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# Intelligent ERPs:
A Guide to incorporate Artificial Intelligence into Enterprise Resource Planning Systems

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Dissertation presented as partial requirement for obtaining the master's degree in Information Management

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# INTELLIGENT ERPS: A GUIDE TO INCORPORATE ARTIFICIAL INTELLIGENCE INTO ENTERPRISE RESOURCE PLANNING SYSTEMS

by

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Dissertation presented as partial requirement for obtaining the master's degree in Information Management, with a specialization in Knowledge Management and Business Intelligence

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# ABSTRACT

Intelligent ERPs (Enterprise Resource Planning) and Artificial Intelligence (AI) are two emerging subjects in the academic and organizational spaces. The simple fact of using intelligent tools into ERPs or around it is something that happens a long time. However, in this dissertation, we analyze the new concept of Intelligent Enterprises, most specifically Intelligent ERPs. This new idea aims to be a kind of approach capable of joining different concepts like RPA (Robotic Process Automation), Machine Learning, UX (User Experience), Advanced Analytics, and Dark Analytics in a single integrated information system. Through the use of Design Science Research (DSR) methodology, this research aims to identify the most acceptable definition of an Intelligent ERP, the relation of this concept with Intelligent Enterprises, and the contribution of Artificial Intelligence to the systems. Besides that, we will analyze the actual scenario and propose new kinds of approaches and architectures to add features that can enhance the systems and make it more useful and related to cognitive and intelligent systems.

# KEYWORDS

Intelligent ERPs; Artificial Intelligence; Machine Learning; Intelligent Enterprises; Robotic Process Automation; User Experience; Advanced Analytics; Dark Analytics.

# RESUMO

ERPs inteligentes (Planejamento de Recursos Empresariais) e Inteligência Artificial (IA) são dois assuntos emergentes nos espaços acadêmicos e empresariais. O simples fato de usar ferramentas inteligentes nos ERPs ou em torno destes é algo que acontece há muito tempo. No entanto, nesta dissertação, analisamos o novo conceito de Empresas Inteligentes, mais especificamente os ERPs Inteligentes. Essa nova idéia visa ser um tipo de abordagem capaz de unir diferentes conceitos como RPA (Automação de Processo Robótico), Aprendizado de Máquina, UX (Experiência do Usuário), Análises Avançadas e Análises Profundas em um único sistema de informação integrado. Com o uso da metodologia de Desenho de Pesquisa Científica (DSR), esta tese tem como objetivo identificar a definição mais aceitável de um ERP Inteligente, a relação desse conceito com as Empresas Inteligentes e a contribuição da Inteligência Artificial para os sistemas. Além disto, analisaremos o cenário atual e proporemos novos tipos de abordagens e arquiteturas para adicionar recursos que podem aprimorar os sistemas e torná-los mais úteis e relacionados a sistemas cognitivos e inteligentes.

# PALAVRAS-CHAVE

ERPs Inteligentes; Inteligência Artificial; Aprendizado de Máquina; Empresas inteligentes; Automação de Processo Robótico; Experiência do Usuário; Análises Avançadas; Análises Profundas.

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# LIST OF ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| **AI** | Artificial Intelligence |
| **BI** | Business Intelligence |
| **BPO** | Business Process Outsourcing |
| **CA** | Cognitive RPA |
| **DSR** | Design Science Research |
| **ERP** | Enterprise Resource Planning |
| **IDC** | International Data Corporation |
| **IMC** | In-Memory Computing |
| **IMS** | Information Management Systems |
| **IS** | Information Systems |
| **I-ERP** | Intelligent Enterprise Resource Planning |
| **ML** | Machine Learning |
| **NLP** | Natural Language Processing |
| **RPA** | Robotic Process Automation |
| **UX** | User Experience |

# 1. INTRODUCTION

The use of terms like “Era of Digital Transformation” and “The 4th Industrial Revolution” in companies brings with it the need for a new vision about data and information inside the enterprises. Milchman (2017) believes that the company must accommodate mainly three types of work: Manufacturing, manipulation of digital (which is called computation), and social type activities. Moreover, regarding transform business processes, usually, the actual ERPs are not so flexible to adapt to this new reality. Because of that, the new concept of Intelligent Enterprises is emerging nowadays and together with the idea of i-ERPs (Intelligent Enterprise Resource Planning) and Artificial Intelligence.

The actual ERPs brings with it a bunch of tools and features related to Analytics or Automation areas, but, most of them are not intelligent in itself, it usually depends on a series of pre-configured requisites that require much time of support and configuration. An example that we are going to analyze in this dissertation is the use of RPA (Robotic Process Automation) in companies. According to Srinivasan (2016), It is a kind of “robot” that repeats the pre-configured steps faster than a human, most accurate, and can work 24x7 (twenty-four hours per seven days a week). Types of “Cognitive” RPAs have been implemented with the objective to let it most independent, and to approximate it of an Artificial Intelligence system. We will analyze the use of this system and the relation of its contribution to making an ERP intelligent, in fact.

Many other concepts have been used to try to make an ERP Intelligent, like Machine Learning and Advanced Analytics. According to International Data Corporation (IDC) in research named “i-ERP (Intelligent ERP): The New Backbone for Digital Transformation” published in 2016, Intelligent ERP applications use ML and advanced analytics to more efficiently predict, study, track, analyze, report, and manage company resources and business methods. Also, in this paper, we notice that as i-ERP software learns, the application allows building forecasting analytics and predictive solutions to get the information needed to adjust and reconfigure business development, adapt UX, and make necessary changes for maximum efficiency. One of the dimensions that will be analyzed the impact of using this kind of approach is the UX (User Experience), the new form of drive business necessarily influence and change the way employees do their jobs. The idea of Dark Analytics in i-ERPs as the way that companies use to shine a light on its untapped data will be explored with the objective of analyzing the real gains in monetizing the insights of data inside the companies and what kind of artificial intelligence is used or can be used in these scenarios.

The use of i-ERPs seems to be the next step to companies to build a foundation on Intelligent technologies that will gain valuable advantages — such as boosting profits, growing faster, entering new markets, and disrupting their industries. With the adoption of i-ERPs, the users will have a more significant role in companies, the ability to learn from exceptions and adapting business rules, i-ERP allows users to uncover new insights, develop more accurate forecasts and outcome predictions, set up process automation, and develop recommendations for next steps. Users can continually monitor information and set defined targets for business transactions or forecasts, for example, and it can help users to focus most on business and less in a repetitive process. However, the way that some companies are doing It just buying new technologies are not the most suitable, there are at least three different common approaches that can be considered and analyzed in this work before a right decision, and methodologies on-premise or Cloud-based indeed differences need to be taking in the account. This search aims to clarify the most common approaches and suggest possible better perspectives, not only based on technology, but also in Artificial Intelligence and new architectures.

## 1.1. BACKGROUND AND PROBLEM IDENTIFICATION

According to International Data Corporation (IDC) in research named "i-ERP (Intelligent ERP): The New Backbone for Digital Transformation" published in 2016, typical/generic ERP applications are the systems designed to automate and optimize business processes, collecting data about the various aspects of the business, including administrative details, transactions, and operations. These processes manage resources including some or all of the following: people, finances, capital, materials, suppliers, manufacturing, supply chains, customers, products, projects, contracts, orders, and facilities. The software can be specific to a particular industry or designed to be more broadly applied to a group of industries. On the other hand, i-ERP applications can be considered as ERP applications or suites that use machine learning and advanced analytics built on a large, curated data set to forecast, track, learn, route, analyze, predict, report, and manage these resources and business processes. They feature an assistive and conversational user experience by automating a set of high-volume repeatable tasks and augmenting (via human-machine interaction) the performance of less frequent, more novel tasks. They are capable of processing, analyzing, and acting on massive volumes of data in real-time, using in-memory computing (IMC) technologies. As a system that learns, an i-ERP application must allow for ongoing reconfiguration to enable process refinements and user experience adaptation.

The author Srinivasan (2016) argues that the use of packaged applications largely due to the length of time it takes to build in-house applications and the rapid changes in the technology landscape that the in-house organizations were unable to keep pace with. However, there have also been huge gaps between such applications and the way enterprises run their operations. Therefore the software does not provide the flexibility to be used out of the box and has required significant and costly customization. Moreover, customizations require extensive programming and often take an inordinate amount of time (Srinivasan, 2016, p.693).

Intelligent ERP is a relatively new concept, and because of that, there are not many studies on the area that can prove its success or failure regarding implementations, however, it is clear that this evolution is necessary to guarantee the success of organizations. The primary challenge nowadays is the change of paradigm regarding actual useful and productive systems to "Intelligent" ones. This kind of change will modify not only the technology sphere but also the process involved and the way people do their work.

## 1.2. Study Relevance and Importance

The Digital Transformation era or 4th Industrial Revolution, is creating new market forces that create pressure for higher speed, effectiveness, and ability to change. Customers expect more significant levels of service, customization, and insight. Business needs to see trends as they emerge and execute solutions before the competition. According to SAP (2017) in its article named "The Definitive Guide to Value Creation with Intelligent Cloud ERP", some dimensions have been measured to incentive companies to join in this changes acquiring a better and new concept of Intelligent ERPs; these dimensions are:

**Higher Profits**

Companies with best-in-class customer experience management achieve year-over-year customer profit margins 527% higher than their peers, and 359% greater company revenue growth.

**Reduced Costs**

Digital supply chains can reduce supply chain process costs by 50%, reduce procurement costs by 20%, and increase revenue by 10%.

**Better Reputations**

Innovative brands experience brand value appreciation 9 times more than brands that are perceived to be less innovative.

**New Revenue Streams**

86% of consumers are willing to pay more for an upgraded experience, and 55% are willing to pay for a guaranteed good experience.

**Faster Growth**

Companies with 50% or more of their revenues from digital ecosystems achieve 32% higher revenue growth and 27% higher profit margins.

Looking at these numbers, we can conclude that usually significant changes like the implementation of an Intelligent ERP can bring big rewards, there are clear signs that this move to incorporate intelligence will be the next wave of enterprise applications. Also, Delloite emphasizes the need for changing the core systems of companies:

*"Organizations are reorienting business capabilities and approaching products, offerings, and processes as a collection of services that can be used both inside and outside of organizational boundaries. IT may need to revitalize legacy core assets by upgrading to the latest ERP platforms or refactoring aging custom code."*

*(Source: Tech Trends 2017: The Kinetic Enterprise. February 2017, Deloitte Consulting LLP)*

However, the use of Artificial Intelligence like a new concept with a variety of other technologies is something entirely new, and the big challenge is to tie everything together, end-to-end.

## 1.3. SPECIFIC OBJECTIVES

The objectives of this research will be to define the dimensions necessary to compose an i-ERP, and it specified path to follow aim to transform a traditional ERP into an Intelligent one using AI. The outcome will be a taxonomy of Intelligent ERPs and a guide with recommendations for building i-ERPs based on what is the role that Artificial Intelligence plays in the concept of Intelligent ERPs. Some questions can be made to achieve this goal, like define the concept of Intelligent ERP, understand the relation and contribution between Artificial Intelligence and i-ERPs and describe the ways to transform a "generic" ERP in an "intelligent" ERP.

