Contributions to IT Project Portfolio Management and Individual Digital Assistants in Higher Education

Der Wirtschaftswissenschaftlichen Fakultät der

Gottfried Wilhelm Leibniz Universität Hannover

zur Erlangung des akademischen Grades

Doktorin der Wirtschaftswissenschaften

- Doctor rerum politicarum -

vorgelegte Dissertation

von

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[redacted]

2023

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Zweitprüfer:

Vorsitzende/r der Prüfungskommission:

Mitarbeitervertreter/in:

Ein großer Dank gilt meiner Familie, die mich während meiner Zeit als Doktorandin immer unterstützt hat. Ebenso möchte ich allen Co-Autoren für die wertvolle Zusammenarbeit danken, ohne die diese Dissertation nicht möglich gewesen wäre. Zudem danke ich meinem Doktorvater und Betreuer Prof. Dr. Michael H. Breiter für die hilfreiche Unterstützung und die generelle Möglichkeit am IWI zu promovieren.

I. Abstract and Keywords

This cumulative dissertation outlines and discusses 12 scientific publications that contribute to the knowledge of Information Technology (IT) project portfolio management and individual digital study assistants in higher education. The papers developed models and frameworks that describe crucial IT project portfolio management phases and activities, enable an objective IT project evaluation, and define IT project portfolio management maturity levels. In addition, they deduced an optimization model for IT project portfolio management evaluation, selection, and scheduling decisions and implemented it in a decision support system prototype. Developed taxonomies and archetypes classify existing IT project portfolio management tools as well as requirements and corporate benefits of IT project manager positions to identify patterns, similarities, and differences. Further, critical success factors, challenges, and requirements for an individual digital study assistant were identified, analyzed, and discussed. Based on these and during several iterations, an individual digital study assistant prototype was developed, evaluated, adapted, and guidelines derived. The articles contribute knowledge on how to design more efficient and value-driven IT project portfolio management processes to minimize subjective influences. Also, they provide knowledge to support higher education institutions in the design, development, and operation of individual digital study assistants. Based on existing limitations, a further research agenda is deduced, including 13 further research directions for IT project portfolio management and individual digital study assistants in higher education institutions. They serve as a basis for further researchers in these fields of topics.

Keywords: Digital Transformation, IT Project Portfolio Management, Models and Frameworks, Decision Support, Individual Digital Study Assistants, Critical Success Factors, Requirements

II. Zusammenfassung und Schlagworte

Diese kumulative Dissertation beschreibt und diskutiert 12 wissenschaftliche Artikel, die einen Beitrag zur Forschung in den Themenbereichen Informationstechnik (IT) Projektportfoliomanagement und individuelle, digitale Studienassistenten an Universitäten umfasst. Dafür wurden Modelle und Rahmenwerke entwickelt, die wesentliche IT Projektportfoliomanagement Phasen und Aktivitäten beschreiben, eine objektive IT Projektevaluation ermöglichen und Reifegrade von IT Projektportfoliomanagement Prozessen bestimmen. Außerdem wurde ein Optimierungsmodell zur Auswahl und Planung des IT Projektportfoliomanagement Prozesses aufgestellt und in einem Entscheidungsunterstützungssystem-Prototypen integriert. Bestehende IT Projektportfoliomanagement Tools, sowie Anforderungen und unternehmerische Vorteile für IT Projektmanager wurden jeweils in Taxonomien klassifiziert, Muster erkannt und Gemeinsamkeiten und Unterschiede aufgezeigt. Zusätzlich wurden kritische Erfolgsfaktoren, Herausforderungen und Anforderungen für individuelle, digitale Studienassistenten identifiziert, analysiert und diskutiert. In mehreren Iterationen wurde basierend darauf ein Prototyp entwickelt, evaluiert, modifiziert und allgemeine Leitlinien für das Design, die Entwicklung und den Betrieb eines individuellen, digitalen Studienassistenten abgeleitet. Die Forschungsarbeiten ermöglichen IT Projektportfoliomanagement Prozesse effizienter und werteorientiert zu gestalten und subjektive Einflüsse zu minimieren sowie Hochschulen bei dem Design, der Entwicklung und dem Betrieb von individuellen, digitalen Studienassistenten zu unterstützen. Basierend auf Limitationen wird eine Forschungsagenda aufgestellt, die 13 weitere Forschungsmöglichkeiten im Themenbereich IT Projektportfoliomanagement und individuelle, digitale Studienassistenten aufzeigt und als Grundlage für weitere Forschung in diesen Themenfeldern dient.

Schlagworte: Digitale Transformation, IT Projektportfoliomanagement, Modelle und Rahmenwerke, Entscheidungsunterstützung, Individuelle Digitale Studienassistenten, Kritische Erfolgsfaktoren, Anforderungsanalyse

III. Management Summary

The persuasive digital transformation and usage of new technologies have become an important information system (IS) research field, along with opportunities and challenges for societies as well as private and public organizations (Abad-Segura et al., 2020; Vial, 2019). Within companies and organizations, the digitization has emphasized the importance of Information Technologies (IT) (Almeida et al., 2020). In the public sector, especially in the higher education context, the digital transformation led to new possibilities for knowledge and competency transmission and changes in teaching, advising, and learning possibilities (Bond et al., 2018).

