Stephan Aier
Peter Rohner
Joachim Schelp *Editors*

# Engineering the Transformation of the Enterprise

## A Design Science Research Perspective

Springer

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# Preface

## Honoring Robert Winter

Robert Winter turned 60 in November 2020. To appreciate his work and to honor him as an esteemed personality, a broad range of professional colleagues and longtime companions both from the Institute of Information Management at the University of St. Gallen and from the international research community dedicated articles to this Festschrift.

The topics in this Festschrift reflect Robert's broad range of research interests: from business engineering and its application in corporate and business networking contexts to design science research as well as applied topics, where those research methods have been employed for modeling, data warehousing, IS management, enterprise architecture management, management of large and complex projects, and enterprise transformation.

At the University of St. Gallen's Institute of Information Management, the relevance of the research work for practice was in the foreground early on. Business engineering developed as a body of corresponding research methods. With the ongoing discussion about rigor and relevance of research, business engineering was also intensively scrutinized by Robert. At the same time, the discussion of design science research (DSR), which was about to be established in the international information systems (IS) research community, was taken up. In numerous projects with practitioners, the applied methods were refined, and contributions for and with practitioners were developed. The contributions of the Festschrift reflect Robert's ambition to uncompromisingly conduct high-class research that fuels the research community on the one hand and to pragmatically contribute to practice on the other hand. He has mentored a large number of young researchers, as evidenced by the many supervised habilitations and dissertations. At the same time, Robert has made his results available to established large organizations within the framework of project collaborations and competence centers, thus providing many valuable impulses for practice.

## The Organization of the Festschrift

We organized the Festschrift into three parts. The first part is rooted in the perspective, where Robert's interest in research methodology took fire: business engineering, the methodology developed in St. Gallen with a strong focus on research being applied in corporate contexts. The second part dives deeper into design science research and spans from reflections on the practice of design science research, perspectives on design science research methodologies, up to considerations to teach design science research methodology. The third part finally comprises applications of design science research and related research methodologies to practical problems and future research topics.

### *Part 1: Business Engineering and Beyond*

The opening chapters have been initiated by Robert's long-term colleagues at the Institute of Information Management: Walter Brenner and Hubert Österle.

Of course, the part on Business Engineering and Beyond begins with a contribution from Hubert Oesterle, who started the business engineering perspective in St. Gallen. And consequently, he develops a new perspective, live engineering, emanating from the business engineering perspective: *From business engineering to life engineering*. He focuses on the individual perspective of the quality of life in contrast to the established corporate value perspective established in business engineering.

In the second chapter, Walter Brenner discusses together with Benjamin van Giffen and Jana Koehler the *Management of artificial intelligence* and focuses on the feasibility, desirability, and viability of artificial intelligence.

Mateusz Dolata and Gerhard Schwabe extend the discussion on artificial intelligence in their chapter by asking *How fair is IS research?* They zoom into algorithmic fairness, corresponding discrimination risks in IS research, and resulting research opportunities for IS researchers.

Susanne Leist, Dimitris Karagiannis, Florian Johannsen, and Hans-Gert Penzel bring the business engineering perpective back and reflect on the role of metamodeling in their contribution *From business engineering to digital engineering – The role of metamodeling in digital transformation*.

Ulrike Baumöl and Reinhard Jung focus again by zooming into modeling with their contribution *Potentials and limits of modeling using the example of an artificial Real-World Model*.

Finally, Henderik A. Proper completes the first part with his contribution *On model-based coordination of change in organizations*, where he reflects on modeling and the resulting need to leave the "boxes-and-lines" metaphor being used in engineering and sets the stage for part two.

## Part 2: Design Science Research

Shirley Gregor opens the sequence of contributions discussing design science research. In *Reflections on the practice of design science in information systems*, she shows existing issues in DSR and discusses them from both contributor and reviewer points of view.

Jan vom Brocke, Manuel Weber, and Thomas Grisold reflect the DSR contributions to the solution of real-world problems in *Design science research of high practical relevance – Dancing through Space and Time*. They discuss their experiences with applied research and develop quality criteria to demonstrate both practical relevance and societal value contributions of DSR.