## 2. LITERATURE REVIEW/THEORETICAL FRAMEWORK

There is not much research conducted about the interaction of Artificial Intelligence with its technologies and its benefits to the concept of Intelligent ERPs. Regardless, there are some interesting scientific articles and thesis that illustrate and complement other sides of this research. Besides that, the research will be separated into two main parts, Artificial Intelligence, and Information Management Systems.

The AI Revolution: In 2018, Jacob Bergdahl examines artificial intelligence and its potential business value in the context of enterprise resource planning systems, from the perspective of a midsize consultancy firm (1). This research is the most recent and the approach is the closest to the one discussed in this thesis; however, the difference is that in this research, the author focus on AI in a high-level organizational context, not considering technologies, concepts, tools and features like RPA (Robotic Process Automation), UX (User Experience), Machine Learning, Advanced Analytics, and Dark Analytics. Another important point of view that this thesis aims to clarify is the most common approaches and suggest possible better perspectives, not only based on technology, but also in Artificial Intelligence and new architectures.

Applications of artificial intelligence in intelligent manufacturing: In 2017, this research was made by Bo-hu Li and other authors by The Second Academy of China Aerospace Science and Technology Corporation and published by Frontiers of Information Technology & Electronic Engineering journal (2). The scope of this research is limited to manufacturing systems architectures, and the cultural context is focused in China, but the overall idea about the development of core technologies in the new era of 'Internet plus AI' inside ecosystems of the manufacturing industry can be useful for this thesis.

A vision of industry 4.0 from an artificial intelligence point of view: In 2016, at the International Conference on Artificial Intelligence (ICAI), researchers from the University of Oviedo, Gijón, Asturias, Spain made a study based on the main challenges of Industry 4.0 and process involved (3). Its background is the combination of hardware and software devices, constructing a "Smart factory" where humans, machines, and resources communicate with each other and work collaboratively. Even though it talks a little about AI, Big Data, Internet of things, Autonomous Robots, and Cloud computing, the context is limited only to the Production and Manufacturing process, not with technology integration or ERP vision, but just focused on the process changes.

[1] http://www.diva-portal.org/smash/record.jsf?pid=diva2%3A1220408&dswid=6380
[2] https://link.springer.com/article/10.1631/FITEE.1601885
[3] https://search.proquest.com/openview/e3d410cd2196f5e17af332a9c0b84be0/1?pq-origsite=gscholar&cbl=1976349

## 2.1. Artificial Intelligence

Burgess (2018) argues that there are many different definitions of what AI is, but the most useful is from the Oxford English Dictionary, which states that AI is “the theory and development of computer systems able to perform tasks normally requiring human intelligence.” This research won’t be going into that philosophical debate about the word “intelligence,” but the focus will be on practical aspects of the use of this concept in technology. (Burgess, 2018, p.5)

Although our focus is on the practical aspects of AI, we must take into account the fact that for AI to work perfectly, there are a number of other previous factors that will directly impact the success of the full use of this technology. There is a huge dependency on the level of trust that companies have in their data, and the level of transparency about how the data is farmed and used must be high. Usually, traditional ERPs try to keep a certain level of standardization in its process to prevent this kind of issue and, consequently, give power to AI grow into companies' areas.

The application of AI in ERPs is fundamentally related to business areas itself, and the only way to truly make the most of AI in business is by having a reasonable understanding of it. Burgess, Andrew argues that the challenge is that AI is fiendishly complicated and full of complex mathematics, and is certainly not within the bounds of what an ‘ordinary’ business person would be expected to grasp.  (Burgess, 2018, p.29)

The author has developed a framework that helps to understand the full complexity of applying AI to business based on eight features. In theory, any AI application should fit into one, allowing the AI worker to quickly evaluate and apply that feature to something related to his business. On the other hand, if there is a specific business challenge, the AI framework can be used to identify the most appropriate AI capacity (s) that could address this need. The features used by Burgess are Image Recognition, Speech Recognition, Search, Data Analysis/Clustering, Natural Language, Optimisation, Prediction, and Understanding.

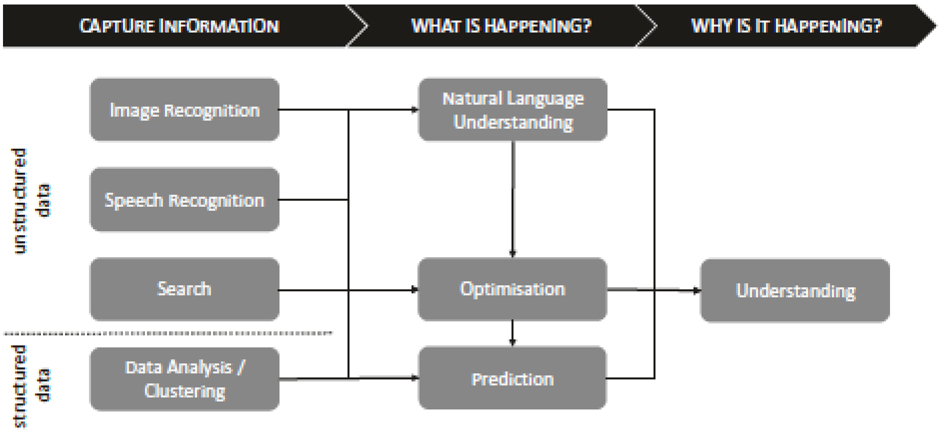


*Figure 1-Burgess AI Framework*

Despite being a useful model to solve specific problems, in this work, we will focus on the most widely approach using what is probably the most important to understand: Capturing Information; determining What is Happening and understanding Why it is Happening.

### 2.1.1. AI Concepts & History

This research will not cover a large range of dates about history, but only the most interesting points about AI that directly impact the topics we are covering in this study. The range coverage will be between 1950 and 2017.

There is a timeline drawn where we can see the most important facts that impact the way we see AI technology nowadays.

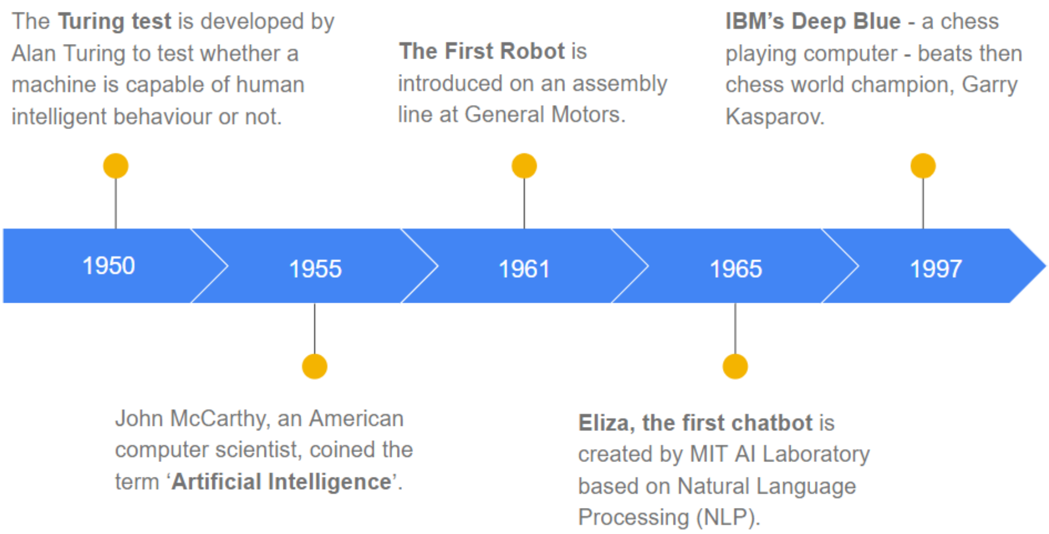


*Figure 2-AI History 1950 to 1997*

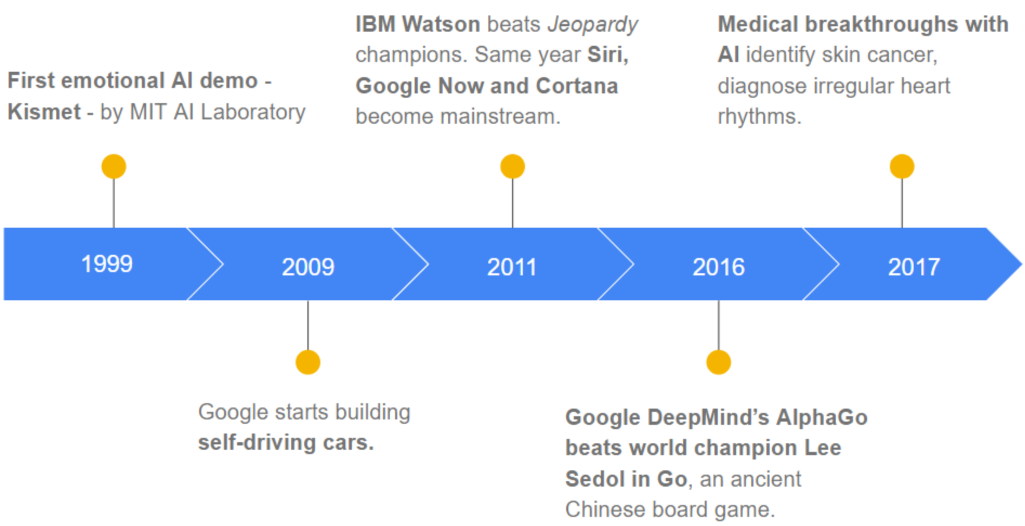


*Figure 3-AI History 1999 to 2017*

### 2.1.2. AI Areas

Thomson Reuters selects some conceptual areas where AI can be applied like Machine Learning, Natural Language Processing (NLP), Expert Systems, Machine Vision, Speech, and Robotics.

Inside these conceptual areas, we could divide it into more terms, but to illustrate the main practical areas where we can see AI applied nowadays, there is a graphic that shows in detail these concepts in action.

