Requirements for Highly Integrated Management Systems

Simulation Expands Past-oriented Documentation to Future-oriented Optimization

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***Abstract*—Despite their advantages, Integrated Management Systems mirror the past. Simulation experts, however, can potentially make use of the processes stored therein to predict the future. Based on personal experiences, the authors assume that many practitioners in Business Process Management are unfamiliar with this possibility. To gain insight into this assumption, they examined the relevance of simulation in Business Process Management literature and education, especially in German degree courses on Business Information Systems. Presented in this paper is a summary which serves as the basis to formulate requirements for a new class of Integrated Management Systems called Highly Integrated Management Systems by combining past-oriented documentation and future-oriented forecasts within one system. From the authors perspective, an implementation of a Highly Integrated Management Systems could make use of high-level Petri nets for the realization of the process part since they are well-proven concerning the modeling and simulation of complex processes in administration and production, but can also be used for visualizations needed in a documentation.**

***Keywords*—Highly Integrated Management System; Process Management; Simulation; Petri nets.**

I. INTRODUCTION

Integrative or Integrated Management Systems (IMS) serve two purposes: 1) They facilitate management by process documentation, thus leading to a better comprehension, optimization and implementation of these processes. 2) They provide means that base on these documented processes for establishing systematic management techniques in different fields such as quality, occupational health and safety, environmental protection, or energy utilization, which can be certified after implementation.

However, as the described processes are inherently past-oriented, this is also the case for IMS. Simulation experts, though, can use processes - especially well-documented ones - to examine change along with its possible effects. This makes different courses of action and their consequences manageable and opens room for optimization.

During their work with and visits to several companies of different size, the authors experience a lack of simulation usage. However, nearly all companies implement some form of management system. This begs the question as to whether those practitioners in the field of Business Process Management (BPM) who work with IMS are oblivious to the possibilities of using their documented processes future-oriented.

The authors assume two possible causes for such a non-use: Either, there simply is a knowledge gap, or there is a lack of suitable tools - or both, which seems to be the case. This paper aims at providing support for these assumptions and a solution for practitioners to benefit from simulation possibilities.

Section II outlines the methodology used. Section III provides information about IMS as they are used nowadays while Section IV examines software for IMS. Afterwards, Section V describes the findings of the literature review. Since no related work to extend IMS by simulation could be found, a new class of IMS is introduced in Section VI along with requirements for supporting software. Section VII deals with the necessity of an expanded simulation education. The paper closes with a conclusion and future work in Section VIII.

II. METHODOLOGY

There are two research questions worked on for this contribution: 1) What is the current scope of simulation use regarding processes documented in IMS? 2) What capabilities are missing in today's IMS supporting software - if so - to assist practitioners in conducting such simulations?

The results of this paper base on desk research. They are derived from specifications of IMS, IMS supporting software, and foundational process management literature as processes are the core models of IMS. Also, degree courses in BIS and similar courses at German universities of applied sciences were examined with regards to process management and simulation. The literature reviewed is listed in Sections III, IV, and V.

This work detected remarkable deficits concerning the simulation education in literature and courses. But also for current software for IMS and process management deficits could be observed as these systems are either past- or future-oriented.

In a second step and in a normative manner, requirements for a new class of IMS are derived that combine past and future in one system.

III. INTEGRATED MANAGEMENT SYSTEMS AND PROCESS MANAGEMENT

According to ISO 9000, management comprises coordinated activities to guide and direct organizations. Hence, a management system is a set of interrelated functions and elements to conduct these tasks but also to determine a company's policies and objectives and the objectives of its processes [1].

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The standardization of management systems by the International Organization for Standardization (ISO) provides companies with a framework to establish such structures. However, this comes along with an extensive documentation obligation if companies seek for a certification. Suitable software can mitigate this effort and the third section gives an overview of corresponding systems. The core of all such documentations is a comprehensive description of the company's processes.

An IMS holistically considers and processes the different elements, functions and perspectives of the organizational structure of a company according to Figure 1 [1][2].