Jan Marco Leimeister, Ernestine Dickhaut, and Andreas Janson reflect the pattern topic in their contribution *Design pattern as a bridge between problem-space and solution-space*. They delve into the codification of design knowledge and its application in both research and practical contexts.

Tuure Tuunanen and Jan Homström reflect another problem dimension between building and using design knowledge by limiting their contribution to and using the research results within a study and across research studies with their chapter *Incremental accumulation of information systems design theory.*

Jannis Beese adds to this perspective the time dimension and asks for *Assessing the temporal validity of design knowledge* in his contribution.

Finally, Alan R. Hevner contributes a scholarly perspective with *Pedagogy for doctoral seminars in design science research* and develops a curriculum for the doctoral level.

## Part 3: Applied Fields

Stephan Aier, Barbara Dinter, and Joachim Schelp reflect in their contribution *Management of enterprise-wide information systems* the part of research work at Robert's chair that focuses on data warehousing, (enterprise) architecture, and transformation.

Lars Baake, René Fitterer, Anke Helmes, Tobias Mettler, and Peter Rohner discuss in their chapter *The competence center health network engineering—A retrospective* the research contributions at Robert's chair to the transformation of the Swiss health system.

Kazem Haki delves into platform ecosystems and develops *A research agenda for studying platform ecosystems*.

Hans-Ulrich Buhl, Björn Häckel, und Christian Ritter develop a management system for integrated risk and earnings management with a focus on increasing resilience in turbulent times in their contribution *A Concept for an IT-supported integrated earnings and risk management to strengthen the resilience of companies in times of crisis*.

Peter Gluchowski discusses using data vaults as a modeling approach for data warehouse systems in his contribution *Data Vault as a modeling concept for the data warehouse*.

Jörg H. Mayer, Christian Hebeler, Markus Esswein, Moritz Göbel, and Reiner Quick stay in the business intelligence context but focus on the usage perspective and are *Evaluating a forward-looking maturity model for enterprise performance management.*

Gunnar Auth reflects *The evolution of IT management standards in digital transformation – Current state and research implications*.

Antonio Fernandes and José Tribolet develop another perspective on enterprise-wide information systems with their contribution *Towards conscious enterprises: the role of enterprise engineering in realizing living sciences paradigms into management sciences*.

Paolo Spagnoletti and Stefano Za add a special perspective to organizations by discussing *Digital resilience to normal accidents in high-reliability organizations.*

Ralf Abraham, Stefan Bischoff, Johannes Epple, Nils Labusch, and Simon Weiss return to the research perspective and contrast it with the practitioners' one. They conclude that there is a gap to be surmounted and deliver some fresh thoughts on it in their contribution *Mind the gap: Why there is a gap between information systems research and practice, and how to manage it.*

Reima Suomi finally reflects humorously *The connection between Winter and information systems*.

St. Gallen, Switzerland

Stephan Aier
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# Part I
# Business Engineering and Beyond

# From Business Engineering to Life Engineering

**Hubert Oesterle**

**Abstract** Starting with a reflection of the business engineering discipline and its focus on the corporate value perspective, this contribution positions life engineering as a new discipline focusing on the individual perspective of the quality of life. Based on the example of a sleep coach it develops the different tasks a discipline life engineering has to address.

**Keywords** Business engineering · Life engineering · Quality of life · Life engineering discipline

## 1 Introduction

In the future, a *digital sleep coach* will help many people achieve healthy sleep and thus contribute significantly to their health and well-being. Today's sleep coach is data-minimal because it is mostly based on movement recordings from a smartwatch or subjective statements from personal entries. A future sleep coach is data-rich if he can access almost all digital personal data, from Internet usage to smartwatches to sensors in homes and vehicles, and even medical data. If he can actually help people with serious sleep problems, they will gladly give consent.