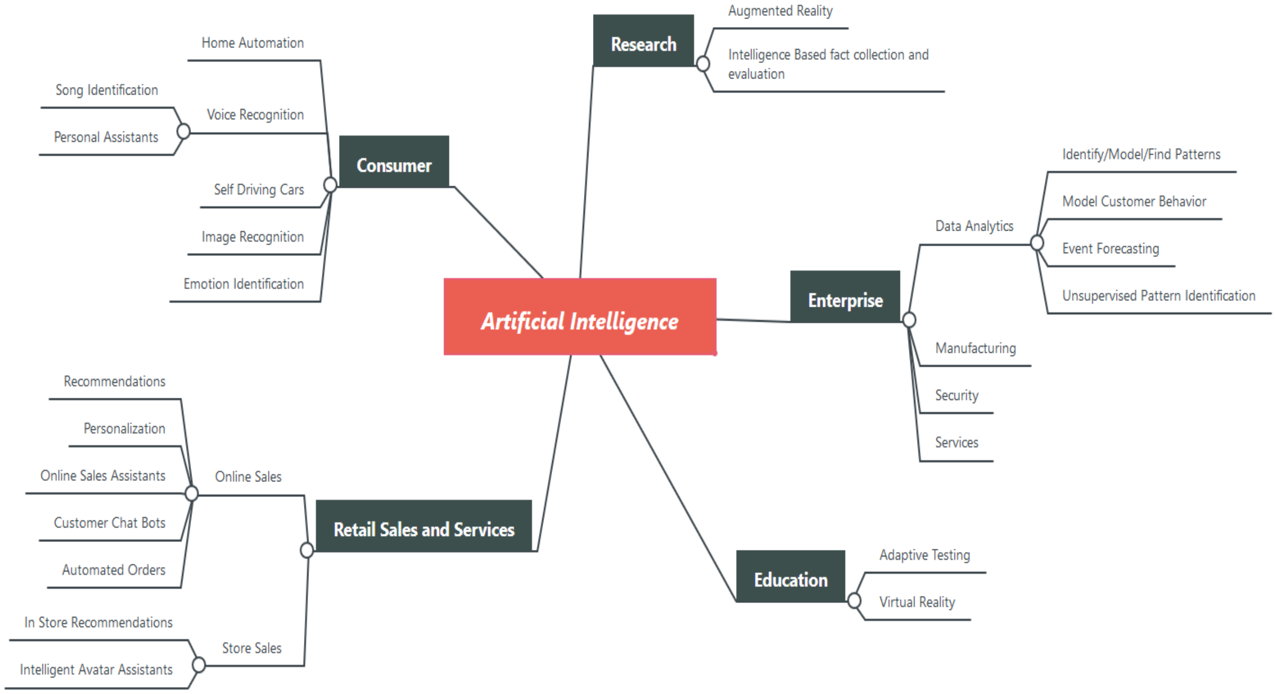


*Figure 4-AI Areas*

### 2.1.3. Machine Learning

The Technology and Services company SAP, defines Machine Learning as "an application of artificial intelligence that enables systems to learn and improve from information and experience, without relying on explicit rules or prescribed behaviors."

Another point of view comes from company Deloitte. Wich understands that Machine learning, deep learning, cognitive analytics, robotics process automation (RPA), and bots, among others, Collectively, these and other tools constitute something called machine intelligence (Deloitte University Press).

### 2.1.4. Deep Learning

One of the most accurate definitions of Deep Learning said that

*"Deep learning is a further advancement within the field of machine learning with superior algorithms. Deep learning uses a technique referred to as neural networks, allowing them to make better use of much larger data sets."*

*(Brynjolfsson and McAfee, 2017)*

There are other most practical definitions like one of Wolchover, 2017, who describe neural networks like a brain and explain that a deep neural network has layers of neurons — artificial ones that are figments of computer memory. When a neuron fires, it sends signals to connected neurons in the layer above. During deep learning, connections in the network are strengthened or weakened as needed to make the system better at sending signals from input data — the pixels of a photo of a dog, for instance — up through the layers to neurons associated with the right high-level concepts, such as "dog."

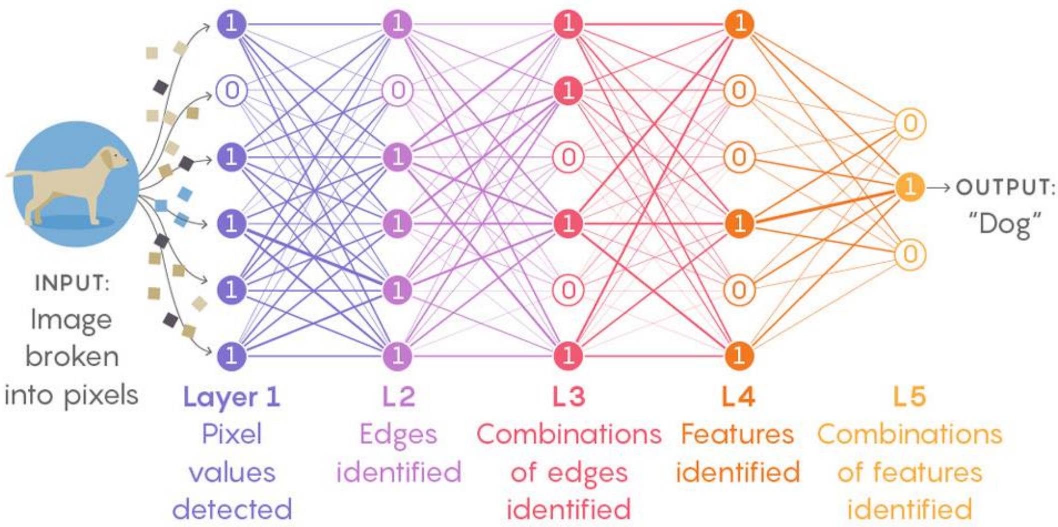


*Figure 5-Lucy Reading-Ikkanda/Quanta Magazine*

## 2.2. Information Management Systems

IMS is a broad term that incorporates many specialized systems. The Smartsheet Inc. company defines it as "tools used to support processes, operations, intelligence, and IT. MIS tools move data and manage information." The history of these systems can reach a wide range of dates, it is growing together with the own evolution of technology and business systems, but to attend the purpose of this research, it will be analyzed as Eras, and not specific dates.

There are at least 6 (six) important Eras regarding IMS history:

- Era 1 – Mainframe
- Era 2 - Minicomputers
- Era 3 - Personal Computers
- Era 4 - Client/Server Networks
- Era 5 - Enterprise Computing

- Era 6 - Cloud Computing

#### 2.2.1. IMS Typology

These tools can be very different and attend a wide variety of purposes. However, the focus of this research is the main IMS connected and used by ERPs. There are some of these systems show below.

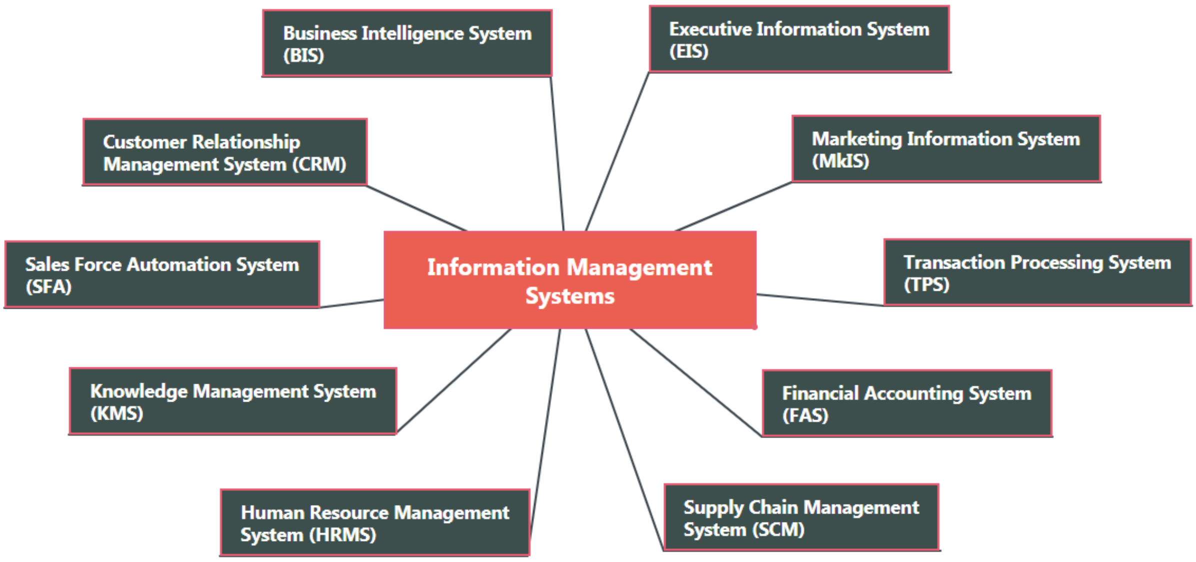


*Figure 6-IMS Typology*

### 2.3. ERPs

According to International Data Corporation (IDC), ERP applications are the systems designed to automate and optimize business processes, collecting data about the various aspects of the business, including administrative details, transactions, and operations. These processes manage resources including some or all of the following: people, finances, capital, materials, suppliers, manufacturing, supply chains, customers, products, projects, contracts, orders, and facilities. The software can be specific to a particular industry or designed to be more broadly applied to a group of industries.

The basic difference between MIS and ERP is that usually, ERPs ensure that all departmental systems are integrated, and MIS uses those connected systems to access data to create reports.

The same idea of maintaining only important historical facts used in AI topics will be applied in this one. There are at least 5 (five) decades, which are really important to understand the evolution of ERPs, according to Brito, S. D. from ABIS Corporation, which are the decades of 1960, 1970, 1980, 1990, and 2000.

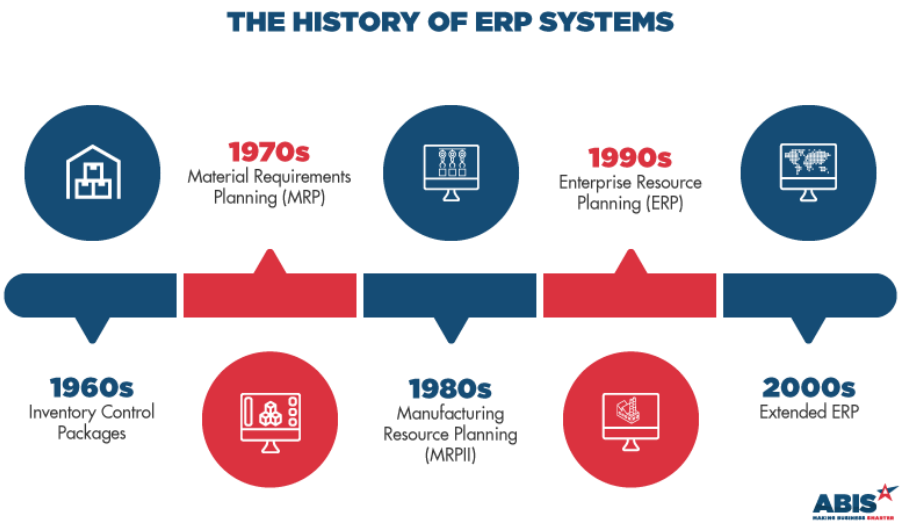


*Figure 7-ERP History*

### 2.3.1. ERP Architecture

ERPs need a complex architecture to work well because these products are complete, integrated systems that manage many aspects of the entire business. The purpose is to align or integrate areas like financial management, human resources, supply chain management, manufacturing, accounting, and other areas like a business warehouse and Controlling. According to Davenport (1998), The database collects data from and feeds data into modular applications supporting virtually all of a company's business activities—across functions, across business units, across the world. When new information is entered in one place, related information is automatically updated.

There is not a single defined architecture of ERP systems, and it depends on the company that develops the product. Large companies like SAP, Oracle, and Microsoft can develop their products using different approaches. There are also companies specialized only in the small and medium segment, seeking to cover a large part of the market without any more advanced customization, that is, with very reduced costs. Examples of this are Intentia, Navision, or QuatroSI, which claim to implement their application in just three months, with low implementation costs, achieved through the limited customization required.

Although there is no single model, the most common approach used to illustrate the architecture is based on the SAP system, which is basically a three-tier Client/Server architecture.

