

AI applications in ERP can be found in various areas. Examples are data analytics, forecasting systems, search engines, machine translation, computer vision, bots, and expert systems (Bingler, 2020). In a survey in German companies, Gold (2020) found that the most desired intelligent functions for ERP systems are voice inputs, predictive analytics, automated translations, data visualization, chatbots, automated document processing, and proactive optimization suggestions. In the same study it was found that the most likely AI ERP use cases are data analysis for decision-making processes (70 %), automation of existing business processes (63 %), chatbots (47 %), speech processing (42%).

Some of the examples can be related to specific modules (Gold, 2020):

- **Sales:** Forecasting of sales or dynamic pricing
- **SCM:** Inventory, routing, delivery time improvement, production scheduling, e-Kanban
- **Human Resources:** Selection process of employees, task monitoring, or training
- **Finance:** Detect fraud, automated risk assessments, or invoice matching/recognition

Bingler (2020) names use cases such as automated translations, predictive maintenance and quality assurance, prediction of customer satisfaction, intelligent assistants, or intelligent variant configuration. According to Anguelov (2021) i-ERP supports the development of new products. The i-ERP can enable application operation using natural language, for example in chat or voice bots or real time translation. The analysis of data allows predictive satisfaction and maintenance.

3.2.4. Benefits and Drawbacks of i-ERP

i-ERP Benefits

Jenab et al. (2019) found that i-ERP has a positive influence on quality criteria. The speed of operations can be improved through better information exchange and decision making. The flexibility of i-ERPs helps in the adoption to specific needs and i-ERP can reduce costs. Gold (2020) points out that the

advantages of i-ERP are more accurate, faster, cheaper, more effective processes and the role of ERP changes towards a proactive assistant. The learning and adoption capability of i-ERP allows adoption to trends and the prediction of developments, resulting in better results and solution suggestions (Gronau, 2021). I-ERP reduces human intervention in ERP processes, which, according to Donatelli et al. (2020), results in fewer errors in data entry, better processes and decisions, and free workers. Productivity can be increased and organizations business operating model can be optimized (Goundar, 2021). The i-ERP can give advice to the management, for optimization and detection of atypical cases and behaviours (Anguelov, 2021). A survey by Gold (2020) showed that the largest chances for i-ERPs are automatization, improved data, and error prevention. Table 6 summarizes main benefits.

| Benefit | Description | Authors |
|-------------------------------------|--|---|
| Workflow efficiency | The decision-making and automation capabilities enable a better process efficiency. | Basl & Novakova (2019), Goundar (2021), Jenab et al. (2019), Gold (2020) |
| Improved communication | Resources and data are connected and centralized improving internal and external communication. | Basl & Novakova (2019), Rizza (2021), Morris et al. (2016), Jenab et al. (2019) |
| Reduced operating costs | Higher efficiency, free workers, automation, reduced errors, and faster processing reduce operation costs. | Basl & Novakova (2019), Goundar (2021), Jenab et al. (2019), Gold (2020), Donatelli et al. (2020) |
| Reduced data processing time | Data processing capabilities ensure faster processing. | Kenge & Khan (2020), Gold (2020), Deloitte (2021) |
| Improved processes | The analysis of data in the process gathered over time allows i-ERP to find bottlenecks, errors, and inefficiencies and help improving those. | Kenge & Khan (2020), Donatelli et al. (2020), Morris et al. (2016) |
| Improved decisions | The analytic capabilities on centralized sources of data allow automatic decisions or recommendations. | Basl & Novakova (2019), Jenab et al. (2019), Donatelli et al. (2020), Rizza and Lava (2021), Morris et al. (2016) |
| Improved quality | The quality of data, processes and products can be improved as less errors will be made. Errors can be avoided by automated entry, rule-based executions, and intelligent validity checks. | Jenab et al. (2019), Donatelli et al. (2020), Deloitte (2021), Gold (2020), Kenge & Khan (2020) |
| Increased flexibility | I-ERPs are flexible, adoptable, and scalable. They allow constant reconfiguration and refinement based on analytics and contentious learning. | Jenab et al. (2019), Rizza and Lava (2021), Morris et al. (2016) |

Table 6 - Benefits of i-ERP

i-ERP Drawbacks

A survey by Gold (2020) showed that the major risks mentioned are false trust in technology, loss of control, and unknown data flows. Challenges are skill shortages and technical barriers, such as incompatible data or lack of interfaces. In addition, ethical and legal aspects, such as technology distrust, implementation of data protection laws, or liability issues in case of incorrect i-ERP decisions, pose risks. Bingler (2020) points out that organizations often own and produce less than in usual BD

contexts. This means that models can be trained with a smaller data set. There is a need to adopt the learning process to a smaller amount of data. The i-ERP could be trained with wrong or inaccurate data which can lead to errors in predictions or automated processes (Bingler, 2020; Gold, 2020). In addition, one must understand the full business process to get best possible results. Often data is understood in a wrong context (Bingler, 2020). I-ERP must be compliant with regulatory, statutory, and business approval policies. To have the desired outcome of i-ERP it is a challenge to understand the relationship of business processes, data, and analytic capabilities (Rizza, 2020). Table 7 summarized the main expected challenges of i-ERP.

| Challenge | Description | Authors |
|-------------------------------|--|-----------------------------|
| Lack of data | The amount of data is often not sufficient for intelligent functions. This poses the need to adopt learning techniques and find new sources. | Bingler (2020), Gold (2020) |
| Inaccuracy of data | The quality or understanding of data is often inaccurate which can lead to wrong outcomes. Data can also be incompatible for certain use cases. | Bingler (2020), Gold (2020) |
| Legal / Ethical issues | Internal policies, legal, and ethical aspects must be considered. Liability can be a major problem. | Gold (2020), Rizza (2020) |
| Trust in system | Trust can be too high, meaning the system is trusted condition less, the trust level can be too low, meaning users overrule everything with their own decisions. | Gold (2020) |

Table 7 - Challenges of i-ERP

3.3. I-ERP TECHNOLOGY CONCEPTS

The number of academic, high-level studies explaining the technology concepts derived for i-ERP in above chapter is small. Many studies are technical, which does not correspond to the goals of this work. The concepts are often unsharply defined and seen from different perspectives by different authors. This leads to a high number of overlaps. An attempt is made to clarify the viewpoint of this thesis and to explain the basic concepts and their relationships. Regarding studies linking (i-)ERP and the technology concepts, some concepts are new in ERP, others have been integrated into ERP earlier and there are respective more studies.

3.3.1. Cloud Computing

CC is as a prerequisite technology concept for i-ERP., The concept is briefly introduced and the role in (i-)ERP is explained.

3.3.1.1. Concept of Cloud Computing

The National Institute of Standards and Technology (NIST) defines CC as *“a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interactive”* (Mell & Grance, 2011, p. 2). CC is about the provision of capabilities (such as servers, databases, software, network components, or storage) using the internet. (Wirtz, 2021). CC can best be described with a set of characteristics published by NIST (Mell & Grance, 2011).

- **On-demand self-service:** Unilateral provision of computing with no human interaction.
- **Broad network access:** Capabilities released via networks and access via standard mechanisms, such as phones, PCs, or laptops.
- **Resource pooling:** Computing resources pooled and assigned according to consumer demand.
- **Rapid elasticity:** Capabilities can be automatically scaled according to consumer needs.
- **Measured service:** Resources are optimized and appropriately, transparently metered according to the type of service. Customers only pay for the resources they consume.

Cloud services are provided by cloud vendors (Wirtz, 2021). There are three service models (Figure 11).

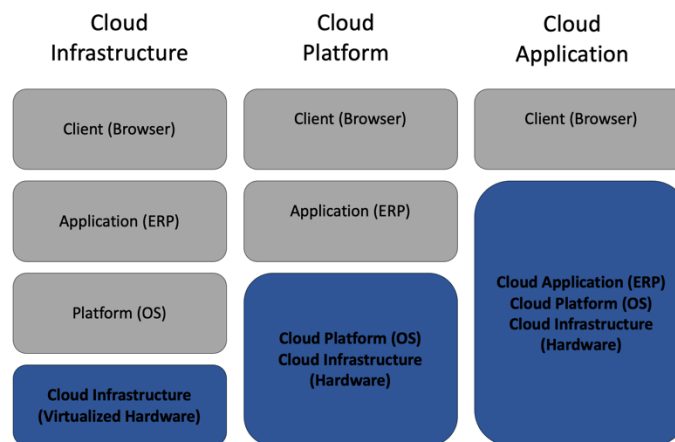


Figure 11 - Cloud ERP service models (own figure, based on (Lenart, 2011))

The models differentiate by the system components in the cloud. Cloud infrastructure (Infrastructure as a Service - IaaS) has virtualized hardware, Cloud Platform (Platform as a Service – PaaS) has the hardware and the operating system in the cloud, and Cloud Application (Software as a Service – SaaS) has everything virtualized and only provides access to the actual application (Lenart, 2011). There are four deployment models. A private cloud, where services are exclusively used by one customer, a community cloud, where a defined community of customers shares the resources, a public cloud, which is open to the general public, and a hybrid cloud, which combines two or more of the previously mentioned concepts (Mell & Grance, 2011). The main advantages are, according to Wirtz (2021) independency of device and location, greater speed and scalability, and reduction of costs.

3.3.1.2. Cloud Computing and ERP

Cloud ERP systems are no new trend and empirical studies with ERP vendors show their ambitions to offer solutions for cloud (Andročec et al., 2018; Basl, 2018; Basl & Novakova, 2019). Cloud is one of the key enablers for other trends and the modernization of ERP (Basl, 2018). An example is that cloud allows the work with BD as it provides scalable processing power and data storage (Bytniewski et al., 2020). Cloud ERP solutions are usually provided as SaaS model, whilst other cloud models are possible but not as popular (Abd Elmonem et al., 2016). More specifically, Cloud ERP means that (parts) of the ERP application and/or the respective data are hosted in the cloud (Peng & Gala, 2014). The ERP application (Application Layer) and the database (DB) are no-longer on-premises but in the cloud. The ERP database and application can be accessed via the internet independently from the geographical location (Katu, 2020; Peng & Gala, 2014). Main characteristics of Cloud ERP are the accessibility via the internet, without installing the system on the user device, independently from the device and geographical location (Abd Elmonem et al., 2016). The software is provided at user location (Kenge & Khan, 2020). A Cloud ERP has the same way of working as traditional ERP systems (Beric et al., 2018). Main benefits of Cloud ERP are, according to a review by Abd Elmonem (2016), lower cost, scalability, rapid implementation, improved accessibility, high availability, and easier update, whilst the key challenges are security risks, performance risks, integration limitations, functionality limitations, SLA issues and data ownerships. This matches very well with the results of other authors (Demi & Haddara, 2018; Lenart, 2011; Peng & Gala, 2014; Tavana et al., 2020).

3.3.2. Big Data

BD is as a prerequisite technology concept for i-ERP. The concept is briefly introduced and the role in (i-)ERP is explained.

3.3.2.1. Concept of Big Data

BD is of increasing importance in recent years. Digitization leads to an exponentially growing data availability. Traditional database systems cannot handle BD (Wirtz, 2021). The term "Big Data" is a buzzword with no uniform scientific definition (Wrobel et al., 2015). BD is commonly characterized by the 5Vs, Volume (size), Variety (structured, semi-structured, unstructured), Velocity (speed), Veracity (quality), Value (business value) and BD capability describes the ability to process this type of data (Simon, 2013). Special systems and functions are required to deal with the 5Vs. Three data types can be distinguished, they are explained below (Simon, 2013).

- **Structured data:** There is a predefined data model of data in tabular form. Relationships between rows and columns are visible and the analysis of this data is simple.
- **Semi-Structured data:** There is no fixed structure, but the data carry structural information. A model can be added later. The data collection can be expanded flexibly.
- **Unstructured data:** Data that has no formal structure and cannot easily be put into one. Analysis and access are very difficult.

BD sources are diverse. It can be transactional data from systems, text documents, social media, video, picture, audio, log, machine, location, etc. They can come from internal and external sources, in various forms and formats (Simon, 2013; Wirtz, 2021).

BD and AI have a reciprocal relationship. AI can help to prepare, process, and analyse BD datasets and AI relies on BD processing to deliver value adding outcomes. Intelligent features in analysis are key for the success of modern businesses and the ability to process BD is one of the vital technological fundamentals (Wirtz, 2021).

3.3.2.2. Big Data and ERP

BD is one of the most significant components of a modern ERP (Babu & Sastry, 2014; Cadarsaib et al., 2018; Tongsuksai & Mathrani, 2020). Shi and Wang (2018) argue that recent technology trends and developments make the integration BD inevitable. It acts as an enabler for other technology trends and their use in ERP (Basl, 2018). BD prepares the analysis of data created inside and outside the company (Elragal, 2014; Suman & Pogarcic, 2017). A study on the 5Vs of BD empirically showed that they significantly influence ERP systems posing a need for adoption (Alzureikat et al., 2021). Basl (2018) found that the majority of ERP vendors used BD in their ERP systems and most remaining vendors aim to use it in upcoming years.

ERP is central knowledge hub for internal data, extended by several, external BD from different sources (Elragal, 2014; Suman & Pogarcic, 2017). Modern ERPs must support structured and unstructured data (Kenge & Khan, 2020). BD sources in ERP can be various, examples are data from social media, web behaviour, repair histories, purchasing, or demographics (Babu & Sastry, 2014). Other sources can be IoT devices. This data must be analysed to gain value (Tavana et al., 2020). Suman and Pogarcic (2017) make clear that BD and its analytics are inseparable, whilst BD is about the production and use of data, value is archived only with analysis. Earlier ERP systems focused on collecting and organizing data, but are not suitable for analysis (Akyurt et al., 2020). Data privacy and security issues become more evidenced and must be handled in relation to ERP (Suman & Pogarcic, 2017). Several challenges, such as infrastructural, architectures, designs and tools, data provision for real time analytics, organisational, security, human, legal and cultural challenges hinder the interoperability of ERP and BD (Cadarsaib et al., 2018).

3.3.3. IoT

IoT is as a prerequisite technology concept for i-ERP. The concept is briefly introduced and the role in (i-)ERP is explained.

3.3.3.1. Concept of IoT

The concept of IoT is one of the major technological developments in recent years, but has no unite definition (Sharma et al., 2019; Wirtz, 2021). McKinsey defines IoT as “sensors and actuators connected by networks to computing systems. These systems can monitor or manage the health and actions of connected objects and machines. Connected sensors can also monitor the natural world, people, and animals” (McKinsey Global Institute, 2015, p. 1). Internet of Things (IoT) describes the interrelation of multiple physical devices with a communication interface (Andročec et al., 2018). It is a network of physical objects that communicate via internet. IoT devices can collect and exchange data using various protocols, enabled by a combination of electronics, software, sensors, actuators and network connectivity (Atzori et al., 2010).

This technology is still at a young stage and further developments are expected (Sharma et al., 2019). IoT is an important basic concept for intelligent objects that can feel, think, and act (Sharma et al., 2019). Wirtz (2021) describes the relation of IoT to different technology concepts as very important. IoT requires BD ability, to process high volumes of data, CC, to manage and store the data amounts, and intelligent technologies, to control IoT devices and allow advanced insights in data gathered. IoT devices can be on business assets, cars, appliances, equipment, etc. (Sharma et al., 2019). IoT can be used in many application contexts (Wirtz, 2021). According to a McKinsey (2015) study, IoT has the biggest potential in factories, followed by cities and humans. Other application areas are retail, “outside” (e.g., ships, planes), vehicles, home, and offices. The application of IoT technology can be used for monitoring and control, as BD source for analytics (Lee & Lee, 2015).

3.3.3.2. IoT and ERP

IoT was found to be one of the most popular trends for ERP (Basl, 2018; Tongsuksai & Mathrani, 2020). IoT can make ERP more flexible and intelligent (Andročec et al., 2018). Around 27% of ERP vendors developed IoT solutions, whilst 50% of companies plan in the next five years (Basl & Novakova, 2019).

ERP with IoT can collect, review, and process data (Bytniewski et al., 2020; Kenge & Khan, 2020). Basl and Novakova (2019) found that most companies use IoT to track and predict. It can be used for the monitoring of assets, people, and goods in their environment (Tongsuksai & Mathrani, 2020). A large amount of data from the physical company environment can be retrieved in real time. Examples are the state of the business processes and resources (people, equipment, tools, materials and products) (Akyurt et al., 2020; Andročec et al., 2018). IoT is related to trends such as ML, AI, or BD in ERP. Data are collected by IoT devices, stored in the cloud, and managed and analysed using an ERP (Tavana et al., 2020). The following figure 12 shows how Cloud ERP integrates with IoT.

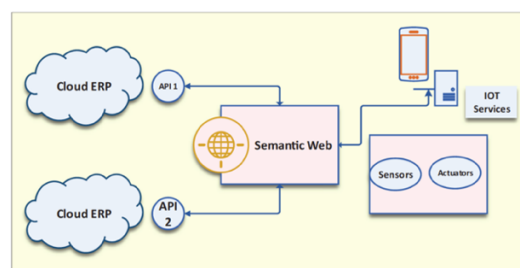


Figure 12 - IoT and ERP integration model (Tavana et al., 2020, p. 5)

IoT devices with sensors collect data based on the actuators action. Using the semantic web, information is shared with (Cloud) ERP(s). The ERP manages and controls the data (Tavana et al., 2020).

The application of IoT in ERP results in real-time data from multiple devices used to gain competitive advantage (Andročec et al., 2018; Basl & Novakova, 2019). The operational efficiency can be improved and the operating costs reduced (Andročec et al., 2018). More data get available and accurate (Akyurt et al., 2020). IoT in ERP results in process optimization (productivity, efficiency, costs) and insights (Bytniewski et al., 2020). IoT builds fundamentals for process automation, warnings, real time information, or tracking (Tavana et al., 2020; Tongsuksai & Mathrani, 2020).

3.3.4. Artificial Intelligence

AI is as an intelligent technology concept for i-ERP. The the concept is introduced with some detail and the role in (i-)ERP is explained.

3.3.4.1. Evolution of Artificial Intelligence

The beginning of AI was in the 1950ies when Alan Turing published his famous test to decide if machines are intelligent (Turing, 1950). In 1955 the term “Artificial Intelligence” was coined by Marvin Minsky and John McCarthy at the Dartmouth Summer Research Project. In 1966 a MIT researcher created the first chatbot named ELIZA (Haenlein & Kaplan, 2019). The mid 1960ies until the mid 1970ties are referred to as the AI Winter, as expectations were too high and computer processing power not sufficient, leading to many failed projects (Buxmann & Schmidt, 2021; Haenlein & Kaplan, 2019). The 1980ies were characterized by the development of Expert Systems. An example is MYCIN to support diagnosis and treatment in health (Buxmann & Schmidt, 2021). The next achievement was IBM’s Deep Blue chess robot beating the world champion in 1997 (Haenlein & Kaplan, 2019). In the 1990ies main developments were driven by advancements in the calculating power (OECD, 2020). In 2011 the IBM Watson, a DeepQA system, won the quiz show Jeopardy. It could understand, predict, decide, learn, and interact. In 2015 a DL program of Google bet the champion of the complex game “Go” which was believed to not be possible (Buxmann & Schmidt, 2021; Haenlein & Kaplan, 2019).

In recent years (2010s and 2020ies), BD, CC, and ML increased the performance, availability, and impact of AI (OECD, 2020). The 100 year study on AI by Stanford University concludes that use cases of AI will strongly increase (Stone et al., 2016). AI is (expected to be) part of our daily live and it will change how firms work (Haenlein & Kaplan, 2019). AI is driving digital transformation of business processes and models bringing forward automation, interaction, optimization, and decision-making (Davenport & Ronanki, 2018). The development is summarized in figure 13.

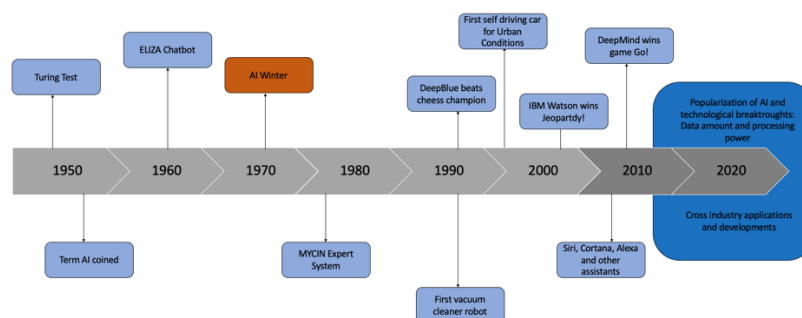


Figure 13 - Overview of AI milestones

3.3.4.2. Concept of Artificial Intelligence

The definition of the term AI is not agreed. The area is very broad and the term intelligent has no definition. There is an agreement that AI is part of computer science and that the goal is the development of intelligent agents (Buxmann & Schmidt, 2021; P. Wang, 2019). The area of AI is universal and can be applied to nearly every intellectual task a human can do.

- „Artificial Intelligence is the study of how to make computers do things at which, at the moment, people are better“ (Rich & Knight, 1991, p. 83).
- “A system’s ability to interpret external data correctly, to learn from such data, and to use those learnings to achieve specific goals and tasks through flexible adaptation” (Haenlein & Kaplan, 2019, p. 1).
- “AI is the ability of a machine to display human-like capabilities such as reasoning, learning, planning and creativity” (European Parliament, 2020, p. n.p.).
- “Artificial intelligence leverages computers and machines to mimic the problem-solving and decision-making capabilities of the human mind” (IBM, 2020, p. n.p.).

The definitions have similarities and differences. Generally, all these definitions say that a machine should show the intelligent behaviour of a human. The goal is to develop something that can process problems on its own and react to influences. AI definitions lead to four AI approaches: Act humanly, think humanly, think rationally, and act rationally. Human means imitating human behaviour, while rational describes an (economically) sensible course of action (Russell & Norvig, 2021).

To achieve AI it must be understood how intelligent behaviour solves problems, then, a system must be created that can automatically create such intelligent solutions (Kreutzer & Sirrenberg, 2019). Accordingly, Russel and Norvig (2021) state that AI is not only about understanding how we think and act but about building something that can act intelligently. One can differentiate “Weak AI” and “Strong AI”. This classification indicates how autonomously a system can act.

- **Weak AI:** The creation of algorithms with a learning ability that can solve defined problems.
- **Strong AI:** The machine can understand cognitive processes and act independently, considering empathy and consciousness. The goal is to mirror the human brain and thinking.

Weak AI has been becoming feasible in recent years. Concepts in this work are considered Weak AI (Buxmann & Schmidt, 2021; Cornelius, 2019). Accordingly, Brynjolfsson and McAfee (2017) make clear that in present a machine can be trained to very specific problems, but any deviation from the problem learned cannot be solved. For example, assuming the machine is trained to see, but it cannot speak, a human could generally solve this, but a machine cannot yet.

AI in business reduces repetitive work, increases productivity, and helps to address complex challenges (Russell & Norvig, 2021). Davenport and Ronanki (2018) did a survey in companies and found the main business benefits of AI are: Enhancement of features, functions, and performance of products, better decisions, creation of new products, optimization of internal operations, free up workers through automation, pursue new markets, capture, and apply scarce knowledge, optimize external processes, and reduce head count trough automation. The potential of AI cannot be realized without effort and solving some challenges. These challenges include obtaining the required data in sufficient quantity and quality, building employee competencies, and adapting organizational

processes (BITKOM & DFKI, 2017). Russel and Norvig (2021) state main risks of AI are surveillance, bias, impact on employment, and cybersecurity. Davenport and Ronanki (2018) mention the biggest challenges to be: Integration with current processes and systems, high price of technology and expertise, missing understanding and skilled workforce, and immature technologies.

3.3.4.3. Areas and Application of Artificial Intelligence

AI is comprised of various sub fields that cannot be seen in isolation and have a certain relationship and dependencies (Grzeszczak, 2020). For example, many authors see ML as part of AI, for others (including this thesis) it is not AI per se (Grzeszczak, 2020; Kreutzer & Sirrenberg, 2019; Russell & Norvig, 2021). There are different approaches that are not agreed (Kreutzer & Sirrenberg, 2019). Some approaches focus on AI technologies (e.g., Grzeszczak, 2020), others on application areas of AI (e.g., Kreutzer & Sirrenberg, 2019). In line with the business approach of this work, the approach according to Kreutzer & Sirrenberg (2019) was chosen. AI is categorized in the four fields (Figure 14).

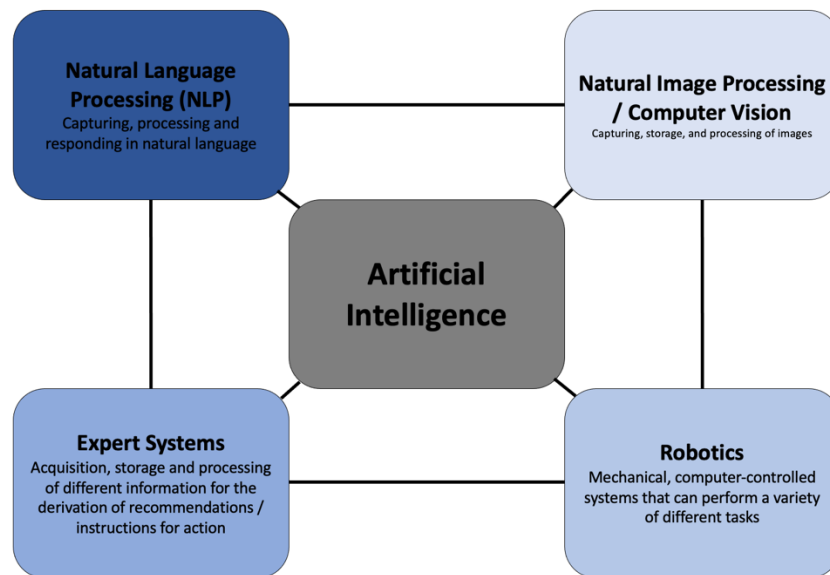


Figure 14 - Areas of AI (own figure adopted from (Kreutzer & Sirrenberg, 2019))

Natural Language Processing and Speech Recognition

NLP is a technology to capture and process natural language (Cornelius, 2019; Kreutzer & Sirrenberg, 2019; Stone et al., 2016). Patterns in speech and text are analysed and information or meanings, such as entities, locations, topics, or sentiments, can be extracted (T. H. Davenport, 2018). The machine can understand and interpret language and act upon the understanding. The goal of NLP is to improve human-machine communication via natural language (Cornelius, 2019; Kreutzer & Sirrenberg, 2019).

This technology is used for chatbots, in customer support, help desks, or social media (BITKOM & DFKI, 2017; Kreutzer & Sirrenberg, 2019; OECD, 2020). The human can send a request in text and the chatbot can understand it, interpret it, and respond to it in natural language (Cornelius, 2019; Kreutzer & Sirrenberg, 2019). Speech-based dialog systems are rely on speech and/or text input and output, such as digital assistants for customer support, or application voice control (BITKOM & DFKI, 2017; Kreutzer & Sirrenberg, 2019). Other applications of NLP can be translation, sentiment analysis, or knowledge gathering (Kreutzer & Sirrenberg, 2019; OECD, 2020; Stone et al., 2016).

Natural Image Processing / Computer Vision (CV)

The idea is to teach computers to "see", by capturing, storing, and processing images and videos. Any form of visual material can be analysed and interpreted: Objects, activities, places, brands, people, motion patterns or emotions (Cornelius, 2019; Kreutzer & Sirrenberg, 2019). The result can be on the one hand an image/video or a data set describing the features of the processed image/video, e.g. in text or voice (Kreutzer & Sirrenberg, 2019).

Possible applications can be recognition or tagging of objects or people or the recognition of emotional states (Kreutzer & Sirrenberg, 2019). This technology provides the basis for facial recognition (BITKOM & DFKI, 2017). Objects, can be monitored and in case of irregularities or defects a warning can be sent (BITKOM & DFKI, 2017; OECD, 2020). CV can be used to sense the environment and documents to detect things (Stone et al., 2016).