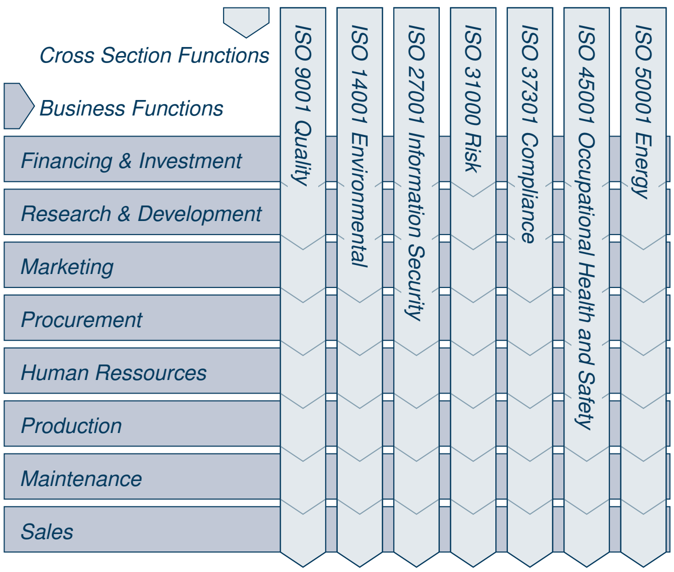

Figure 1. View of companies as network of functions by Integrated Management Systems (based on [2]).

The following overview is intended to show the most important management systems:

ISO 9001:2015: Introduced in 1987, this standard for quality management systems today also serves as the basis for the other standards listed in this section, as well as further (quality management) standards like ISO 13485 for medical devices, ISO 29001 for petrochemicals, or ISO 90003 for software engineering.

ISO 14001:2015: An environmental management system supports a continuous improvement of environmental performance based on material flow analyses.

ISO 27001:2013: Information security management systems are used to assess and address such risks.

ISO 31000:2018: Despite the variability of potential risks, ISO attempts to standardize operational risk management.

ISO 37301:2021: Compliance management systems aim to identify, prevent, or respond to non-compliant behavior.

ISO 45001:2018: This standard for occupational health and safety management systems integrates two formerly independent standards in one.

ISO 50001:2018: Energy management systems facilitate an environmentally friendly use of energy sources.

IV. State of the Art of Software for Integrated Management Systems

This section summarizes the presumably most important characteristics of software for IMS as database-driven systems to collect and link the process documentations for the various management systems.

Table I shows a set of criteria that have been used in [3] to compare the nine modeling software systems for IMS listed in Table II. This catalog extends a former one discussed in [4] by criteria used in students' projects and by criteria considered in evaluation portals. Naturally, the description of processes constitutes an important part. However, it also contains previously unexamined criteria, such as that for executability.

TABLE I. COMPARISON CRITERIA FOR SOFTWARE FOR INTEGRATED MANAGEMENT SYSTEMS (BASED ON [3])

Group	Criterion	Example characteristics
Process modeling	Modeling languages	BPMN/EPC/Petri nets/...
	Process saving	
	Process description	Model integrated/...
	Process indicators	
	Simulation	
	Animation	
	Search	Keywording/Full text
	Swimlanes	
	Subprocesses	
	Process adaptability	
	Modelint guidelines	
	Comments	Model integrated/...
	Versioning	
Overviews	Process map	
	Organigram	
Usability	Multi language	English/German/French/...
	Individual views	Everyone/Admin only
	Individual start page	Everyone/Admin only
Role management	User groups	Own/Predefined
	Permission release	
	Task management	News/Reminders
Quality management	Documentation	Online/Offline/Exportable
	ISO-Certification	ISO 9001/14001/27001/...
	Audit-Organisation	Planing/Feedback
	Maturity assessment	
	Process qualification	
Implementation	Operating systems	Windows/Mac/Linux/...
	Availability	On-premise/SaaS
	Maintenance/Updates	On-premise/Remote
	Interfaces	Graphs/XML/...
	Mobile	iOS/Android/Web-App
User support	Hotline	Phone/Chat/Email
	Training	Seminar/Webinar
	Offline manual	Online manual/Videos
	Help Assistant	Auto complete/Suggestions
Pricing	Fees	
	Licensing	
Application	Sector specific	Automotive/Financial/...
	Department	Purchasing/Logistics/...
Real life execution	Indicator evaluation	Yes/No/...
	Evaluation in maps	
	Release workflow	Approvals/Tasks
	Third-party extensions	
	Release online	
	Process analysis	

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The selected groups, criteria and possible characteristics cover a broad range from various process modeling approaches, integrated quality management, role management, but also usage aspects. Group *real life execution* considers different possibilities to link stored documentations to real world phenomenons.

The tools listed in Table II have been selected for personal reasons or due to being mentioned in other tool comparisons. Their evaluation concerning the mentioned criteria was conducted by evaluating information supplied by the manufacturers' websites and through subsequent interviews with the providers, to which all but two were willing to respond.