According to Boeder, 2014, the data is stored in a central database system, while processing is performed in many servers that communicate with the user interface clients; this is called "cluster architecture." The figure below shows the overall architecture, called by Davenport as ERP Anatomy.

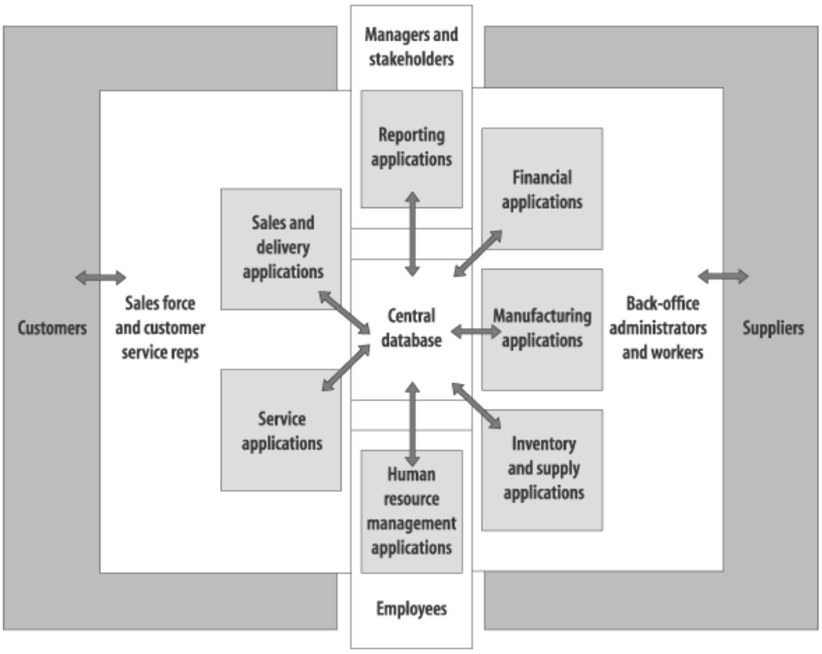


*Figure 8-ERP Anatomy (Davenport, 1998)*

## 2.4. Intelligent ERP Foundations

There are some different definitions of the term i-ERP; one of the most complete is provided by the International Data Corporation (IDC), which argues that "i-ERP is not monolithic, and it is not a "product." Rather, it is a highly modular collection of components sourced more likely from an ecosystem than from a single vendor, at least in its early stages. Later, as with previous ERP evolution cycles, buyer sentiment will shift from assembling and integrating "best of breed" elements to buying end-to-end suites sourced from single vendors. The software elements of i-ERP will be cloud-based by default but may contain important elements that remain on-premises indefinitely. Enterprises will create their i-ERP environments by drawing on extensive and dynamic ecosystems of software, content, and services providers".

There is a great opportunity for companies to be not only intelligent but also efficient. According to Srinivasan, V. (2016), to be an intelligent enterprise and at the same time, a sufficient one requires the ability to monitor and analyze internal and external threats and opportunities continuously, and to make adjustments in operational processes to counter such threats or leverage opportunities. The ability to integrate such analytical processes into its normal operational processes and analyze an enormous amount of data structured and unstructured will follow this kind of evolution into companies, without integrating these two sets of processes, enterprises will not achieve the desired results and can not be considered an Intelligent Enterprise.

Srinivasan, V. argues that the enterprise of tomorrow has the opportunity to be intelligent in addition to being efficient, and an intelligent enterprise will need to seamlessly integrate such analytical processes into its normal operational processes. The figure below shows the most common features that can possibly create a system capable of corresponding to this concept of future companies, which is, at the same time, intelligent and efficient.

The author Braun Diepeveen, & Östhed defends that complex generic ERP systems help run organizations, but they do a poor job supporting companies' aspirations to develop nimbler ways of working and unlock the benefits of digitalization and cloud computing, for example.

Additionally, they argue that what most companies need instead are flexible systems that allow them to respond rapidly to customer needs and new opportunities in an increasingly competitive environment. This next-generation, modern i-ERP systems are likely to have a smaller core of critical business processes (such as transaction management and tracking), with lightweight connections to more specific functional and industry applications that live on the cloud, including third-party solutions such as Workday for human resources and Salesforce.com for customer relationship management (see Figure 8). By maintaining their connections to the legacy systems that keep the company running and deploying flexible microservices, modern ERP systems can help companies achieve a competitive advantage. (Braun, Diepeveen, & Östhed, 2019)

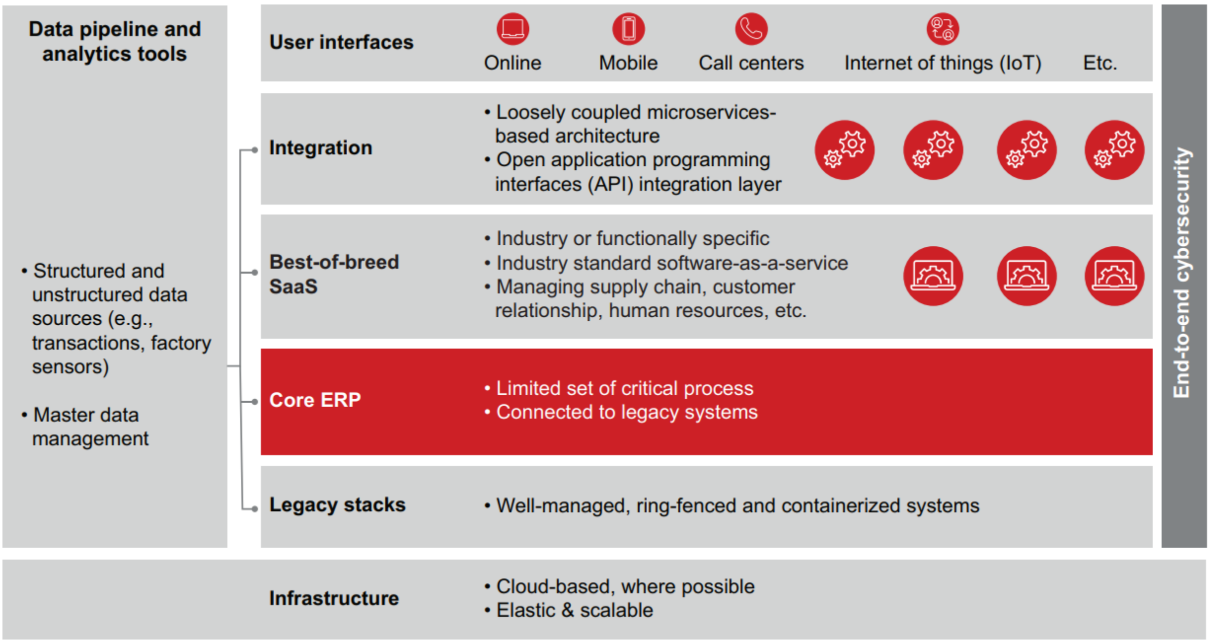


*Figure 9-Modern architectures – Source Bain & Company*

As described, there are many important dimensions/features that need to be part of an i-ERP to really make it effective and profitable at the end of the day.

This part of the research intends to analyze the most important aspects around each one of these six dimensions (AI Foundation, Robotic Process Automation, User Experience, Machine Learning, Advanced Analytics, and Dark Analytics) and to present the role it plays in the i-ERP.

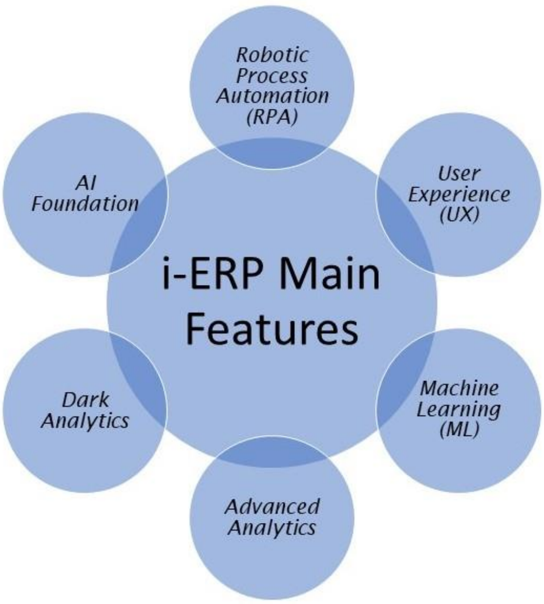


*Figure 10-i-ERP Main Features*

### 2.4.1. AI Foundation

According to International Data Corporation (IDC), an i-ERP system should be built on a machine learning foundation that accesses a rich data set, enabling automation and augmentation opportunities. Such an intelligent system, powered by ML and NLP methods, expands the range of full or partial-task automation overtime via the application of machine learning and natural language processing analytical methods.

SAP (2017) says that Enterprises should focus on business results enabled by applications that exploit narrow AI technologies and leave general AI to the researchers and science fiction writers and the ability to use AI to enhance decision making, reinvent business models and ecosystems, and remake the customer experience will drive the payoff for digital initiatives through 2025.

Considering that the intelligence of an enterprise comes primarily from people, we can understand that at the moment when a task can be automated, the person is able to create and invest effort in other most valuable tasks. This value can only be created when the company is embedded by tools that are in its foundation composed of artificial intelligence. According to IDC, people should consider i-ERP as an aid in redefining roles and responsibilities in advancing digital transformation. With more tasks in play for automation, the mix of tasks in a job will change, favoring those tasks that are outside the scope of automation and tasks that lend themselves to augmentation via human-machine interaction.

### 2.4.2. RPA

One of the most important concepts regarding Intelligent ERPs is Robotic Process Automation (RPA). According to Srinivasan, this technology can be used in many areas and can benefit manly solutions that replicate manually operated processes; one of those that has been in vogue is in BPO firms. This has gained popularity because a large portion of BPO processes are very mechanical and involve keying in data into client systems. While robots can address such mechanical processes, robotic automation is hardly the long-term solution to increase agility and flexibility at a more fundamental business process level (Srinivasan, V. (2016)).

The focus on this research is specifically the two most autonomous types of RPA, the Cognitive and the Intelligent RPAs, and it is more focused on software robots rather than physical robots. Anyway, it is important to elucidate the concept of traditional RPA and the evolution of Cognitive RPA before advancing to Intelligent ones. This is necessary because of the concept of Intelligent itself, it is not easy to understand and apply to technologies, and there are many studies and researchers that disagree about it.

#### 2.4.2.1. RPA Cognitive and i-RPA

According to Prodapt Ltd. Company, there are 3 (three) types of RPAs, Basic Robotic Automation, Cognitive RPA, and Intelligent RPA. The timeline is different depending on the maturity level of the automation model, as well as the type of tasks and the technology involved. The figure below synthesizes the differences.