Expert Systems

Expert Systems are systems to capture, store, and process information obtained from domain experts. Recommendations and instructions can be derived, by imitating the decision-making capability of humans (Kreutzer & Sirrenberg, 2019). It is a rule based system centred around a clearly defined topic (T. H. Davenport, 2018; Kreutzer & Sirrenberg, 2019). It is a type of non-statistical AI based on a knowledge base constructed by human experts. The systems are easy to understand and decision paths can be traced based on the rules applied (T. H. Davenport, 2018).

Common use cases are in structured tasks, such as insurance or bank credit underwriting (T. H. Davenport, 2018). Expert Systems can be used for creative processes, such as the completion of an art piece or image analysis. Expert Systems can replace humans, e.g., a general consultation. They can help in quality assurance or rule based flows of goods (Kreutzer & Sirrenberg, 2019).

Robotics

Robots are mechanical and computerized systems that can perform various tasks and are able to interact with the environment (Kreutzer & Sirrenberg, 2019; Stone et al., 2016). With AI machines can take over complex physical tasks (Cornelius, 2019).

Robots can be used for transport of goods and people, such as self-driving cars. Applications can be home and service robots (Stone et al., 2016). Robots can be used to manage inventory or for internal transport or as co-bots (BITKOM & DFKI, 2017; OECD, 2020). Robots can do a wide variety of service tasks, such as delivery, advise, or assistance (BITKOM & DFKI, 2017; Stone et al., 2016).

3.3.4.4. AI and ERP

AI in ERP is one of the main developments in the recent years (Bytniewski et al., 2020; Goundar, 2021; R. Wang, 2021). This trend is dominant for the development of i-ERPs (Basl & Novakova, 2019; Katuu, 2020). AI allows ERP to train and learn for accurate patterns and predictions (Goundar, 2021). 73% of the vendors plan to use AI in their ERP systems (Basl, 2016). The use cases vary between authors and the definition presented in this work, as the understanding of AI differentiates a lot.

Goundar (2021) explains that AI integration with ERP systems allows to reveal patterns and forecasts in a fast and accurate way. Tasks in ERP can be done more accurate, faster, cheaper, more effective,

with less manual work AI use cases could be digital assistants, chatbots for internal and external use, or predictions and planning (Gold, 2020). An AI infused ERP can support companies in making and taking over decisions and enhance automation. It can help to understand human preferences and values, give advice, optimize, or recognize anomalies (Anguelov, 2021). AI in an ERP system can develop and learn independently, to make decisions and derive indications (Gronau, 2021). AI in ERP can enable the understanding natural language for a user conversation (Vlasov et al., 2017). According to Basl and Novakova (2019) AI in ERP can be used for predictive management, data analysis and processing, and decision support. Operating costs can be reduced, and efficiency increased.

3.3.5. Machine Learning

ML is as an intelligent technology concept for i-ERP. The concept is introduced with some detail and the role in (i-)ERP is explained.

3.3.5.1. Concept of Machine Learning

Most modern AI approaches are based on ML (Russell & Norvig, 2021; Stone et al., 2016). ML is the overarching term for other methods, such as Neural Networks (NN). DL is an specific application of NN (Grzeszczak, 2020; Kreutzer & Sirrenberg, 2019).

- *“Machine learning: a computer observes some data, builds a model based on the data, and uses the model as both a hypothesis about the world and a piece of software that can solve problems”* (Russell & Norvig, 2021, p. 669).
- *“The machine’s ability to keep improving its performance without humans having to explain exactly how to accomplish all the tasks it’s given”* (Brynjolfsson & McAffe, 2017, p. 4).

ML are algorithms that evolve based on data (Cornelius, 2019). ML can identify correlations in data sets to make predictions (Buxmann & Schmidt, 2021). A large amount of high-quality data is required for learning (Kreutzer & Sirrenberg, 2019). ML is a paradigm shift in software creation, as developers no longer have to code and explain knowledge, but the software can learn independently based on data. ML opens new ways of automation, as it can grasp and understand things that are hard to write down for programmers and have a self-learning capability (Brynjolfsson & McAffe, 2017).

One can differentiate two types. In classification the outcome is a finite set of values, e.g., true/false. In regression the outcome is infinite, e.g., temperature (Russell & Norvig, 2021). Three types of learning are known: Supervised, unsupervised, and reinforcement learning (Cornelius, 2019). The most used and successful in recent years is supervised learning (Brynjolfsson & McAffe, 2017).

Supervised Learning: Using input-output pairs a machine learns a function that can give the right output to a unknown input of the same type (Russell & Norvig, 2021). The data for learning consist of so-called features (sample data points) and labels (results) (Cornelius, 2019). The algorithm learns to derive answers from a given data set with the highest possible precision. A set of sample data is used from which the algorithm can learn (training data). The algorithm learns the relation of features and labels. The algorithm is applied to a training data set and improved based on feedback. Once it is sufficiently accurate, it can be applied to unknown data and predict the most likely output (Kreutzer & Sirrenberg, 2019). The algorithm continues to learn and adopt when used (Cornelius, 2019).

A regression example would be an algorithm that gets input data such as the price, size, origin, maximum speed, etc. of cars and the price of the cars as labels. It learns from those data and is then capable of building a model and predicting the price of an unknown car (Kreutzer & Sirrenberg, 2019). An example for classification could be pictures of animals and the animal names as labels. The trained algorithm could now classify an unknown picture (Cornelius, 2019).

Unsupervised Learning: In unsupervised learning patterns are extracted from the data. Clusters and anomalies can be found (Cornelius, 2019). The ML program learns patterns based on unlabelled input data. No feedback is received in the learning process (Russell & Norvig, 2021). There are no predefined target values. The system must recognize similarities and patterns independently based on similar behaviours or characteristics (Kreutzer & Sirrenberg, 2019).

For example, many animal pictures are provided (features), but no labels are given. The algorithm must find categories by itself. The categorization is not predefined, so it can happen that the machine does an own characterization. This can lead to problems but also the discovery of new patterns that a human would not have recognized (Buxmann & Schmidt, 2021; Russell & Norvig, 2021).

Reinforcement Learning: The algorithm learns from rewards and punishments from its actions (Russell & Norvig, 2021). The goal is to learn an optimal strategy for a given problem (Buxmann & Schmidt, 2021). The algorithm knows the state of the environment, performs actions, and receives feedback. It learns the rules of the environment and the actions required for the maximum reward (Cornelius, 2019). At the start of the learning phase, the optimal solution path is unknown. The system must try out solutions independently in a trial-and-error process. This learning approach is suitable if only few training data are available, when the ideal outcome is unclear, or when learning from interactions with the environment is required (Kreutzer & Sirrenberg, 2019). It is suitable for planning processes, games, resource management, and robotics (Cornelius, 2019).

An example could be a chess robot playing multiple games. In the end of the game, it either won (receives reward) or lost (receives punishment). It then independently must decide which of its actions led to the positive or negative result. These actions must then be maintained or changed in order to improve the outcome (Russell & Norvig, 2021).

3.3.5.2. Artificial Neural Networks and Deep Learning

The goal of artificial neural networks (ANN) is the simulation of the human brain. It consists of nodes (neurons) and edges (synapses) (Buxmann & Schmidt, 2021). ANN form the basis for many ML applications and became possible through increased development of computing power and the availability of Big Data. In short, ANNs modify their code, i.e., they learn by determining relationships and patterns between features and labels and create a complex statistical model (OECD, 2020). One can differentiate three types of neurones (Figure 15) (Kreutzer & Sirrenberg, 2019).

- **Input Units (x):** Input data arrive at the input units. These are the data to input in the model to train the model or use it for prediction.
- **Hidden Units: (h1, hn):** They represent the units between input and output, there is at least one layer, but it can be a (nearly) infinite number.
- **Output Units (y):** The output units represent the output data of the model, i.e., the results.

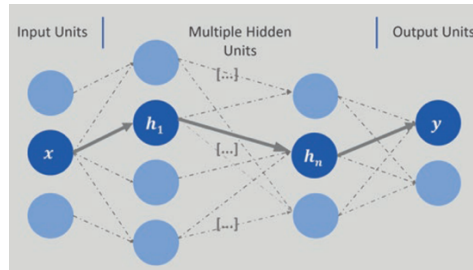


Figure 15 - Multilayer Artificial Neural Network (Buxmann & Schmidt, 2021, p. 14)

The input data is entered the system in the input units (x). Within the neuron, mathematical operations take place to determine the output of the neuron. They are based on an activation function. The neurones are connected via edges. Then all hidden units (h_1, h_n) of the model are passed. The input of the next neuron is the output of the previous one. The strength of the influence for the model of one neuron is determined by the so-called weight. Once reaching the Output Unit (y) the result of the model is shown, e.g., the class in a classification or the number value in a regression (Buxmann & Schmidt, 2021; Goodfellow et al., 2016). The rules in the nodes are constantly improved in course of learning to achieve the optimal result (Kreutzer & Sirrenberg, 2019).

DL is the use of multilayer (many hidden layers) ANN (Russell & Norvig, 2021). The availability increase of data and faster processors opened new possibilities (Buxmann & Schmidt, 2021; Kreutzer & Sirrenberg, 2019). The combination of a large amount of input data, many hidden layers, and optimization methods can detect deep patterns and correlations that previous algorithms did not recognize (Buxmann & Schmidt, 2021; Kreutzer & Sirrenberg, 2019). The advantage of DL algorithms is that they can make great use of BD. While in traditional ML models the quality of the predictions only increases up to a certain point with the amount of data, in a DL network more data leads to better results (Brynjolfsson & McAfee, 2017). The machine gradually assembles complex concepts from simpler elements, using a large number of layers and thus learning deep (Kreutzer & Sirrenberg, 2019).

3.3.5.3. ML and ERP

Authors agree that ML will be one of the next big developments in ERP (Bytniewski et al., 2020; Goundar, 2021; R. Wang, 2021). The trend builds on the previously introduced trends of IoT, BD, and CC (Tavana et al., 2020). According to a study by Basl (2016) ML is in present used by a few vendors, but the trend shows that 60% of vendors plan the use.

Complex, often unstructured, data can be processed rapidly and insights can be gained directly from ERP (Kenge & Khan, 2020). These developments enable companies to use their ERP for real time and very accurate insights (Tavana et al., 2020). The integration in ERP enables rapid access and analysis of information and automatic (Bytniewski et al., 2020). ML in ERP allows companies to store, manage, and analyse their data. They can gain value-adding insights in data and make better their decisions based on ML models (ElMadany & Mostafa Aref, 2022). ML in ERP can be used for optimization and supported/automated decision making (Majstorovic et al., 2020). Use cases can be management of a warehouse, e.g., demand and disruptions, to forecast demand (suggestions), verification of financial / accounting transactions, process and data integration, customer service, production processes, automation of sales, or selection of applicants in Human Resources (Tavana et al., 2020). ML in ERP allows the adoption to business rules based on experience, enabling process, planning, and prediction improvement and the learning of workflows (Jayender & Kundu, 2021). Proven use cases are fraud

detection with ML in ERP (Fuchs et al., 2021), inventory control (Farhat & Owayjan, 2017) prediction of equipment failures (Kohli, 2018), or forecast and improvement of human resources, machinery, and inventory management (Rupa et al., 2019).

3.3.6. Robotic Process Automation

RPA is as an intelligent technology concept for i-ERP. The concept is introduced with some detail and the role in (i-)ERP is explained.

3.3.6.1. Concept of RPA

According to Syed et al. (2020) RPA has seen a quick practical adoption whilst the academic literature does yet not deliver many foundations. RPA is not industry specific (Czarnecki & Fettke, 2021).

- „*Robotic Process Automation (RPA) emerges as software-based solution to automate rules-based business processes that involve routine tasks, structured data and deterministic outcomes*“ (Aguirre & Rodriguez, 2017, p. 65).
- “*Robotic process automation (RPA) is the application of technology that allows employees in a company to configure computer software or a “robot” to capture and interpret existing applications for processing a transaction, manipulating data, triggering responses and communicating with other digital systems*” (IRPAAI - Institute For Robotic Process Automation & AI, 2021, p. n.p.).
- “*RPA is an umbrella term for tools that operate on the user interface of other computer systems in the way a human would do. RPA aims to replace people by automation done in an ‘outside-in’ manner*” (van der Aalst et al., 2018, p. 1).

RPA is software that helps to automate processes (Hofmann et al., 2020). The RPA tools (software-based robots) act in the UI of a computer system and imitate a human (van der Aalst et al., 2018). The term robot in case of RPA is not a physical robot but a software based solution (Lacity & Willcocks, 2016). Van der Aalst et al. (2018) point out that RPA does not change IS, making RPA comparably easy and cheap to implement.

Repetitive, and simple tasks can be taken over by RPA, freeing up workers for value adding work (Aguirre & Rodriguez, 2017). Applications can be automated payment, data updates, or document generations (Lacity & Willcocks, 2016). RPA is not decoupled from humans. Humans set rules for the RPA bot and exceptions not covered by the rules require human intervention (van der Aalst et al., 2018). It is vital to optimize the process in advance, as RPA but does not change the process (Hofmann et al., 2020). The process performance and efficiency can be improved, processes become scalable, the error rate can be reduced, and security improved. Process compliance and auditability can be guaranteed (Hofmann et al., 2020; van der Aalst et al., 2018).

According to research the potential of RPA is not yet fully used (Hofmann et al., 2020; Lacity & Willcocks, 2016; van der Aalst et al., 2018). Traditional automation technologies allow automation of few, high frequency, cases. RPA opens a wide range of new automation opportunities with lower frequency. Full automation is not possible as very infrequent and exceptional cases still must be handled by humans (van der Aalst et al., 2018). Processes that contain unstructured data (e.g., text, video, images) are not suitable for traditional RPA (Langmann & Turi, 2021). A new development is intelligent RPA (i-RPA) (Hofmann et al., 2020; van der Aalst et al., 2018).

3.3.6.2. Intelligent RPA

In a study Viehhauser (2020) showed that the cognitive capability of recent RPA solutions is limited. AI in RPA helps to overcome limitations of classical RPA, making it more flexible and adoptive (Herm et al., 2021). RPA repeatably applies predefined rules and i-RPA is self-learning (Hofmann et al., 2020). Intelligent RPA is characterized by minimizing human training and the automation of complex tasks, including decision making (Chakraborti et al., 2020).

I-RPA can extract information from unstructured data, such as audio, text, or images, and has the ability to prioritize tasks (Schatsky et al., 2016). Intelligent robots are adoptable and can handle non-standard, low frequency cases, cases during system errors, unexpected behaviours, or changing structures. This results in robustness and new automation opportunities (van der Aalst et al., 2018). The robots are not based on predefined rules, but learn based on their experience and adopt their configuration (Hofmann et al., 2020). Examples of technologies used with i-RPA are ML, Predictive Analytics, NLP, Computer Vision, or BD (Langmann & Turi, 2021).

Figure 16 shows i-RPA vs. RPA. RPA focusses on the automation of individual, repetitive tasks with a limited scope, shown in grey. The focus of intelligent automation is wider. The bot performance is continuously monitored, and the data sources are updated. Based on the data and the performance automation opportunities are identified and the bot is improved (Chakraborti et al., 2020).

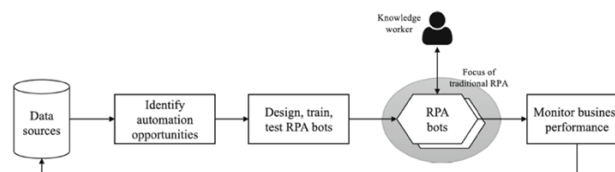


Figure 16 - i-RPA bot in comparison to traditional RPA (Chakraborti et al., 2020, p. 220)

A simple example of i-RPA is the change of the interface of an application. A traditional RPA robot would fail as it cannot apply the rules trained. Human intervention is needed for adoption to the new environment. An intelligent robot could adopt to the new interface by itself and work without human intervention (van der Aalst et al., 2018). An example to illustrate the use RPA and i-RPA together is a simple ERP invoice payment system. In a manual process the accountant must handle the invoice, scan, and upload it in the ERP, extract, and then book the consumption values manually. The automated process with (i-)RPA could replace four out of five manual steps. The accountant handles the invoice, the scan and upload of the invoice can be done by a traditional RPA. The extraction of consumption values can be done by an i-RPA robot based on NLP. The extracted information can then be booked by another traditional robot (Czarnecki & Fettke, 2021).

3.3.6.3. RPA and ERP

The execution of business processes in ERP requires easy, repetitive, and time-consuming tasks, RPA promises a solution (Aguirre & Rodriguez, 2017). It is important for enterprises to integrate RPA in ERP (Katu, 2020). RPA can compensate deficits in ERP systems in terms of openness, networking, and flexibility (Bingler, 2020). RPA can be used in ERP to provide, control, and monitor data (Gajra et al., 2020). Manual steps can be automated and executed according to rules. RPA is integrated at the top architectural level of an ERP model, the user interface layer. RPA can automate and accelerate

processes without changing existing ERP systems (Gronau et al., 2021). In general there are three areas of application of RPA in ERP (Bingler, 2020).

- **RPA as “Integrator”:** RPA can be used to map interfaces, APIs and support the ERP in the integration of other systems or services.
- **RPA as “Ergonomics Patch”:** RPA can take over repetitive and error-prone tasks and help the company automate processes.
- **RPA as “Test Robot”:** RPA can help companies test new software or updates based on defined rules and thus ensure faster releases.

Gajra et al. (2020) show that repetitive ERP processes can be automated with success. They argue that a similar integration could be reached in other organizations and use cases. They also see the need and opportunity to integrate intelligent technology concepts, such as AI and ML with RPA in ERP to automate more processes. Kaya et al. (2019) found that RPA in ERP can reduce human work, costs, and increase efficiency, by reducing errors and enhancing accuracy. RPA and i-RPA in ERP can process transactions, change data, trigger jobs, and communicate. The use of traditional RPA is expected to decrease, but cognitive RPA is expected to increase, e.g., for customer self-service (Bingler, 2020).

3.3.7. Data Analytics

DA is as an intelligent technology concept for i-ERP. The concept is introduced with some detail and the role in (i-)ERP is explained.

3.3.7.1. Concept of Data Analytics

Davenport and Harris (2007, p. 7) describe Analytics as *“the extensive use of data, statistical, quantitative analysis, exploratory and predictive models, and fact-based management to drive decisions and actions. The analytics may be input for human decisions or may drive fully automated decisions.”* Data Analytics is an interdisciplinary field. In modern analytics computer programs are applied to large data sets to analyse data (Runkler, 2020). According to Davenport (2018) many modern AI systems are based on statistics and other analytics methods.

The basic workflow in Data Analytics has multiple phases. First data must be collected, assessed, and the ones considered suitable for the project are selected. The next step is the filtering and cleaning of the data. The cleaned data can then be visualized and analysed using different techniques. The results from the analysis can be used for interpretation and evaluation (Runkler, 2020).

Seiter (2019) proposes to categorize analytics in two areas, namely Business Intelligence and Advanced Analytics and uses the popular Gartner “Value Escalator” to separate the areas (Figure 17).

Descriptive Analytics: What happened?

This is a form of past-oriented data analysis. The data is described, and simple analyses and comparisons are performed to identify patterns or anomalies. Data visualization is very basic (EBA, 2020; Seiter, 2019).

Diagnostic Analytics: Why did something happen?

This is a form of past-oriented data analysis. Anomalies can be identified based on descriptive analysis, hidden associations and causal relationships can be discovered (EBA, 2020; Seiter, 2019).

Predictive Analytics: What will happen?

This is a form of future-oriented data analysis to predict future developments based on past data. To improve the accuracy of the prediction, advanced data mining and statistical techniques are used (EBA, 2020; Seiter, 2019).

Prescriptive Analytics: What needs to be done?

This is a combination of past-oriented and future-oriented data analysis, to recommend an optimal solution based on data. Complex statistical techniques enable accurate modelling of solutions and their impact (EBA, 2020; Seiter, 2019).

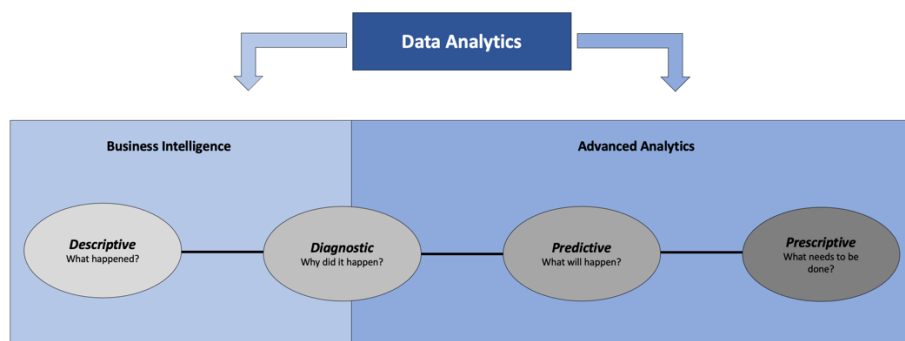


Figure 17 - Fields of Data Analytics (own figure, based on (Oehler, 2019; Seiter, 2019))

BI can be classified in descriptive analytics and the beginnings of diagnostic analytics, it is past-oriented. AA encompasses diagnostic analytics, predictive, and prescriptive analytics. The focus is on the future. Despite other approaches this categorization presented is used as it complies with the ideas of i-ERP literature. Authors mentioned AA as part of i-ERP, while BI was already integrated with ERP in the past.

3.3.7.2. Business Intelligence

“BI – to present data to business people so they can use it to gain knowledge” is a general and high level definition by Sherman and Imhoff (2015, p. 15). According to Davenport and Harris (2007, p. n.p.), BI can be defined as: *“a set of technologies and processes that use data to understand and analyze [sic!] business performance”*. A modern BI system offers specific data dashboards and allow data queries and presentation trough for example scorecards, online analytical processing, tables, or basic visualizations (Sherman & Imhoff, 2015).

BI is based on historical data and allows description of and diagnosis with data (Seiter, 2019). The focus is on what has happened and why it has happened. Modern BI uses dashboards, with real time, visualized, data available on multiple devices (Sherman & Imhoff, 2015). BI can give insights in trends, operations, and changes (Laudon & Laudon, 2019).

The data source of BI are relational (structured) data, mostly from enterprise applications such as ERP and CRM. They are integrated into the Data Warehouse (a central data repository for BI) and made

available for BI analysis and insights (Sherman & Imhoff, 2015). The data from internal, systems can be complemented by external data (Laudon & Laudon, 2019).

3.3.7.3. Advanced Analytics

Advanced Analytics allows a holistic view on operations and environment. It is an umbrella term for multiple analytics techniques for gaining and analysing data and predicting outcomes (Bose, 2009). A widely used definition comes from Gartner (2021a, p. n.p.): *“Advanced Analytics is the autonomous or semi-autonomous examination of data or content using sophisticated techniques and tools, typically beyond those of traditional business intelligence (BI), to discover deeper insights, make predictions, or generate recommendations.”* AA adds a future-oriented component to BI. Based on historical data methods can be applied to provide future-oriented perspectives (Sherman & Imhoff, 2015).

Advanced Analytics is based on methods of classical statistics (Oehler, 2019). BD is often mentioned together with AA. It can be used to understand BD and to base actions (EBA, 2020). Big Data Analytics is the application of AA to BD (Sherman & Imhoff, 2015). In this context, In-memory computing enables the rapid access and analysis of large data amounts in a short period of time using the computer memory (Laudon & Laudon, 2019).

According to Sherman and Imhoff (2015) Advanced Analytics is composed of two main areas, namely Predictive Analytics and Data Mining.

Predictive Analytics: Predictive Analytics is a *“Technology that learns from experience (data) to predict the future behaviour of individuals in order to drive better decisions”* (Siegel, 2016, p. 33). Data and algorithms are used to create forecast models. Models can be of various types, e.g., mathematical formulas, decision trees, or "if/else" rules (Seiter, 2019). Along with the algorithm, data and time play a vital role (Boobier, 2018). Predictive Analytics is not a specific tool but a capability. Statistical and other empirical methods are used to make predictions or assess quality of such. The practical usability is high and it can be used for theory building (Shmueli & Koppius, 2011).

Data Mining: Laudon and Laudon (2019, p. 628) define Data Mining as the *“analysis of large pools of data to find patterns and rules that can be used to guide decision making and predict future behaviour.”* The goal is to find nonobvious patterns (clusters, anomalies, dependencies) in data which that cannot be found with simple analysis technologies (Sherman & Imhoff, 2015). Data Mining is discovery driven. Business rules are derived from patterns and relationships. It supports decision making, modelling, and forecasting. The main features of Data Mining to collect and aggregate information are associations (Occurrence linked to single event), sequences (Events linked over time), classifications (Definition of groups through patterns of predefined characteristics), clusters (Groups without predefined characteristics), forecasts (Use of existing values to forecast their future) (Laudon & Laudon, 2019). Examples for the use of Data Mining are verifications, root-cause analysis, or scenario modelling and analysis (Bose, 2009).

Two main sub-fields of Data Mining are Text Mining and Web Mining (Bose, 2009; Laudon & Laudon, 2019). Text Mining allows to discover knowledge and filter information (Bose, 2009) Text is unstructured data in natural language, e.g., emails, contracts, transcripts, or reports (Laudon & Laudon, 2019). Web mining is the discovery of patterns, relations, and information from web. Modern

forms can extract information from image, audio, and video (Laudon & Laudon, 2019). A main use case are recommender systems to support the user with decisions (Bose, 2009).

Visualization is used to present and communicate the results to a user and to extract value from insights. In BI, the first graphical elements and diagrams were introduced, in AA more sophisticated, goal-oriented visualisations are used to show the relationships and patterns (Sherman & Imhoff, 2015). Advanced visualization tools are used derive value from AA insights. For the best possible insights Sherman and Imhoff (2015) recommend providing a self-service BI to allow individualized access to data across sources, the advanced visualization of data, and the combination of analytics and visualization to allow best possible business insights.

3.3.7.4. Dark Analytics

Dark Data are „*the information assets organizations collect, process and store during regular business activities, but generally fail to use for other purposes for example, analytics, business relationships and direct monetizing*” (Gartner, 2021b, p. n.p.). Dark Analytics the analytics of Dark Data. Dark Analytics extends the use of Advanced Analytics to a vast number of new data sources and opportunities (Deloitte, 2017). Many companies and scientists focus on the data that is visibly available. Dark Data can be of high value, but no one is aware of its existence (Schembera & Durán, 2020). Dark Analytics offers the chance to enhance the competitive advantage and shape future business models and processes (Ahmed & Pathan, 2018). Examples of dark data can be emails, documents, presentation files, IoT data, multimedia files (audio, video, images), geographical data, log files, etc (Deloitte, 2017). They can be in various forms and formats or even be meta data of other data (Ahmed & Pathan, 2018). In general, one can decide three groups of data for Dark Analytics (Deloitte, 2017):

Untapped data already in your possession: This can be structured or unstructured data that is already available but not used. Examples are unlinked silos of data, or unstructured data that is not available in relational databases and the technology to use it was missing (Deloitte, 2017).

Non-traditional unstructured data: The use of new technologies and methods from AI and ML, enables insights in unstructured data such as multimedia (images, text, sound, video), which was previously not possible (Deloitte, 2017).

Data in the deep web: The deep web is not indexed (structured) like the "traditional" web. It cannot be accessed with standard browsers, so data remains hidden (Ahmed & Pathan, 2018). New methods, such as data mining, allow better access other methods are in research (Deloitte, 2017).

Ahmed and Pathan (2018) make clear that is not always easy to access and use dark data, but the opportunity should be evaluated. Ignoring data can result in unused opportunities. Accordingly, Deloitte (2017) highlight the importance of Dark Analytics but point out that it no always adds value.