Such digital assistants will accompany us in all areas of life in a few years, in diabetes therapy, financial retirement planning, nutrition, entertainment, education, and so on. However, this raises some critical questions: How is the privacy of the individual to be safeguarded if personal and environmental data must be comprehensively collected and evaluated in order to model sleep behavior, and if the sleep coach needs the personal data of the specific user for individual coaching? Who develops such a sleep coach? A pharmaceutical company, an internet company, a health insurance company [1], the employer [2], the state? What interests do these

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pursue with the sleep coach? What else could a developer do with the data? How does a young company get hold of the data lying in the silos of the mega portals? Does a sleep coach endanger human autonomy? Who has the right or the duty to encourage people to sleep healthily?

*Business engineering* aims at business *value*. Sales of products and services, expansion of the customer base, customers' profitability (e.g. ARPU, Annual Revenue per User in the telecommunications industry), process costs in customer care, compliance and risk avoidance, return on sales, customer loyalty and need creation are just a few examples of business engineering concepts [3].

*Life engineering* aims at people's *quality of life*. Quality of life can mean pleasure and joy from food, sex or appreciation, but also avoidance of pain and suffering from illness, effort or humiliation. In the long run, people are concerned with meaning in life and satisfaction. But the path to quality of life is not as clear to science or the individual as it is in the case of sleep quality. That is why a whole happiness industry could develop, which is concerned with wellness, lifestyle, happiness training, self-discovery, ethics, philosophy and the like.

When the needs of self- and species-preservation, i.e., food, security, sex, and avoidance of effort become sufficiently satisfiable, the needs of selection come to the fore. We strive for status symbols, appearance, circle of friends, personal income, and wealth to improve our rank within our peer group. When we meet our own expectations, it boosts our self-esteem and thus conveys *satisfaction* [4].

Digital services, i.e. Tinder, Instagram and Amazon, influence our needs and accelerate the hamster wheel of consumption and money-making. Opinion forming, advertising and influencing use the entire toolkit of psychology, which derives knowledge more and more from personal data to influence our behavior (e.g. nudging).

Never before have people had such comprehensive, up-to-date, and automatically collected *behavioral data* (Quantified Self [5]). Never before have they had such powerful algorithms and machines to *recognize patterns* in this data. Never before has there been such close *collaboration between humans and machines* in all areas of life. So never before has it been possible to *control* people so effectively. Those mechanisms reveal themselves as manipulated information channels (e.g., filter bubbles), individualized communication of values, consumer offers, and even various forms of social scoring (e.g., credit reports and traffic offence registers).

Mankind is on the verge of a *socio-technical evolutionary leap*. Digitalization offers new mechanisms for social control, which companies, political parties and other organizations are already using intensively for their interests. Machine-based behavior control can be a unique opportunity to improve people's quality of life if development is driven by human interests, or an underestimated danger if interests other than those of the individual, guide development.

The Internet, sensor technology, and digital assistants from navigation to social media and online stores to automated insulin pumps illustrate this development. Data collection and machine learning are accelerating sociotechnical evolution [6]. It cannot be stopped; we can only try to guide it for the benefit of humans.

For this, we need a discipline of life engineering that brings together the findings of disciplines such as political science, psychology, neuroscience, machine learning, ethics and economics and derives concepts for living with a highly developed technology. Life Engineering is the further development of Business Engineering with the aim of improving quality of life.

## 2 Socio-cultural Evolution

Biological evolution is based primarily on mutation, recombination and selection and, apart from breeding experiments and, more recently, genetic manipulation, is hardly influenced by humans. Socio-cultural or socio-technical evolution obeys the same evolutional mechanisms, but partly follows a man-made, planned design of technology and organization.

### *2.1 Technological Evolution*

Machine intelligence has been regarded as a central driver of social change ever since Daniel Bell's work on the "post-industrial society" in 1973 [7]. The Internet with its countless digital services, the digital assistants as apps on our end user devices, the mega portals from Facebook to Tencent, and finally the integration of these services in so-called superapps [8] have already massively changed our daily lives. *Sensor technology* together with powerful *wireless networks* (especially 5G) will add a dimension to the already gigantic data collections in the coming years [9]. Increasingly sophisticated machine learning algorithms and processors are taking knowledge about our lives to a new level. New forms of cooperation between humans and machines, especially *actuator technology*, integrate intelligent machines, for example autonomous navigation in cars, into our lives [10].