TABLE II. SOFTWARE SELECTION FOR TOOL COMPARISON (BASED ON [3])

Tool	Publisher	IMS
Aeneis	Intellior AG	Yes
ARIS	Software AG	Yes
Bflow* Toolbox	Prof. Dr. R. Laue & Team	No
BIC Cloud	GBTEC Software + Consulting AG	Yes
Business Transformation	iGrafx LLC	Yes
Camunda BPM	Camunda Services GmbH	No
Process Manager	Signavio GmbH	Yes
Prozessdesigner	JobRouter AG	No
Smart Process	CWA GmbH	Yes

The following results are to be highlighted in summary:

- Seven tools offer evaluation of process indicators.
- Four products fully implement release workflows.
- Six manufacturers claim possibilities for process simulation, although in some cases only the actual process flow is represented and a connection with real data is impossible although this would be important for execution.
- Those tools that cannot be classified as software for IMS support according to Table II lack options for linking the models in a process map, the possibility of storing the models in a central database, or the representation of responsibilities with the aid of organizational charts.

Only two of these products support all of these features, namely *Process Manager* by *Signavio* and *Smart Process* by *CWA*. Most simulation solutions only provide means to check the basic feasibility of the processes. In some cases, however, simulations of throughput times, costs or bottlenecks are included. Since real world data such as current stock levels or customers' orders cannot be factored in, the simulation results remain on a primitive level.

(Pro-)active opportunity and risk management and the support of a culture of continuous improvement are two subtasks of IMS [5]–[7]. Still, they are not sufficiently implemented by the systems' past-orientation thus far. At the same time, they testify to the need for a stronger future-orientation.

This aspect is also evident in the High Level Structure (HLS), a meta standard according to which ISO has organized the structure of its management system standards since 2012. The common requirements for management systems - or their standards - can be summarized in a basic management system and extended by sector-specific properties [5].

The HLS is described in a document called Annex SL, consisting of ten chapters according to which a management system should be implemented and documented [8]. Annex SL establishes uniform terms and definitions, an overarching architecture for all new ISO management system standards and revisions, and guaranteed identical text modules in the clauses of all standards [9]. Using the same outline for different management systems simplifies their integration.

V. Process Management from a Business Information Systems Perspective

As this article is partially derived from German education in BIS, several German sources are quoted in this section. However, also comparable literature in English is referred to where applicable. For an introduction to BIS the authors recommend [10] and for one to BPM [11]. According to [10],

> *A business information system is a group of interrelated components that work collectively to carry out input, processing, output, storage and control actions in order to convert data into information products that can be used to support forecasting, planning, control, coordination, decision making and operational activities in an organisation.*

This definition clarifies the future-oriented character of the subject. The role of BPM in this task is shown by the structure of [12], which starts with this topic in advance of an introduction to enterprise resource planning systems or information systems for specific industries. Also, considerations concerning a digital transformation of organizations begin with a process perspective [13].

A similar view is found in the relevant literature to BPM itself. [14] points out that the hierarchical order of an organization should follow its processes. [15] and [16] also emphasize the formative role of BPM, with the latter also clarifying the relation to IMS. The envisioned complex applications of BPM developed by these authors cannot be imagined without suitable software to support this management approach.

BPM is also of central importance for process enactment in Workflow Management Systems (WfMS) [17]. This is further accentuated [18]–[20], who consider the influence of digitalization on process optimization. The considerations of [21], who see processes as the key to digital transformation, go even further and are an important contribution to BIS research.

The German Informatics Society's framework recommendations for teaching BIS also see the design-oriented construction of information systems as a key objective [22]. Again, process management sits at the core with topics as strategic process management, enterprise and process modeling, process mining, analysis, mining and optimization, and domain-specific reference models. IMS, though, only play a marginal role.

This view can also be confirmed after an analysis of a selection of process management modules in courses of study in BIS or in computer science with a corresponding specialization.

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For this purpose, the authors examined 46 study programs at 34 German universities of applied sciences and classified the characteristics of the modules. A total of 96 modules were identified in the context of process management, 35 of which were included in the evaluation because at least 5 topics of BPM were clearly named. Table III shows an overview of the examined module descriptions. The modules' titles have been translated to English equivalents; for reference, the original German titles can be found as an appendix.