3.3.7.5. Data Analytics and ERP

The integration of BI with ERP systems was an early trend (Basl, 2018). BI uses the information stored in ERP and extends the reporting and analytics capabilities of ERP which leads to more accurate decisions (D. C. Chou et al., 2005). BI tools are available as modules to ERP or as standalone applications integrated with ERP (Suman & Pogarcic, 2017). BI systems heavily rely on the data the ERP system generates (Hawking & Sellitto, 2010; Polkowski et al., 2016). According to Hawking and

Sellitto (2010) BI systems consolidate, transform, and analyse data obtained from the ERP. The idea of BI in ERP is to give insight in the data collected by the ERP system, such as transactional data (Zhao & Shi, 2008). BI allows the creation of reports, tables, graphics, dashboards, scorecards, or key performance indicators (Suman & Pogarcic, 2017). Zhou (2012) describe that BI and ERP complement each other. ERP is for the operation and BI is a tool for decision making and reduces information costs and improves decision making.

New ERP solutions have analytical capabilities, such as reports, data visualization, or embedded analytical tools (Babu & Sastry, 2014). Real-time analytics from large data sources can be used in modern ERPs (Jayender & Kundu, 2021). Majstorovic et al. (2020) show that Big Data Analytics is essential for modern ERP systems for data visualization, data integration and intelligence, the creation of data driven models, or increasing automation. Babu and Sastry (2014) created a framework integrating Data Analytics (Predictive Analytics) in an ERP to improve operational decision making. Advanced Analytics in ERP enables finding patterns, deriving meaning, making decisions and recommendations, and leads to more intelligence. Predictive Analytics in ERP systems enhances the accurate determination of outcomes, likelihoods and allows informed decisions. New ERP functionalities improve analytics capabilities beyond basic internal BI towards Big Data Analytics considering external data, resulting in a more complete picture of the enterprise performance (Hurbean & Fotache, 2014).

4. PROPOSAL OF ARTIFACTS

In this chapter, the artifacts of this thesis are proposed. The following artifacts are created:

- **i-ERP Concept:** The concept should give a categorised overview of the features of an i-ERP to understand the functions and necessities. It should also show which technologies play a role and in what way.
- **i-ERP Model:** The i-ERP model should graphically represent the concept to understand the components and interrelationships of i-ERP.
- **i-ERP Taxonomy:** The taxonomy is intended to show possible development stages starting from a traditional ERP to i-ERP.
- **i-ERP Assessment:** The assessment makes it possible to classify an existing system into the taxonomy levels of the i-ERP, to give a clear overview of the state of the system, and to make suggestions on how the system can become more intelligent.

The artifacts are based on what was learned in the literature review about ERP, i-ERP, and i-ERP technologies. Figure 18 describes the workflow and the interrelationships of the artifacts.

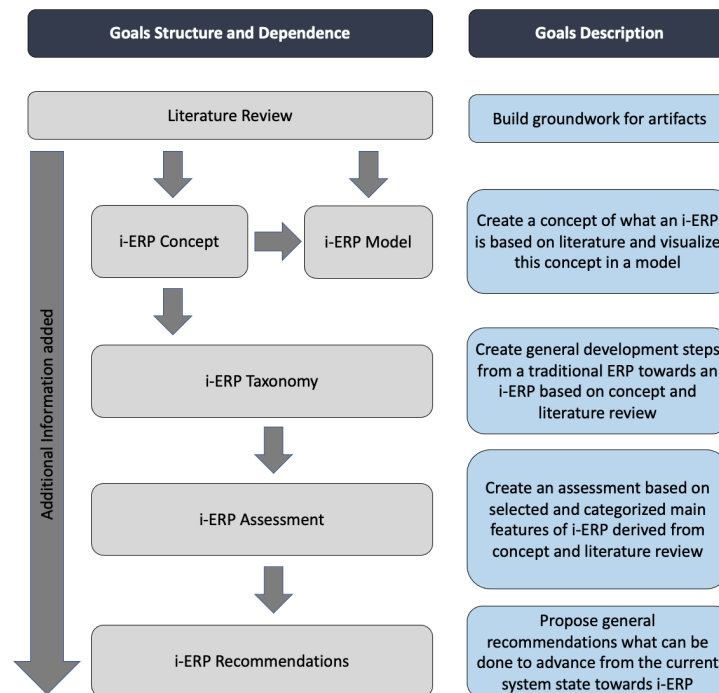


Figure 18 - Artifact creation process and relation

The literature review is the fundament of the work. The i-ERP concept should be based on functions and features of an i-ERP and is strongly based on a synthesis of the different sources of literature review. The model represents the interrelationships and features of i-ERP based on the concept. The structure of the concept is adopted in the further course of the work and a taxonomy is created. The taxonomy is then transformed into an assessment to evaluate a system intelligence. The final step are recommendations based on the assessment. The artifacts can be divided into two main areas:

1. Functions, composition, and appearance of an i-ERP: i-ERP Concept, i-ERP Model

2. Development stages, system state, and system advancement: i-ERP Taxonomy, i-ERP Assessment

4.1. ASSUMPTIONS

The purpose of this chapter is to briefly describe how the findings from the literature review are used to frame the creation of the artifacts and to highlight why the artifacts are presented the way they are. Based on what has been explored in the literature review on ERP, i-ERP, and i-ERP technologies, the artifacts are based on the ideas of various authors and the logical conclusion from the content learned and creativity, to construct innovative artifacts like recommended by Hevner (2004). It is not intended to be a summary of every detail used in the artifacts but an overview of the most important information. It should be proven that the author is able to create artifacts based on the knowledge gathered. The literature review is split in three sections.

The ERP part helped to understand what ERP systems are and why organizations implement them, how they differ, and how they evolved over time. Important conclusions can be drawn about how the i-ERP, based on the basic idea, can be built, how specific or general the approach can be, and how possible development stages of ERP looked like in the past and could look like in the future. The part on i-ERP systems provided insights into the functions and possible composition of i-ERPs. It also showed which technologies play a role and how. Possible development stages can be derived. The part about technologies provided information about technologies used to obtain a certain function. It helps to derive development stages from the functional understanding of the technologies

In the ERP literature, some main ideas could be derived that also play an essential role for i-ERPs. ERP systems have certain main characteristics that should not disappear in future developments, the main ones are displayed in table 8.

| Characteristic | Author(s) |
|---|--|
| Collection of software modules (modularized) | e.g., (Davenport, 1998), (Bahssas et al., 2015), (Rashid et al., 2002), (Bytniewski et al., 2020) |
| Centralized database | e.g., (Davenport, 1998), (Rashid et al., 2002), (Bytniewski et al., 2020), (Jacobs & Weston, 2007) |
| Integrated modules and information flow | e.g., (Nazemi et al., 2012), (Jacobs & Weston, 2007), (Rashid et al., 2002), (Bytniewski et al., 2020) |

Table 8 - ERP characteristics summary

- ERP systems have seen a gradual development. The evolution is based on changes in the business environment and technical developments. The incorporation of new, intelligent technologies is the next logical step in development. The i-ERP is the next logical development step (Bahssas et al., 2015; Majstorovic et al., 2020; Rashid et al., 2002). However, it can be assumed that an i-ERP will also adopt the basic structures of a traditional ERP.
- ERP systems are composed of different modules that are all connected to a central database. The individual modules can fulfil different functions in the company and the combination and number of modules is highly individual (Gronau, 2021). It can be concluded that a potential i-ERP will not look the exact same for every company.
- ERP systems have their roots in the manufacturing industry. Today, ERP systems can be found in all kinds of industries (Gronau, 2021). The use and functions can be very different. However, the literature reviews showed that general functionality of the systems is the same in all cases,

which makes a general approach appropriate. It must be understood that the composition of ERP systems can be very different, but the main characteristics the same. A general i-ERP concept does not need to distinguish between the different areas as the commonalities prevail.

- ERP systems have several advantages for companies, these reasons why companies implement ERP should not be hindered by an i-ERP. On the other hand, there are disadvantages, or reasons why companies hesitate to implement ERPs. An i-ERP should avoid and reduce these disadvantages, so that i-ERPs can be used in more companies, because the benefits outweigh the disadvantages and companies see an economic advantage in i-ERPs.

In the literature review, some of the main features of i-ERP were described.

- I-ERP systems do not lose the traditional ERP functions (Accenture, 2019). Meaning the i-ERP idea can be based on ERP main characteristics and literature.
- I-ERP systems should have the intelligent functions / technologies integrated into core and these should not only be offered as an add-on (Accenture, 2019). The i-ERP should have a core model where the intelligent technology concepts are in.
- The functionalities of i-ERP are mostly based on data (e.g., Bouchemal & Bouchemal, 2019; Gold, 2020; Kenge & Khan, 2020; Morris et al., 2016). Data should be internal and external (Rizza & Lava, 2021). Most intelligent functions of the i-ERP are based on the data it collects and processes (Gold, 2020; Slowik & Burian, 2020). The central integration of different data sources should therefore be an important component.
- An i-ERP can sense and understand the environment, to act autonomously based on its continuous learning from data and its own actions (Gold, 2020). These three steps should become visible.
- Feedback plays an essential role in the learning and improvement process of i-ERP (Becker et al., 2021; Gold, 2020). Learning is vital for the i-ERP functions (Bauer & Bingler, 2020; Morris et al., 2016).
- The role of the user in the i-ERP is shifting away from a manual system to an automated and self-learning partner for the user (Rizza & Lava, 2021). This means that the user is no longer the main driver of the actions in the system, but the system itself.
- The LR shows that the functions and features of i-ERP can be summarised in different ways. The author Morris et al. (2016) proposes a categorisation of the i-ERP characteristics into the three dimensions Data, Process, UX. These dimensions seem to be consistent with the ideas of other authors and can be roughly adopted for this work.

The authors in literature review list several features i-ERPs should have to enable new functionality. The following table 9 categorizes the main opinions of the authors. It will be used in the further course.

| Characteristic | Author(s) |
|-------------------------------|---|
| Flexible Application | (Morris et al., 2016), (Accenture, 2019), (Goundar, 2021), (Jenab et al., 2019), (Rizza & Lava, 2021) |
| Flexible Database | (Rizza & Lava, 2021), (Accenture, 2019), (Basl & Novakova, 2019), (Majstorovic et al., 2020), (Gold, 2020), (Morris et al., 2016) |
| Variety of datatypes | (Rizza & Lava, 2021), (Gold, 2020), (Cognizant, 2019), (Majstorovic et al., 2020), (Gold, 2020), (Morris et al., 2016) |
| Real-Time Environment Sensing | (Cognizant, 2019), (Majstorovic et al., 2020), (Basl & Novakova, 2019) |
| Real-Time Complex Processing | (Bouchemal & Bouchemal, 2019), (Kenge & Khan, 2020), (Gold, 2020) |

Table 9 - General i-ERP requirements summary

In the literature (possible) i-ERP functions could be found by different authors. The functions are very similar. In the following table 10, the functions were categorized and grouped according to the dimensions of Morris et al. (2016). This categorization is used for the following work.

| Characteristics | Authors |
|--|--|
| Data Dimension | |
| Personalized, Context Specific, Real Time Data Provision | (Gold, 2020), (Morris et al., 2016), (Rizza & Lava, 2021), (Accenture, 2019) |
| Advanced Data Insights | (Bauer & Bingler, 2020), (Bouchemal & Bouchemal, 2019), (SAP, 2018), (Rizza & Lava, 2021), (Gronau, 2021) |
| Intelligent Creation and Improvement of Data | (Deloitte, 2021), (Gronau, 2021) |
| Process Dimension | |
| Autonomous Process Execution | (Accenture, 2019), (Goundar, 2021), (Morris et al., 2016), (Gold, 2020), (Basl & Novakova, 2019), (Jenab et al., 2019), (Donatelli et al., 2020), (Deloitte, 2021) |
| Process Optimization | (SAP, 2018), (Accenture, 2019), (Goundar, 2021), (Gold, 2020), (Rizza, 2020), (Deloitte, 2021), (Donatelli et al., 2020) |
| Process Redefinition | (SAP, 2018), (Accenture, 2019), (Goundar, 2021), (Morris et al., 2016), (Slowik and Burian, 2020), (Gronau, 2021) |
| UX Dimension | |
| Proactive User Assistance | (Morris et al., 2016), (SAP SE, 2017a), (Bauer & Bingler, 2020), (SAP SE, 2017a), (Bingler, 2020) |
| Conversational System Interaction | (Morris et al., 2016), (Gold, 2020) |
| Responsive User Interface and Design | (Slowik and Burian, 2020), (Morris et al., 2016), (SAP SE, 2017a), (SAP SE, 2018), (Rizza & Lava, 2021) |

Table 10 - i-ERP characteristics sorted by i-ERP dimension

- To deliver intelligent functions, an i-ERP comprises not one but multiple technologies (Bouchemal & Bouchemal, 2019). From this it can be assumed that an i-ERP is composed of several technology concepts which are part of the system with different degrees of intensity. Some of them are prerequisite for the intelligent features and some enable the intelligent features. In the LR, the opinions of other authors were also presented. In table 11 the most mentioned technologies, classified by prerequisite technology concepts and intelligent technology concepts are shown.

| Area | Technology | Authors |
|---|-----------------------------------|---|
| Prerequisite Technology Concepts | Cloud Computing | (Accenture, 2019), (Goundar, 2021), (Morris et al. 2016), (Basl & Novakova, 2019), (Majstorovic et al., 2020), (Slowik and Burian, 2020) |
| | Internet of the Things | (Goundar, 2021), (Cognizant, 2019), (Basl & Novakova, 2019), (Majstorovic et al., 2020), (Bouchemal and Bouchemal, 2019) |
| | Big Data | (Goundar, 2021), (Cognizant, 2019), (Majstorovic et al., 2020), (Morris et al. 2016), (Slowik and Burian, 2020), (Bouchemal and Bouchemal, 2019), (Rizza & Lava, 2021) |
| Intelligent Technology Concepts | Artificial Intelligence | (Accenture, 2020a), (Morris et al. 2016), (Slowik and Burian, 2020), (Bouchemal and Bouchemal, 2019), (Donatelli et al. 2020), (Rizza & Lava, 2021), (Wang, 2021), (SAP SE, 2018) |
| | Machine Learning | (Accenture, 2020a), (Jenab et al., 2019), (Morris et al. 2016), (Rizza, 2020), (Slowik and Burian, 2020), (Bouchemal and Bouchemal, 2019), (Rizza & Lava, 2021), (SAP SE, 2018) |
| | Data Analytics | (Accenture, 2020a), (Jenab et al., 2019), (Morris et al. 2016), (Slowik and Burian, 2020), (Bouchemal and Bouchemal, 2019), (Rizza & Lava, 2021), (Wang, 2021), (SAP SE, 2018) |
| | Robotic Process Automation | (Accenture, 2020a), (Rizza, 2020), (Donatelli et al. 2020), (Rizza & Lava, 2021), (Wang, 2021) |

Table 11 - i-ERP technology concepts summary

4.2. I-ERP UNDERSTANDING

In this sub-chapter, first, an i-ERP concept is derived closely from the literature review. It illustrates the functions of an i-ERP and highlights the role of different technology concepts. In the second part, an i-ERP model is shown. It is derived from the concept and shows the main components and interrelationships of an i-ERP.

4.2.1. i-ERP Concept

The concept of i-ERP is based on the studies from the literature review. It is a business-oriented concept and non-technical approach.

The concept has the following objectives:

- Understand on a high level the main i-ERP functions and characteristics
- Understand high level goals of the main i-ERP functions and characteristics
- Understand on a high-level the role of selected technologies in i-ERP

The proposed concept is graphically summarized in figure 19.

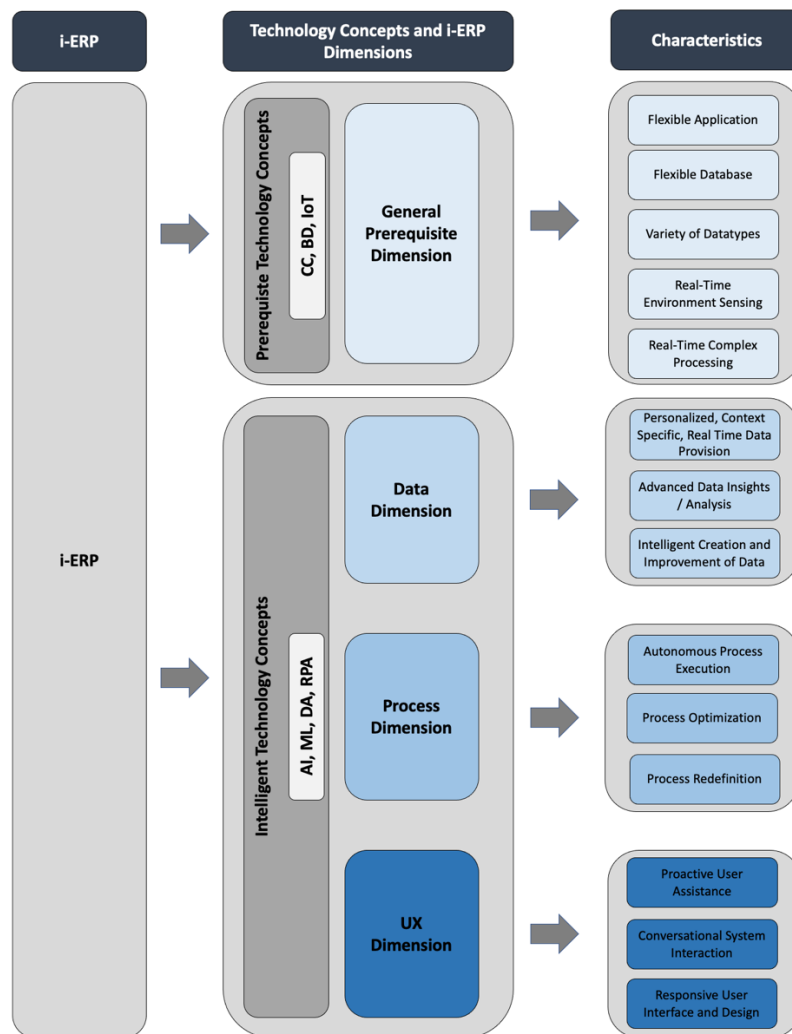


Figure 19 – Proposed i-ERP high level concept

This concept enables an integrated understanding of the characteristics of ERP and the high-level role of the technologies.

The i-ERP concept is composed of two types of technologies shown in the graphic above:

- **Prerequisite Technology Concepts:** Technology concepts that enable the intelligent, namely Cloud Computing, Big Data, and Internet of the Things
- **Intelligent Technology Concepts:** Technology concepts that deliver the intelligent features, namely Artificial Intelligence, Machine Learning, Data Analytics, Robotic Process Automation

The intelligent technology concepts are merged with the three i-ERP dimensions and characteristics from the literature review and extended by a fourth dimension, general prerequisite dimension, depicting the characteristics of the prerequisite technology concepts.

- Prerequisite Technology Concepts result in the **General Prerequisite Dimension** and the respective characteristics.
- Intelligent Technology Concepts result in the **Data, Process, and UX Dimension** and the respective characteristics.

Colours were assigned to the dimensions in table 12. They are used in further course of the work.

| Dimension | Colour |
|-------------------|--------|
| General Dimension | |
| Data Dimension | |
| Process Dimension | |
| UX Dimension | |

Table 12 - i-ERP dimension colour assignment

In course of this concept, the four dimensions are defined as follows.

1. **General Prerequisite Dimension:** This dimension is intended to address characteristics and functions that are prerequisites for an ERP to have intelligent functions. It is about characteristics of the system and not about business prerequisites (such as availability of data, skilled workforce, budget, etc.).
2. **Data Dimension:** This dimension is about the access to and insights into data that i-ERP gathers or creates and how this data is visualized for the user.
3. **Process Dimension:** This dimension is about flexible automation, optimization, and redefinition of digitized business processes mapped in i-ERP.
4. **UX Dimension:** This dimension describes i-ERP characteristics that make it a partner of the user to work better, faster, and more efficient with the application and interact with the application in the easiest way.

A uniform tabular structure is used for to describe the dimensions of the concept. It is depicted in table 13.

| Dimension | | | | | | |
|-------------------------|----------------------|------------------|-----------------|-----------------|-----------------|-----------------|
| Characteristic | Description | Goal(s) | Tech 1 | Tech 2 | Tech 3 | (Tech4) |
| Characteristic X | Description X | Goal(s) X | Use Case | Use Case | Use Case | Use Case |
| Characteristic Y | Description Y | Goal(s) Y | | | | |

Table 13 - Uniform tabular structure for i-ERP dimensions

The dimension is shown on top of each table. It is broken down into the characteristics, depicted in the leftmost column (in the example "Characteristic X, Y"). The respective characteristic is then described (in the example "Description X, Y"). In the next column, some main goals of this characteristic are derived (in the example "Goals X, Y").

The following columns show, on a high level, the possible roles of the technology concepts for the respective dimension, overarching all characteristics. In the General Prerequisite Dimension, the three Prerequisite Technology Concepts (in the example "Tech 1, 2, 3") are used and in the other three dimensions the four Intelligent Technology Concepts (in the example "Tech 1, 2, 3, 4") respectively. Possible high level use cases are presented (in the example "Use Case"). The technology use cases are the understanding of the technologies and i-ERP from the literature consulted. It is impossible within the scope and general approach of this work to highlight all use cases of the technology concepts. Therefore, they are limited to key use cases based on the i-ERP functions and kept to a very general level. This complies with the business view of this work.

In the following the concept is described for the four dimensions in tables 14 to 17.

| General Prerequisite Dimension | | | | | |
|--------------------------------------|--|--|--|--|--|
| Characteristic | Description | Main Goal(s) | Cloud Computing | Big Data | IoT |
| Flexible Application | Flexible application for new functions, updates, and/or upgrades. | <ul style="list-style-type: none"> System flexibility Up-to-date system | <ul style="list-style-type: none"> Provide scalability for data storage Provide scalability and rapid processing power Vendor managed system allows rapid and easy updates and upgrades Flexible system for customization (no changes of IS infrastructure) Accessibility from multiple devices and locations, local and mobile | <ul style="list-style-type: none"> Handling of different data types Handling of high data volumes Handling of structured, semi-structured, and unstructured data Support a high volume, variety, velocity, veracity, value of data Enable data driven approaches in i-ERP (intelligent technologies based on data) Work with multiple traditional and non-traditional data sources Preparation of all types of data for use | <ul style="list-style-type: none"> Track and Monitor assets, goods, people in the physical environment of an organization Real Time data availability High accuracy of available data Extendable and flexible data source Collect, review, and process data Foundation for automation, optimization, and insights Source new data from the organization |
| Flexible Database | Scalable database for high data volumes in different forms and formats. | <ul style="list-style-type: none"> Use of all data (no restrictions in quantity) Data availability for intelligent functions | | | |
| Variety of Datatypes | Support of structured, semi-structured, and unstructured data handling. | <ul style="list-style-type: none"> Use of all data (no restrictions in type) Data fundament for intelligent functions | | | |
| Real-Time Environment Sensing | Sense the required physical environment in real time, e.g., assets, goods, people. | <ul style="list-style-type: none"> Real-Time and accurate data availability Monitoring, tracking, insights | | | |
| Real-Time Complex Processing | Handle complex computation tasks reliable, fully scalable, and in real time (in-memory). | <ul style="list-style-type: none"> Processing fundament for intelligent functions | | | |

Table 14 - i-ERP Concept: General Prerequisite Dimension

| Data Dimension | | | | | | |
|---|---|--|--|--|---|--|
| Characteristic | Description | Main Goal(s) | AI | ML | DA | RPA |
| Personalized, Context Specific, Data Provision | Data access / provision in real time personalized to the individual using the system and its context (task and environment). | <ul style="list-style-type: none"> • Rapid data access • Targeted data provision | <ul style="list-style-type: none"> • Preparation and cleaning of data • Understanding of data in image, audio, text etc. • Creation of data in image, audio, text etc. • Creation of recommendations, rule-based interpretation of data (Expert Systems) | <ul style="list-style-type: none"> • Learn user individual workflows • Learn workflows / actions in specific contexts • Classification, forecasting, and correlations (e.g., verifications, anomalies, errors, weak signals) • Learn importance of specific data / insights and create new KPIs, reports, etc. | <ul style="list-style-type: none"> • Prediction e.g., behaviours, events, needs • Real-time creation of data analytics/KPIs/ reports • Create, analyse, evaluate scenarios/ recommendations / models • Root causes • Analytics of Dark Data, e.g., web, text, audio, image • Find anomalies, dependencies, patterns, relationships, clusters, sequences, or associations • Intelligent visualization | <ul style="list-style-type: none"> • Insert and change data in the system • Generation of documents / reports / KPIs based on predefined rules |
| Advanced Data Insights | Provision of intelligent insights in all types of data. New discoveries through e.g., predictions, patterns, classifications, statistics etc. Use of advanced visualization techniques. | <ul style="list-style-type: none"> • Data insights • Decision and planning fundament | | | | |
| Intelligent Creation of Data | Creation of reliable and accurate data autonomously and creatively, such as complex scenarios, explanations, root causes, new KPIs, reports, etc. | <ul style="list-style-type: none"> • Availability of information • Data quality improvement • Decision and planning fundament | | | | |

Table 15 - i-ERP Concept: Data Dimension

| Process Dimension | | | | | | |
|-------------------------------------|---|--|---|--|--|---|
| Characteristic | Description | Main Goal(s) | AI | ML | DA | RPA |
| Autonomous Process Execution | Automation of repetitive and non-repetitive operational, tactical, and strategic internal and external ERP processes. Judgment, prioritization, and decision-making capabilities. Real time reaction and adoption to changes. | <ul style="list-style-type: none"> Increased efficiency and speed Improved quality | <ul style="list-style-type: none"> Voice, Text, and/or Image recognition / analysis / processing for automation, understanding of data, or monitoring Judgement, prioritization, decision making, recommendations, or planning based on predefined / learned rules (e.g., Expert Systems) | <ul style="list-style-type: none"> Learn how to reach process outcomes (built / understand business rules), find optimal solution path Optimize planning and scheduling Learn rules for judgment, prioritizations, decisions, verification, or matching Forecast changes Detect anomalies in process or environment | <ul style="list-style-type: none"> Create / analyse KPIs to evaluate process efficiency and find problem areas (root cause) Predict process environment / requirement changes Create and evaluate scenarios and recommendations for redefinitions / optimizations Detect anomalies, dependencies, patterns, cluster, associations in process data for redefinition / optimization Detect weak signals | <ul style="list-style-type: none"> Automate repetitive tasks (predefined rules) Automate non repetitive tasks, decisions, judgment, prioritizations etc. (i-RPA) Autonomous adoption of software robots to changes in requirements or for optimization Insert and change data in the system Automate interfaces between IS (internal and external) |
| Process Optimization | Sense process inefficiencies and find optimal solutions, based on learnings. Optimize desired processes autonomously or augment the user in the optimization. | <ul style="list-style-type: none"> Continuous process improvement Improved process quality | | | | |
| Process Redefinition | Learn business rules and sense and predict changes of business/environment requirements. Redefine (adopt) desired processes or augment the user in the redefinition. | <ul style="list-style-type: none"> Up-to-date processes Flexible (customizable) processes | | | | |

Table 16 - i-ERP Concept: Process Dimension

| UX Dimension | | | | | | |
|---|---|--|--|---|--|---|
| Characteristic | Description | Main Goal(s) | AI | ML | DA | RPA |
| Proactive User Assistance | Assist user with information provision e.g., warnings, advice, or recommendations in complex situations. Intelligent assistants (e.g., chatbots, translators, etc.) for user work support. | <ul style="list-style-type: none"> User support: Improve quality and decisions Personalized experience Productivity and speed increase Facilitation of use | <ul style="list-style-type: none"> Input / Output: Voice, text, image User Conversation: NLP (e.g., Chatbots (in/-external)) Intelligent assistants (e.g., translation, search engines, Q&A, Document scanning, matching, automated filling) Support user in understanding of data, recommendation of next steps, explanations, advice, decision support Warning and monitoring | <ul style="list-style-type: none"> Learn user workflow to predict / recommend next steps or adopt system interface Learn user preferences (most used functions, clickstream etc.) Learn user role, context, habits Understand user needs to adopt UI Understand of context to adopt UI Detection of anomalies, give advice, recommendation, warnings, etc. Data discovery and prediction | <ul style="list-style-type: none"> Information dashboards (KPIs, Statistics) Data query tools Warnings (weak signals, events) Accurate, real-time reports Analytics tools / OLAP Advanced data visualization tools | <ul style="list-style-type: none"> Facilitated input of data Generation of outputs Support in clickstreams Enhanced system flexibility Automation to free user |
| Conversational System Interaction | Consider contexts and habits in user-system interaction. Understand user requests in different forms (e.g., audio, text, image) and respond in respective way in a conversational attitude. | <ul style="list-style-type: none"> Better human computer interaction User support Efficiency improvement Facilitation of use | | | | |
| Responsive User Interface and Design | Adoptive UI to task, context, and user habits. Predict and recommend next steps and show information and functions accordingly in the system interface. | <ul style="list-style-type: none"> Efficiency improvement User motivation User support Facilitation of use | | | | |

Table 17 - i-ERP Concept: UX Dimension

4.2.2. i-ERP Model

The i-ERP model graphically illustrates the components, interrelationships, and main functions of i-ERP. It is a high level, general model, with a business and not a technology focus.