### *2.2 Homeostasis as a Driver of Evolution*

Just as physiological homeostasis ensures the survival and further evolution of organisms, sociotechnical homeostasis allows technologies and forms of organization to emerge or disappear. Knowledge, power and capital are the dominant criteria of sociocultural selection [4].

## 2.3 Quality of Life

Evolution controls people through feelings (quality of life), through joy (happiness) and sorrow (harm) [11]. These feelings arise from the effect of perceptions on needs (see [4]). Greatly simplified, there are genetically determined, inherited needs such as food, safety, and sex, as well as avoidance of effort. With their cognitive abilities, humans derive patterns (secondary needs) from perceptions, for example by recognizing the effect of a high-calorie energy drink on their need for food, but at the same time learning that too much energy intake leads to fat formation and, in the longer term, health and attractiveness in selection suffer as a result. In many cases, humans have to weigh up between short-term satisfaction of needs (hedonia) and long-term satisfaction (eudaimonia).

Hedonia cannot be increased at will and, above all, it is not permanent due to accommodation. A long-term satisfaction is considered as the goal of humans in psychology and philosophy. Even if genes determine one third of satisfaction, individual life circumstances are responsible for two thirds and can be influenced by people and society for better or worse [11].

## 2.4 Options in Evolution

Companies act in the interests of *capital*, i.e. shareholders. Although they repeatedly profess their commitment to stakeholders and also fulfill this commitment if the pressure is great enough, the company's management is ultimately measured by its financial performance. Capital is the criterion for the development of new products and services, for the form of marketing, for pricing, etc., but above all for the performance assessment of employees. Capital is de facto the driver of sociotechnical evolution. This would not be a problem if people knew what was good for them and, more importantly, acted on it. Drug addiction, obesity, consumerism, environmental degradation, leisure stress, mental illness and indebtedness are indications that people do not always use technological opportunities for their own good.

Society needs to think about how it will incorporate machine intelligence and other technologies into reshaping its life. The technologization of society cannot be stopped. There are enough developers and companies in this world that can improve their situation through innovative business solutions. Those who opt out of the development race fall into the dependency of the technological leaders, as their solutions keep replacing conventional products and services, i.e. pushing them out of the market. If someone advocates quality of life, as we Europeans like to pretend to do, and believes that this sets them apart from allegedly primitive capital-driven societies, they have to realize that only those who lead the development can influence it in the sense of their values. Even well-intentioned regulation such as the GDPR can do little to change this. Sociotechnological evolution cannot be stopped, and it appears more threatening ex ante than ex post. Who today would want to return to a development level of 50 years ago?

We have the choice of leaving the control of development to capital alone or finding mechanisms to prioritize quality of life without lagging behind in development. This is not a call for an alternative economic system, but an encouragement to complement capitalist control with the possibilities of digitalization. Numerous initiatives by governmental and non-governmental organizations from consumer protection, education for digital independence, environmental protection, labor law, etc. recognize the need for action and advocate for people's goals from the perspective of humanism [12], ethics [13–15], Social Development Goals [16], etc. Although it may sound politically undesirable, it is precisely a social scoring system, such as China is testing in different variants, that has significant potential to ensure quality of life.

## 3 Sleepcoach Example

The call for a discipline of life engineering seems very academic. Therefore, let us illustrate with an example of how life engineering could have an effect. Today, there are numerous sleep apps that are supposed to bring people the sleep they urgently seek and that could noticeably improve their quality of life. Free access to all the data that determines sleep quality and that is available in many data silos from eMail, the social networks, medical findings and DNA analysis, as well as sleep trackers available on the market, could already lead to new and, above all, sound insights using machine learning techniques. The world of miniaturized, low-cost, and mobile sensors for skin resistance measurement, heart rate recording, blood pressure or blood glucose measurement, noise level measurement, air quality, exercise, etc., will open up a host of new indicators and, most importantly, enable real-time interventions (e.g., recommending a break from work). The sensor technology enables a *leap innovation* for a sleep coach and addresses a market with several millions of customers.