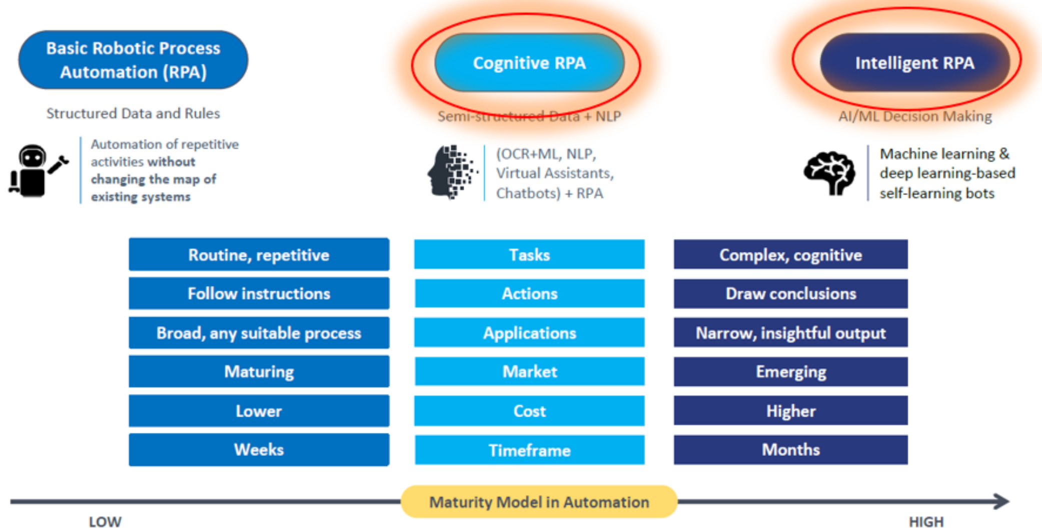


*Figure 11-Tmforum/Prodapt Ltd.*

Besides the difference in the maturity level of the automation model, we need to consider the evolution in aspects of automation like a path to give humans a new kind of job, and people are going to be more thinkers than executors. Lacity and Willcocks define this concept very well when they say that:

> *"Today, we can say that robotic process automation takes the robot out of the human; cognitive automation complements and amplifies both the human and RPA."*
>
> (Lacity & Willcocks, 2018)

The role of Cognitive automation can be understood as an evolution path that leads to more human freedom and the best traditional RPAs practices. To help make sense of this landscape, we can separate it into two broad classes of tools; the first is RPA and the second Cognitive RPA (CA).

The RPA leads essentially with structured types of data and a rule-based process. Basically, it uses software to automate repetitive tasks normally made by humans that uses a rule-based process with structured data and intend to outcome deterministic results. Most of these tools can connect with existing software (like ERPs) by assigning the login credentials, as soon as a human can do. Some of the most popular companies that provide this kind of RPAs include Blue Prism, Automation Anywhere, and UiPath.

Regarding Cognitive RPAs, the type of data usually is unstructured, and it is capable of inference-based processing. Lacity & Willcocks defends that CA is software used to automate or augment tasks that use inference-based algorithms to process structured and unstructured data to produce probabilistic outcomes. The use of Natural Language interfaces is common in this software, and intend to read, build patterns and relationship among data and apply this knowledge to solve problems in companies. Sometimes the objective is not to give the answers to specific problems, but to give the right questions to be made and to understand the customer behavior, for example. Amongst the most popular and well-known providers are the companies IBM Watson, Workfusion, and IPsoft´s Amelia.

Intelligent RPA is a term used to qualify a different type of robotic system. This is, in theory, more complex, draw conclusions instead of repeat tasks, give insightful outputs, and usually have higher costs to implement. The problem here is related to the term AI when it is used in the context of robots; there is more than one opinion about the correct term or if it is really a correct term to be used in technology developments.

Usually, the term AI is used when technology information people want to describe the act of a machine mimics ‘cognitive’ functions that humans are able to do associated with human minds. The researcher Margaret Boden defends that AI intends to make computers do many things related to psychological skills such as perception, association, prediction, planning, motor control just like humans can do (Boden, 2016). On the other hand, there are researchers who believe that AI in the context of robots addresses an ‘algorithmic’ category of processes, needing a human design, and cannot be compared to ‘intelligence’ in human beings (Aleksander, 2017). Aleksander argues that when the word ‘intelligence’ is used, this is done differently for robots and people because that when is needed a designer it needs to be related with robots while things related with human beings there is no one, except, sometimes, as a divine entity or something like that.

The evolutionary process of technology regarding AI robot capacity shows the progress that seems to be more elusive than the predictions of many futurologists. Aleksander comments that this progress leads to exaggeration and prompts belief that robots will become super-intelligent in a short while, and even after 60 years of intense scientific effort, the intelligent robot vying with the intelligence of a human being is not proving the past predictions.

### 2.4.3. User Experience

The user experience tends to be a big challenge to actual ERP systems because of its standard format, usually, not updated with the new interaction and visualization technologies. Accenture argues that artificial intelligence (AI) is about to become a digital spokesperson for companies. Moving beyond a back-end tool for the enterprise, AI is taking on more sophisticated roles within technology interfaces.

There are at least 3 (three) big projections made by Accenture that must be taken into account when the subject is user experience.

- In five years, more than half of your customers will select your services based on your AI instead of your traditional brand.
- In seven years, most interfaces will not have a screen and will be integrated into daily tasks.
- In ten years, digital assistants will be so pervasive they will keep employees productive 24/7/365, operating in the background for workplace interactions, like creating video summaries right after an important meeting.

(Accenture's 2017 Technology Vision report)

The need for the adoption of this new era is changing the way companies see their customers and employees. There is now the "People First Approach" concept that must be a focus in all areas of any enterprise, to understand the way that customers and employees interact with technology and their goals and needs must come in the first place, and that can be a great differential comparative with others competitors.

Over time we are seeing that technological development itself is becoming a commodity, and our biggest innovations are not the technology tools themselves, but the ability to design them with people in mind.

The AI revolution plays a very important role in terms of user experience. That is moving beyond to be not more just back end development tools, but the front end uses directly to the final users that can bring real value. From autonomous driving vehicles that use computer vision to live translations made possible by artificial neural networks, AI is making every interface both simple and smart – and setting a high bar for how future interactions will work. In a near-future, It will act as the face of a company's digital brand and a key differentiator.

Regarding the implementation of these technologies in ERPs, that is a kind of evolution path that is necessary before the transformation from traditional ERP to i-ERP with UX (User experience) capabilities. According to International Data Corporation (IDC), the "users will see the difference in this new generation of applications as the user experience (UX) begins to incorporate assistive, collaborative conversational styles (with a mobile-first design) driven by advances in natural language processing (NLP) and machine learning." And these advances will come after the complete adoption and incorporation of AI to the traditional ERPs.

### 2.4.4. Machine Learning in i-ERP

In recent times, computer systems are developing the ability to improve their performance through exposure to large volumes of data without the need to follow explicitly programmed instructions; this is called unsupervised systems. A good definition of machine learning can be the process of automatically finding patterns in the data, and once identified, the next step would be to use a pattern to make predictions.

According to Deloitte, the amount of data created is growing much faster than in past years, and effectively managing rapidly growing data volumes requires advanced approaches to master data, storage, retention, access, context, and stewardship. From signals generated by connected devices to the line-level detail behind historical transactional data from systems across all businesses and functions, handling data assets becomes a crucial building block of machine intelligence ambitions.

With the use of most sophisticated and powerful algorithms, the idea is to explore the concept of cognitive insights; Delloite also said that it is possible because machine intelligence can provide deep, actionable visibility into not only what has already happened but what is happening now and what is likely to happen next. This can help business leaders develop prescribed actions to help workers augment their performances. For example, in call centers around the globe, service representatives use multifunction customer support programs to answer product questions, take orders, investigate billing problems, and address other customer concerns. In many such systems, workers must currently jump back and forth between screens to access the information they need to answer specific queries. (Deloitte University Press)

### 2.4.5. Advanced Analytics

Gartner (2020) defines Advanced Analytics as “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.”. This concept uses in its major applications the Business Intelligence tools, which are prepared to use a Data Warehouse as it mainly sources, despite this, that is an immense field with many subfields and a lot of buzzwords around it. The figure below shows some of the most important fields where we can apply the Advanced Analytics concept.

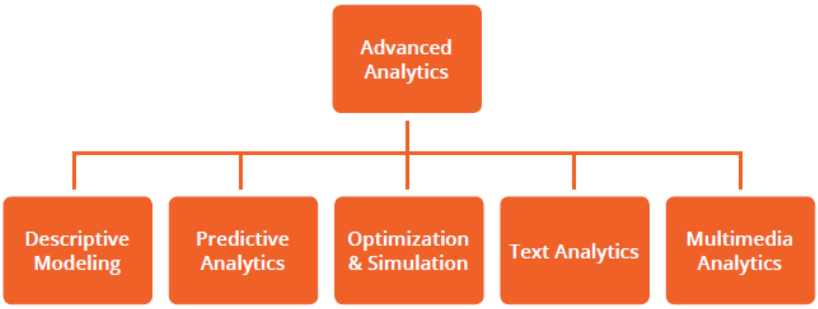


*Figure 12-Advanced Analytics Fields*

There is much more applicability for Advanced Analytics than only predictive models or traditional BI techniques, and these concepts can not be confusing, as argues Tony Boobier quoting Dr. Colin Linsky, a leading analytics expert at IBM:

*“Predictive analytics is a subset of all advanced analytics techniques. There are plenty of more advanced analytics algorithms and routines that are not predictive. Commonly, models that are built to describe when used again on fresh data would (also) be said to be predictive. Some are, by design, looking at future time periods and would be thought of as predictive, whereas others just classify or segment. They only become predictive by being used on a later subsequent set of data to which the outcome of the business problem is unknown.”*

(Boobier, 2018)

In other words, the nature of the data used to solve a problem and the time frame is very important to determine predictions, and not only the algorithms used. Organizations can take advantage of advanced analytics using it in many different applications, depending on the nature of the problem and the time frame. As we can see in table 1, there are different kinds of algorithms that can be used in different areas, like risk management, biology, inflation rates, healthcare, market-basket analysis, customer behavior, capital asset pricing models, fraud detection and many others. In an environment of intelligent companies, the most adaptable with the smartest strategy will not only survive but outperform their competitors.