The model has the following goals:

- Show components of the proposed i-ERP
- Show how i-ERP components are interrelated
- Visualize main i-ERP characteristics from the i-ERP concept

The model is based on the composition of a traditional ERP system as learned in the literature review and adopted to requirements of i-ERP. For coherence with the i-ERP concept, requirements and assumptions for an i-ERP model are derived from the i-ERP characteristics and the understanding of the technology concepts in table 18.

| Dim. | Characteristic | Model Requirement(s) |
|--------------------------------|---|--|
| General Prerequisite Dimension | Flexible Application | The model should show that the application is in a flexible cloud infrastructure. |
| | Flexible Database | The model should show that the database is in a flexible cloud infrastructure. It must be accessible by the ERP modules for Create, Read, Update, Delete (CRUD) operations. |
| | Variety of Datatypes | The model should show the databases' and i-ERP modules' ability to handle Big Data from internal and external Big Data sources in different forms and formats. |
| | Real-Time Environment Sensing | The model should show the ability to sense the physical organization environment (assets, goods, people) with IoT in real time and the accessibility of those data for i-ERP. |
| | Real-Time Complex Processing | The model should show the real time processing ability of the i-ERP module(s). |
| Data Dimension | Personalized, Context Specific, Real Time Data Provision | The model should show the provision personalized, real-time data as output of the i-ERP modules for the user/organization. This is enabled by intelligent technologies in the core of the i-ERP modules. |
| | Advanced Data Insights | The model should show outputs for e.g., discovery, decision making, etc. from the i-ERP modules and the ability to visualize the results e.g., in Dashboards or visualisation tools directly integrated in the user interface. |
| | Intelligent Creation of Data | The model should show output of self-created data (e.g., recommendations, scenarios, KPIs etc.) from the i-ERP modules to the user / organization. |

| | | |
|--------------------------|---|--|
| Process Dimension | Autonomous Process Execution | The model should show that an i-ERP digitally mapped process can be automated by the i-ERP. |
| | Process Optimization | The model should show that an i-ERP digitally mapped process can be optimized by the i-ERP. |
| | Process Redefinition | The model should show that an i-ERP digitally mapped process can be redefined by the i-ERP. |
| UX Dimension | Proactive User Assistance | The model should show functions for the assistive user support with information access and intelligent assistants. |
| | Conversational System Interaction | The model should show that different interaction methods can be used to archive a conversational interaction (e.g., audio, text, image). |
| | Responsive User Interface and Design | The model should show that the UI of the system is responsive, and adoptive to the user needs and context. |

Table 18 - i-ERP Model requirement derivate

The i-ERP model is presented, and the components and relationships are defined. Subsequently, the i-ERP model is described in written form for a better understanding.

i-ERP Model

The following model (Figure 20) is derived from the model requirements supplemented by the understanding of an (i-)ERP system as presented in the literature review. The numbers (components of the model) and letters (relationships in the model) are used for identification and explained below.

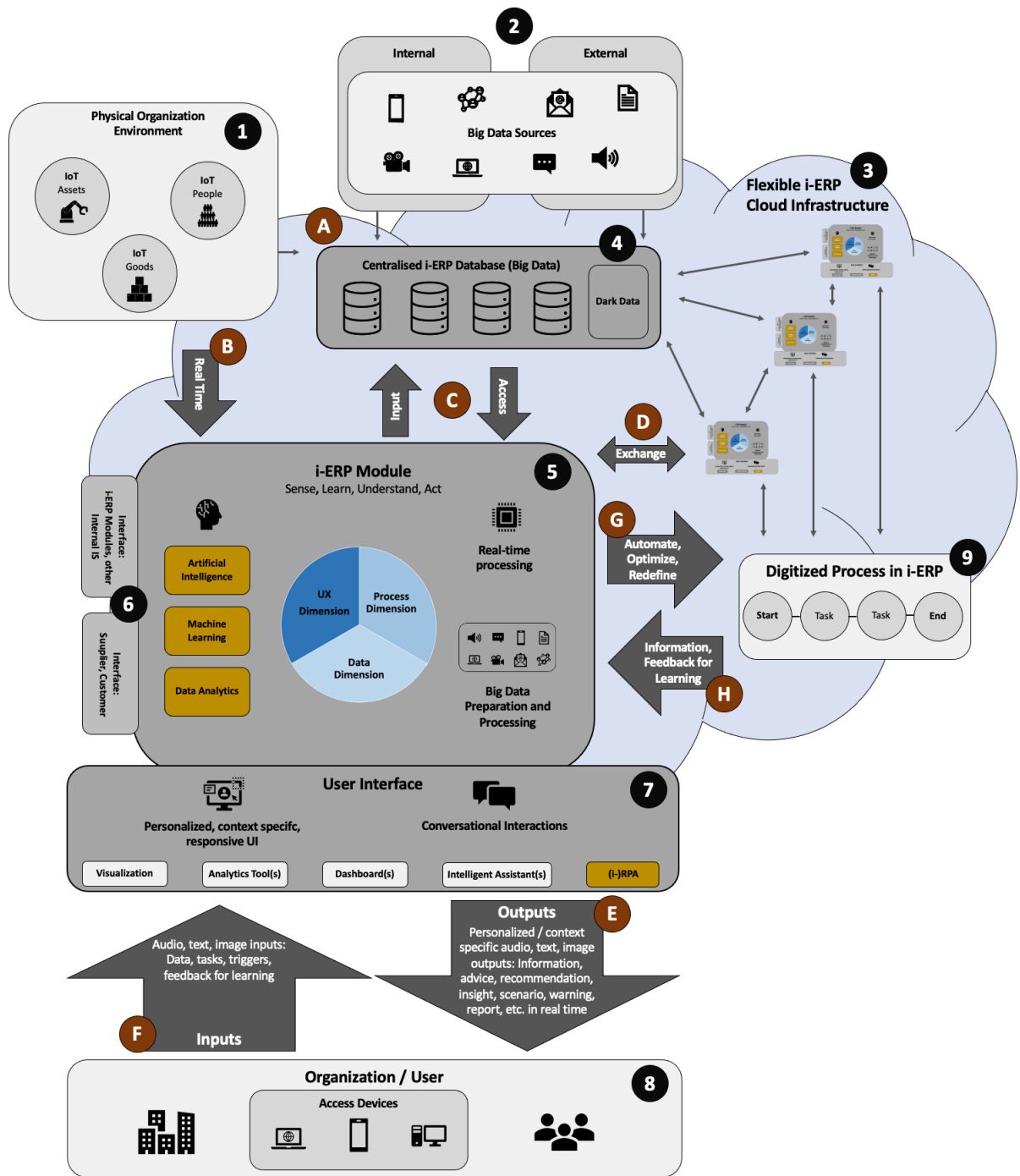


Figure 20 – Proposed i-ERP conceptual model

Model Components

The proposed model components are explained in table 19. In the first column is the number of the respective element in the model, the second column names the model component, and in the third column the component is described.

| Number | Component | Description |
|--------|--|--|
| 1 | Physical Organization Environment | The assets, goods, people in the organization. They are monitored / controlled / tracked with IoT devices, providing accurate real time data. |
| 2 | Big Data Sources | Different internal and external data sources of different data types result in a variety of Big Data. These data are beyond regular transaction data. |
| 3 | Flexible Cloud Infrastructure | The cloud infrastructure provides scalable data storage and processing power to handle Big Data and conduct intelligent computing tasks. It provides flexibility to the system for updates, upgrades, changes, etc. |
| 4 | Centralized i-ERP Database | The central database centralizes data from various sources. The sources can be the system itself (transaction processing data, master data, etc.), the physical company environment, and any other internal and external source desired by the organization. |
| 5 | i-ERP Module(s) | The interrelated i-ERP Modules provide i-ERP functionalities. The three dimensions of Data, Process, and UX are enabled by the intelligent technology concepts AI, ML, and DA in the core. The i-ERP modules have the capability to prepare and process Big Data in real time. |
| 6 | External Interfaces | The i-ERP modules (can) have interfaces to other internal or external suppliers/customers IS. Data and information can be exchanged. |
| 7 | User Interface | The user interface is adaptive, assistive, and conversational. It includes chatbots, information dashboards, and intelligent assistants. The fourth intelligent technology, RPA/i-RPA resides here. |
| 8 | Organization / User | The organization or user interacts with/uses the i-ERP module(s) by making inputs and receiving outputs. Different mobile and local device types can be used to access the system. |
| 9 | Digitized Process | The process is one illustrative example process digitally mapped and executed in one or multiple modules of the i-ERP. It can be fully or partially automated by the ERP module(s) or manually executed by the user via the UI with augmentations from the i-ERP. |

Table 19 - i-ERP Model: Components

Model Interrelationships

The components proposed have several connections. The following table 20 shows model relations derived from the model requirements and the understanding of an ERP system as presented in the literature review. In the first column is the number of the respective element in the model and the second column explains the model connection.

| Letter | Description |
|--------|---|
| A | The data from the different sources are stored in the centralized i-ERP database. |
| B | The data from the physical organization environment are available for the i-ERP modules in real time. |
| C | I-ERP modules and database are in constant data exchange (CRUD operations). The modules can input new data in the database, such as transaction information, user inputs, data gathered from feedback etc. and the modules can access the data in real time for executing processes, creating information output, doing any intelligent calculation, etc. |
| D | The i-ERP modules are connected and integrated as needed. They are in constant exchange, e.g., current state of work, intelligent coordination. |
| E | The organization / user receives outputs from the i-ERP modules they are personalized, context, specific, and in real time. The outputs can be in various forms and formats, such as audio, text, image. |
| F | The i-ERP modules receive inputs from the organization / user. The inputs can be in various forms and formats, such as audio, text, image, e.g., data, tasks, triggers, etc. The i-ERP also receives feedback for learning based on its actions. |
| G | The i-ERP modules can automate, optimize, and redefine processes, based on the user inputs and the intelligent functions of the i-ERP modules. |
| H | The i-ERP modules receive data generated (transaction data, feedback, etc.) by the process execution. It is processed by the module and stored in the i-ERP database. |

Table 20 - i-ERP Model: Relationships

Model Description

The description gives a general understanding of the proposed model and shows how the characteristics from the i-ERP in the concept can be found in the model. The description follows the structure of an i-ERP workflow of sensing, understanding, acting, and learning like introduced in the literature review.

The i-ERP database and modules are hosted in a flexible and scalable cloud infrastructure (3). Most intelligent i-ERP functions are based on data and the i-ERP has many different sources of data to allow sensing. Real-time data from the physical organization environment (1) and data from other internal and external BD sources (2) are stored (A) in the centralized, flexible i-ERP cloud database. It supports structured, semi-structured, and unstructured data (4). The database contains traditional transaction processing data and data from i-ERP modules, such as master or meta data (C). The database is the central data repository and can be accessed in real time by the i-ERP modules (C). Data from the physical environment can directly be accessed by the i-ERP modules e.g., for real time warnings, tracking, and monitoring (B). The different i-ERP are connected to each other (D) allowing exchange and coordination and avoiding functional silos.

In the model, one of the modules was zoomed in for a closer look (5). The module(s) including the UI (7) are the core of i-ERP. The intelligent technologies in i-ERP allow to understand the data, learn from it, and to act autonomously. It constantly improves and becomes better through feedback and new data. The three intelligent functional dimensions of i-ERP (Data, Process, and UX) are shown in the centre of the i-ERP module, the prerequisite dimension is depicted trough the model. The i-ERP

modules have capabilities to process Big Data and do complex calculations in real time. The i-ERP is intelligent from the core by applying intelligent technology concepts. AI, ML, and DA are embedded in the modules and allow the functionalities and learning ability of the system. DA includes traditional BI, which previously was not in the core of ERP.

An i-ERP module can have multiple interfaces with other i-ERP modules, internal IS, or external IS, such as suppliers or customers (6). Data and information can be exchanged via interfaces. The user interface of the i-ERP Module (7) is adaptive and assistive. It has chatbots and other intelligent assistants for the proactive user support and for a conversational interaction between system and user. Data dashboards and analytics tools allow simple data insights and there are tools for visualization. In the UI RPA/i-RPA can imitate a user and trigger actions in the i-ERP automatically and autonomously.

The organization/user (8) receives outputs from the i-ERP module via the User Interface (E) and the i-ERP modules receive inputs from the organization/user (F). The UI is responsive and adoptive to the individual user and the context. The inputs in the system can be data or action triggers, they can be in different predefined (e.g., forms, fields) and non-predefined formats (e.g., audio, text, image). An important input is the feedback on actions / outputs of the i-ERP as it supports the learning process of the system. The outputs of the system can be in different forms and formats and include information, insights, recommendations, and advice, supporting the user / organization in process execution, decision making, and planning. The system can provide advanced data insights and newly created data. The outputs are personalized, context specific, and provided in real-time.

Digitally mapped processes (9) in i-ERP are executed via i-ERP module(s). The execution can either be manual through user inputs and augmented by the i-ERP (F) or automated by the system (G). In addition, i-ERP allows support and automation in processes optimization and redefinition using intelligent technology concepts. Process execution generates new data, and the system receives this data and feedback for system learning to improve future actions (H).

4.3. I-ERP ASSESSMENT

Different development stages towards i-ERP are derived. This builds the fundament for an assessment to classify an ERP system regarding its intelligence level. Based on the assessment results, targeted recommendations can be given to advance towards i-ERP.

4.3.1. i-ERP Taxonomy

The taxonomy identifies ERP development stages. It starts from traditional ERP and ends with i-ERP.

The taxonomy has the following goals:

- Show the development from a traditional ERP to an i-ERP
- Understand the characteristics of the i-ERP Dimensions in the respective taxonomy levels

The creation is based on the i-ERP concept and what could be learned in the LR about the technology concepts. The four dimensions identified in the concept are used to structure the taxonomy. This approach guarantees a balance between overview and accuracy and an alignment with the concept. In addition, the role of the system for the user is added to show the expected change of the system role.

This results in the following dimensions for the taxonomy:

- System Role
- General Prerequisite Dimension
- Data Dimension
- Process Dimension
- UX Dimension

The taxonomy focuses on system characteristics and functions in the respective dimensions. There is no classification of technologies, as it is not meaningful and realistic to create a hierarchy of different technology concepts. Rather, it depends on how and to what extent technologies are used in what areas / processes of the system and what functions or use cases are archived. The consultation of similar models from different IS domains showed that most authors use five levels to get from the base state to the final state. This approach is adopted. The base state in this case is a traditional ERP system and the end state is an i-ERP system. In between there are three levels of development. The intermediate levels could be derived by logically interfering from the understanding of the technology concepts and the i-ERP characteristics. The main delimitation criteria for the different levels are: Use of intelligent functions, extent of use (number and type of areas or processes), complexity of the task/process (simple, daily, complex), repetitiveness of the task/process (repetitive, less repetitive, non-repetitive), or the need of human intervention / teaching (self-learning capability). The naming was chosen in ascending order of intelligence level to achieve a common understanding.

This results in the following five proposed levels for the taxonomy:

Level 1: *Elementary ERP*: There are no intelligent functions.

Level 2: *Advanced ERP*: The system fulfils initial basics and prerequisites to become intelligent.

Level 3: *Elementary Intelligent ERP*: The system shows its first intelligent features.

Level 4: Partially Intelligent ERP: The system has advanced intelligent features.

Level 5: Intelligent ERP: The system has all intelligent features of an i-ERP.

Figure 21 shows the taxonomy levels, sorted by dimension. On the left are the dimensions and at the top are the number (1-5) and name of the levels. In the boxes is a short description of the respective dimension in the respective level. All dimensions of one level together define the system in that level. The main aspects of the system levels are described for a better understanding.

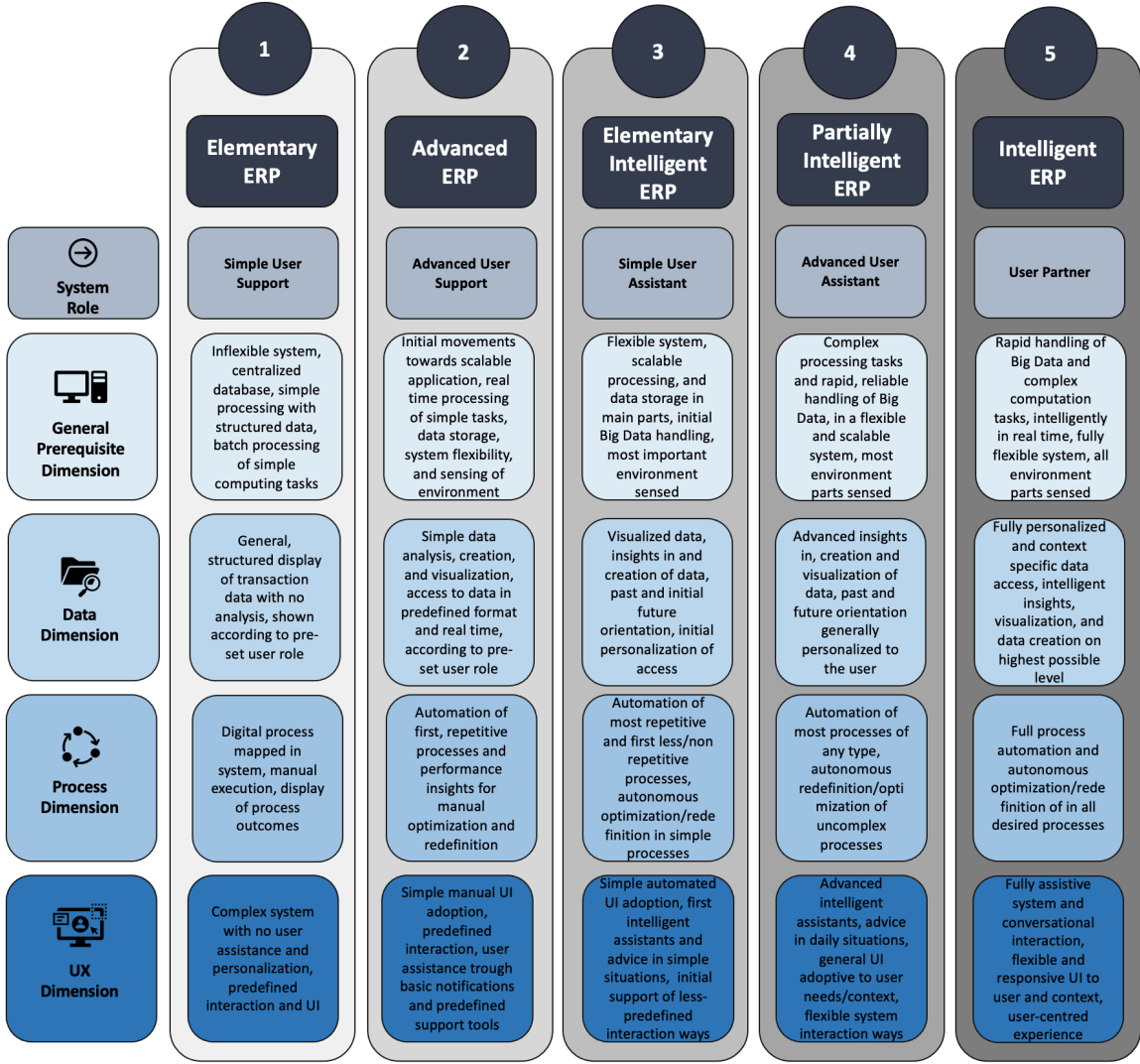


Figure 21 - Proposed i-ERP Taxonomy

Level 1: Elementary ERP

The first level describes an ERP system as modular software application with no intelligent features. Functional modules are integrated with a central on-premises database and work with simple calculations on structured data. It allows integration and seamless information flow between modules but with time delay as batch processing is used. The system cannot sense the physical organization environment. The system processes and records transactions and displays data in a structured, predefined manner, often in tabular form. It does not provide any type of analysis but can display the data according to the pre-set user (access) role in the system. The processes are digitally mapped in

the system and executed manually by the user. The system is complex to use. It does not provide any specific user assistance and in-/outputs are done in predefined fields. It is a mean for purpose for the execution of business processes and a single source of information for the user.

Level 2: Advanced ERP

The second level describes an ERP system that fulfils basic requirements to become intelligent. Initial movements towards scalable, real-time processing and data storage, allow more data to be consumed and processed. The availability of first real time data from the physical environment allows insights in the organization. The system provides simple analysis and basic visualizations. First repetitive processes can be automated freeing up users and giving more time for tasks such as optimization or redefinition of processes, which are supported by the system through simple (performance) insights. The UX of the system provides first assistance through basic notifications, e.g., low stock etc. Freedoms in the UI, such as self-service adoptions, help the user to individualize the experience.

Level 3: Elementary intelligent ERP

The third level has initial intelligent features, it is not yet intelligent, but first approaches make it possible to initiate possible features to enable continuous further development and extension. Scalability of processing power and data storage to handle Big Data and complex processing is being realised in main system areas. The number of available data sources is growing, and the system can handle initial types of (Big) data. The capabilities in processing and data storage open new opportunities for insights in data and initial individualized personalization, new data creation, and visualisations. Process automation is possible with first, main less/non repetitive processes and most repetitive processes. Growing insights in data help to find optimization or redefinition potentials, which can be automatically implemented, or the user can be augmented. The UX is increasingly assistive. It allows more adoption to the user needs. The initial use of intelligent assistants (e.g., chatbots, translators, etc.) supports users in simple situations. The system allows first non-predefined ways for in- and output, such as text or image scans of basic structured documents.

Level 4: Partially intelligent ERP

In the fourth level, intelligent features are extended. The system is increasingly an assistant to the user, supporting in everyday work by taking away tasks and speeding up the work by providing information and support. The flexible and scalable system can handle most complex processing tasks with all types of Big Data with good reliability and speed. Most of the organization physical environment can be sensed. Data access can, in a general but reliable manner, be personalized. Advanced data insights, creation, and visualization allow decision support in most situations the organization faces. The automation of processes is far progressed, and the increasing intelligent features allow automated redefinitions and optimizations of processes in uncomplex processes. The user can be supported by the i-ERP with advanced intelligent assistants, information, and recommendations in most daily situations and the system is increasingly adopting to the users' needs and context, which it can learn and understand. The in-/output methods are improving and are moving towards flexible and open interaction.

Level 5: intelligent ERP

The fifth level is the intelligent ERP. The system is a full partner of the user with first characteristics of human behaviour. The system is fully scalable in processing power and data storage and can reliably and rapidly handle any complex and intelligent computation task in real time. It supports all forms and formats of Big Data and can treat it as if it was structured. It can sense the full (desired) physical organization environment. The data access is personalized and context specific. It allows deep insights to discover new things, predict the future, make superior decisions, and can create new data intelligently. The data can be presented in visualized format on the highest possible level. Any (desired) process can be automated, and the i-ERP can optimize and redefine processed autonomously where needed and desired. The UX is assistive, through intelligent assistants and provision of information, and conversational, offering a flexible and responsive UI and design based on the user needs and context, ensuring a user-centred experience as a partner to the user.

4.3.2. i-ERP Assessment Tool

This tool allows the classification of an ERP system into the taxonomy and to derive high-level recommendations to improve to the next taxonomy level(s). The tool can be used by all types of organizations related to ERP, such as users, vendors, consultants, below others. The tool has a high-level business approach. It is not focussed on technical details, specific systems, or modules.

The assessment has the following goals:

- Assess maturity of an ERP system towards i-ERP
- Show in what areas the system needs improvement (tabularly and graphically)
- Provide general actions to reach the next level

To carry out the assessment and make targeted recommendations, the following "Assessment to Recommendation Process" is proposed (Figure 22). The process has three consecutive phases.

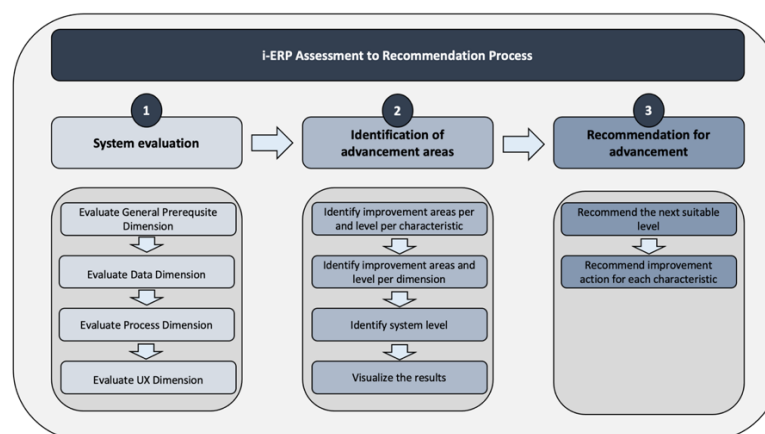


Figure 22 - i-ERP Assessment to Recommendation Process

System evaluation: The user assesses the system at hand according to the four i-ERP dimensions.

Identification of advancement areas: The user receives a tabular and visualised evaluation of the assessment and can derive advancement areas per i-ERP characteristic and dimension. Furthermore, the user learns how intelligent the system is assessed.

Recommendation for advancement: The user is shown which next level to reach / maintain and given a targeted recommendation on how to proceed.

The phases are transferred into an assessment tool and the proposal explained in detail.

1. System Evaluation

The assessment is based on the i-ERP concept and the taxonomy. The four i-ERP dimensions and the respective 15 i-ERP characteristics along five taxonomy levels allow a precise evaluation. The assessment structure is shown in table 21.

| Dimension X | | | | | | | |
|------------------|--------------|-----------|-----------|-----------|-----------|-----------|---------|
| Characteristic | Definition | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 | Score |
| Characteristic X | Definition X | Level 1 X | Level 2 X | Level 3 X | Level 4 X | Level 5 X | Score X |
| Characteristic Y | Definition Y | Level 1 Y | Level 2 Y | Level 3 Y | Level 4 Y | Level 5 Y | Score Y |

Table 21 - i-ERP Assessment Structure Example

On top the i-ERP dimension is depicted (in the example "Dimension X"). The first column shows the characteristics of the respective dimension (in the example "Characteristic X, Y"), which are then defined for understanding (in the example "Definition X, Y").

This is followed by short statements how each characteristic could be expressed in the respective taxonomy level (in the example "Level 1 X, Y, Level 2 X, Y, etc.). It can be assumed that the functions of the lower levels are retained in higher levels if not replaced or supplemented by a better function.

In the last column, the user of the assessment must enter a score. This score can be between 1 and 5 (integral numbers) and should represents which level best describes the system assessed (in example "Score X, Y"). It corresponds to the five taxonomy levels.

Recommendations for each of the levels are intended to give the assessment user a suggestion and direction of thought for advancing to the next higher level or, in the case of level 5, to maintain the level. It does not recommend how to do it but a direction of thought on what could be done.