TABLE III. SAMPLE OF PROCESS MANAGEMENT MODULES IN GERMAN BUSINESS INFORMATION SYSTEMS DEGREE PROGRAMS

University	Level	Module
FH Aachen	Bachelor	Business Information Systems
	Bachelor	Business Process Management
	Bachelor	ERP Systems Implementation and Extension
HS Augsburg	Bachelor	Business Process Modeling
	Master	Business Process Modeling
HTW Berlin	Bachelor	Business Processes and Operational Applications
	Master	Applications in Business Administration 2
TH Brandenburg	Bachelor	Fundamentals of Process Modeling
	Master	Process Modeling and Analysis
	Master	Process Implementation
HTW Dresden	Bachelor	Business Process Modeling
HS Flensburg	Bachelor	Business Process Management
HS Furtwangen	Bachelor	Business Process Design
HS Kaiserslautern	Bachelor	Operational Business Process Modeling
HS Karlsruhe	Bachelor	Modeling IT Systems
	Bachelor	IT Systems Planing
	Master	Process Integration and Organizational Development
	Master	Processes Design & Implementation
HS Mainz	Bachelor	Business Process Management
HS Mannheim	Bachelor	Advanced Business Process Management
TH Mittelhessen	Bachelor	Digital Business Processes
HS Niederrhein	Bachelor	Business Process Management
HS Pforzheim	Bachelor	Business Process and Project Management
	Master	Enterprise Information Systems
OTH Regensburg	Bachelor	Business Process Analysis and Design
HS RheinMain	Bachelor	Business Process Management
	Bachelor	Process Digitalization
HS Stralsund	Bachelor	Business Processes
HS Trier	Bachelor	Strategic Enterprise Process Management
	Master	Business Process Management
FH Wedel	Bachelor	System Modeling
	Bachelor	Process Model Implementation
TH Wildau	Bachelor	Business Process Management
HS Worms	Bachelor	Business Process Management
	Master	Process Management

The content shown in Table IV was derived from the subject-specific module descriptions. Due to varying degrees of detail in the module manuals, this overview is still incomplete but reflects the relevant tendencies.

TABLE IV. PROCESS MANAGEMENT TOPIC AREAS OF THE MODULES EXAMINED

Topic	Occurrences	
Requirement analysis	7	
Automation / RPA	BPMS & WfMS: 13	RPA: 1 Other: 7
Documentation	4	
Implementierung	SAP: 2	Other: 11
Integration	5	
Process indicators / Controlling	8	
Lifecycle	5	
Mathematical basics	Graph theory: 2	Other: 1
Modeling	25	
Modeling languages	BPMN: 23 BPEL: 3	EPC: 12 Petri nets: 2 Other: 17
Modeling tools	ARIS: 5 Signavio: 1	Camunda: 4 Other: 10
Process Mining	5	
Process analysis & tools	17	
Reengineering / Optimization	17	
SCOR	2	
Views	ARIS house: 6	Other: 3
Simulation	3	
Strategic tools	Process maps: 7 Strategy development: 1	Culture: 1
Others	Cost Accounting: 5	Other: 9

In 17 modules, the analysis of process models is addressed, the same applies to reengineering and optimization. 13 modules cite implementation in connection with business process or workflow management systems.

Focusing on more rarely mentioned topics, strategic aspects are stated nine times, key indicators or process controlling are only included eight times, and process documentation (beyond the actual modeling) is mentioned only four times.

Of major importance to the SIMUL conference series is the observation that simulation is only considered three times. This is possibly related to the low use of Petri nets, which are taught seldom and - if at all - only with regard to their basic concepts. The exciting possibilities for innovating software for IMS with high-level Petri nets are almost not considered.

Standards and certifications that are of major importance for many industries and for operational practice are not included in any of the module descriptions.

VI. Requirements for Software for Highly Integrated Management Systems

While the previous part of this article was descriptive, it is continued with a normative definition of a new kind of IMS, which combines the contrary contributions discussed so far. Simulation, being the core theme of the SIMUL conferences, is also the key concept for this entirely new approach:

> *A Highly Integrated Management System combines a holistic documentation with multi-perspective simulations across different management systems.*

While management and control are comprehensively reflected in IMS and their supporting software, other topics like planning, change and transformation are still underrepresented.