*Table 1 - Typical Capabilities Used in Advanced Analytics*

| Typical capabilities used in Advanced Analytics. | | |
|---|---|---|
| **Capability** | **Function** | **Typical usage** |
| **Pareto Analysis** | Often known as the 80/20 rule, it is a form of analysis that identifies the top proportion of causes for the majority of problems. 80/20 implies that 80% of all problems arise due to 20% of causes, but this is not a hard and fast rule. | The application of Pareto's rule in risk management helps organizations focus on those causes which are likely to comprise the greatest risk. |
| **Clustering/K-means** | Clustering is a way of grouping a set of objects together in some way, based on the fact that the objects in the cluster are more similar to each other than to those in a different cluster. | In biology, used to make spatial comparisons of communities. In market research, used to partition general groups of consumers. K-means clustering means to partition each group into a cluster based on the mean of that group; it is used in data mining to minimize intracluster variance. |
| **Forecasting using Holt-Winters methodology** | Also known as triple exponential smoothing, it's a process that can be used to forecast data points in a series, provided that the series is repetitive (or seasonal) over some period. | Used for making certain assumptions, such as calculating or recalling some data; for example, trending of house prices and inflation rates. |
| **Decision-Tree Analysis** | A decision support tool that uses a tree-like graph or model of decisions and their possible consequences. | Used in decision management to identify a strategy to reach a goal; often used in management science, healthcare, and operations management. |
| **Rules of Association** | Rules-based learning method that identifies relationships between variables in large databases coupled with levels of confidence. | Promotional pricing, product placement, market-basket analysis. |
| **Logistic Regression** | Also known as a logit model, it is a type of linear model that estimates the probability or dependency of a certain outcome. | Determines whether a customer will buy a product based on (for example) age, gender, geography. |
| **Linear Regression** | An approach for modeling the relationship between a data set and one particular variable. Think of it in terms of finding a single line on a graph that represents a range of data points. Can show changes in data over time. | Used in creating trend lines (e.g., for GDP and oil prices). Capital asset pricing model. |

| | | |
|---|---|---|
| **Correlation** | A broad set of statistical relationships, although usually relating to two variables that appear to have a linear relationship with each other. Useful, as it can identify a predictive relationship with its members. | Correlation between electrical demand and weather. (This is a causal relationship, in that one is dependent on the other – but correlation is not necessarily causality.) |
| **Bayes** | Also known as Bayes Law, or Bayes Rule, it describes the probability of something happening based on prior knowledge that it may be related to an event. | Can be used in medical diagnosis or fraud detection, for example, but can be affected by false positives, which is, in effect, a statistical anomaly that shows positive when the answer should be negative and vice versa. |

### 2.4.6. Dark Analytics

According to Deloitte University Press. (2017), Dark Analytics (or “Dark Data”) refers to information that, for some reason, is hidden into the companies, unexplored or extremely difficult to use. Another important point is that the huge amount of information and the speed with which it is generated makes managing this data a challenge for any entity.

The concept of Dark Analytics aims to identify hidden patterns and generate value with that data, or in other words, Illuminate opportunities hidden within unstructured data. According to Deloitte, “few organizations have been able to explore non-traditional data sources such as image, audio, and video files; the torrent of machine and sensor information generated by the Internet of Things; and the enormous troves of raw data found in the unexplored recesses of the “deep web.” (Deloitte University Press)

For this reason, dark analytics is a powerful tool to the process of transforming dark data into smart insights, where organizations can leverage this information to generate new perspectives into their business strategy, their customers, their products, or in other forms of innovation. The final result will not just to catalog huge amounts of unstructured data, but to add value to everyone who is connected with certain information. The opportunity to analyze untapped data sources will bring more value to companies, investors, and consumers, allowing even the smallest companies to set standards that were previously unknown.

There is an uncomfortable limit in the usual analytics systems, which is its possibility of analyzing just the data that are within the source systems around that tools and the necessity of clean the data and manipulate (ETL process) it before the use. The use of dark analytics aims to break this limit and use all the potential that companies can. The report (Deloitte University Press, 2017) describes that the efforts to achieve this goal will typically focus on three dimensions:

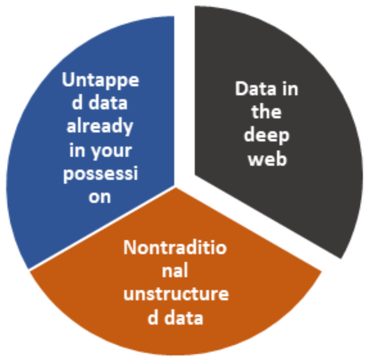


*Figure 13-Dark Analytics dimensions*

#### 2.4.6.1. Untapped data already in your possession

There is a large amount of data, structured and unstructured, that is not used inside the companies. Most of the structured data that is not used is because of difficult to extract or integrate between the diverse systems, and because of that, the potential value is not explored.

Regarding unstructured data that already exist in companies, there is a lot of kinds of data like emails, notes, messages, documents, logs, and notifications (including from IoT devices), which usually is not part of the daily extraction routine. According to Delloite, this information is "text-based and sits within organizational boundaries but remains largely untapped, either because they don't live in a relational database or because until relatively recently, the tools and techniques needed to leverage them efficiently did not exist." (Deloitte University Press)

Some estimates show that at least 80% of the information inside companies is unstructured, although its data inside the companies boundaries, the non-use will impact a great loss of potential value and differentiation in a competitive environment.

#### 2.4.6.2. Nontraditional unstructured data

Another different kind of unstructured data is based on audio, video, and other similar media. This kind of data can not be mined using traditional extraction, reporting, or analytics techniques, and because of that, it is most uncommon its uses. The AI revolution brings the solution for these cases, now using computer vision, advanced pattern recognition, and video and sound analytics, companies can mine data contained in non-traditional formats to better understand their customers, employees, operations, and markets. (Deloitte University Press)

#### 2.4.6.3. Data in the deep web

Regarding Deep Web, Delloite argues that the deep web offers what may contain the largest body of untapped information—data curated by academics, consortia, government agencies, communities, and other third-party domains. But the domain's sheer size and distinct lack of structure can make it difficult to search. For now, only data mining and analytics efforts that are bounded and focused on a defined target—for instance, licensable data owned by a private association—will likely yield relevant, useful insights. Just as the intelligence community monitors the volume and context of deep web activity to identify potential threats, businesses may soon be able to curate competitive intelligence using a variety of emerging search tools designed to help users target scientific research, activist data, or even hobbyist threads found in the deep web. (Deloitte University Press)

# 3. METHODOLOGY

This research adopts design science research and theoretical inference as major methodology, and the conclusion aims to be valued in both academic and practical worlds.

The aim of this thesis is to gain a good understanding of how organizational processes covered by generic ERP systems can, or already do, benefit from AI, and its comparison with what would be the best definition of a complete Intelligent ERP. According to Hevner, the Design Science Research (DSR) methodology is the most appropriate in this case because

*"It seeks to create innovations that will define the ideas, practices, technical capabilities, and products through which the analysis, design, implementation, management, and use of information systems can be effectively and efficiently accomplished."*

*(Hevner, March, Park, & Ram, 2004)*

As we have the objective of produce an artifact as the output of this thesis, it is relevant to explain the delimitate of what exactly we mean. According to (Hevner, 2004), it can be broadly defined as constructs (vocabulary and symbols), models (abstractions and representations), methods (algorithms and practices), and instantiations (implemented and prototype systems). In this case, we are looking for a model and method that is able to define a taxonomy that can be understood and address the problems inherent in developing and successfully implementing information systems within organizations, more specifically, Intelligent ERPs.

At the moment we identify the business problem related to the evolution of technology and in parallel the use of generic ERPs, we can apply this methodology to understand those information systems (IS) are not only about technology evolution but involves the construction of a wide range of socio-technical artifacts such as decision support systems, modeling tools, governance strategies, methods for IS evaluation, and IS change interventions (Gregor & Hevner, 2013).

## 3.1. Design Science Research (DSR) Application

The use of DSR methodology is recommended to this thesis because of its relevance related to the objectives described before.

There are two paradigms in Information Systems Research that we need to consider, Behavioral Science and Design Science. (Hevner, 2004)

- Behavioral Science: Develop and verify theories that explain or predict human or organizational behavior. An IT artifact, implemented in an organizational context, is often the object of study in IS behavioral-science research.

- Design Science: Extend the boundaries of human and organizational capabilities by creating new and innovative artifacts. Design science usually creates and evaluates IT artifacts intended to solve identified organizational problems.

This methodology involves the construction of a wide range of socio-technical artifacts such as decision support systems, modeling tools, governance strategies, methods for IS evaluation, and IS change interventions, in this way we can study and understand the actual situation of the traditional ERPs and its problems and the future, based on what could be implemented to became really intelligent ones.

To develop this methodology has been used the definition of a Process Model, bellow, we see the synthesis presented by Peffers et al. (2007-2008), which is characterized by six activities in a nominal sequence.

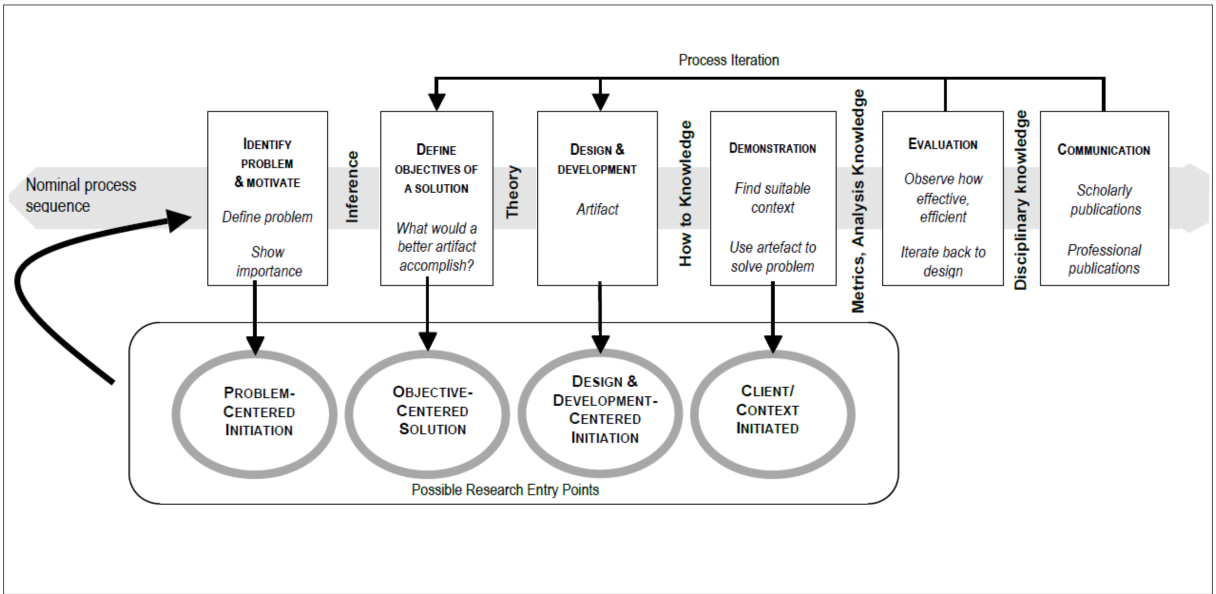


*Figure 14-DSRM Process Methodology (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007)*

These activities can be understood as follows.