Table 22 shows the structure used in further course. On top the i-ERP dimension is depicted (in the example "Dimension X") and in the first column are the characteristics (in the example "Characteristic X, Y"). The next five columns give a recommendation statement for each level (in the example Level 1 Action X, Y, Level 2 Action X, Y, etc.) on how to advance to the next higher level.

| Dimension X | | | | | |
|------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| Characteristic | Level 1 Action | Level 2 Action | Level 3 Action | Level 4 Action | Level 5 Action |
| Characteristic X | Level 1 Action X | Level 2 Action X | Level 3 Action X | Level 4 Action X | Level 5 Action X |
| Characteristic Y | Level 1 Action Y | Level 2 Action Y | Level 3 Action Y | Level 4 Action Y | Level 5 Action Y |

Table 22 - i-ERP Recommendations Structure Example

The proposed assessment tool (Table 23) and recommendations (Table 24) for the four dimensions are presented below. This tool is available in the appendix of this work. Instead of the "x" in the figure the level would be entered by the evaluation user.

i-ERP Assessment Questions

| General Prerequisite Dimension | | | | | | | |
|----------------------------------|--|--|--|--|---|---|-------|
| Characteristic | Definition | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 | Score |
| Flexible Application | Flexibility towards new functions, updates, and upgrades. | The system is inflexible. | Initial system parts (e.g., modules) are flexible. | Main system parts are flexible. | Most system parts are flexible. | The application is fully flexible. | x |
| Flexible Database | The ability to store a high data volume, scalable and centralized. | Data is stored in a centralized but inflexible database. | Initial database parts are scalable. | Main database parts are scalable. | Most database parts are scalable. | The database is fully scalable. | x |
| Support a Variety of Data Types | The capability to handle high data volumes in different forms and formats (Big Data). | The system works with structured data. | The use of semi-structured data is possible. | Initial types of Big Data are supported. | The for the organization most important Big Data types can be handled. | The system can work with all required forms of (Big) data. | x |
| Environment Sensing in Real Time | The ability to sense the physical organization environment (e.g., assets, goods, people) in real time. | Real time environment data is not available. | Initial setups allow first environment data. | Most important assets, goods, and people are sensed. | Most assets, goods, and people are sensed. | All required assets, goods, and people are sensed. | x |
| Real Time Complex Processing | The capability to conduct complex processing, rapidly, reliably, and fully scalable. | Simple computing is done in batches. | Basic computing tasks are done in real time. | First, specific complex computing tasks are done with restrictions in speed and scalability. | Most main complex computations are done with restrictions in speed and scalability. | All required complex computation tasks are done fast, reliable, and scalable. | x |

| Data Dimension | | | | | | | |
|--|--|--|--|---|--|--|-------|
| Characteristic | Definition | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 | Score |
| Personalized, Context Specific, Data Provision | The capability to provide data in real time considering the user individual habits and context of the task. | Predefined data is provided in batches defined by a pre-set user role. | Predefined data is provided in real time defined by a pre-set user role. | Data is provided defined by simple and very repetitive habits and context in defined, general situations. | Data is provided defined by individual repetitive user habits and context in specific, but complex situations. | Data is provided in real time according individual user habits and context in any complex situation. | x |
| Advanced Data Insights | Insights in data gained through analysis, e.g., predictions, patterns, classifications, statistics etc. to support decisions and discoveries and the way data can be visualized. | Simple reports / summaries of data, mostly in tabular form. | Simple past-oriented analysis and basic visualizations. | Past- and simple future-oriented insights in simple, daily situations. Data presented in visualized format. | Advanced future and past oriented insights in initial complex situations. Advanced visualization capabilities. | The system provides intelligent insights in and visualization of data in all situations. | x |
| Intelligent Creation of Data | Create new data based on data, such as scenarios, explanations, or recommendations. | The system records transaction data. | Creation of simple past oriented data. | Creation of past-oriented data and future orientation in specific, simple tasks. | Creation of complex past-oriented and advanced future-oriented data. | Creation of reliable data autonomously in all system areas and complex situations. | x |

| Process Dimension | | | | | | | |
|------------------------------|---|---|---|---|---|--|-------|
| Characteristic | Definition | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 | Score |
| Autonomous Process Execution | The automation of any operational, tactical, and strategic internal and external ERP process or task. | Processes are mapped digitally in the system but executed manually by the user. | Simple frequent, repetitive, deterministic, processes can be automated. | Most repetitive and first less/non repetitive processes can be automated. | Repetitive processes and most non/less repetitive processes can be automated. | All desired processes can be automated. | x |
| Process Optimization | Detect inefficiencies and respective solutions based on learnings, to autonomously improve the process or to augment in manual optimization efforts. | The system does not offer support for process optimization. | Insights in simple process inefficiencies to support the user in manual optimization efforts. | In defined, simple, repetitive processes inefficiencies can automatically be detected, understood. Optimal solutions can be proposed / implemented. | In main and low complexity processes inefficiencies can automatically be detected, understood and, optimal solutions can be proposed / implemented. | In all desired processes, inefficiencies can be understood and optimal solutions can be found. Processes are optimized autonomously. | x |
| Process Redefinition | Detect and understand process requirement changes (environment/business) and autonomously improve the process or to propose changes and augment in manual redefinition efforts. | The system is inflexible and does not support in process redefinitions. | Insights in simple requirement changes supporting in manual optimization. | In defined, simple, repetitive processes requirement changes can automatically be detected, understood and, solutions can be proposed/implemented. | In main and low complexity processes requirement changes can automatically be predicted, understood, and solutions can be proposed/implemented. | Adoption to and prediction of changing business/environment rules in desired, and complex processes. | x |

| UX Dimension | | | | | | | |
|--------------------------------------|---|---|---|--|--|--|-------|
| Characteristic | Definition | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 | Score |
| Proactive User Assistance | The use of intelligent assistants (e.g., automated filling, translations, chatbots, etc.) for user support and the provision of information for recommendations and advice. | The system provides no user assistance. | Basic insights and notifications to assist the user. | In simple situations and clearly defined areas advice/recommendation is provided. First intelligent assistants for basic user support. | In most daily situations advice/recommendation is provided. Intelligent assistants support daily user work. | In any complex situation advice/recommendation is provided and intelligent assistants support complex tasks. | x |
| Conversational System Interaction | The conversational interaction of user and system (in- and outputs) in different ways and consideration of user habits and context. | Predefined system interaction. | Initial, input with very structured and basic data (e.g., structured documents) but not fully predefined. | Alternative interaction (e.g., voice, text, image) in clearly defined areas and with simple, defined rules. | Flexible input in daily situations and basic personalized / context specific outputs (e.g., 'question answer' format). | Conversational interaction, unstructured data input and outputs considering contexts and habits in complex situations. | x |
| Responsive User Interface and Design | The adoption of the system UI (e.g., data or functions shown) to the individual user needs / habits and the context and prediction of next steps to adopt accordingly. | No UI personalization is possible. | Manual UI adjustments are possible. | Understanding and learning of simple workflows and contexts in specific areas and UI adoption accordingly. | Understanding and learning of daily user workflows and contexts in main processes and UI adoption accordingly | UI adoption to user context and habits in any complex situation and predictive adoption. | x |

Table 23 - Proposed i-ERP Assessment structured by dimension

i-ERP Assessment Recommendations

| General Prerequisite Dimension | | | | | |
|---|---|--|--|--|---|
| Characteristic | Level 1 Action | Level 2 Action | Level 3 Action | Level 4 Action | Level 5 Action |
| Flexible Application | Initiate flexibility efforts for first system parts. | Extend efforts to main system parts with most flexibility needs. | Extend efforts to other system parts with most flexibility needs. | Extend flexibility efforts to remaining system parts. | Maintain the system and look for new future developments. |
| Flexible Database | Initiate scalability efforts for first database parts. | Extend efforts to main database parts with most scalability needs. | Extend efforts to other database parts with most scalability needs. | Extend scalability efforts to remaining database parts. | Maintain the system and look for new future developments. |
| Support a Variety of Data Types | Begin with the support of semi-structured data. | Extend processing capability to initial Big Data formats. | Extend capability to for the organization most important Big Data formats. | Extend data processing capability to remaining desired types of Big Data. | Maintain the system and look for new future developments. |
| Environment Sensing in Real Time | Set up first devices on most suitable assets, goods, and/or people. | Extend the use to most interesting assets, goods, people. | Extend the use to additional suitable assets, goods, people. | Extend the use to remaining assets, goods, people. | Maintain the system and look for new future developments. |
| Real Time Complex Processing | Introduce real time processing for simple tasks. | Implement first capabilities for complex processing in specific tasks. | Extend processing capabilities for complex tasks to main system tasks. | Make complex processing available all areas and invest in speed and scalability. | Maintain the system and look for new future developments. |

| Data Dimension | | | | | |
|---|---|---|--|---|---|
| Characteristic | Level 1 Action | Level 2 Action | Level 3 Action | Level 4 Action | Level 5 Action |
| Personalized, Context Specific, Data Provision | Introduce real time data provision. | Implement capabilities to learn simple user habits and contexts defined situations. | Extend learning capabilities for habits and context to more complex but repetitive situations. | Extend learning capabilities for habits and context to desired complex situations. | Maintain the system and look for new future developments. |
| Advanced Data Insights | Enable simple data visualization and first past-oriented analysis capabilities. | Implement capabilities for insights with past- and initial future orientation for simple, daily situations and improve visualization. | Enable advanced and complex analysis with past- and future-orientation and visualization. | Extend analysis and visualization capabilities to the highest available level and all complex situations. | Maintain the system and look for new future developments. |
| Intelligent Creation of Data | Initiate simple data creation capabilities with past-orientation. | Initiate future-oriented data creation, for specific, simple tasks. | Extend complexity of situations data can be created for. | Extend data creation capabilities to all desired situations of any complexity level. | Maintain the system and look for new future developments. |

| Process Dimension | | | | | |
|-------------------------------------|--|--|--|--|---|
| Characteristic | Level 1 Action | Level 2 Action | Level 3 Action | Level 4 Action | Level 5 Action |
| Autonomous Process Execution | Initiate the automation of first, simple repetitive processes. | Extend automation of repetitive and initiate the automation of first non/less repetitive processes | Automate remaining repetitive and extend the automation to main non/less repetitive processes. | Extend the automation of non/less repetitive processes to all processes. | Maintain the system and look for new future developments. |
| Process Optimization | Implement first functions for process performance insights to support in manual optimization. | Implement capabilities to detect, understand, and solve inefficiencies in defined, simple, processes. | Extend optimization capabilities to main and first less repetitive (more complex) processes. | Extend the optimization capabilities to remaining, desired processes. | Maintain the system and look for new future developments. |
| Process Redefinition | Implement first functions for insights in process requirement changes to support in manual redefinition. | Implement capabilities to detect, understand, and solve requirement changes automatically in defined, simple, processes. | Extend redefinition capabilities to main and first less repetitive (more complex) processes. | Extend the optimization capabilities to remaining, desired processes. | Maintain the system and look for new future developments. |

| UX Dimension | | | | | |
|---|---|---|---|---|---|
| Characteristic | Level 1 Action | Level 2 Action | Level 3 Action | Level 4 Action | Level 5 Action |
| Proactive User Assistance | Implement simple insights and notifications. | Implement basic intelligent assistants and in defined areas enable advice/recommendation for simple situations. | Extend the abilities of intelligent assistants and enable provision of advice / recommendation in daily situations. | Implement functions for advice/recommendation and support (intelligent agents) in complex situations. | Maintain the system and look for new future developments. |
| Conversational System Interaction | Initiate non fully predefined but structured input. | Enable simple, alternative interactions (e.g., voice, text, image) in clearly defined areas. | Extend complexity of alternative input ways and adopt outputs to simple user habits and context. | Enable conversational, flexible, and personalized interaction in complex situations. | Maintain the system and look for new future developments. |
| Responsive User Interface and Design | Enable (predefined) manual adjustments of the UI. | Implement capabilities to understand simple user workflows and data / functions needs in defined areas. | Extend capabilities to understand daily user workflows and data / functions needs in main processes. | Extend UI adoption capabilities to all desired, complex workflows and enable a predictive approach. | Maintain the system and look for new future developments. |

Table 24 - Proposed i-ERP recommendations structured by dimension

2. Identification of advancement areas

The following explains how the assessment tools is evaluated and the results are graphically presented.

Assessment results table

The results of the assessment are presented in a results table (Table 25). The assessment is created per characteristic, dimension, and i-ERP system and based on the inputs given by the user in the previous questions. The values allowed correspond to the taxonomy levels and are integral numbers 1-5. The user gets an immediate insight into more and less intelligent parts of the system.

| Dimension | Characteristic | Score | Dimension Score | i-ERP Score |
|-------------|-------------------|----------|-------------------|-------------|
| Dimension X | Characteristic X1 | Score X1 | Score Dimension X | Score i-ERP |
| | Characteristic X2 | Score X2 | | |
| Dimension Y | Characteristic Y1 | Score Y1 | Score Dimension Y | |
| | Characteristic Y2 | Score Y2 | | |

Table 25 - Assessment result table example

In the two left columns are the i-ERP dimension (in the example, "Dimension X") and the i-ERP characteristic (in the example, "Characteristic X, Y"). The next column shows the score for each characteristic entered by the user in the assessment (in the example, "Score X1, Y1, etc."). Based on this, in the next column, the Dimension Score is calculated, showing the i-ERP level per each of the four dimensions (in the example, "Score Dimension X, Y"). The last column shows the i-ERP score, based on all four dimensions together comprising an i-ERP (in the example, "Score i-ERP").

The assessments are calculated as follows:

- **Assessment per characteristic:** The value entered by the user in the assessment.
- **Assessment per dimension:** The minimum of all characteristics of one dimension in the Assessment per Characteristic, without decimals, assuming the weakest link.
- **Assessment per i-ERP:** The rounded average of all dimensions in the Assessment per dimension, without decimals, assuming not every dimension is fully needed.

For the assessment per dimension, it was considered to use the minimum instead of the average to cover the weakest link of the mostly related characteristics of a dimension. For the assessment per i-ERP the decision for the average was made. A general approach is taken and not every company has the exact same requirements on a system and might not want/need to have all the features required in a dimension to full extend. The use of the average provides some margin, whereas the minimum would always hold it back to any lowest link and never let the i-ERP grow.

The numbers / levels in the assessment are colour coded as follows. For an example refer to chapter 4.4.

| | | | | |
|---------|---------|---------|---------|---------|
| Level 1 | Level 2 | Level 3 | Level 4 | Level 5 |
|---------|---------|---------|---------|---------|

In table 26 is a blank version of the evaluation table. Every "x" represents a number in the table when used in a real assessment. A demonstration of a fictional case can be found in chapter 4.4 of this work.

| I-ERP Dimension | I-ERP Characteristic | Score | Dimension Score | i-ERP Score |
|--------------------------------|---|-------|-----------------|-------------|
| General Prerequisite Dimension | Flexible System | x | x | x |
| | Flexible Database | x | | |
| | Support a Variety of Data Types | x | | |
| | Environmental Sensing in Real Time | x | | |
| | Complex Processing in Real Time | x | | |
| Data Dimension | Personalized, Context Specific Data Provision | x | x | |
| | Advanced Data Insights | x | | |
| | Intelligent Creation of Data | x | | |
| Process Dimension | Autonomous Process Execution | x | x | |
| | Process Optimization | x | | |
| | Process Redefinition | x | | |
| UX Dimension | Proactive User Assistance | x | x | |
| | Conversational System Interaction | x | | |
| | Responsive User Interface and Design | x | | |

Table 26 - Blank assessment results table

Results Visualization

The assessment results are automatically visualized in different charts. They serve the purpose of better understanding and insights. The charts all have the same structure and type.

Visualization is provided for:

- All i-ERP characteristics assessed
- All i-ERP characteristics sorted by dimension
- All i-ERP dimensions compared

The structure and understanding of the charts are explained with an unspecific example. All charts and a demonstration on a fictional case can be found in chapter 4.4 and a general example is in figure 23.

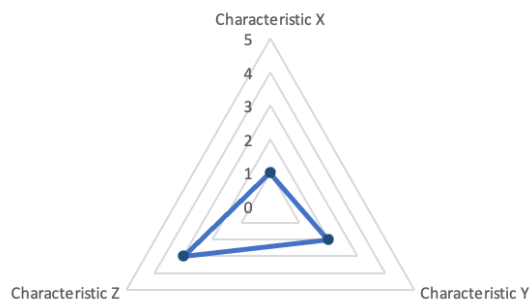


Figure 23 - Assessment visualization example

The diagram has five lines (5 taxonomy levels) the data points can be on (0 would mean there is no data available). The assessment score is shown according to the respective i-ERP characteristic (in the example “Characteristic X, Y, Z”) as a data point (dot) on one of the five lines. In the example: Characteristic X score is 1, Characteristic Y score is 2, and Characteristic Z score is 3. The dots are all connected by lines. Using this type of visualisation, one can see on one view where effort is needed to get towards and i-ERP and where the system is already well progressed.

3. Recommendations for advancement

In the final step, recommendations are proposed based on the assessment outcomes per i-ERP characteristic. The recommendations are general and advice on how the next higher level can be reached to obtain an i-ERP. They are intended to serve as a thought direction to then enable an optimally adapted approach to the respective situation and goals of the organization with their system. The assessment recommendations are presented in tabular form shown in table 27.

| Dimension | Characteristic | Next level to archieve | Recommendation |
|-------------|-------------------|------------------------|-------------------|
| Dimension X | Characteristic X1 | Level X1 | Recommendation X1 |
| | Characteristic X2 | Level X2 | Recommendation X2 |
| Dimension Y | Characteristic Y1 | Level Y1 | Recommendation Y1 |
| | Characteristic Y2 | Level Y2 | Recommendation Y2 |

Table 27 - Assessment recommendation table example

In the two left columns are the i-ERP dimension (e.g., “Dimension X”) and the i-ERP characteristic (e.g., “Characteristic X”). The next column calculates the next level to reach for based on the score of the assessment (current level plus one). In case it is already in level 5, there is no level to achieve, but level 5 is to be maintained. The last column then shows the recommended action to be taken to reach this next level/maintain the level. The recommendations are taken from the before presented recommendation tables in the respective dimensions and characteristic.

In table 28 is a blank version of the table. The “x” represents a level or a recommendation when used in a real assessment. A demonstration with recommendations on a fictional case can be found in chapter 4.4 of this work.

| I-ERP Dimension | I-ERP Characteristic | Next level to achieve | Recommended Action to archive the next level |
|--------------------------------|---|-----------------------|--|
| General Prerequisite Dimension | Flexible System | x | x |
| | Flexible Database | x | x |
| | Support a Variety of Data Types | x | x |
| | Environmental Sensing in Real Time | x | x |
| | Complex Processing in Real Time | x | x |
| Data Dimension | Personalized, Context Specific Data Provision | x | x |
| | Advanced Data Insights | x | x |
| | Intelligent Creation of Data | x | x |
| Process Dimension | Autonomous Process Execution | x | x |
| | Process Optimization | x | x |
| | Process Redefinition | x | x |
| UX Dimension | Proactive User Assistance | x | x |
| | Conversational System Interaction | x | x |
| | Responsive User Interface and Design | x | x |

Table 28 - Blank i-ERP assessment recommendations table

4.4. EXAMPLE OF THE PROPOSED ARTIFACTS

The next step of the chosen methodology according to Peffers et al. (2007b) is a demonstration of the proposed artifacts. In case of this thesis, two areas were distinguished, first, the understanding of i-ERP (i-ERP concept and model) and, second, the assessment of i-ERP (i-ERP levels and assessment).

For area one, it was decided not to do a full demonstration, as this would require building an i-ERP, which is beyond the scope of this work. However, the consultation of experts from practice and science should also confirm its correctness in subsequent course of the work (chapter 4.5).

For the second area, the demonstration is carried out through a fictional example (instantiation) of the assessment. Each of the steps is documented, and the results are explained. This exemplary use case shows that and how the assessment works.

Fictional example i-ERP Assessment

The following structure is according to the Assessment Process Model. All scores used are fictitious and for illustrative purposes. It describes the actions of a potential assessment user and the conclusions that can be drawn from the steps and results. The example assumes that a i-ERP is to be achieved step by step.

1. System evaluation

The system evaluation step is carried out by the user. The score in the assessment sheet must be filled. To determine the score, the level that best describes the system assessed must be chosen based on the expertise of the user and the information the user gathers from the organization. This level (1-5) is entered in the field provided. The field is automatically coloured in the respective level colour.

For this example, the scores are presented in the screenshots. The screenshots tables 29-32 can be read as the following example: In the “General Prerequisite Dimension” the first characteristic, “Flexible Application” is evaluated in the level 3 (colour yellow).

System Evaluation of the General Prerequisite Dimension:

| General Prerequisite Dimension | | | | | | | |
|----------------------------------|---|--|--|--|---|---|-------|
| Characteristic | Definition | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 | Score |
| Flexible Application | <i>Flexibility towards new functions, updates, and upgrades.</i> | The system is inflexible. | Initial system parts (e.g., modules) are flexible. | Main system parts are flexible. | Most system parts are flexible. | The application is fully flexible. | 3 |
| Flexible Database | <i>The ability to store a high data volume, scalable and centralized.</i> | Data is stored in a centralized but inflexible database. | Initial database parts are scalable. | Main database parts are scalable. | Most database parts are scalable. | The database is fully scalable. | 5 |
| Support a Variety of Data Types | <i>The capability to handle high data volumes in different forms and formats (Big Data).</i> | The system works with structured data. | The use of semi-structured data is possible. | Initial types of Big Data are supported. | The for the organization most important Big Data types can be handled. | The system can work with all required forms of (Big) data. | 4 |
| Environment Sensing in Real Time | <i>The ability to sense the physical organization environment (e.g., assets, goods, people) in real time.</i> | Real time environment data is not available. | Initial setups allow first environment data. | Most important assets, goods, and people are sensed. | Most assets, goods, and people are sensed. | All required assets, goods, and people are sensed. | 3 |
| Real Time Complex Processing | <i>The capability to conduct complex processing, rapidly, reliably, and fully scalable.</i> | Simple computing is done in batches. | Basic computing tasks are done in real time. | First, specific complex computing tasks are done with restrictions in speed and scalability. | Most main complex computations are done with restrictions in speed and scalability. | All required complex computation tasks are done fast, reliable, and scalable. | 4 |

Table 29 - i-ERP Assessment: Example General Prerequisite Dimension

System Evaluation of the Data Dimension:

| Data Dimension | | | | | | | |
|--|---|--|--|---|--|--|-------|
| Characteristic | Definition | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 | Score |
| Personalized, Context Specific, Data Provision | <i>The capability to provide data in real time considering the user individual habits and context of the task.</i> | Predefined data is provided in batches defined by a pre-set user role. | Predefined data is provided in real time defined by a pre-set user role. | Data is provided defined by simple and very repetitive habits and context in defined, general situations. | Data is provided defined by individual repetitive user habits and context in specific, but complex situations. | Data is provided in real time according individual user habits and context in any complex situation. | 4 |
| Advanced Data Insights | <i>Insights in data gained through analysis, e.g., predictions, patterns, classifications, statistics etc. to support decisions and discoveries and the way data can be visualized.</i> | Simple reports / summaries of data, mostly in tabular form. | Simple past-oriented analysis and basic visualizations. | Past- and simple future-oriented insights in simple, daily situations. Data presented in visualized format. | Advanced future and past oriented insights in initial complex situations. Advanced visualization capabilities. | The system provides intelligent insights in and visualization of data in all situations. | 4 |
| Intelligent Creation of Data | <i>Create new data based on data, such as scenarios, explanations, or recommendations.</i> | The system records transaction data. | Creation of simple past oriented data. | Creation of past-oriented data and future orientation in specific, simple tasks. | Creation of complex past-oriented and advanced future-oriented data. | Creation of reliable data autonomously in all system areas and complex situations. | 3 |

Table 30 - i-ERP Assessment: Example Data Dimension

System Evaluation of the Process Dimension:

| Process Dimension | | | | | | | |
|------------------------------|--|---|---|---|---|--|-------|
| Characteristic | Definition | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 | Score |
| Autonomous Process Execution | <i>The automation of any operational, tactical, and strategic internal and external ERP process or task.</i> | Processes are mapped digitally in the system but executed manually by the user. | Simple frequent, repetitive, deterministic, processes can be automated. | Most repetitive and first less/non repetitive processes can be automated. | Repetitive processes and most non/less repetitive processes can be automated. | All desired processes can be automated. | 4 |
| Process Optimization | <i>Detect inefficiencies and respective solutions based on learnings, to autonomously improve the process or to augment in manual optimization efforts.</i> | The system does not offer support for process optimization. | Insights in simple process inefficiencies to support the user in manual optimization efforts. | In defined, simple, repetitive processes inefficiencies can automatically be detected, understood. Optimal solutions can be proposed / implemented. | In main and low complexity processes inefficiencies can automatically be detected, understood and, optimal solutions can be proposed / implemented. | In all desired processes, inefficiencies can be understood and optimal solutions can be found. Processes are optimized autonomously. | 2 |
| Process Redefinition | <i>Detect and understand process requirement changes (environment/business) and autonomously improve the process or to propose changes and augment in manual redefinition efforts.</i> | The system is inflexible and does not support in process redefinitions. | Insights in simple requirement changes supporting in manual optimization. | In defined, simple, repetitive processes requirement changes can automatically be detected, understood and, solutions can be proposed/implemented. | In main and low complexity processes requirement changes can automatically be predicted, understood, and solutions can be proposed/implemented. | Adoption to and prediction of changing business/environment rules in desired, and complex processes. | 2 |

Table 31 - i-ERP Assessment: Example Process Dimension

System Evaluation of the UX Dimension:

| UX Dimension | | | | | | | |
|--------------------------------------|---|---|---|--|--|--|-------|
| Characteristic | Definition | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 | Score |
| Proactive User Assistance | The use of intelligent assistants (e.g., automated filling, translations, chatbots, etc.) for user support and the provision of information for recommendations and advice. | The system provides no user assistance. | Basic insights and notifications to assist the user. | In simple situations and clearly defined areas advice/recommendation is provided. First intelligent assistants for basic user support. | In most daily situations advice/recommendations provided. Intelligent assistants support daily user work. | In any complex situation advice/recommendation is provided and intelligent assistants support complex tasks. | 3 |
| Conversational System Interaction | The conversational interaction of user and system (in- and outputs) in different ways and consideration of user habits and context. | Predefined system interaction. | Initial, input with very structured and basic data (e.g., structured documents) but not fully predefined. | Alternative interaction (e.g., voice, text, image) in clearly defined areas and with simple, defined rules. | Flexible input in daily situations and basic personalized / context specific outputs (e.g., 'question answer' format). | Conversational interaction, unstructured data input and outputs considering contexts and habits in complex situations. | 2 |
| Responsive User Interface and Design | The adoption of the system UI (e.g., data or functions shown) to the individual user needs / habits and the context and prediction of next steps to adopt accordingly. | No UI personalization is possible. | Manual UI adjustments are possible. | Understanding and learning of simple workflows and contexts in specific areas and UI adoption accordingly. | Understanding and learning of daily user workflows and contexts in main processes and UI adoption accordingly. | UI adoption to user context and habits in any complex situation and predictive adoption. | 3 |

Table 32 - i-ERP Assessment: Example UX Dimension

2. Identification of advancement areas

In this step, the assessment calculates the results based on automated formulas. The score per characteristic, dimension, and system are derived. The strengths and weaknesses of the system intelligence level are identified. This allows target areas to be acknowledged in which advancement actions are necessary to advance to the next higher level. The results table is presented in table 33.

| I-ERP Dimension | I-ERP Characteristic | Score | Dimension Score | i-ERP Score |
|--------------------------------|---|-------|-----------------|-------------|
| General Prerequisite Dimension | Flexible System | 3 | 3 | 3 |
| | Flexible Database | 5 | | |
| | Support a Variety of Data Types | 4 | | |
| | Environmental Sensing in Real Time | 3 | | |
| | Complex Processing in Real Time | 4 | | |
| Data Dimension | Personalized, Context Specific Data Provision | 3 | 3 | |
| | Advanced Data Insights | 4 | | |
| | Intelligent Creation of Data | 3 | | |
| Process Dimension | Autonomous Process Execution | 4 | 2 | |
| | Process Optimization | 2 | | |
| | Process Redefinition | 2 | | |
| UX Dimension | Proactive User Assistance | 3 | 2 | |
| | Conversational System Interaction | 2 | | |
| | Responsive User Interface and Design | 3 | | |

Table 33 - i-ERP Assessment: Example Results Table

Identify improvement areas per and level per characteristic

The improvement areas per characteristic can be found in the "Score" column of above table. The scores equal the scores entered by the assessment user in the previous step 1. In this example one can see that the "Flexible Database" is already developed like in an i-ERP. The "Process Optimization",

“Process Redefinition”, and “Conversational System Interaction” are the weakest links in the system and some effort should be put in advancing those characteristics.