### *3.1 Target*

A pharmaceutical company certainly wants to improve people's sleep, naturally thinking first of all of the sale of sleeping pills. So it will probably develop a sleep app that reminds the consumer to take the pill, at best making the dosage dependent on the consumer's (patient's) machine-measured state of arousal [17]. Business engineering optimizes the process from identifying potential customers, influencing them via medical portals, recommending them to their family doctor, reminding them to take the tablet, measuring the quality of their sleep and thus measuring the benefits, and finally automating the supply of the sleeping pills to the patient. The pharmaceutical company's metrics are the quantity sold and the price charged. It may accept the risk that the patient becomes addicted, i.e. can no longer sleep without the sleeping pill, possibly even that the dose has to be increased again and again.

Life Engineering seeks to improve the *quality of human life through healthy sleep*. It determines the connection between sleep and well-being as well as the possible influences on sleep, for example the food consumed, eMail usage in the evening and physical activity during the day. It is possible that a digital sleep coach does not recommend sleep medication and thus does not generate pharmaceutical sales.

At first glance, the goal of business and life engineering appears to be the same: healthy sleep. The implementation, on the other hand, is very different. Of course, the pharmaceutical company would also be willing to forego selling sleeping pills if customers used a digital sleep coach and paid for it. At least for now, this customer behavior is an illusion in the seemingly free world of the Internet, especially since taking a sleeping pill requires less personal behavior change than, say, taking a walk before bed. So one challenge for life engineering is to monetize a sleep coach that will eventually be available. One route might be through health insurance.

### 3.2 Data Access

Sleep apps have had very limited success so far. While there have been many attempts and start-ups, the benefits seem limited. For the most part, the apps are content with measuring sleep without surveying the influencing factors. The aforementioned *sensors and a wireless network like 5G* will fundamentally change the picture. Influencing factors such as the noise level, smartphone usage or heart rhythm will become usable together with the measured sleep quality.

However, this data is not yet available to the developer of a sleep app, but lies in the data silos of the mega portals. Article 20 of the GDPR (right to data portability) basically requires that all "data collectors" *transfer the data* to another digital service provider at the request of the consumer. This would theoretically enable the provider of a digital sleep coach to obtain all data relevant to sleep from various sources. However, what that might look like for real-time access to heart rhythm data, for example, is completely unclear. Life engineering should provide a technical and organizational answer.

### 3.3 Data Collection and Update

In conclusion, the first thing a start-up company with very limited resources has to do is requesting all the data from sources such as Google, Apple, Facebook, Netatmo, and Fitbit, clean it, and build a machine learning database from it. For the ongoing operation of the sleep coach, the sleep coach has to be able to use all these data sources in real time. This will overwhelm the technical and organizational capabilities of even the best-intentioned of all companies in the affected ecosystem.

Life engineering must therefore ensure that this data flow is possible and meets data protection requirements. It may be possible to achieve this with a Data Space (data marketplace) as conceived in GAIA-X [18] and IDS [19]. The European Public Spheres [20] of the German Federal Government and the European Union attempt to organize not only the Data Space, but the entire ecosystem for individual spheres of life [18, 21].

Regardless of whether government organizations or private-sector initiatives create the necessary data infrastructure, there is a need for *standards, procedures, mechanisms, and rules for collaboration* within such ecosystems. A life engineering discipline can act as a facilitator and contribute theoretical foundations.

### 3.4 Machine Learning

One challenge for life engineering is its extraordinarily broad interdisciplinarity. Being able to draw on the knowledge of disciplines such as psychology, sociology, ethics, philosophy, neuroscience, computer science, especially machine learning, business administration, and not least economics, is necessary.

Machine learning generates knowledge about the behavior of people and their environment. The Google Knowledge Graph is probably the best-known knowledge base, Google's Selfish Ledger a special further development for understanding human behavior. Knowledge bases documenting patterns for subdomains of human behavior are emerging in a variety of locations. Their goal is to predict and extract a particular behavior, such as buying behavior, but also political attitudes. The developers of a sleep coach need a comprehensive and detailed model of human behavior around sleeping. Ideally, they will have a structured access to existing knowledge that has been derived in various locations using analytical tools.