- **Activity 1**: Problem identification and motivation
  - These methodology phases consists of defining the specific research problem and justifying the value of a solution. Because problem definition will be used to develop

an artifact that can effectively provide a solution, it may be useful to detail the problem conceptually so that the solution can capture its complexity. Resources required for this activity include knowledge of the state of the problem and the importance of its solution. (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007-2008)

- **Activity 2**: Define the objectives for a solution
    - This activity will infer the goals of a solution from problem definition and knowledge of what is possible and feasible. Objectives can be quantitative or qualitative. Objectives must be rationally inferred from the problem specification. Resources required for this include knowledge of the state of problems and current solutions, if any, and their effectiveness. (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007-2008)
- **Activity 3**: Design and development
    - In this activity, artifacts are effectively created, determining their desired functionality and architecture. These artifacts are potentially constructs, models, methods, or instantiations (each broadly defined) or "new properties of technical, social, and / or informational resources." Conceptually, a design research artifact can be any project object in which a research contribution is embedded in the design. (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007-2008)
- **Activity 4**: Demonstration
    - Demonstrate the use of the artifact to solve one or more instances of the problem. This demonstration is usually done through its use in experimentation, simulation, case study, testing, or other appropriate activity. (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007-2008)
- **Activity 5**: Evaluation
    - Observe and measure how well the artifact supports a solution to the problem. This activity involves comparing the objectives of a solution with the actual observed results of using the artifact in the demonstration. It may include items such as a comparison of artifact functionality with solution objectives, objective quantitative performance measures, or satisfaction survey results. It may also include quantifiable measures of system performance, such as response time or availability. Conceptually, this assessment may include any appropriate empirical evidence or logical proof. At the end of this activity, researchers can decide whether to return to activity three to try to improve the effectiveness of the artifact or to continue with communication and to make further improvements in subsequent projects.(Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007-2008)
- **Activity 6**: Communication

- This activity communicates the problem and its importance, the artifact, its usefulness and novelty, the rigor of its design, and its effectiveness to researchers and other relevant audiences, such as professionals, when appropriate. In academic research publications, researchers can use the structure of this process to structure the article, as well as the nominal structure of an empirical research process (problem definition, literature review, hypothesis development, data collection, analysis, results, discussion, and conclusion), is a common framework for empirical research work. (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007-2008)

## 3.2. Methodology Implementation

The six phases described has an application in our case, and in this section, we will explore the possible use of the methodology in this thesis.

The problem identification phase was described in the literature review as the “change of paradigm regarding actual useful and productive systems to ‘Intelligent’ ones.”. The problem faced by companies nowadays regarding this challenge of turn systems intelligent using AI is the pain point we want to focus on.

Define the objectives for a solution is the second step we intend to achieve. The main objectives described in the literature review will make it possible to know which areas the basis of this study should have according to requirements that fitted the solution’s goal.

The design and development of taxonomy were possible because of the collection of information related to state of the art and what could be a good fit for companies to follow related to digital transformation. Technology, concepts, and implementation models are the main features of the design in this artifact.

The step of demonstration of this artifact will not be applied with some kind of experimentation because it’s a bunch of solutions not effective with no real-world information, which is accessible only through the real implementation in a company. The idea is to demonstrate the theory, and according to the literature review and the expert interviews, prove that the option is valid.

The Evaluation step will be done based on interviews with expert professionals who can validate the product that was applied with the intent to provide appropriate empirical evidence or logical proof with the use of all material provided in the literature review and the artifact output.

The communication step of this thesis provides the necessary output to other researchers (or any other people) to be able to use the structure of this process to structure their own article, as well as the nominal structure of an empirical research process.

# 4. A PROPOSAL FOR AN I-ERP TAXONOMY AND GUIDELINE FOR I-ERP IMPROVEMENT

Based on the information acquired in this thesis, we can analyze that the business process, the people, and the technology must be considered almost like different individuals in the process of digital transformation. That happens because there are different concerns related to each one of these “areas” that need special attention; In fact, it is inevitable that ERP solutions enabled by AI, by default, will consequently affect the entire company and even day-to-day operations. The synergy between people, processes, and technology will change compared to what we have today. It is a fact that those repetitive and routine tasks performed by human beings will be assumed by AI processes modeled with these functions. This specific change is mainly driven by a continuing need to reduce costs and increase profits, as we could see in section 1.2. This path is already ongoing and has no way to come back.

To manage well this kind of transformation, organizations must rethink their IT systems deployment strategies and roadmaps and understand the value of artificial intelligence and the integration of ERP (Enterprise Resource Planning). These technologies are essential because they converge towards the same goal. There is a great potential for ERP solutions enabled for AI, and there are different paths to be traced, with different steps that can be followed for the implementation of this type of projects, that is not possible to cover all possibilities and describe all necessary steps, but we will propose a general scope of steps to describe witch level of maturity determined company is related to the most intelligent ERP it can become.

As shown in the literature review, i-ERP’s features can be driven by machine learning and advanced analytics, but it is also fully integrated with AI Foundation, Robotic Process Automation, User Experience, and Dark Analytics. These bunch of concepts can offer a myriad of opportunities for enterprises to compete in hyper-competitive landscapes. The proposal taxonomy aims to clarify the level of maturity that each company is at the moment and can be in the future with the use of these technologies.

There are also important questions that need to be considered before an evaluation of the maturity level of the companies regarding the integration of AI in ERPs. A study published by (PwC Belgium and Gondola Group, 2017) provides some of these questions that can be analyzed in view of the implementation of AI projects to already existent ERP environments or the implementations from scratch.

One of the most important business questions that someone who aims to do this kind of implementation needs to ask themselves is: "*What should I consider and focus on to prepare my business for AI*?" and in consequence of this question, there are others that are related to each different environment.

1. How vulnerable is the business for AI disruption?
2. Will the change come soon?
3. Are there game-changing possibilities within your market? How can you take advantage of these?
4. Do you have skilled people, good data, and advanced technologies to help understand and seize the opportunities AI presents?

Although these are very AI-oriented questions, there are more business-oriented ones that need to be taken on consideration when you decide to begin the AI integrated to ERP journey:

1. Can I Identify the processes, products, or services that would benefit from improved decision-making or from more efficient and personalized ways of interacting with clients?
2. Can I select a few of those processes and embark upon the iterative development of AI pilots? Before doing so, look at data quality and quantity. AI needs large data sets for learning and testing. Do I have that information?
3. About the evaluation criteria, what is the desired outcome, and how would you measure its success?
4. It is not only AI experts that you need but also process experts and experts who can help you design the user experience, do you have these professionals in your team?

Successfully answering these questions will help to start the process thinking to understand better your own business and needs related to an Intelligent ERP.

### 4.1. ASSUMPTIONS

It is virtually impossible to preview the use of AI in all its aspects and the application that it could have inside the variety of enterprise environments, because of that, this taxonomy proposed in the thesis will not cover all aspects related to AI use in companies areas but only focus on ERP use in general. There are specific examples that can be seen in areas like described bellow that will just be mentioned to enrich the thought process.

AI technology is emerging Inside the Customer service area. A very interesting AI solution in this area has appeared to improve the answer to customer questions received through different social media channels. This type of AI-enabled ERP solution for customer service can, for example, integrate and enhance customer interaction with the company's work order management process, improving the process chain and giving the best experience to the customer.

The functional area of Product maintenance is another one in which AI can be integrated with ERP solutions. A good example is digital assistants (DA) who can assist the service technician in analyzing the root cause for corrective maintenance problems and also in preventing possible known errors.

To develop the taxonomy described in the next section was analyzed the literature review and defined that to become an i-ERP, the traditional ERP should contain all that six dimensions (RPA, Advanced Analytics, Dark Analytics, Machine Learning, UX and AI Foundation) and pass through six levels of maturity, and it is embedded with the concepts and technologies described in this thesis. The term “autonomous ERP” is used in the next section to describe a type of self-executing business processes system, but not yet an intelligent one. What we aim is to determine the trust level needed in order for organizations to allow the autonomous ERP to leave this status to become an Intelligent ERP, which is autonomous, but not only that.

## 4.2. TAXONOMY

**Level 1: Basic ERP**

The characteristics of a called *Level 1 - Basic ERP*, are a basic level of environment where human controls it all. Based on what we study manly in section 2.3, there is a link between business and IT entirely for static and pre-configuration on the system. There are a few options for customization and depend on core implementation. It is not necessary for a robust end-user training program, and the interface is usually poor of functionalities.

**Level 2: Generic ERP**

On *Level 2 - Generic ERP*, the ERP is the same as level 1, but with the ability to execute batch jobs automatically or raise alerts on specific risks or threats from transactional monitoring. As we could examine in section 2.3, Davenport (1998) assumes that at this level, the ERP is already the backbone of enterprise applications, and the role of business in ERP is well defined. The system usually will have limited capabilities or unused functionalities; besides that, usually in this level, the ERP should be augmented with other tools or applications that make it more robust and useful in the entire company. The end-users will be able to fulfill ERP functions without excessive help desk or support assistance. This level will not have real-time data, big data, or any kind of Dark Analytics functionality. Also, at this level, we will not find any RPA or AI functionality.

**Level 3: Automated ERP**

On *Level 3 - Automated ERP*, we will start to see different functionalities that have been implemented with the objective of let repetitive tasks automated, to take less time to people to execute those processes. In this environment, the people can create an automated task and even schedule that but must be ready to take control of the results or even the process execution. In section 2.4, we analyze that this is where the automation of business processes (Robotic Process Automation) are being used today. On this level, we will not see Cognitive RPA, either Intelligent RPA, but only basic RPA process that can help in daily activities. Here we can see that the business has active ownership of the business process, and currently, KPI is measured, and it facilitate the use of basic and custom pre-configured and automated reports. In this scenario, usually, the end-users will receive periodic refresher training and will be able to make little customizations to the process.

**Level 4: Semi-Autonomous ERP**

On *level 4 - Semi-Autonomous ERP*, the aspect of confidence in the system will start to play an important role in the company. This is the level when the people will make decisions based on the part of the information processed and distributed partially with no human supervision by the computer. This is where the trust factor plays a major role in convincing the enterprise to start believing that it is safe to trust their ERP system to manage some part of the business operation. People will be able to shift safety and critical functions to the ERP and will need to monitor data for real-time decision making. While the people are not required to monitor the autonomous functionalities like the same way as level 3, they must be alert and intervene if necessary. This level requires a flexible enterprise application infrastructure to support the implementation of RPA systems and integration with already existent systems. Because of the interaction between RPA and Humans, that is necessary constant end-user training mainly in subjects related to the business process to ensure that the results are really the expected. As shown in section 2.4, another important factor in this level is the beginning of the use of a massive quantity of data and the quality of that information, which is important for reports using advanced analytics and for the process of dark analytics to collect and organize the created data.

**Level 5: Autonomous ERP**

On *Level 5 - Autonomous ERP*, it will be fully autonomous. This is limited to the operational design domain of the ERP, meaning it does not cover every human interaction scenario. Based on what was analyzed in section 2.4, this is where AI, ML, RPA, Advanced Analytics, Dark Analytics, and User experience will fully operate but is constrained by, perhaps, specific industry domains or line of business functions. On this level, we will have ERP data been used for proactive business management, data used for strategic decision making and unstructured data used as it was not unstructured (after pass through all data preparation process). The confidence in the system at this level is total, and the users do not need to revise or to monitor the process, but just to use the information with the most elevated level of trust. The business process change is guided by KPI performance, and configuration is in the hands of the business. Also, end-user job performance is linked to business process performance, which shows the evolution of the company based on its performance.

**Level 6: Intelligent ERP**

Based on entire subjects treated in this thesis, on the last *Level 6 - Intelligent ERP*, the suggestion is that the ERP performance is now an equivalent of a human decision-maker and can adapt to every business scenario, including extreme conditions. In this level, we can see all the functionalities of level 5 and more, now the infrastructure is leverage simple and faster using the cloud platform like a plug and play feature. The end-user is totally specialized in business problems and see the ERP as a partner to help the company with the most complex problems and decisions. The ERP core functions are all based on AI foundation with ML and Intelligent RPA, and the decisions can be made by modern Advanced Analytics technologies based on a robust process of acquiring cleansing and transformation of structured and unstructured data using Dark Analytics. The user experience is on another level, having the ERP features totally adaptable to the sentiment of the customer, providing a much better experience to the user without any human intervention.