Identify improvement areas and level per dimension

The improvement areas per dimension can be found in the “Dimension Score” column of above table. The score is the minimum of all dimension characteristics of the respective dimension.

General Prerequisite Dimension: This dimension is evaluated with score 3. This dimension is advanced regarding its intelligence level. One characteristic is already in level 5, two are in level 4, and two in level 3.

Data Dimension: This dimension is evaluated with score 3. This dimension is advanced regarding its intelligence level but has some weaker links. One characteristic is in level 4 and two are in level 3.

Process Dimension: This dimension is evaluated with score 2. This dimension has initial advancements regarding its intelligence level. One characteristic is already advanced in level 4, but the other two levels are the weak links of this dimension and still in level 2.

UX Dimension: This dimension is evaluated with score 2. This dimension has initial advancements regarding its intelligence level. Two characteristics are in level 3, and one is still in level 2.

Identify system level

The system level can be found in the “i-ERP Score” column of above table. The score is the average of all i-ERP dimension scores. The system in the example can be classified in in i-ERP level 3 (Elementary Intelligent ERP).

Visualize the results

The following figures show the different visualizations of the levels in every stage in a network diagram.

Figure 24 shows the level per characteristic in this example. There is no further description as it is the visualization of the above explained data from the table.

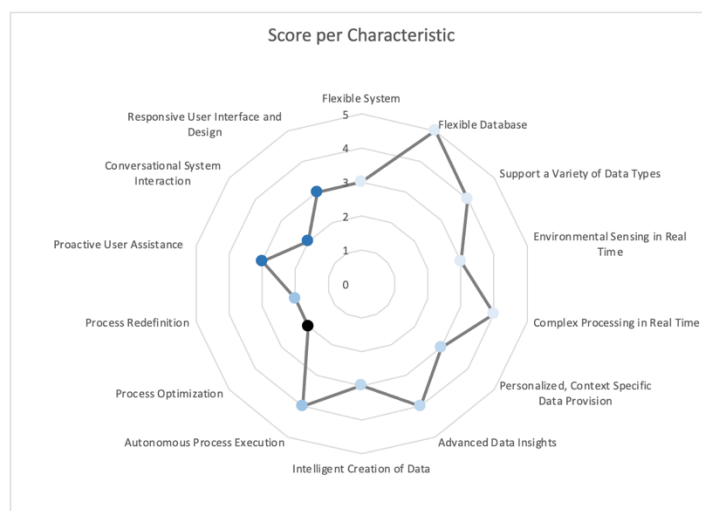


Figure 24 - i-ERP Assessment: Example visualised score per characteristic

Figure 25 shows the levels of the characteristics categorized by the four i-ERP in this example.

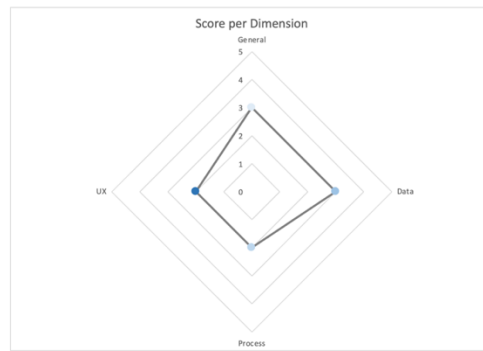


Figure 25 - i-ERP Assessment: Example visualized i-ERP dimensions

Figure 26 compares the level of the four i-ERP dimensions in this example.

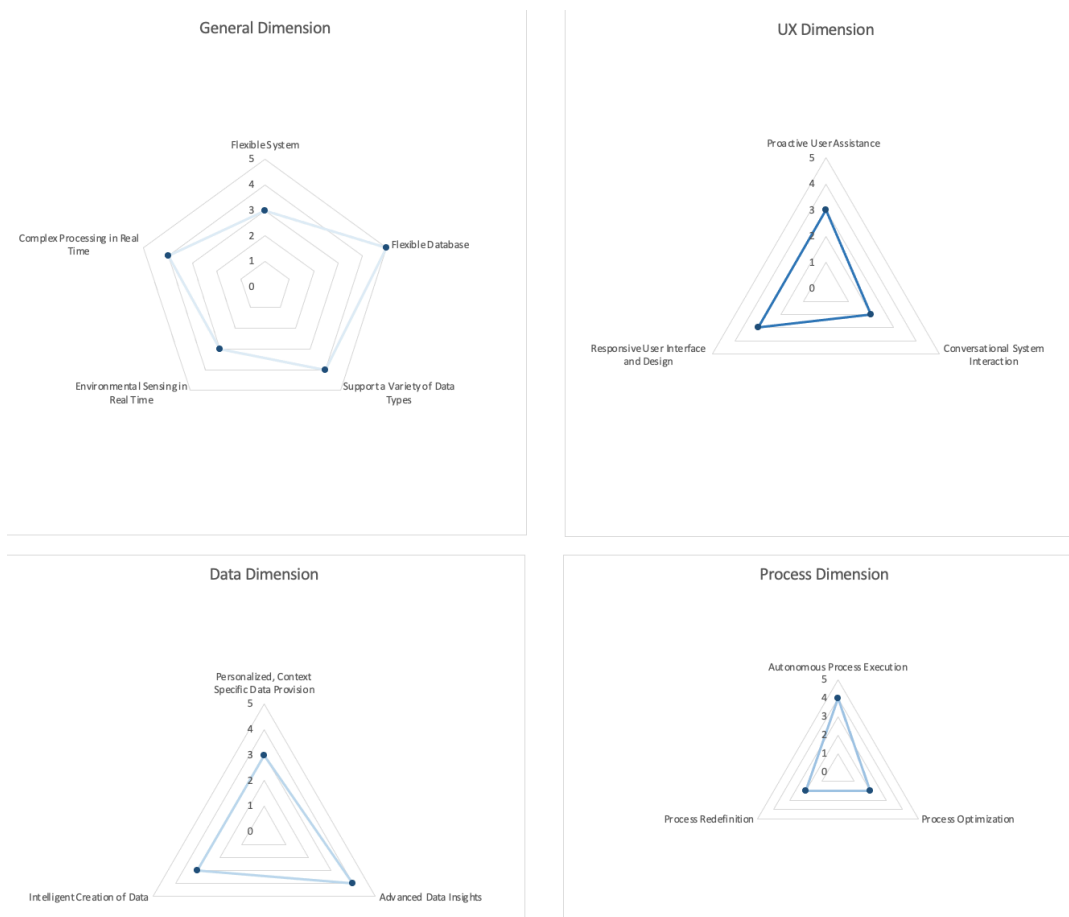


Figure 26 - i-ERP Assessment: Example Visualised characteristics per dimension

3. Recommendations for advancement

In the last step of the assessment, targeted recommendations for action are derived from the results of the evaluation. For this purpose, the next level to be reached or the level to be maintained is displayed to the user and a general recommendation is given to move up to the next higher level. Table 34 is the recommendations table for this example.

| I-ERP Dimension | I-ERP Characteristic | Level to achieve/sustain | Recommended Action to archive the next level |
|--------------------------------|---|--------------------------|--|
| General Prerequisite Dimension | Flexible System | 4 | Extend efforts to other system parts with most flexibility needs. |
| | Flexible Database | 5 | Maintain the system and look for new future developments. |
| | Support a Variety of Data Types | 5 | Extend data processing capability to remaining desired types of Big Data. |
| | Environmental Sensing in Real Time | 4 | Extend the use to additional suitable assets, goods, people. |
| | Complex Processing in Real Time | 5 | Make complex processing available all areas and invest in speed and scalability. |
| Data Dimension | Personalized, Context Specific Data Provision | 4 | Extend learning capabilities for habits and context to more complex but repetitive situations. |
| | Advanced Data Insights | 5 | Extend analysis and visualization capabilities to the highest available level and all complex situations. |
| | Intelligent Creation of Data | 4 | Extend complexity of situations data can be created for. |
| Process Dimension | Autonomous Process Execution | 5 | Extend the automation of non/less repetitive processes to all processes. |
| | Process Optimization | 3 | Implement capabilities to detect, understand, and solve inefficiencies in defined, simple, processes. |
| | Process Redefinition | 3 | Implement capabilities to detect, understand, and solve requirement changes automatically in defined, simple, processes. |
| UX Dimension | Proactive User Assistance | 4 | Extend the abilities of intelligent assistants and enable provision of advice / recommendation in daily situations. |
| | Conversational System Interaction | 3 | Enable simple, alternative interactions (e.g., voice, text, image) in clearly defined areas. |
| | Responsive User Interface and Design | 4 | Extend capabilities to understand daily user workflows and data / functions needs in main processes. |

Table 34 - i-ERP Assessment: Recommendations Table Example

Recommend the next suitable level

In the column “Level to achieve/sustain” one can see which the next level is to achieve, or, in case of level 5, to maintain. In this example one can see that the levels to be reached/maintained are five times levels 5, six times level 4, and three-times level 3.

Recommend improvement action for each characteristic

The column “Recommended Action to archive the next level” displays the recommendation for the advancement in the next level. The recommendations can be read in the table above.

This example of one instantiation shows that and how the proposed assessment and levels work as proposed and result in goal-oriented recommendations on how to make a system more intelligent. The next step is the validation of the artifacts using an empirical method – namely expert interviews.

4.5. VALIDATION OF THE PROPOSED ARTIFACTS

The next step of the according to Peffers et al. (2007b) is the validation of the artifacts. The goals of this step were to gather opinions, ideas, and validation on the artifacts and the main characteristics. This step is of great importance in the present study because of the short demonstration of only a part of the artifacts, so the expert opinions have a high value for this work.

Preparation of the interview:

First, an interview schedule was developed. The interview questions are created general and semi-structured to allow open discussions and holistic insights. The interview is divided into two parts:

1. Understanding of i-ERP (i-ERP Concept, i-ERP Model)
2. Assessment of i-ERP (i-ERP Taxonomy, i-ERP Assessment).

A presentation was prepared to briefly present the outcomes before asking the interview questions. To allow preparation of the interview and a deeper insight into the proposed work, the presentation was and sent to the interview partners before the interview. This extended presentation with more details was also used during the interviews for questions, explanations, and clarifications. The interview questions are asked after the presentation and clarification of questions of the respective interview section.

First Section: i-ERP Understanding Questions:

1. *Do you agree with the proposed idea of i-ERP? Please explain.*
2. *Do you have any suggestions for improvement? If yes, please explain.*

Second Section: i-ERP Assessment Questions:

1. *Do you think the proposed assessment and levels are useful for science and/or practice? Why?*
2. *Do you agree with the proposed assessment and levels? Please explain.*
3. *Do you have any suggestions for improvements or future extensions?*

The interview guide and the presentation were tested with an experienced family member for its duration and understandability. Small adaptations were made to guarantee optimal understanding in the final interviews.

Second, expert interview partners had to be found. An expert is a person with an extensive knowledge on a subject. The goal of this evaluation was to acquire information from professionals through interviews. To find experts a cover letter was drafted, and relevant experts were contacted via e-mail or LinkedIn. With the respondents a personal appointment for the interview was arranged. The specialists were chosen based on their ERP experience in practice, academia, or a combination of both.

The interviewers come from Portugal and Germany. The interview partners make up a non-representative sample of the population, which is any user, vendor, consultant, creator, etc. of ERP. The four interviewees' profiles are presented; names, companies, and universities are kept private.

Interviewee 1 (I1): The interviewee is Portuguese and professor in information systems. He has a strong academic relationship to the ERP vendor SAP, as well he has (co-)authored several academic publications and books. He has year-long international experience in multinational companies.

Interviewee 2 (I2): The interviewee is German and Product Owner at an SAP consultancy. He graduated business school in Germany. His consultancy focus lies on FS-CD and is mainly in charge of customers on the insurance industry.

Interviewee 3 (I3): The interviewee is Portuguese and professor in information systems. He is a director in an IT support and consultancy company. He has practical experience at Microsoft working on enterprise solutions and led the launch of the first commercial Internet services in Portugal

Interviewee 4 (I4): The interviewee is Portuguese and professor in information systems. He is working at Microsoft for many years, with a focus on business apps, data, and AI.

Conduction of the interviews:

Interviewer: Yannic Bertram, MSc. Student at NOVA IMS, German, author of this work

Timing: The interviews were conducted between January 18th, 2022, and February 15th, 2022.

Duration: The duration of the interviews was between 30 and 40min, including a 10min presentation of the research and the outcomes and the remainder of the time for questions, interview questions, and open discussion about i-ERP.

Location: Due to the Covid-19 pandemic and scheduling reasons the interviews were conducted via a video conferencing tool (Zoom), with cameras on and a shared screen.

Language: The interviews were conducted in English, which in all cases is not the native language of the interviewee and interviewer.

The interviews started with a short introduction. Both participants had the chance to introduce themselves and the research and its goals were presented. The structure of the interview was explained, and the interviewee was again reminded to ask any question if needed for a better understanding or to build an opinion of the work. The presentation was done, and the questions were discussed as described in the above chapter. Small deviations of the questions are possible to guarantee a broad insight into the topic and to gather as many relevant information as possible. The interview partners expressed their ideas and considerations in response to the questions and small discussions about the topic were held. The presentation used during the interviews can be found in the appendix of this work.

Evaluation of the interview results:

The interviews were recorded using the Zoom recording function to allow a close analysis of the answers after the interview. A full transcription was not considered useful. The recordings were listened to multiple times and notes were taken. The recordings can be made available upon request.

The evaluation's goal is to gain a broad, general understanding of the experts' opinions. The goal is not to highlight every single point raised. The evaluation is focused on content, intonation, speaking speed, and other factors are not considered in the analysis. The experts' statements were transformed into written English in the case of direct citations. There were no changes made to the contents.

For a structured evaluation, the responses of the experts were analysed and compared categorized by each question asked. The relevant information was filtered by listening the answers of the interview partners several times and reading the transcript. Coherences and contradictions were revealed, and preliminary inferences and interpretations reached. This approach facilitates an understanding of the strengths and weaknesses of the work presented, shows potential for improvement, and provides feedback.

Results of the Interview:

This section discusses the most important replies and thoughts of the different interview partners for each question respectively. If additional notes were made at the end of the interview they were added to the respective and best suiting category of questions.

Section 1: Understanding of i-ERP:

1. Do you agree with the proposed idea of i-ERP? Please explain.

I1 mentioned that the big vendors, especially SAP, go a similar way like the idea proposed. The availability on the market is not as comprehensive as the idea proposed yet but has the same direction. He sees vendors offering similar solutions soon and mentioned that he expects bigger vendors to be first in the market. He sees a big trend in the use of different interaction ways (voice, touch, etc.) interactions with the i-ERP, which is covered as well by the idea proposed. I2 agreed with the idea and highlights the good structure in the concept and the graphics. He explained that there are already automated modules but sees the weakness in their self-learning capability which is very restricted still and often involves human intervention. Another thing highlighted was that a technical change also involves the adoption of the physical environment, such as for example IoT which is include in the model. He mentioned that it is very important to consider to what the customer wants and can imagine. I3 agreed with the general idea and main points of the idea, such as the technologies used, and main points covered. He pointed out one important issue, namely the general approach with no specific use case given, making it hard to say of the idea is correct, as it always depends on the company and its use cases. For some organizations this idea might be too comprehensive already, for other companies it is correct. I4 fully agreed with proposals. He pointed out that the technologies, both prerequisite and intelligent, are well mapped correct for the purpose of an intelligent ERP.

2. Do you have any suggestions for improvement? If yes, please explain.

I1 repeated that the idea is already very comprehensive and includes the most important most recent technologies. He sees other new technologies, such as Blockchain, also moving into ERP but fully agrees with the mainstream technologies used. In the UX Dimension he adds that gamification could play an important role, especially when implementing new functionalities of an i-ERP (adoption and change management). I2 said that it would be important to define the term user in the case of the system, is it the user of the system or the end user. In case it is the end user it was mentioned that this type of user does not access the system directly, but different layers are in-between. In relation to the model, he proposed to differentiate two parts of the database, namely an in-memory database for real time / fast data access and a long-term oriented database comparable to a traditional ERP which works slower than the other DB but is way cheaper in price. I3 proposes as improvement to show the benefits for an organization, or the problems solved with i-ERP to show the value and need of the system better, as the ERP (and i-ERP) is mostly driven by business users. I4 recommended to add give the ideas a more practical touch. Functional capabilities of different ERP modules could be added, this would make the approach more touchable, as the understanding of what an ERP is and what modules belong to it can vary a lot between organizations. The use cases of technology concepts can vary a lot between the modules, as they all have a different functionality and focus (e.g., internal / external). I4 recommended to add the benefits several interest groups can obtain. The focus should be on the organization using the i-ERP, but also on other stakeholders (customers, suppliers, etc.). He also recommended to find KPIs to quantify the goals for a better measurement.

Section 2: Assessment of i-ERP

1. Do you think the proposed assessment and levels are useful for science and/or practice? Why?

I1 sees the levels and assessment very useful for a use in practice. In the target group he sees especially software vendors and system integrators. He saw the topic as too complicated for regular users and mentioned that the vendor offer evolution is an essential part for the evolution of i-ERP. He could see a use case in the tool for vendors to derive how they can improve their offer. Another use case can also be consultants, but at the end, it is implemented what the vendors can offer. I2 sees the best use case for the tool and levels in ERP consultancy. It can be used for system analysis, concluding where the organization is and then to show where it could go. He states as well that consultants must adopt to the wishes and risk affinity of the organizations consulted. The change projects in the ERP area can go for years and the risk of the adoption of a new system makes companies hesitate to try new functions which would be available on the market. I3 stated that it is generally useful in practice, and he has used similar tools before in his professional career to create a type of roadmap of where organizations are and where they could/should go. He mentioned that the usefulness depends on the foundation of the i-ERP levels as they are important for the outcomes and might not be understood in practice as they do not comply with any industry standard. As target groups he sees especially consultants and internal teams and departments. I4 sees the higher management levels in internal departments (C-suite) as user of the proposal. In his opinion those groups have the highest level of information and understanding for the needs and possibilities for the organization. Regular end users have, in his opinion, not enough understanding of the ERP and the opportunities that are available.

2. Do you agree with the proposed assessment and levels? Please explain.

I1 fully agrees with the proposed assessment and levels with no further explanation. I2 also agrees with the content and highlights the very structured, comprehensive, and easy to understand approach for the tools and the levels as well as the relation to the previous concept. I3 mentions that he would prefer to base the levels on something existent or related for a better understanding and it might be correct but makes it hard to build a final opinion. I4 confirmed that the proposed level make sense. He added that the idea of the assessment tool itself is correct.

3. Do you have any suggestions for improvements or future extensions?

I1 has no specific suggestions and points out that the work is already very comprehensive and complete. I2 proposed some improvements. ERP systems often consists of different modules, those modules are not essentially on the same technical and functional level. Therefore, he recommends doing the assessment per module and bring those results together for a full system assessment. This would lead to a clearer result. Related to this he said that not all questions would essentially be suiting for all types of modules and maybe a module related approach could be considered. The last recommendation he made is to quantify the idea of the assessment, to make a better use of the score and add more objectivity in the assessment levels and process. He proposes to use known organization KPIs or to come up with other measures. I3 proposed to adopt the level to some industry standard for a better usability, which would, in his opinion, lead to a better understandability and usability. A second point he added was the benefit or outcome of achieving the next level, to allow organizations to

understand why they should move to the next respective level. I4 said that the assessment can lead to different results in different organizations as they define their ERP differently. He added that in companies different modules often are in different development levels, an improvement could be to cover these differences somehow in the proposal. I4 proposed that the assessment could be quantified, and that's benchmarking is always interesting for organizations. He recommended to find a way to include intelligence benchmarking to peers in industry, therefore data would need to be available. He proposed to find a way to prioritize actions / recommendations to define which actions should be taken first. The last idea was to connect the recommendations to specific KPIs/benefits like I4 proposed in the understanding of i-ERP section. Companies could then see how a specific action affects KPIs and base their decisions on this.

4.6. DISCUSSION OF THE RESULTS

In this chapter several aspects of attention in the research outcomes are discussed based on the literature review and the information obtained from the experts in the validation step. The focus of this chapter is on utility and validity of the proposal and the improvement recommendations received from the experts. The aim is to evaluate what has been proposed and to highlight possible advancements, strengths, and weaknesses. The chapter is separated in two sections, the understanding of i-ERP and the assessment of i-ERP.

The literature review showed that i-ERP will play an important role in near future and that organizations plan to add more intelligent features to their i-ERP systems. The offer and adoption of i-ERP systems is low. The i-ERP is a concept that evolved based on traditional ERP systems. A fundamental understanding of i-ERP with concept and model helps to better grasp the idea of i-ERP for academic and practice. The i-ERP assessment with levels is an important practice-oriented tool for the system status and the basis for a possible roadmap for advancement.

Understanding of i-ERP

The relevance of the proposals could be confirmed, as all interviewees understood and confirmed the idea of i-ERP and its early stage of development. The vendors in the market have some offers in the area, but they seem to be less comprehensive than the concept and model proposed. This opinion complies with the findings from the literature review that sees i-ERP in an early stage of development (Accenture, 2020a) and the low offer of such features (Gold, 2020). In one of the interviews, it is explained that companies often hesitate to implement something that complex and new as the risk is very high. The requirements for i-ERP come from the organizations, but to implement a solution there must be an offer from (at least) one vendor. Missing functions in the market compared to the concept proposed are according to the experts especially in the self-learning capability. Human intervention is often still needed. The reality described by this expert comes close to what was introduced as RPA in course of this work and is one step towards an i-ERP. This could be related to the lack of data quality data to implement learning but needs further research.

The proposed idea of i-ERP comes close to a possible reality. The experts agreed to the general idea and technology concepts used in the i-ERP proposal. In particular, the correct selection and categorization of prerequisite technologies and intelligent technologies was highlighted repeatedly. A question that arose is the need of an i-ERP for organizations. The question is what level of complexity and comprehensibility is needed for the use cases of a specific organization. This confirms that the

general idea is correct, but there might be adoptions needed for specific organizations or modules in the functions offered and technology concepts used, according to the use cases. The idea of the thesis was the creation of a general approach, to get a fundament for i-ERP, but it was not examined if every organization needs a full i-ERP and what factors could be used to determine this need. In the ERP literature it could be shown that ERP systems differ in many aspects, but the general idea is very similar (Gronau, 2021). The approach chosen for this work was a general approach to better understand the general idea of i-ERP. In a real-life implementation, e.g., the creation of an i-ERP module, specifics should be considered and only functions that bring value to the respective module should be implemented. Therefore, more specific studies will be necessary and for the application of i-ERP a less general approach that matches defined use cases is essential. In addition, some specifics of the modules could be addressed, as the technology use cases also depend strongly on the specific functions in the module. The use cases presented in the concept were therefore kept general and it must be understood that in such a new topic, other proposals are also possible, which are very different from this idea. For scientific progress, it is essential to bring together different points of view to obtain the best possible result and this approach could be confirmed to be suitable.

The experts confirmed that other technologies might play a role in i-ERP now and in the future, this complies with the idea of a gradual development of the ERP over years. New functions and changes are to be expected along with technical developments and requirement changes of the companies (Bahsas et al., 2015; Majstorovic et al., 2020; Rashid et al., 2002). The functions of i-ERP might change as new technology use cases will evolve or company requirements change. ERP is an industry driven concept and company needs and changes affect its development (Moon, 2007). The proposed understanding provides the base for the further development and can expect many changes in functions and components in the future. An example of another technology concept which might be added to i-ERP could be Blockchain, which was mentioned by one of the authors in the literature review (Bouchemal & Bouchemal, 2019) and one of the experts. However, it is not yet a main i-ERP technology, as the literature review showed that most authors did not mention this concept. Related, a specific improvement proposal from the experts for the i-ERP concept was the addition of information regarding the benefits for an organization and other stakeholders (e.g., customers, suppliers, etc.), in the best case quantified KPIs. The concept shows some main goals that can be reached with the characteristics, but it could be gone more in detail, so companies can “select” their i-ERP features and composition based on the benefits expected or weaknesses to be removed, helping them to make detailed decisions. In the literature review a look was taken at the weaknesses of current ERP systems and at the strengths of i-ERP. This opens an interesting opportunity to take this improvement idea and research the effects of the proposed i-ERP idea on the weaknesses of ERP. The idea was not to design an own i-ERP based on the weaknesses of an ERP, but to conceptualize an i-ERP idea based on the current state of research. There has not yet been a model of an i-ERP. The only reference point in this direction was the ERP 4.0 model, which, however, has a very general and unspecific approach (Majstorovic et al., 2020) and functions, components, and relationships are not clear. It also seems that the intelligent functions are not in the core of the i-ERP, which is required by other authors (Accenture, 2019). Compared to the existing ERP 4.0 model, the model proposed has become more specific and closer to reality. The basis was therefore primarily a basic understanding of i-ERP and ERP compositions. Minor improvements could be made with small changes such as a better separation of the different database types an i-ERP can have, e.g., through the separation of an in-memory database for rapid throughput and access and a long-term storage for big data amounts. An

idea added by one of the interviewees is the addition of gamification functionalities in the UX Dimension to improve the adoption success in organizations, as it helps to the system users to make better and easier use of the functionalities offered. This idea goes in the direction of adoption of systems which was not core of this work. However, this proposal can make a point for works needed in that direction as they are not yet available according to the literature review. One point mentioned by one of the experts is the alternative control of the i-ERP with, for example, a touch screen. In this work, the new possibilities of data input, e.g., voice or text, were discussed, but not the use of new devices to interact with the ERP, which could be a possibility to extend the model and concept. This aligns with another expert's point that other areas in the company need to be adapted to be successful with i-ERP. The ERP has an impact on People, Processes, and Technologies (Morris et al., 2016) and is not just a technology change (Davenport, 1998).

Assessment of i-ERP

The experts agreed that the utility for the proposals is in practice. None of the experts mentioned an academic use case. The levels and assessment tool can, according to the experts, be used for a system analysis to show where the system stands and to create a roadmap of system improvement. Two main user groups were mentioned, first related to i-ERP vendors and second to i-ERP customers. Software vendors and system integrators can use the proposals to improve the system offer towards a more intelligent ERP system. This helps them in reaching their goal in archiving an i-ERP offer for the market, which is not fully available yet (Bauer & Bingler, 2020). Consultants and internal teams can use the tool to assess a system status and to recommend improvements for the system. Although this has no direct connection to ERP vendors, the desires of the customers put pressure on the market to create solutions that comply with those ideas. At the beginning of the work, ERP users were assumed to be part of the target group, but in course of the interviews it became clear that most experts see such a tool is too complex for a regular user, even if they are technically experienced, but there were some disagreements about that, as another expert saw the main use in internal departments. The main use seems to lay within ERP vendors and (internal/external) consultants. It is always essential to ensure that the users of the assessment have access to the necessary information and an understanding of the current market.