Life engineering thus needs access not only to the data of the digitized world, but also to the knowledge derived from it. This requires a *standardization of the knowledge representation*, an extremely demanding task, even if one disregards the legitimate interests of competitors in proprietary solutions. Here, too, a life engineering discipline can collect the existing approaches and propose further developments from them.

### 3.5 Market Access for a Digital Sleep Coach

Once sleep behavior and its influencing factors are sufficiently understood so that a digital sleep coach can help achieve sustainably better sleep, the knowledge to be translated into a digital service. There are several ways to achieve this:

- a new stand-alone app, i.e. an application on the smartphone, smartwatch, smartring and a server
- the redesign of an existing sleeping service already established on the market
- the integrated functionality of a mega portal like Apple, Google or Tencent
- a program that can be integrated into any app via API
- an open-source program and funding via the collected user data

If life engineering is to make a difference, it is crucial to understand market supply and market mechanisms to the extent that its concepts have a realistic chance of operating in an economically sustainable manner.

## 3.6 Funding for a Digital Sleep Coach

A sleep coach, as indicated above, requires considerable development effort. University research can at best provide basic concepts, building blocks and prototypes. A marketable sleep coach requires many times the resources of academic research projects.

Such financing is readily available if there is a compelling business model. Approaches that focus on quality of life rather than a capital objective alone call for novel mechanisms that leverage multiple revenue streams. Health insurers are increasingly coming up with applications to improve the health of their customers. Employers have an interest in rested employees with increased performance capabilities, and pharmaceutical companies can increase the effectiveness of their products. In some circumstances, even consumers of a sleep coach may be willing to pay a monthly subscription fee.

Life engineering faces the challenge of *adding the quality of life criterion to the capital criterion* in such a way that the necessary financial resources can be obtained for development and operation.

## 3.7 Public Regulation

The social market economy has produced a multitude of regulations designed to protect citizens from the harmful effects of an exclusively capital-driven economy. Examples include consumer protection, data privacy, drug laws and environmental standards. The possibilities of digitalization expand the question: can the state not only prevent negative developments, but even promote or require positive options. Chinese social scoring shows that digitized social governance can be used to encourage desirable behavior, for example, by awarding bonus points when a citizen engages in social goals. Corporate social scoring, i.e., the evaluation of corporate behavior, is even a realistic implementation opportunity for previously relatively ineffective standards such as ISO 26000 [22] on corporate social responsibility.

Such forms of intervention in social and economic life are very quickly labeled with terms such as paternalism, loss of freedom, and bureaucracy and are understood as the downfall of a liberal world order. Life engineering can develop proposals for replacing today's personnel-intensive and sometimes arbitrary control mechanisms with efficient, transparent, and objectifiable procedures [23]. Is a speed camera check carried out by police officers at considerable expense, with the subsequent bureaucratic processing and entry in a public traffic offender file, preferable to an automated speed check via the car's on-board electronics or via cameras on the roads with an automatic debiting of the penalty and a machine assessment of driving behavior? Insurance companies are already trying to assess the individual risk of insured persons with data from the on-board electronics and to calculate the insurance premium accordingly. That, too, is social scoring.

Life engineering offers the opportunity to make *societal governance mechanisms* more efficient, fairer and more consistent in many areas. It must address the extent to which government organizations have the *right* or even the *duty* to use digitization to implement democratically agreed rules.

## 3.8 Tasks of a Discipline Life Engineering

Before calling for a new scientific discipline, one should look very carefully to see if it does not already exist, under a different name. Psychology covers many aspects, but hardly makes use of the possibilities of a digitized world, apart from a few highly interesting approaches to recognizing personality traits from e-mails or social networks or subsuming the neurosciences. Statistics and computer science deal with the machine recognition of patterns in personal data, but do not connect them with psychology. Marketing science uses the findings of psychology and computer science but is primarily oriented to the sale of products and services and the short-term benefit for the buyer, if this is decisive for the purchase, but not towards the quality of life. Similar things can be said about the other disciplines mentioned, so that a separate discipline of life engineering is called for here. Although the interdisciplinarity required therein represents a difficult hurdle, the attempt must be dared, because what is at stake is too great: digitization for its own sake or for the sake of capital, or to safeguard people's quality of life.