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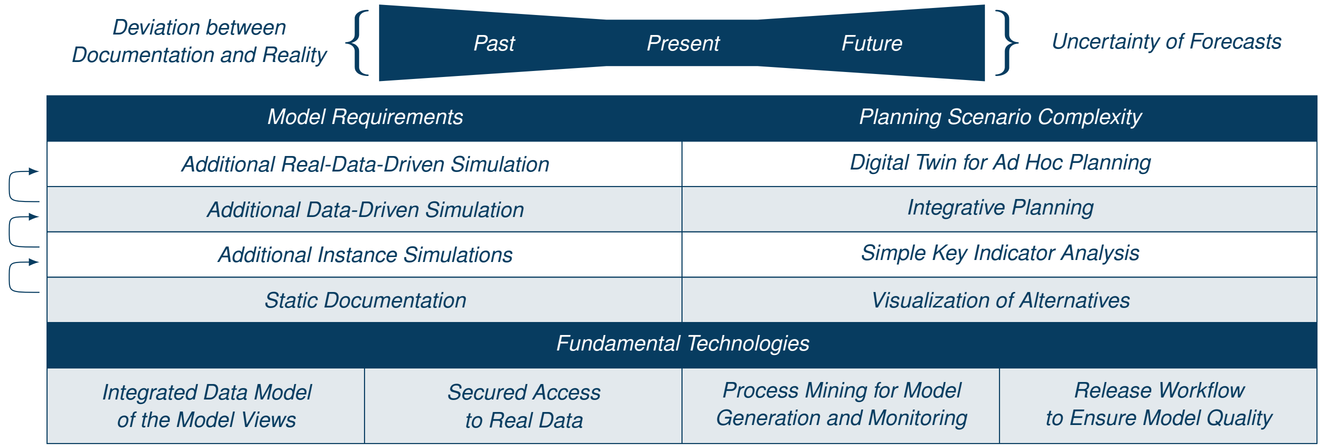

Figure 2. Characteristics of a Highly Integrated Management System (own illustration).

The disadvantage of this deficit can be illustrated by a problem many companies may face in the near future:

Due to regulatory requirements, a company strives to decarbonize its production and, for this purpose, stores the expected costs for emission certificates in the environmental management system. At the same time, customers inquire about the carbon footprint of products, which leads to corresponding entries in the quality management system. An emergent simulative planning could show the interactions between these two systems, but also provide information of the effects on other connected systems such as energy management or even production itself. To this end, it would be necessary to link this simulation extensively with current production data.

A comparable scenario can neither be described by means of current IMS nor are these systems suitable to support the transformation processes to develop a company in the described manner. One major reason for this is that in current IMS software processes are described with BPMN, flow chart diagrams or EPCs that have their strengths in rapid process visualization but their weaknesses concerning simulation. At best, instance simulations can provide information regarding the correct executability of processes [23][24]. However, since no formal mathematical semantics are defined for the mentioned modeling languages even these instance simulations may vary depending on the tool used [23][25][26].

For the described problem, however, it rather would be necessary to consider the different views in a holistic, multi-perspective simulation. Against this background, a return to Petri nets seems to be helpful for two reasons:

1. As theoretical underpinning of process mining, Petri nets can be used to automatically generate process models from transaction data of operational information systems, which simplifies the modeling task significantly and ensures a better match between reality and model [27].

2. With high-level Petri nets, in which places can be interpreted as tables in a database, complex production processes can be modeled and the consequences of strategic changes such as one from push to pull production can be estimated in advance [28][29].

In both application areas of Petri nets, powerful modeling, analysis and simulation tools are needed. Such tools are available and they have contemporary user interfaces. However, a fusion with the requirements for software to support IMS is still pending.

Figure 2 visualizes these requirements for an HIMS and for software to support it. The goal is an optimal supply of information in the present by mapping the current situation and at the same time enabling forecasts into the future. The further back in time the model representing the current situation was created, the greater the deviation between reality and documentation becomes. Likewise, the occurrence probability of forecasts decreases the further they are projected into the future. This is accompanied by the desire for new functionalities that go beyond the possibilities of current IMS software.

These functionalities are shown in the middle part of the figure. The demands on the models and their analysis and execution increase with the complexity of the planning scenarios that can be expressed with them. A simulation environment that is able to simulate processes parallel to reality on the basis of fed-in real data, may be regarded as a digital twin.

In addition, there are requirements regarding the fundamental technologies that make model integration and operational use possible in the first place. These range from data storage and secure access to release workflows that ensure the necessary model quality.

There are probably two options for the development of corresponding systems: Either the simulation features of software for the support of IMS are extended, for example following the capabilities of higher Petri nets, or simulation tools are extended by functionalities such as a management of shared documents, monitoring of key performance indicators and release workflows.