## 4.3. GUIDELINES FOR I-ERP IMPROVEMENT

The next table shows some guidelines defined based on the taxonomy that can be used to implement the theory of improvement of an i-ERP.

*Table 2 – Guidelines for i-ERP Improvement*

| **Maturity Level** | **Main Characteristics** | **Actions to implement and improve to the next level** |
|---|---|---|
| **Level 1: Basic ERP** | • The system is almost totally controlled by the human process.<br>• Static and totally pre-configured system. | • Implement a process to execute batch jobs automatically.<br>• Implement a process to send alerts on specific risks in the process. |
| **Level 2: Generic ERP** | • ERP is able to execute batch jobs automatically and send alerts to the transactional monitoring process.<br>• ERP uses other tools or applications that make it more robust and useful in the entire company. | • Implement Robotic Process Automation (RPA) process.<br>• Implement pre-configured and automated reports.<br>• Keep end-users receiving periodic training. |
| **Level 3: Automated ERP** | • ERP already has an RPA process implemented.<br>• Business people have active ownership of the business process.<br>• End-users receive periodic training. | • Make the infrastructure environment flexible to adopt new technologies.<br>• Convince people to trust in the system.<br>• Discover the data using Dark Analytics and use it through Advanced Analytics. |
| **Level 4: Semi-Autonomous ERP** | • People trust their ERP system to manage some parts of the business operation.<br>• Flexible enterprise application infrastructure.<br>• Constant end-user training.<br>• That is a common use of a massive quantity of data.<br>• The process of Advanced Analytics and Dark Analytics is in action. | • Reinforce the trust in the system.<br>• Make use of AI, ML, RPA, Advanced Analytics, Dark Analytics, and UX at least in one segment or product.<br>• Make use effectively of unstructured data.<br>• Provide enough training, business process, and technology to give business people control about system configurations. |

| | | |
|---|---|---|
| **Level 5: Autonomous ERP** | • Confidence in the system at this level is total.<br>• The operational design domain of the ERP is fully autonomous.<br>• AI, ML, RPA, Advanced Analytics, Dark Analytics, and UX will fully operate at least to specific industry domains or line of business functions.<br>• Unstructured data is largely used.<br>• System configuration is in the hands of the business people. | • Improve technologies and processes regarding ERP core functionalities. Implement Cognitive and Intelligent RPA.<br>• Migrate entire infrastructure to the cloud with total control by business people.<br>• Improve training to end-user at the expert level on business problems.<br>• Improve the UX at the autonomous level with max customer satisfaction. |
| **Level 6: Intelligent ERP** | • ERP performance is equivalent to a human decision-maker.<br>• The system can adapt to every business scenario.<br>• Infrastructure is leverage simple and faster using the cloud platform like a plug and play feature.<br>• End-user is totally specialized in business problems.<br>• ERP core functions are all based on AI foundation with ML and Intelligent RPA.<br>• The User Experience is using the ERP features totally adaptable to the sentiment of the customer without any human intervention. | |

The table presented below synthesizes the principal authors that corroborate with the presented view of the taxonomy and their respective themes.

*Table 3 – Authors and Themes for the Taxonomy*

| Authors | Themes |
|---|---|
| **Books, Journals, Researchers, Papers** | |
| Lacity, Mary and Willcocks, Leslie P. | RPA and Cognitive RPA |
| Milchman, A. | Artificially Intelligent Enterprise |
| Burgess, Andrew | Artificial Intelligence, Neural Networks |
| Srinivasan, V. | Machine Learning, Deep Learning, Big Data |
| Boobier, T. | Advanced Analytics, AI, ML, NLP |
| Deloitte University Press | Dark Analytics, ML, Deep Learning, RPA |
| SAP | AI Foundation |
| PwC Belgium and Gondola Group | AI and RPA |
| IDC - International Data Corporation | i-ERP, User Experience (UX) |

## 4.4. VALIDATION / DISCUSSION

The validation of this taxonomy was carried out by interviews with ERP experts based on a literature review with established definitions of key terms and concepts. The purpose of the interviews is to understand the true level of use of Intelligent ERP components and technology, in relation to what was investigated during the literature review and assumptions.

There are a limited number of experts in this area, and it was not necessary to explain all the concepts related to ERPs and i-ERP to the selected interviewees. However, it was also ensured that all respondents understood the interview and its questions, regardless of their knowledge and relevance in the area of ERP or i-ERP concepts and related technologies.

Three questions were considered as fundamental for the understanding of the possible results, whose objective is to try to investigate and clarify the applicability of the referred taxonomy in the organizations regarding the adoption of the mentioned guideline for the current ERP environments in order to improve to the highest possible level of an i-ERP.

**Interviewees Identification**

Name:

Company:

Brief Professional Background:

1. Do you think it is useful to have a taxonomy for i-ERP?
2. Do you agree with the presented taxonomy?
3. What improvements do you suggest to be implemented?

The interviews were done with two of the professors of Nova IMS University, and are described in annex.

The discussion was related to the dimensions that were used to understand and define an Intelligent ERP, the implications of the technology, and the impact of human behavior in this context. The professors highlighted the importance that this technology could bring to the companies and also the critical considerations that should be taken into account about a dimension of Ethics. It was helpful to understand and consider that there is a lot of research about this theme and sources like the ACM Code of Ethics and Professional Conduct and the IEEE organization, that is in its own words “the world’s largest technical professional organization dedicated to advancing technology for the benefit of humanity.”

That was a much valuable discussion to confirm some important topics, and the suggestions of improvements related to new dimensions to analyze and case studies will be considered in this thesis as suggestions for future work.

# 5. CONCLUSIONS

## 5.1. SUMMARY OF THE RESEARCH

Over the decades, many companies have grown complex and standardized ERP landscapes. They have created these ERP legacy landscapes, which are now almost all inflexible and monolithic. The need for innovation is increasingly significantly fast over time, and the early adopters are generally the most profitable in the future. As shown in this thesis, these generic ERP landscapes do not lead to executive expectations either to customer experience. And in particular, they are hindering their progress toward digitalization and transformation of business and technologies. The generic ERP does not allow for the speed of change anymore, which is required nowadays, and, unfortunately, most of them do not integrate easily with new technologies or business needs.

There is so much pressure for change coming from many sides, like, for example, the own providers of technology like SAP and Oracle, that have recently announced the end of the standard support for their most popular ERP software. But, it is necessary to ask ourselves what it really means? The easy answer is that we are in a unique time for the executive to rethink their overall IT architecture and think about their ERP landscape. The solution as we studied in this thesis could be the focus on having a small ERP core - leveraging "plain vanilla" as much as possible in order to benefit from best practices - coupled with some best-of-breed industry-specific or functional-specific applications where there are differentiating processes, incorporating step by step the power of AI, ML, Advanced Analytics, Dark Analytics, RPA, and UX. In order to achieve this flexibility and the speed of change required by customer expectations, companies should follow the levels of maturity from Basic ERP to Intelligent ERP, and, in the and of the day, it will be successful. The most optimistic and theoretical view is that by maintaining the subtle art of best-of-breed application between a small ERP core and some leading software-as-a-service applications based in the taxonomy proposed, companies can leverage their IT system in order to maintain their competitive advantage and achieve better results in the future.

On the other hand, we must be fair enough to say that there are some very important points to analyze regarding human beings and economic scenarios that can be impactful to the advance of technology and to follow the proposed path for adoption in various companies. When we talk about autonomous and intelligent systems, we need to think about responsibilities regarding possible errors and, consequently, liabilities. The software vendors, for example, could them be the ones for being financially liable for such tasks with the complex and ever-changing integrations necessary to transform a generic ERP in an Intelligent ERP? What if something goes wrong and causes an organization to go out of business? That is a critical situation that usually is not mentioned but needs to be taken into consideration when we talk about Intelligent systems.

The integration between AI and ERP is a great evolution, and the interest and excitement seem to be of big urgency. Companies wanting to become future leaders must overcome organizational challenges in order to fundamentally reinvent their business processes through the use of AI technologies. That is not an easy way and must be taken into consideration the critical points of the human being to full adoption, but the future is bright.

## 5.2. LIMITATIONS AND RECOMMENDATIONS FOR FUTURE WORK

The scope of this work is not specific to a determined size of companies, and not limited to a specific scenario. At the same time, it is important to point out that because of the complexity and variety of subjects related to the theme, I could not cover all areas and functions or technologies related to AI and ERP. The project does not aim to be a definitive guide on how to build an ERP or either AI system. The aim was to define an Intelligent ERP, to understand the relation between AI and ERP and propose a taxonomy composed of six levels of maturity that any company is able to figure out the level that is inside and plan its own project aiming to reach the next level until to become an enterprise with an Intelligent ERP.

The purpose of this work is not to be definitive and extensive and can be used by others to expand the subjects/dimensions, increase case studies, do an extensive survey, and cover more diversified professionals and areas, for example. Unfortunately, I could not cover all areas I would like, and also what was confirmed as important during the development and the interviews, that it could aggregate much more value if it was included another dimension of "Ethics" and all kinds of Use cases showing some examples of applications.

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# APPENDIX - INTERVIEWS

**Interviewee Identification**

**Name:** Interviewed 01

**Company:** Nova IMS

**Brief Professional Background:** From the economic-financial area, Professor at Information Management School (NOVA IMS), Universidade Nova de Lisboa, Portugal. Holds a Ph.D. in Information Management from Universidade Nova de Lisboa (UNL). Earned MSc. in Information Studies from ISCTE-IUL. Research interests include the evaluation of information systems effectiveness, notably the implementation and use of information technology in organizational information systems. Also interested in e-learning systems success research. Conducted a bibliometric study on e-learning evolution concepts and proposed two different business models for massive online open courses (MOOCs). Work appeared in Information & Management, Journal of Educational Technology & Society, Internet and Higher Education, Computers in Human Behavior, and others. Is a member of ACM (Association for Computer and Machinery) and is chair of the EuroSIGDOC/ACM chapter and also belongs to ACM Women.

**1.** Do you think it is useful to have a taxonomy for i-ERP?

Yes, and it must be done.

**2.** Do you agree with the presented taxonomy?

Yes, if it is about the various levels of classification for ERPs.

**3.** What improvements do you suggest to be implemented?

I believe that the Ethics dimension can not be ignored and could be mentioned because of its importance regarding the theme.

**Interviewee Identification**

**Name:** Interviewed 02

**Company:** Nova IMS

**Brief Professional Background:** Since 2015, Assistant Professor at NOVA IMS in curricular units of information systems; coordinates the postgraduate studies in “Digital Enterprise Management” and other specific projects related to Digital Transformation. In parallel, it also develops research on the impact that business software made available as a service has on the performance and competitiveness of organizations as a "Ph.D. Candidate."

**1.** Do you think it is useful to have a taxonomy for i-ERP?

Yes, because I have never seen any other.

**2.** Do you agree with the presented taxonomy?

Yes.

**3.** What improvements do you suggest to be implemented?

It could be given examples of use cases to increment and give more value.