A discipline Life Engineering has the following tasks:

- Quality of life model that allows evaluation of technological options.
- Access to anonymous personal and factual data so that research and companies can identify patterns in it
- Use of individual personal and factual data in the digital services
- Behavioral model that summarizes the findings of the various disciplines in a machine accessible form (e.g., in a neural network)
- Measurement of quality of life (Hedonia and Eudaimonia)
- Digitized control mechanisms

- Guidance for the construction of digital services
- Implementation of the findings in politics, companies and individuals

Years ago, it was my great pleasure to work with Robert Winter to establish the Business Engineering discipline and create a comprehensive range of research and education. Wouldn't it be a fascinating idea that Robert Winter could repeat his success story with the Executive MBA in Business Engineering with the goals of Life Engineering.

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# Management of Artificial Intelligence: Feasibility, Desirability and Viability

**Walter Brenner, Benjamin van Giffen, and Jana Koehler**

**Abstract** Artificial Intelligence is evolving and being used in more and more products and applications in business and society. Research in artificial intelligence is dominated by computer science. The focus is on the development of innovative algorithms and the design of processors and storages required for different application scenarios. Numerous prototypes are developed for a wide variety of applications. Only a few of these prototypes make it into productive applications that create lasting business benefits. Discussions with numerous companies show that professional processes and structures are needed to develop and operate artificial intelligence applications. We refer to these processes and structures as management of informatics. This article describes our understanding of artificial intelligence, shows examples of concrete business benefits, lists exemplary challenges, and describes the basic processes of the management of artificial intelligence. This article is based on a comprehensive literature review as well as numerous structured and open discussions with people from applying companies and computer scientists from the academic environment who deal with artificial intelligence and its use. An extended version of the article has been published in the German Springer Essentials series titled "Bausteine eines Managements Künstlicher Intelligenz: Eine Standortbestimmung".

**Keywords** Artificial intelligence · Machine learning · Project management

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# 1 Artificial Intelligence

Artificial intelligence (AI) addresses the question of whether intelligent behavior can be computed. The basis of modern AI is the metaphor of the intelligent agent [1, 2]. An intelligent agent can perceive its environment and, based on these perceptions, makes decisions that determine its further actions. If it is a rational agent, then its decisions must lead to the best possible action for it. We base our discussion on this definition, even though there are very different understandings of artificial intelligence in the literature. Since the 1950s, countless researchers in computer science and related fields have been engaged in the development of artificial intelligence methods and their use in business and society.

There are many different forms of artificial intelligence. Numerous authors give the impression that it is only a matter of time until there is artificial intelligence whose problem-solving power is equal to that of humans ("Strong AI" or "Artificial General Intelligence") or even surpasses it ("Super AI") [3]. Today, and in this paper, we are concerned with weak Artificial Intelligence, often referred to as "Narrow AI" or "Weak AI". This manifestation of Artificial Intelligence is capable of handling specific, constrained problems on its own. There are numerous algorithmic methods that are subsumed under the term Artificial Intelligence. A distinction is made between stochastic and deterministic methods. In deterministic methods, the output is completely determined by the parameter values and the initial state. Stochastic methods combine probability theory and statistics and are characterized by the fact that some parameters are described with random variables, so that for a given initial state the output is not necessarily always the same. Currently very successful AI methods such as machine learning or modern search algorithms that use Monte Carlo simulations belong to the stochastic methods. In particular, training neural networks for supervised machine learning employs stochastic methods. However, the application of a trained network to a given data set is deterministic, since the input values and the weights set in the network by training determine the output value. We understand machine learning as methods in which algorithms recognize patterns in data without being explicitly programmed [4].