The experts mostly agreed with the proposals. One point mentioned is the naming and separation of the i-ERP levels. One expert mentioned that for a better understanding in industry the use of an already known methodology would be easier, all the other experts agreed with the levels and said that they are understandable and make sense. In the research progress it was found that most similar tools and taxonomies use five levels in different categories. This idea was adopted in this research. There are two models that go in a similar direction, which were presented in the literature review (Basl & Novakova, 2019; de Carvalho Silva, 2020). These models have in common that they start with a traditional ERP system and end with an i-ERP / ERP 4.0. This approach has also been adopted in this work. However, no clear structure could be found in the explanations of the models or derived in either model that could have been adopted for this research. Known models from software development and models from enterprise systems related to ERP were consulted regarding the levels, but no fit was found for this approach. The concern of the interview partner was that the levels might be incomprehensible for practice without a known methodology. The demonstration of this work was limited to a fictive example. It should be attempted to test the proposed levels in practice to see how they are understood and used. The aim of this thesis was to get a more understandable and structured

approach than the two existing models, also in relation to the recommendations for the next levels. In the de Carvalho Silva (2020) model, these are present but not related to individual categories but very unstructured, which could already be very much improved in this proposal and the validity of the categories could be confirmed in the previous evaluation of the i-ERP concept. Hevner (2004) makes clear that in DSR, innovative progress is the goal and not a perfect, fully true solution must be achieved. A step forward from what existed before could be achieved and validated. This is a proposal of possible steps derived from the concept presented earlier and the related literature. It does not exclude that there are other ways to distinguish i-ERP development steps that differ from this proposal.

Some improvements were mentioned which should be discussed. The path chosen for this work was a general approach, this approach assumes that all modules are on the same intelligence level, which is according to the experts not essentially the case in real world systems. An idea would be to do the assessment by module to cover different development stages in the different modules. A second idea would be to add some module specific questions to evaluate the intelligence level. Complying with what was said in the validation, that not every organization has use cases for all functionalities offered, which is assumed by the proposal of this work. This work and the assessment have a qualitative approach. One recommendation for improvement was the use of a quantitative score as it would add more objectivity in the results. This is a practical approach, but numbers would be very hard to back up with knowledge gathered in an academic approach like this work. It could for example be created together with experts or in a case study approach. The practical use would be undoubtedly higher. An interesting improvement proposed would be the addition of the benefits gathered when achieving the next level, to make organizations understand why they should invest in approaching the next higher level. In the best case the benefits of advancing to the next higher level would be quantified on specific KPIs, which could be related to the i-ERP concept from section one, and information about benchmarks towards other organizations on the market to have a comparison. To do a better improvement roadmap, one of the experts proposed to prioritize the actions to be taken, which was considered a very good proposal and can be interesting for further studies, an idea would be to connect this prioritization with the benefits / KPIs the organization is planning to improve.

In summary, the experts in both sections confirmed the utility and validity of the proposals. Some interesting opportunities for improvement were collected and discussed and for some it would make sense to conduct a subsequent study and improve the artifacts or add value to the new topic of i-ERP. Some points for new studies have already been raised in the discussion and will be discussed in more detail in the next chapter.

5. CONCLUSION

In this chapter main conclusions are drawn, and the research is summarized. Limitations of the work are outlined, and future research opportunities related to this work are proposed.

5.1. SYNTHESIS OF THE DEVELOPED WORK

In this work research towards i-ERP was conducted. The problem identified was a gap in academic literature about the understanding and conceptualization of i-ERP and the lack of use / offer of i-ERP systems. The idea of i-ERP has become increasingly relevant in practice in recent years and consulted studies have shown that the concept will grow in practical and academic relevance in the coming years but is not covered by a lot of studies, especially not academic studies.

Four artifacts were created, an i-ERP concept, i-ERP model, i-ERP taxonomy, and i-ERP assessment. It was possible to show which functions and features a possible i-ERP could have, which technology concepts it could include and what role they could play. The idea of an i-ERP including possible main components, interrelationships, and functions could be visualized and presented. In addition, five development stages could be derived, starting with a traditional ERP, and concluding with an i-ERP. An i-ERP assessment with recommendations could be created to enable organizations the analysis of the system regarding the intelligence level and to give recommendations and a direction of thought for a system advancement.

The work conducted started with a literature review. The literature was separated in three related sections. First, the concept of ERP and its evolution were outlined to provide reader and author with a solid fundament about the basic concepts and ideas. Second, the idea and research state of the art of i-ERP were introduced to understand where i-ERP stands today and what ideas other authors have around this topic. Third, main technology concepts that could comprise an i-ERP and their potential use cases in i-ERP were explained to have a holistic insight into the possibilities and to understand the role of technology concepts. The literature served as fundament for the development of the proposed artifacts using DSR for Information Science.

The work had two research questions and aimed at the creation of four artifacts. The objectives of this research could be achieved. Regarding the first research question of what an i-ERP is and how it is composed, the i-ERP concept and model were created. It could be shown what functions an i-ERP can have using four i-ERP dimensions and several characteristics. It could as well be outlined what goals the several characteristics have for an organization. The i-ERP concept could provide an insight in use cases of intelligent and prerequisite technology concepts in i-ERP to achieve the intelligent functions. In the i-ERP model different components, relations, and functions of i-ERP could be visualized and a holistic overview could be provided of how an i-ERP could look like.

Regarding the second research question of how different development stages of i-ERP could be delimited and how it can be achieved, the i-ERP Taxonomy and i-ERP Assessment were created. In the i-ERP Taxonomy different development stages from a traditional ERP towards an i-ERP could be derived from the understanding of ERP, i-ERP, and the technology concepts and structured in accordance with the dimensions known from the i-ERP concept. For the i-ERP Assessment a level three step process could be defined to analyse an available system according to its intelligence level. Based on the

assessment result, targeted recommendations can be derived to advance and ERP regarding its intelligence.

Demonstration and validation were carried out to show the usability and correctness of the outcomes. Due to the scope of this work, the demonstration focused on the i-ERP taxonomy and assessment. Using a fictitious example, it was possible to show that the artifacts work and produce the desired result. In the validation, four experts from practice and academics were interviewed about the artifacts. The experts confirmed the correctness of the outcomes and were able to make some suggestions for improvement, which can be incorporated into the following DSR iterations of this work or future other studies related to i-ERP.

The artifacts can be used in the use cases described in the first chapter and have greatly expanded the academic literature around i-ERP. However, some limitations can be derived which result in new research opportunities.

5.2. LIMITATIONS OF THE STUDY

The study has some limitations which will be briefly discussed below. Some were already addressed in the discussion (chapter 4.6) and raised by the experts in the interviews and should not be repeated.

The studies and documents used come from practice and academics. Due to the shortage in academic work, however, practice documents were used to a larger extent. Consulting, international organizations, or vendor documents may be biased towards a product or vendor. It can happen that biased information is included in the work, which does not make the information wrong but restricts the content and excludes possible other opinions.

Due to the general approach of the stud, the artifacts were not targeted to specific modules, organizations, or industries. The goal was to have a general approach, which was met, but this implies that full transferability to every system or organization is not essentially possible. In relation to this, not every company needs an i-ERP, but individual functions may be completely sufficient for the use cases, which is not covered by the i-ERP assessment. In one of the interviews, it was also mentioned that it would make sense to divide the system into modules to have a more specific approach.

The usability of two of the artifacts could be shown with a fictional example, but a practical implementation or a case study in a real company or ERP is missing. It can therefore not be concluded that the idea of i-ERP works and is also useful in real organizations as presented in the study and only serves as general overview.

The validation was conducted with four experts. A more reliable result could be achieved if more experts were consulted. A more reliable insight could be reached if experts come in equal numbers from the different domains and target groups of this study or if a qualitative approach could be used for validation with more participants.

The idea of i-ERP is based on the mainstream opinion of the authors consulted. Not all technology concepts that can be somehow related to ERP were highlighted. It may also be that other authors use different concepts and therefore conclude different / additional functions and characteristics for i-ERP. Today, technologies are developing at a very fast pace. Soon, new use cases and possibly even new technologies will emerge that can advance an i-ERP but have not yet been considered in this work. For

this reason, no end has been set in the assessment, but when level 5 is reached, the market should always be kept in sight to remain competitive.

Ethical and legal aspects, which play a significant role in the selection, adoption, and use of the system, were also not addressed in the paper.

No own data was collected, and only available studies and documents were used as data source. However, by using expert interviews, the accuracy of the results could be confirmed, and evidence (primary data) could be collected, which can be used as further input besides the documents. The methodology requires creative activity and logical reasoning based on the knowledge base. This approach often results in increasing subjectivity and can include the authors opinion and must not be fully backed up by previous works but should include innovation. This makes more innovative artifacts available, but also makes the research dependent from validation and demonstration phases. Another weakness is that the artifact of a DSR process does not have to be completely correct (but it can be), so it cannot be relied upon to fully represent reality. The DSR also requires a definition of "requirements of a solution", this phase is prone to errors due to incorrect assumptions from the environment or the needs (Cruz & Cruz, 2020).

5.3. FUTURE RESEARCH

Research on i-ERP systems is only at the beginning of many new possibilities with this study. In the following, some suggestions for possible studies based on the results and limitations of this study are given. Some were already addressed in the discussion (chapter 4.6) and raised by the experts and should not be repeated.

The DSR methodology used has the possibility to perform several iterations, as explained in chapter 3.1. This research represents one iteration. A possible future study would be a second iteration of this work, incorporating the feedback from the validation (which is available in chapter 4.5 and 4.6) and communication phase (which will be available after the submission of this work) and extending or adapting the artifacts with current research findings from other studies in the i-ERP field.

The outcomes of this work could be validated on large scale with more experts in a qualitative or quantitative manner. For demonstration building an i-ERP in real environment for demonstration can be a future study which will require a big amount of time and funds and can for example be conducted as a case study.

One idea would be to conduct an additional study with a different approach and collect primary data, e.g., by interviewing experts previously to the development of an idea and to merge it with the results of this work. This would be a different scientific approach than this study and have a more practical touch. This would add new information to the concept especially because not a lot of different opinions and views on i-ERP could be found in literature yet.

In this study, a general approach was taken and not industry or module specific. The general approach has proven to be possible, but it should also be investigated how the different i-ERP modules differ from each other. It would therefore make sense to do a study on specific modules and to adapt the assessment to individual modules. It would be a future study opportunity to find ways, both in the concept and in the assessment, to present benefits to organisations so that they understand why they should use i-ERP. Ideally, the benefits should be quantifiable in this study.

An important study would be to make individual use cases and case studies in organisations of different kinds using the ideas proposed in this work. Due to the rather theoretical approach of this study, it would be interesting to check whether the proposed use cases of intelligent technologies can be implemented in practice or which restrictions apply here. The demonstration phase of this work could be improved by using a case study approach on one or multiple artifacts and make adoptions based on that.

I-ERP is a comparatively new topic, many changes and new developments are to be expected in the next years. It is important to keep studying new technologies and advancements of technologies to explore the potential role in i-ERP. Related to this also new dimensions, characteristics, and functions for i-ERP could be researched.

In relation to the last point mentioned, studies should also be conducted regarding the implementation and adoption of i-ERP systems in organisations. There are many interesting approaches, as not many such systems have been implemented yet and this information is important for practice to implement more i-ERP systems in the future. There is some information in the interviews that can serve as input. These studies are very important because the best system is of no use if organisations do not implement it and employees do not adopt it.

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APPENDIX

Appendix 1: i-ERP System Assessment

| General Prerequisite Dimension | | | | | | | |
|----------------------------------|--|--|--|--|---|---|-------|
| Characteristic | Definition | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 | Score |
| Flexible Application | Flexibility towards new functions, updates, and upgrades. | The system is inflexible. | Initial system parts (e.g., modules) are flexible. | Main system parts are flexible. | Most system parts are flexible. | The application is fully flexible. | x |
| Flexible Database | The ability to store a high data volume, scalable and centralized. | Data is stored in a centralized but inflexible database. | Initial database parts are scalable. | Main database parts are scalable. | Most database parts are scalable. | The database is fully scalable. | x |
| Support a Variety of Data Types | The capability to handle high data volumes in different forms and formats (Big Data). | The system works with structured data. | The use of semi-structured data is possible. | Initial types of Big Data are supported. | The for the organization most important Big Data types can be handled. | The system can work with all required forms of (Big) data. | x |
| Environment Sensing in Real Time | The ability to sense the physical organization environment (e.g., assets, goods, people) in real time. | Real time environment data is not available. | Initial setups allow first environment data. | Most important assets, goods, and people are sensed. | Most assets, goods, and people are sensed. | All required assets, goods, and people are sensed. | x |
| Real Time Complex Processing | The capability to conduct complex processing, rapidly, reliably, and fully scalable. | Simple computing is done in batches. | Basic computing tasks are done in real time. | First, specific complex computing tasks are done with restrictions in speed and scalability. | Most main complex computations are done with restrictions in speed and scalability. | All required complex computation tasks are done fast, reliable, and scalable. | x |

| Data Dimension | | | | | | | |
|--|--|--|--|---|--|--|-------|
| Characteristic | Definition | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 | Score |
| Personalized, Context Specific, Data Provision | The capability to provide data in real time considering the user individual habits and context of the task. | Predefined data is provided in batches defined by a pre-set user role. | Predefined data is provided in real time defined by a pre-set user role. | Data is provided defined by simple and very repetitive habits and context in defined, general situations. | Data is provided defined by individual repetitive user habits and context in specific, but complex situations. | Data is provided in real time according individual user habits and context in any complex situation. | x |
| Advanced Data Insights | Insights in data gained through analysis, e.g., predictions, patterns, classifications, statistics etc. to support decisions and discoveries and the way data can be visualized. | Simple reports / summaries of data, mostly in tabular form. | Simple past-oriented analysis and basic visualizations. | Past- and simple future-oriented insights in simple, daily situations. Data presented in visualized format. | Advanced future and past oriented insights in initial complex situations. Advanced visualization capabilities. | The system provides intelligent insights in and visualization of data in all situations. | x |
| Intelligent Creation of Data | Create new data based on data, such as scenarios, explanations, or recommendations. | The system records transaction data. | Creation of simple past oriented data. | Creation of past-oriented data and future orientation in specific, simple tasks. | Creation of complex past-oriented and advanced future-oriented data. | Creation of reliable data autonomously in all system areas and complex situations. | x |

| Process Dimension | | | | | | | |
|------------------------------|---|---|---|---|---|--|-------|
| Characteristic | Definition | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 | Score |
| Autonomous Process Execution | The automation of any operational, tactical, and strategic internal and external ERP process or task. | Processes are mapped digitally in the system but executed manually by the user. | Simple frequent, repetitive, deterministic, processes can be automated. | Most repetitive and first less/non repetitive processes can be automated. | Repetitive processes and most non/less repetitive processes can be automated. | All desired processes can be automated. | x |
| Process Optimization | Detect inefficiencies and respective solutions based on learnings, to autonomously improve the process or to augment in manual optimization efforts. | The system does not offer support for process optimization. | Insights in simple process inefficiencies to support the user in manual optimization efforts. | In defined, simple, repetitive processes inefficiencies can automatically be detected, understood. Optimal solutions can be proposed / implemented. | In main and low complexity processes inefficiencies can automatically be detected, understood and, optimal solutions can be proposed / implemented. | In all desired processes, inefficiencies can be understood and optimal solutions can be found. Processes are optimized autonomously. | x |
| Process Redefinition | Detect and understand process requirement changes (environment/business) and autonomously improve the process or to propose changes and augment in manual redefinition efforts. | The system is inflexible and does not support in process redefinitions. | Insights in simple requirement changes supporting in manual optimization. | In defined, simple, repetitive processes requirement changes can automatically be detected, understood and, solutions can be proposed/implemented. | In main and low complexity processes requirement changes can automatically be predicted, understood, and solutions can be proposed/implemented. | Adoption to and prediction of changing business/environment rules in desired, and complex processes. | x |

| UX Dimension | | | | | | | |
|--------------------------------------|---|---|---|--|--|--|-------|
| Characteristic | Definition | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 | Score |
| Proactive User Assistance | The use of intelligent assistants (e.g., automated filling, translations, chatbots, etc.) for user support and the provision of information for recommendations and advice. | The system provides no user assistance. | Basic insights and notifications to assist the user. | In simple situations and clearly defined areas advice/recommendation is provided. First intelligent assistants for basic user support. | In most daily situations advice/recommendations provided. Intelligent assistants support daily user work. | In any complex situation advice/recommendation is provided and intelligent assistants support complex tasks. | x |
| Conversational System Interaction | The conversational interaction of user and system (in- and outputs) in different ways and consideration of user habits and context. | Predefined system interaction. | Initial, input with very structured and basic data (e.g., structured documents) but not fully predefined. | Alternative interaction (e.g., voice, text, image) in clearly defined areas and with simple, defined rules. | Flexible input in daily situations and basic personalized / context specific outputs (e.g., 'question answer' format). | Conversational interaction, unstructured data input and outputs considering contexts and habits in complex situations. | x |
| Responsive User Interface and Design | The adoption of the system UI (e.g., data or functions shown) to the individual user needs / habits and the context and prediction of next steps to adopt accordingly. | No UI personalization is possible. | Manual UI adjustments are possible. | Understanding and learning of simple workflows and contexts in specific areas and UI adoption accordingly. | Understanding and learning of daily user workflows and contexts in main processes and UI adoption accordingly | UI adoption to user context and habits in any complex situation and predictive adoption. | x |

Appendix 2: i-ERP Recommendations

| General Prerequisite Dimension | | | | | |
|---|---|--|--|--|---|
| Characteristic | Level 1 Action | Level 2 Action | Level 3 Action | Level 4 Action | Level 5 Action |
| Flexible Application | Initiate flexibility efforts for first system parts. | Extend efforts to main system parts with most flexibility needs. | Extend efforts to other system parts with most flexibility needs. | Extend flexibility efforts to remaining system parts. | Maintain the system and look for new future developments. |
| Flexible Database | Initiate scalability efforts for first database parts. | Extend efforts to main database parts with most scalability needs. | Extend efforts to other database parts with most scalability needs. | Extend scalability efforts to remaining database parts. | Maintain the system and look for new future developments. |
| Support a Variety of Data Types | Begin with the support of semi-structured data. | Extend processing capability to initial Big Data formats. | Extend capability to for the organization most important Big Data formats. | Extend data processing capability to remaining desired types of Big Data. | Maintain the system and look for new future developments. |
| Environment Sensing in Real Time | Set up first devices on most suitable assets, goods, and/or people. | Extend the use to most interesting assets, goods, people. | Extend the use to additional suitable assets, goods, people. | Extend the use to remaining assets, goods, people. | Maintain the system and look for new future developments. |
| Real Time Complex Processing | Introduce real time processing for simple tasks. | Implement first capabilities for complex processing in specific tasks. | Extend processing capabilities for complex tasks to main system tasks. | Make complex processing available all areas and invest in speed and scalability. | Maintain the system and look for new future developments. |

| Data Dimension | | | | | |
|---|---|---|--|---|---|
| Characteristic | Level 1 Action | Level 2 Action | Level 3 Action | Level 4 Action | Level 5 Action |
| Personalized, Context Specific, Data Provision | Introduce real time data provision. | Implement capabilities to learn simple user habits and contexts defined situations. | Extend learning capabilities for habits and context to more complex but repetitive situations. | Extend learning capabilities for habits and context to desired complex situations. | Maintain the system and look for new future developments. |
| Advanced Data Insights | Enable simple data visualization and first past-oriented analysis capabilities. | Implement capabilities for insights with past- and initial future orientation for simple, daily situations and improve visualization. | Enable advanced and complex analysis with past- and future-orientation and visualization. | Extend analysis and visualization capabilities to the highest available level and all complex situations. | Maintain the system and look for new future developments. |
| Intelligent Creation of Data | Initiate simple data creation capabilities with past-orientation. | Initiate future-oriented data creation, for specific, simple tasks. | Extend complexity of situations data can be created for. | Extend data creation capabilities to all desired situations of any complexity level. | Maintain the system and look for new future developments. |

| Process Dimension | | | | | |
|-------------------------------------|--|--|--|--|---|
| Characteristic | Level 1 Action | Level 2 Action | Level 3 Action | Level 4 Action | Level 5 Action |
| Autonomous Process Execution | Initiate the automation of first, simple repetitive processes. | Extend automation of repetitive and initiate the automation of first non/less repetitive processes | Automate remaining repetitive and extend the automation to main non/less repetitive processes. | Extend the automation of non/less repetitive processes to all processes. | Maintain the system and look for new future developments. |
| Process Optimization | Implement first functions for process performance insights to support in manual optimization. | Implement capabilities to detect, understand, and solve inefficiencies in defined, simple, processes. | Extend optimization capabilities to main and first less repetitive (more complex) processes. | Extend the optimization capabilities to remaining, desired processes. | Maintain the system and look for new future developments. |
| Process Redefinition | Implement first functions for insights in process requirement changes to support in manual redefinition. | Implement capabilities to detect, understand, and solve requirement changes automatically in defined, simple, processes. | Extend redefinition capabilities to main and first less repetitive (more complex) processes. | Extend the optimization capabilities to remaining, desired processes. | Maintain the system and look for new future developments. |

| UX Dimension | | | | | |
|---|---|---|---|---|---|
| Characteristic | Level 1 Action | Level 2 Action | Level 3 Action | Level 4 Action | Level 5 Action |
| Proactive User Assistance | Implement simple insights and notifications. | Implement basic intelligent assistants and in defined areas enable advice/recommendation for simple situations. | Extend the abilities of intelligent assistants and enable provision of advice / recommendation in daily situations. | Implement functions for advice/recommendation and support (intelligent agents) in complex situations. | Maintain the system and look for new future developments. |
| Conversational System Interaction | Initiate non fully predefined but structured input. | Enable simple, alternative interactions (e.g., voice, text, image) in clearly defined areas. | Extend complexity of alternative input ways and adopt outputs to simple user habits and context. | Enable conversational, flexible, and personalized interaction in complex situations. | Maintain the system and look for new future developments. |
| Responsive User Interface and Design | Enable (predefined) manual adjustments of the UI. | Implement capabilities to understand simple user workflows and data / functions needs in defined areas. | Extend capabilities to understand daily user workflows and data / functions needs in main processes. | Extend UI adoption capabilities to all desired, complex workflows and enable a predictive approach. | Maintain the system and look for new future developments. |

Appendix 3: Evaluation Interview Presentation Slides

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MSc. Information Management:
Information Systems and Technologies Management

Intelligent ERP:
The general concept and a guide to make an ERP more intelligent

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January 2022

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Introduction: What will we do and how?

- **First, I want to thank you for the interview!**
- If you have time I would appreciate if you could have a short look at this presentation in advance to make the use of our time more efficient and shorter.
- In the meeting I will present to you only the non-hidden slides. They contain main outcomes developed, without details.
- The hidden slides are for explanation and contain details. Those information are for your reading and if you have questions during the interview we will use those. (labelled as Backup)
- I prepared a small introduction for different parts of the presentation for a better understanding in order to understand the topic goals. (labelled as Intro)

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Main Goals of the Thesis and Structure of the Evaluation

Part 1:
Understanding of i-ERP

- i-ERP Concept
- i-ERP Model

Part 2:
i-ERP Assessment

- i-ERP Levels (Taxonomy)
- i-ERP Assessment

i-ERP = intelligent Enterprise Resource Planning System

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Intro: i-ERP Concept and Model Goals

- First we will talk about the understanding of i-ERP.
- **i-ERP Concept** : A concept of an i-ERP system is presented based on the ideas and studies from the literature review. It is a business-oriented concept and no technical approach. It is about understanding the functions and features of an i-ERP and shows the main roles of selected technologies.
- **i-ERP Model**: The model graphically illustrates the components, interrelationships, and main functions of an i-ERP. It is a very high level, general model, with a business (characteristics, functions, components, etc.) and not a technology focus.

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Part 1: i-ERP Concept
General idea of an i-ERP.

CC – Cloud Computing
BD – Big Data
IoT – Internet of the Things
AI – Artificial Intelligence
ML – Machine Learning
DA – Data Analytics
RPA – Robotic Process Automation

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Backup: Explanation General Prerequisite Dimension

| Characteristics | Description | Main Goals | Cloud Computing | Big Data | IoT |
|-------------------------------|---|--|--|---|--|
| Flexible Application | Flexible application for new functions, updates, and/or upgrades. | • System flexibility • Up-to-date system | • Provide scalability for data storage • Provide scalability and rapid processing power | • Handling of different data types • Handling of high data volumes | • Track and Monitor assets, goods, people in the physical environment of an organization |
| Flexible Database | Scalable database for high data volumes in different forms and formats. | • Use of all data (no restrictions in quantity) • Data availability for intelligent functions | • Vendor managed system allows rapid and easy updates and upgrades • Flexible system for customization (no changes of its infrastructure) | • Handling of structured, semi-structured, and unstructured data • Support a high volume, variety, velocity, value of data | • Real Time data availability • High accuracy of available data |
| Variety of datatypes | Support of structured, semi-structured, and unstructured data handling. | • Use of all data (no restrictions in type) • Data fundamnet for intelligent functions | • Accessibility from multiple devices and locations, local and mobile | • Enable data driven approaches in IERP (Intelligent technologies based on data) | • Expandable and flexible data source • Collect, review, and process data |
| Real-Time Environment Sensing | Sense the required physical environment in real time, e.g., assets, goods, people. | • Real-Time and accurate data availability • Monitoring, tracking, insights | | • Work with multiple traditional and non-traditional data sources | • Foundation for automation, optimization, and insights |
| Real-Time Complex Processing | Handle complex computation tasks, reliable, fully scalable, and in real time (in-memory). | • Processing fundamnet for intelligent functions | | • Preparation of all types of data for use | • Source new data from the organization |

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Backup: Explanation Data Dimension

| Characteristic | Description | Main Goals | AI | ML | DA | RPA |
|--|---|--|---|---|---|--|
| Personalized Context Specific Data Provision | Data access / provision in real time personalized to the individual using the system and its context (task and environment). | • Rapid data access • Targeted data provision | • Preparation and cleaning of data • Understanding of data in image, audio, text | • Learn individual workflows / actions in specific contexts (e.g., verification, anomalies, errors, weak signals) | • Prediction e.g., events, needs • Real-time creation of data reports / KPIs based on predefined rules | • Insert and change data in the system • Generation of documents / reports / KPIs based on predefined rules |
| Advanced Data Insights | Provision of intelligent insights in all types of data. New discoveries through e.g., predictions, patterns, classifications, statistics etc. Use of advanced visualization techniques. | • Data insights • Decisions fundament • Planning fundament | • Creation of data in image, audio, text • Creation of recommendations, rule-based interpretation of data (Expert Systems) | • Classification, forecasting, and correlations (e.g., verification, anomalies, errors, weak signals) | • Root causes • Analytics of Dark Data, e.g., web, text, audio, image | |
| Intelligent Creation of Data | Creation of reliable and accurate data autonomously and creatively, such as complex scenarios, explanations, root causes, new KPIs, reports, etc. | • Availability of information • Data quality improvement • Decisions fundament • Planning fundament | • Learn importance of specific data / insights and create new KPIs, reports, etc. | • Find anomalies, dependencies, patterns, relationships, clusters, sequences, or associations | • Intelligent visualization | |

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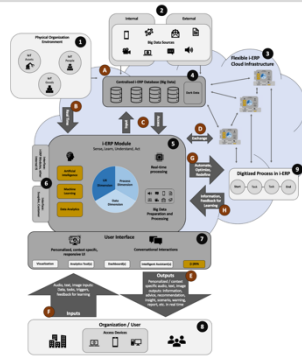
Backup: Explanation Process Dimension

| Characteristic | Description | Main Goals | AI | ML | DA | RPA |
|------------------------------|---|--|--|--|--|--|
| Autonomous Process Execution | Automation of repetitive and non-repetitive operational, tactical, and strategic internal and external ERP processes. Judgment, prioritization, and decision-making capabilities. Real-time reaction and adoption to changes. | • Increased efficiency and speed • Improved quality | • Sense process inefficiencies and find optimal solutions, based on learnings. Optimize desired processes autonomously or augment the user in the optimization | • Voice, Text, and/or image recognition / analysis / processing for automation, understanding of data, or monitoring of judgment, prioritization, decision making, recommendations, or matching (e.g., Expert Systems) | • Learn how to reach process outcomes (built / understand business rules). • Predict process environment / requirements / changes. • Create and evaluate scenarios and recommendations for redefinitions / optimizations | • Automate repetitive tasks (predefined rules) • Automate non-repetitive tasks, judgment, decisions, etc. (RPA) |
| Process Optimization | Learn business rules and sense and predict changes of Business/Environment requirements. Redefine (adapt) desired processes or augment the user in the redefinition. | • Continuous process improvement • Improved process quality | • Up-to-date processes (customizable) processes | • Detect anomalies, dependencies, patterns, cluster, associations in process data for redefinition / optimization • Detect weak signals | • Automate adoption of software robots to changes in requirements or for optimization process data for redefinition / optimization • Insert and change data in the system • Automate interfaces between IS (internal and external) | |

NOVA IMS Backup: Explanation UX Dimension

| Characteristics | Description | Main Goals | UX Dimension | ML | DA | RPA |
|---|--|---|---|--|--|---|
| Proactive User Assistance | Assist user by providing information e.g., warnings, advice, or recommendations in complex situations and easy to access way. Intelligent assistants (e.g., chatbots, translators, etc.) for the support of user work in the system. | <ul style="list-style-type: none"> User support improve quality and decisions Personalized experience Productivity and speed increase Facilitation of use | <ul style="list-style-type: none"> Input / Output: Voice, text, image User Conversation: NLP (e.g., Chatbots (Intelligent assistants (e.g., translators, search engines, Q&As, Document, etc.) Learn user preferences (most used functions, clickstream etc.) Accurate, real-time reports Analytics tools Advanced data visualization tools | <ul style="list-style-type: none"> Learn user workflow to predict / recommend next steps or adapt system interface Learn user preferences (most used functions, clickstream etc.) Learn user role, context, habits Understand user needs to adapt UI Understand of context to detect anomalies, give advice, recommendations, warnings, etc. Data discovery and prediction | <ul style="list-style-type: none"> Information dashboards (RPA, Statistics) Data query tools Warnings (weak signals, events) Accurate, real-time reports Analytics tools Advanced data visualization tools | <ul style="list-style-type: none"> Facilitated input of data Generation of outputs Support clickstream Enhanced system flexibility Automation to free user |
| Conversational System Interaction | Consider contexts and habits during user-system interaction. Understand user requests in different forms (e.g., audio, text, image) and respond in a respective way in a conversational attitude. | <ul style="list-style-type: none"> Better human computer interaction User support Efficiency improvements Facilitation of use | <ul style="list-style-type: none"> Document, search engines, Q&As, etc.) Learn user role, context, habits Understand user needs to adapt UI Understand of context to detect anomalies, give advice, recommendations, warnings, etc. Data discovery and prediction | | | |
| Responsive User Interface and Design | Adaptive UI to task, user context, and user habits. Predict and recommend next steps and show information and functions accordingly in the system interface. | <ul style="list-style-type: none"> Efficiency improvement User motivation User support Facilitation of use | <ul style="list-style-type: none"> Understand of context to detect anomalies, give advice, recommendations, warnings, etc. Data discovery and prediction | | | |

NOVA IMS Part 1: i-ERP Model Visualization of the i-ERP idea.