VII. Simulation Education

Supplying companies with simulation capabilities by means of HIMS is one part of the challenge. The other one is providing them with competent workforce as modeling and domain expertise often only exist separately (cf. [30]).

Opportunities, methods, limitations, and applications of simulation should play a more integral part in the education of BPM, of BIS, and also of IMS. The simulation community should engage intensively in this field.

The first field of possible engagement is the development of appropriate tools. Domain experts need HIMS that make modeling easy and simulation experts have to learn how to adopt specific domain knowledge and especially, how to produce visualizations of the simulation results that are understood by the domain experts, i.e. an HIMS also must provide visualization components.

This, however, requires personnel who are able to work in an interdisciplinary manner. Therefore, university education must provide students with factual and interdisciplinary knowledge but also - and probably more important - with the skills to gain cross-disciplinary insights themselves.

VIII. Conclusion and Future Work

This paper provides support for two assumptions regarding the use of simulation in the context of IMS: The first one is a lack of IMS software suited for process simulation and, therefore, optimization. However, the examined tools supposedly are but a fraction of available software. The second assumption is the missing simulation competencies many practitioners show in the authors' anecdotal experience. This is supported by literature both for practice and education. Both points, though, base on German sources, possibly illustrating a country-specific phenomenon. Thus, international inquiries seem beneficial - if only to improve the situation in Germany.

The authors see two paths for research to follow from here on. The first is the creation of an HIMS suitable for practical use. Since this idea is completely new and contradicts existing assumptions on how an IMS should work and look like, a fast commercial implementation cannot be expected. An experimental research environment at a university or research department seems to be better suited for this task. Further, since conferences like SIMUL show that the development of novel simulation techniques often takes place in a research context, adding IMS capabilities to an existing process simulation environment would be reasonable. As a Petri net-based modeling and simulation tool is in active development by the authors, it seems obvious to use this as a starting point to proof the concept.

The second path refers to simulation education: How differ other countries' degree courses in BIS from the ones examined so far? What are the implications of such differences on HIMS? What can be learned from simulation in other fields of study, for example physics, social science, but also business management games?

We cordially invite the interested community to reach out for an exchange on different - or missing - points of view, established handling, best practices or planned changes - both in education and in implementing suitable software for (Highly) Integrated Management Systems.

Appendix

TABLE V. ORIGINAL GERMAN MODULE TITLES OF TABLE III

University	Level	Module
FH Aachen	Bachelor	Business Information Systems
	Bachelor	Geschäftsprozessmanagement
	Bachelor	ERP Systeme implementieren und erweitern
HS Augsburg	Bachelor	Geschäftsprozess-Modellierung
	Master	Geschäftsprozess-Modellierung
HTW Berlin	Bachelor	Geschäftsprozesse und betriebliche Anwendungen
	Master	Betriebswirtschaftliche Anwendungen 2
TH Brandenburg	Bachelor	Grundlagen der Prozessmodellierung
	Master	Modellierung und Analyse von Prozessen
	Master	Implementierung von Prozessen
HTW Dresden	Bachelor	Geschäftsprozessmodellierung
HS Flensburg	Bachelor	Business Process Management
HS Furtwangen	Bachelor	Geschäftsprozessdesign
HS Kaiserslautern	Bachelor	Modellierung Betrieblicher Leistungsprozesse
HS Karlsruhe	Bachelor	Modellierung von IT-Systemen
	Bachelor	Planung von Informationssystemen
	Master	Process Integration and Organizational Development
	Master	Processes Design & Implementation
HS Mainz	Bachelor	Business Process Management
HS Mannheim	Bachelor	Advanced Business Process Management
TH Mittelhessen	Bachelor	Digitale Geschäftsprozesse
HS Niederrhein	Bachelor	Geschäftsprozess-Management
HS Pforzheim	Bachelor	Geschäftsprozess- und Projektmanagement
	Master	Unternehmensinformationssysteme
OTH Regensburg	Bachelor	Geschäftsprozessanalyse und -design
HS RheinMain	Bachelor	Geschäftsprozessmanagement
	Bachelor	Digitalisierung von Prozessen
HS Stralsund	Bachelor	Geschäftsprozesse
HS Trier	Bachelor	Strategisches Unternehmensprozessmanagement
	Master	Geschäftsprozessmanagement
FH Wedel	Bachelor	Systemmodellierung
	Bachelor	Prozessmodellimplementation
TH Wildau	Bachelor	Geschäftsprozessmanagement
HS Worms	Bachelor	Geschäftsprozessmanagement
	Master	Prozessmanagement

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