Supervised machine learning uses annotated examples from input/output data to learn statistically significant patterns for the relationship between input and output, i.e., to approximate the underlying function that must be applied to the input to produce the output. Currently, Deep Learning, i.e., so-called deep neural networks that combine many layers of simple computational units, is particularly successful in performing such tasks [5]. Training data is of particular importance for managing artificial intelligence, which we will discuss later in this article. While in supervised learning training data is described, i.e., a picture of a dog is also labeled "dog", in unsupervised learning an algorithm searches for previously unknown patterns, distributions, or dependencies in the data [2] without any additional annotation. Even this rough description shows that the application areas of these two methods of artificial intelligence are very different.

In recent years, a kind of equation has become established in science and practice: "Artificial Intelligence = Machine Learning = Deep Learning". While we are convinced of the power of Deep Learning, we are of the opinion that it is part of the responsible and benefit-oriented handling of Artificial Intelligence to search for the appropriate method of Artificial Intelligence for an existing problem and not to proceed pragmatically according to the principle "If the only tool you have is a hammer, you tend to see every problem as a nail" and, accordingly, reduce Artificial Intelligence to Neural Networks and Deep Learning.

In 1943, McCulloch and Pitts [6] described elementary units that can represent logical functions in a linked manner and thus founded the beginnings of neural networks. Norbert Wiener founded cybernetics in the 1940s and investigated analogies between the actions of machines and living organisms [7]. McCarthy coined the term "artificial intelligence" in 1956, distinguishing himself from previous research activities to give more space to a logic-based approach to AI [2]. About 35 years ago, there was an initial hype about Artificial Intelligence in the context of expert systems. Data not available in sufficient volume, procedures for handling uncertain knowledge not yet developed, and limitations in storage and processing capabilities ended the euphoria. The next 15 years saw the so-called "winter" of artificial intelligence. The expectations raised in the hype were not fulfilled and, as a result, Artificial Intelligence was considered a very unattractive field in science and practice. About 10 years ago, Artificial Intelligence experienced a rebirth. The abundance of available data, massively increased storage and processing capabilities, and much more powerful algorithms led to an upswing that continues today. Anyone who has followed the development of speech recognition over the last few decades has seen how systems have improved. The future importance of artificial intelligence for solving numerous problems in business and society is undisputed.

## 2 Competitive Factor

Artificial intelligence is becoming a decisive competitive factor in more and more industries. Depending on the problem, both deterministic and stochastic methods are used. However, artificial intelligence, even if it is ultimately decisive for success, is only part of the overall solution. It is integrated into a software system that is connected to mechanical or electrical components in industrial applications, for example. The decisive factor is that the software system is used productively. Only then can it generate business benefits.

Increasing the productivity of elevators is a successful example of the use of artificial intelligence. In the 1990s, the elevator industry discussed the idea of so-called destination call control, in which passengers enter their destination floor via a terminal before starting their journey and are then assigned to one of the available elevator via a display. Figure 1 shows an input unit for a destination call control system.


**Fig. 1** Destination call control for an elevator (own image)

Passengers specify the desired floor on the call control unit. For most passenger requests, the destination call control system calculates the best possible distribution of passengers to the available elevators. In the example from Fig. 1, the system tells the passenger to use elevator D.

Various attempts to use artificial intelligence methods, such as genetic algorithms, neural networks or fuzzy logic, did not achieve the desired performance. If one looks at the problem more closely, one finds that it is a combinatorial optimization problem in which a set of available passenger trips from different starting floors to different destination floors must be optimally distributed among a set of elevators so that the waiting and travel times of the passengers are minimized and thus the transportation performance of the elevator system can be maximized. In the 1970s–1990s, so-called heuristic search algorithms were developed in the artificial intelligence discipline, which were used, among other things, in Deep Blue's victory over Gari Kasparov in 1997. These algorithms had matured to the point where they could find the optimal travel sequence for an elevator out of the billions to trillions of possible travel sequences in a few hundredths of a second on a standard industrial PC. They were also able to further reduce the complexity of the optimization