NOVA IMS Backup: Model Parts

| Number | Component | Description |
|--------|-----------------------------------|---|
| 1 | Physical Organization Environment | The assets, goods, people in the organization. They are monitored / controlled / tracked with IoT devices, providing accurate real time data. |
| 2 | Big Data Sources | Different internal and external data sources of different data types result in a variety of Big Data. These data are beyond regular transaction data. |
| 3 | Flexible Cloud Infrastructure | The cloud infrastructure provides scalable data storage and processing power to handle Big Data and conduct intelligent computing tasks. It provides flexibility to the system for updates, upgrades, changes, etc. |
| 4 | Centralized i-ERP Database | The central database centralizes data from various sources. The sources can be the system itself (transaction processing data, master data, etc.), the physical company environment, and any other internal and external source desired by the organization. |
| 5 | i-ERP Module(s) | The interrelated i-ERP Modules provide i-ERP Functionalities. The three dimensions of Data, Process, and UX are enabled by the intelligent technology concepts AI, ML, and DA in the core. The i-ERP modules have the capability to prepare and process Big Data in real time. |
| 6 | External Interfaces | The i-ERP modules (can) have interfaces to other internal or external suppliers/customers I.E. Data and information can be exchanged. The user interface is adaptive, assistive, and conversational. It includes chatbots, information dashboards, and intelligent assistants. Its fourth intelligent technology, RPA/i-RPA resides here. |
| 7 | User Interface | The organization or user interacts with/uses the i-ERP module(s) by making inputs and receiving outputs. Different mobile and local device types can be used to access the system. |
| 8 | Organization / User | The process is one illustrative example process digitally mapped and executed in one or multiple modules of the i-ERP. It can be fully or partially automated by the ERP module(s) or manually executed by the user via the UI with augmentations from the i-ERP. |
| 9 | Digitized Process | |

NOVA IMS Backup: Model Interrelations

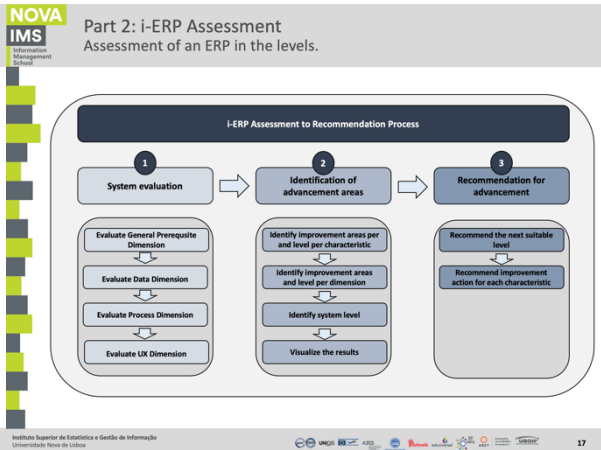
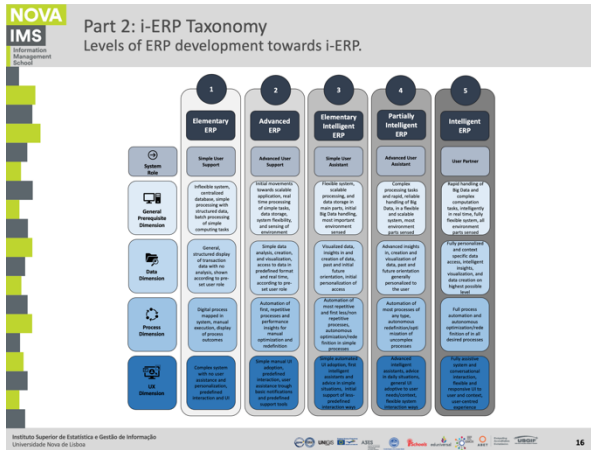
| Letter | Description |
|--------|---|
| A | The data from the different sources are stored in the centralized i-ERP database. |
| B | The data from the physical organization environment are available for the i-ERP modules in real time. |
| C | i-ERP modules and database are in constant data exchange (CRUD operations). The modules can input new data in the database, such as transaction information, user inputs, data gathered from feedback etc. and the modules can access the data in real time for executing processes, creating information output, doing any intelligent calculation, etc. |
| D | The i-ERP modules are connected and integrated as needed. They are in constant exchange, e.g., current state of work, intelligent coordination. |
| E | The organization / user receives outputs from the i-ERP modules they are personalized, context, specific, and in real time. The outputs can be in various forms and formats, such as audio, text, image. |
| F | The i-ERP modules receive inputs from the organization / user. The inputs can be in various forms and formats, such as audio, text, image, e.g., data, tasks, triggers, etc. The i-ERP also receives feedback for learning based on its actions. |
| G | The i-ERP modules can automate, optimize, and redefine processes, based on the user inputs and the intelligent functions of the i-ERP modules. |
| H | The i-ERP modules receive data generated (transaction data, feedback, etc.) by the process execution. It is processed by the module and stored in the i-ERP database. |

NOVA IMS Part 1 Understanding of i-ERP: Interview Questions

| | |
|----|--|
| Q1 | Do you agree with the proposed idea of i-ERP? Please explain. |
| Q2 | Do you have any suggestions for improvement? If yes, please explain. |

NOVA IMS Intro: i-ERP Taxonomy and Assessment Goals

- The second part is an assessment of the development level towards an i-ERP.
- i-ERP Taxonomy:** The taxonomy identifies ERP development stages. It starts from traditional ERP and ends with i-ERP.
- i-ERP Assessment:** This tool allows the classification of an ERP system into the taxonomy and to derive high-level recommendations to improve to the next taxonomy level(s). The tool can be used by all types of organizations related to ERP, such as users, vendors, consultants, below others. The tool has a high-level business approach. It is not focussed on technical details, specific systems, or modules.



Example Instance Step 1: Evaluation

System evaluation

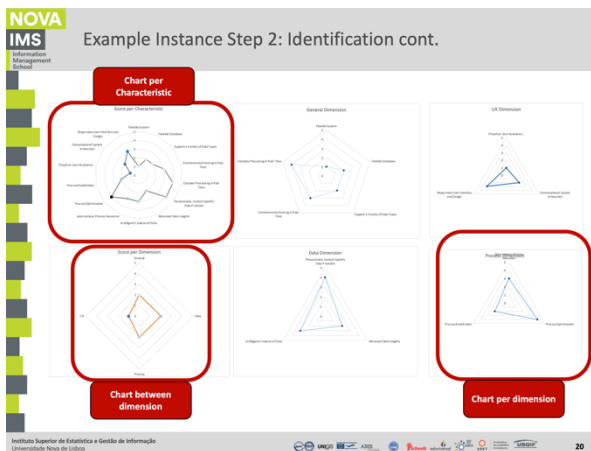
| Characteristic | Definition | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 | Score |
|-------------------------------------|---|---|--|---|---|---|-------|
| Autonomous Process Execution | The automation of any operational, tactical, and strategic internal and external ERP process or task. | Processes are mapped digitally in the system but executed manually by the user. | Simple frequent, repetitive, deterministic processes can be automated. | Most repetitive and routine processes can be automated. | Repetitive processes and most core data repetitive processes can be automated. | All desired processes can be automated. | 3 |
| Process Optimization | Detect inefficiencies and propose solutions based on insights, to autonomously improve the process or to support manual optimization efforts. | The system does not offer support in process optimization. | Insights in simple process inefficiencies support the user in manual optimization efforts. | In defined, simple, repetitive processes inefficiencies can be automatically detected, understood and optimal solutions can be proposed/implemented. | In more and low complexity processes inefficiencies can be understood and optimal solutions can be found and implemented. | In all desired process inefficiencies can be understood and optimal solutions can be found and implemented. | 4 |
| Process Redefinition | Detect and understand process requirement changes (environment/business) and autonomously propose the process or to propose changes and support in manual redefinition efforts. | The system is inflexible and does not support in process redefinitions. | Insights in simple requirement changes supporting in manual application. | In defined, simple, repetitive processes requirement changes can automatically be detected, understood and optimal solutions can be proposed/implemented. | In more and low complexity processes requirement changes can automatically be detected, understood and optimal solutions can be proposed/implemented. | Adaptation to and prediction of changing business/environmental rules in desired, and complex processes. | 2 |

Note: This is done for all four dimensions, this is only an example for one dimension.

Example Instance Step 2: Identification

Identification of improvement areas

| i-ERP Dimension | i-ERP Characteristic | Score | Dimension Score | i-ERP Score |
|--------------------------------|--|-------|-----------------|-------------|
| General Prerequisite Dimension | Flexible System | 1 | 3 | 3 |
| | Flexible Database | 2 | | |
| | Support a Variety of Data Types | 2 | | |
| | Environmental Sensing in Real Time | 3 | | |
| Data Dimension | Complex Processing in Real Time | 4 | 4 | 4 |
| | Personalized Content Specific Data Provision | 4 | | |
| | Advanced Data Insights | 2 | | |
| | Intelligent Zoning of Data | 2 | | |
| Process Dimension | Autonomous Process Execution | 3 | 3 | 3 |
| | Process Optimization | 4 | | |
| | Process Redefinition | 2 | | |
| UX Dimension | Proactive User Assistance | 1 | 3 | 3 |
| | Conventional System Interaction | 2 | | |
| | Responsive User Interface and Design | 3 | | |



Example Instance Step 3: Recommendation

Recommendation

| i-ERP Dimension | i-ERP Characteristic | Level to achieve/sustain | Recommended Action to archive the next level |
|--------------------------------|--|--------------------------|--|
| General Prerequisite Dimension | Flexible System | 2 | Initiate flexibility efforts for first system parts. |
| | Flexible Database | 3 | Grant efforts to main database parts with most suitability needs. |
| | Support a Variety of Data Types | 3 | Extend processing capability to initial Big Data formats. |
| | Environmental Sensing in Real Time | 4 | Extend the use to additional suitable assets, goods, assets. |
| Data Dimension | Complex Processing in Real Time | 4 | Make complex processing available all areas and invest in speed and suitability. |
| | Personalized Content Specific Data Provision | 4 | Extend learning capabilities for habits and content to desired complex situations. |
| | Advanced Data Insights | 4 | Implement capabilities for insights with past- and initial future orientation for simple, daily situations and insight. |
| | Intelligent Zoning of Data | 4 | Extend complexity of situations data can be stored for. |
| Process Dimension | Autonomous Process Execution | 4 | Automate remaining repetitive and extend the automation to main non/low repetitive processes. |
| | Process Optimization | 3 | Extend the optimization capabilities to remaining, desired processes. |
| | Process Redefinition | 3 | Implement capabilities to detect, understand, and solve requirement changes automatically in defined, simple, processes. |
| UX Dimension | Proactive User Assistance | 2 | Extend learning capabilities for habits and content to desired complex situations. |
| | Conventional System Interaction | 3 | Enable simple, alternative interactions (e.g., voice, text, image) in clearly defined areas. |
| | Responsive User Interface and Design | 4 | Extend capabilities to understand daily user workflows and data / Functions needs in main processes. |

Example Instance Step 3: Recommendation

Recommendation

| i-ERP Dimension | i-ERP Characteristic | Level to achieve/sustain | Recommended Action to archive the next level |
|--------------------------------|--|--------------------------|--|
| General Prerequisite Dimension | Flexible System | 2 | Initiate flexibility efforts for first system parts. |
| | Flexible Database | 3 | Grant efforts to main database parts with most suitability needs. |
| | Support a Variety of Data Types | 3 | Extend processing capability to initial Big Data formats. |
| | Environmental Sensing in Real Time | 4 | Extend the use to additional suitable assets, goods, assets. |
| Data Dimension | Complex Processing in Real Time | 4 | Make complex processing available all areas and invest in speed and suitability. |
| | Personalized Content Specific Data Provision | 4 | Extend learning capabilities for habits and content to desired complex situations. |
| | Advanced Data Insights | 4 | Implement capabilities for insights with past- and initial future orientation for simple, daily situations and insight. |
| | Intelligent Zoning of Data | 4 | Extend complexity of situations data can be stored for. |
| Process Dimension | Autonomous Process Execution | 4 | Automate remaining repetitive and extend the automation to main non/low repetitive processes. |
| | Process Optimization | 3 | Extend the optimization capabilities to remaining, desired processes. |
| | Process Redefinition | 3 | Implement capabilities to detect, understand, and solve requirement changes automatically in defined, simple, processes. |
| UX Dimension | Proactive User Assistance | 2 | Extend learning capabilities for habits and content to desired complex situations. |
| | Conventional System Interaction | 3 | Enable simple, alternative interactions (e.g., voice, text, image) in clearly defined areas. |
| | Responsive User Interface and Design | 4 | Extend capabilities to understand daily user workflows and data / Functions needs in main processes. |

Backup: Full i-ERP Assessment

- We saw an example on the process dimension.
- We do not want to go in detail, but for your interest and to handle eventual questions I have included in the following the assessment questions and levels for each step, followed by the recommendations collections to proceed to the next higher level.
- They can all be used like in the previous example and give an assessment cross dimensions for a full system.

NOVA IMS Backup: Assessment General Prerequisite Dimension

| Characteristic | Definition | General Prerequisite Dimension | | | | | Score |
|---|--|--|--|---|--|---|-------|
| | | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 | |
| Flexible Application | Flexibility towards new functions, updates, and upgrades. | The system is inflexible. | Initial system parts (e.g., modules) are flexible. | Main system parts are flexible. | Most system parts are flexible. | The application is fully flexible. | x |
| Flexible Database | The ability to store a high data volume, scalable and normalized. | Data is stored in a centralized but inflexible database. | Initial database parts are scalable. | Main database parts are scalable. | Most database parts are scalable. | The database is fully scalable. | x |
| Support a Variety of Data Types | The capability to handle high data volumes in different forms and formats (Big Data). | The system works with structured data. | The use of semi-structured data is possible. | Initial types of Big Data are supported. | The for the organization most important Big Data types are handled. | The system can work with all required forms of (Big) data. | x |
| Environment Sensing in Real Time | The ability to sense the physical organization environment (e.g., assets, goods, people) in real time. | Real-time environment data is not available. | Initial setups allow first environment data. | Most important assets, goods, and people are sensed. | Most assets, goods, and people are sensed. | All required assets, goods, and people are sensed. | x |
| Real Time Complex Processing | The capability to conduct complex processing, readily, reliably, and fully available. | Simple computing is done in batch. | Basic computing tasks are done in real time. | First, specific, complex computing tasks are done with restrictions in speed and scalability. | Most main complex computing tasks are done fast, reliable, and scalable. | All required complex computing tasks are done fast, reliable, and scalable. | x |

NOVA IMS Backup: Recommendations General Prerequisite Dimension

| Characteristic | General Prerequisite Dimension | | | | |
|---|---|--|--|--|---|
| | Level 1 Action | Level 2 Action | Level 3 Action | Level 4 Action | Level 5 Action |
| Flexible Application | Initiate flexibility efforts for first system parts. | Extend efforts to main system parts with most flexibility needs. | Extend efforts to other system parts with most flexibility needs. | Extend flexibility efforts to remaining system parts. | Maintain the system and look for new future developments. |
| Flexible Database | Initiate scalability efforts for first database parts. | Extend efforts to main database parts with most scalability needs. | Extend efforts to other database parts with most scalability needs. | Extend scalability efforts to remaining database parts. | Maintain the system and look for new future developments. |
| Support a Variety of Data Types | Begin with the support of semi-structured data. | Extend processing capabilities to initial Big Data formats. | Extend capability to for the organization most important Big Data formats. | Extend data processing capability to remaining desired types of Big Data. | Maintain the system and look for new future developments. |
| Environment Sensing in Real Time | Set up first devices on most suitable assets, goods, and/or people. | Extend the use to most interesting assets, goods, people. | Extend the use to additional suitable assets, goods, people. | Extend the use to remaining assets, goods, people. | Maintain the system and look for new future developments. |
| Real Time Complex Processing | Introduce real time processing for simple tasks. | Implement first processing in specific tasks. | Extend processing capabilities for complex tasks to main system tasks. | Extend processing capabilities to all areas and invest in speed and scalability. | Maintain the system and look for new future developments. |

NOVA IMS Backup: Assessment Data Dimension

| Characteristic | Definition | Data Dimension | | | | | Score |
|---|--|--|--|---|--|---|-------|
| | | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 | |
| Personalized, Context Specific, Data Provision | The capability to provide data in real time, considering the user individual habits and context in a specific, complex situation. | Predefined data is provided in batches defined by a pre-set user role. | Predefined data is provided in real time defined by a pre-set user role. | Data is provided defined to simple and very repetitive habits and context in defined, general situations. | Data is provided defined to individual repetitive user habits and context in specific, but complex situations. | Data is provided in real time according to individual user habits and context in any complex situation. | x |
| Advanced Data Insights | Insights in data gathered through analysis, e.g., prediction, patterns, classifications, statistics, etc. to support decisions and discoveries and the way data can be visualized. | Simple reports / summaries of data, mostly in tabular form. | Simple past-oriented analysis and basic visualizations. | Past- and simple future-oriented insights in simple, daily situations. Data presented in visualized format. | Advanced future and past-oriented insights in initial complex situations. Advanced visualization capabilities. | The system provides intelligent insights in real time, automatically in all situations. | x |
| Intelligent Creation of Data | Create new data based on data, such as summaries, explanations, or recommendations. | The system records transaction data. | Creation of simple past-oriented data. | Creation of past-oriented data and future-orientation in specific, simple tasks. | Creation of complex past-oriented data and advanced future-orientation data. | Creation of reliable data automatically in all system areas and complex situations. | x |

NOVA IMS Backup: Recommendations Data Dimension

| Characteristic | Data Dimension | | | | |
|---|---|---|---|---|---|
| | Level 1 Action | Level 2 Action | Level 3 Action | Level 4 Action | Level 5 Action |
| Personalized, Context Specific, Data Provision | Introduce real time data provision. | Implement capabilities to learn simple user habits and context in defined situations. | Implement capabilities for habits and context to more complex but repetitive situations. | Extend learning capabilities for habits and context to desired complex situations. | Maintain the system and look for new future developments. |
| Advanced Data Insights | Enable simple data visualization and first past-oriented analysis capabilities. | Implement capabilities for insights with past- and initial future orientation for simple, daily situations and improve visualization. | Enable advanced and complex analysis with past- and future orientation and visualization. | Extend analysis and visualization capabilities to the highest available level and all complex situations. | Maintain the system and look for new future developments. |
| Intelligent Creation of Data | Initiate simple data creation capabilities with past-orientation. | Initiate future-oriented data creation, for specific, simple tasks. | Extend complexity of situations data can be created for. | Extend data creation capabilities to all desired situations of any complexity level. | Maintain the system and look for new future developments. |

NOVA IMS Backup: Assessment Process Dimension

| Characteristic | Definition | Process Dimension | | | | | Score |
|-------------------------------------|--|---|--|--|--|---|-------|
| | | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 | |
| Automation Process Execution | The automation of key operational, tactical, and strategic internal and external ERP process or task. | Processes are mapped digitally in the system but executed manually by the user. | Simple frequent, repetitive, deterministic processes can be automated. | Most repetitive and frequent repetitive processes can be automated. | Repetitive processes and most non-repetitive processes can be automated. | All desired processes can be automated. | x |
| Process Optimization | Detect inefficiencies and repetitive solutions based on insights, to automatically improve the process or to suggest or request an optimizer efforts. | The system does not offer support for process optimization efforts. | Insights in simple process inefficiencies support the user in manual optimization efforts. | In defined, simple, repetitive processes inefficiencies can automatically be detected, understood and optimal solutions can be proposed / implemented. | In main and low complexity processes inefficiencies can automatically be detected, understood and optimal solutions can be proposed / implemented. | In all desired processes, inefficiencies can be understood and optimal solutions can be found in defined, simple, repetitive processes. | x |
| Process Redefinition | Detect and understand process requirement changes (environment/business) and automatically improve the process or to propose changes and support in manual redefinition efforts. | The system is inflexible and does not support process redefinitions. | Insights in simple requirement changes support in manual optimization. | In defined, simple, repetitive processes requirement changes can automatically be detected, understood and solutions can be proposed/implemented. | In main and low complexity processes requirement changes can automatically be detected, understood and solutions can be proposed/implemented. | Adaptation to and prediction of changing business/environment rules in defined, simple, and complex processes. | x |

NOVA IMS Backup: Recommendations Process Dimension

| Characteristic | Process Dimension | | | | |
|-------------------------------------|--|--|--|--|---|
| | Level 1 Action | Level 2 Action | Level 3 Action | Level 4 Action | Level 5 Action |
| Automation Process Execution | Initiate the automation of first, simple repetitive processes. | Extend automation of repetitive and initiate the automation of first non/less repetitive processes. | Automate remaining repetitive and extend the automation to main non/less repetitive processes. | Extend the automation of non/less repetitive processes to all processes. | Maintain the system and look for new future developments. |
| Process Optimization | Implement first functions for process performance insights to support in manual optimization. | Implement capabilities to detect, understand, and solve inefficiencies in defined, simple, repetitive processes. | Extend optimization capabilities to main and first less repetitive (more complex) processes. | Extend the optimization capabilities to remaining desired processes. | Maintain the system and look for new future developments. |
| Process Redefinition | Implement first functions for insights in process requirement changes to support in manual redefinition. | Implement capabilities to detect, understand, and solve requirement changes automatically in defined, simple, processes. | Extend redefinition capabilities to main and first less repetitive (more complex) processes. | Extend the optimization capabilities to remaining desired processes. | Maintain the system and look for new future developments. |

NOVA IMS Backup: Assessment UX Dimension

| Characteristic | Definition | UX Dimension | | | | | Score |
|---|--|---|--|---|--|--|-------|
| | | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 | |
| Proactive User Assistance | The use of intelligent assistants (e.g., automated filing, predictions, insights, etc.) to support and the provision of relevant intelligent recommendations and advice. | The system provides no user assistance. | Basic insights and notifications to assist the user. | In simple situations and clearly defined areas intelligent recommendations are provided. First, intelligent assistants support daily user work. | In most daily situations (advice/recommendations) is provided. Intelligent assistants support daily user work. | In any complex situation intelligent assistants are provided and intelligent assistants support complex tasks. | x |
| Conversational System Interaction | The conversational interaction of user and system (in- and out-of-voice) and different ways and combination of user habits and context. | Predefined system interaction. | Initial input with very structured and basic data (e.g., structured documents) but not fully predefined. | Alternative interaction (e.g., voice, text, image) in clearly defined areas and with simple, defined rules. | Flexible input in daily situations and less structured data (e.g., unstructured data) and complex situations. | Conversational interaction, unstructured data input and output considering context and habits in complex situations. | x |
| Responsive User Interface and Design | The adaptation of the system UI (e.g., data or functions shown) to the individual user needs, habits and the context and prediction of next steps to adapt accordingly. | No UI personalization is possible. | Manual UI adjustments are possible. | Understanding and learning of simple user habits and context in specific areas and UI adaptation accordingly. | Understanding and learning of daily user habits and context in main processes and UI adaptation accordingly. | In relation to user context and habits in complex situations and predictive and adaptive behavior. | x |

NOVA IMS Backup: Recommendations UX Dimension

| Characteristic | UX Dimension | | | | |
|---|--|---|---|---|---|
| | Level 1 Action | Level 2 Action | Level 3 Action | Level 4 Action | Level 5 Action |
| Proactive User Assistance | Implement simple intelligent assistants and notifications. | Implement basic intelligent assistants and enable provision of advice/recommendation for simple situations. | Extend the abilities of intelligent assistants and enable provision of advice / recommendation in daily situations. | Implement functions for advice/recommendation and support (intelligent agents) in complex situations. | Maintain the system and look for new future developments. |
| Conversational System Interaction | Initiate non fully predefined but structured input. | Enable simple, alternative interactions (e.g., voice, text, image) in clearly defined areas. | Extend complexity of alternative input ways and adopt outputs to simple user habits and context. | Enable conversational, flexible, and personalized interaction in complex situations. | Maintain the system and look for new future developments. |
| Responsive User Interface and Design | Enable (predefined) manual adjustments of the UI. | Implement capabilities to understand simple user workflows and data / functions needs in defined areas. | Extend capabilities to understand daily user workflows and data / functions needs in main processes. | Extend UI adoption capabilities to all desired (complex) workflows and enable a predictive approach. | Maintain the system and look for new future developments. |

| | |
|----|--|
| Q1 | Do you think the proposed assessment and levels are useful for science and/or practice? Why? |
| Q2 | Do you agree with the proposed assessment and levels? Please explain. |
| Q3 | Do you have any suggestions for improvements or future extensions? |

Do you have any final comments or considerations or do you want to add anything?

Thank you for your time!

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