Companies and organizations need to strategically address the digital transformation and adapt their structures to enable value creation and remain competitive (Vial, 2019). Thereby, organizational IT has a crucial influence on this (Bezdrob et al., 2020). In general, there are more IT projects to select from than can be implemented. A value-driven evaluation, selection, and scheduling aligned with the organizational strategy is part of the IT project portfolio management (PPM) (Asosheh et al., 2010; Daniel et al., 2014; Linhart et al., 2020). However, organizational ITPPM often misses structures and decisions are based on a gut feeling, resulting in deviations from objectives, incomplete projects, and high failure rates (Varajão & Trigo, 2016). Using an ITPPM tool to support processes can lead to more efficient, transparent, and consistent decisions (Caniëls & Bakens, 2012; Killen et al., 2020). Companies and organizations need adequate, structured, and value-driven ITPPM processes and guidelines aligned to their strategy to increase performance, objectivity, decision quality, and remain competitive (Chiang & Nunez, 2013; Kester et al., 2011).

Within higher education institutions (HEI), new technologies resulting from the digital transformation enable better accessibility to learning content and educational resources (Abad-Segura et al., 2020; Telukdarie & Munsamy, 2019). Previous reforms in HEI led to higher student numbers and more diverse backgrounds. Thus, the need for personal counseling and advising increased (Clarke et al., 2013; Van der Wende, 2000; Wong & Li, 2019). Digital assistants provide solutions to react to these changes and challenges. One example are individual digital study assistants (IDSA) that support students in learning on a reflective level, enable automatized first-level support, and strengthen self-regulation and self-organization abilities. Relying on different information sources, individual objectives, interests, and competencies, IDSA support students with recommendations and reminders (Karrenbauer et al., 2023b; König et al., 2023b). While there is already much research on requirements and design principles for pedagogical conversational agents (PCA) (e.g., Hobert, 2019; Wambsganss et al., 2021a), research for IDSA is still limited. It requires detailed and user-centric analyses of their critical success factors (CSF), requirements, design-, and implementation processes.

This cumulative dissertation consists of 12 scientific papers of which eight are already published and four are submitted or currently under peer-review. All articles contribute to the knowledge base of either ITPPM or IDSA in HEI research. They enable more objective, efficient, and value-driven ITPPM processes and support HEI in the design, development, and operation of IDSA for students. Therefore, we developed and deduced different CSF, requirements, models, frameworks, taxonomies, and archetypes. In doing so, we used different research designs, including Design Science Research (DSR), Action Design Research (ADR), mixed methods, taxonomy and archetype development, and various research methods, such as literature reviews, qualitative and quantitative studies.

The research field of ITPPM in this dissertation includes six scientific publications. A structured ITPPM is critical to align IT projects with organizational strategy and achieve goals. However, these structures are often missing within companies and organizations, leading to resource exceedances and failure (Daniel et al., 2014; Trigo & Varajão, 2020). Guided by DSR with literature reviews and expert interviews, in Karrenbauer and Breitner (2022b), we developed an integrated ITPPM process model that synthesizes and expands existing ones. Our proposed process model supports value-driven and objective ITPPM, provides flexibility to adapt to changes and uncertainties, integrates different stakeholders, and allows re-cycles between and within phases and activities.

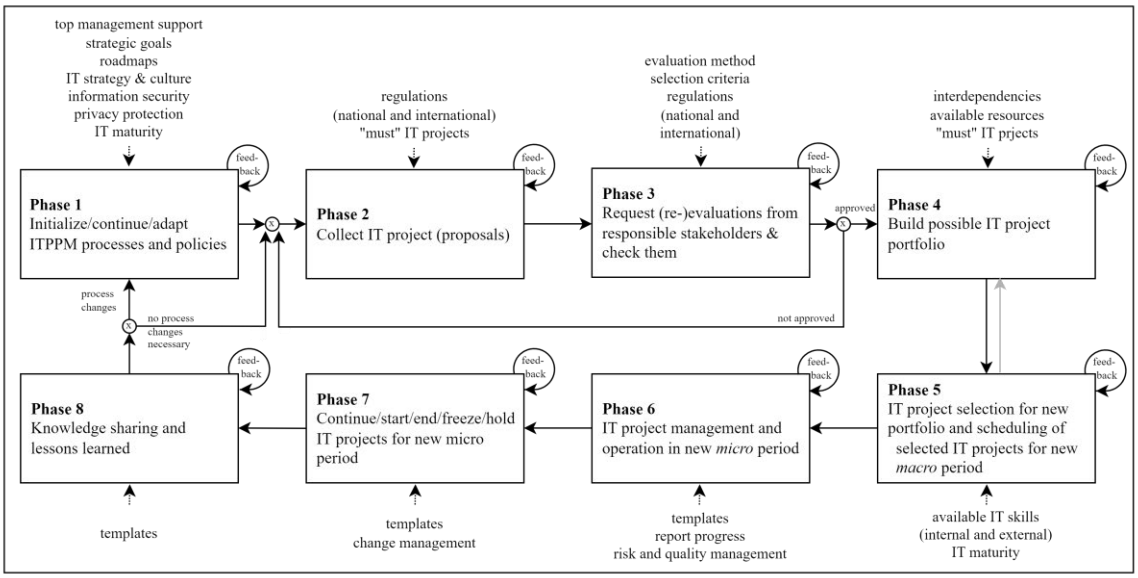

Figure 1. Process model for ITPPM (Karrenbauer & Breitner, 2022b)

Figure 1 shows the derived process model for ITPPM. It consists of eight phases with various activities. Further, Table 1 illustrates all identified ITPPM phases with their activities, compares

them with existing process models, and shows how often the activities and phases were named in literature and expert interviews.

Table 1. Activities within an ITPPM process (Karrenbauer & Breitner, 2022b)

Phase (P)/ Activity		Authors: Ajjan et al. (2016)	Alaeddini and Mir-Amini (2020)	Archer and Ghasemzadeh (1999)	Chiang and Nunez (2013)	Ghannadpour et al. (2021)	Miller (2002)	Montgomery (2007)	Project Management Institute (2017)	British Standards Institution (2015)	Number of experts	Number of literature
P1	Define roles, tasks, & responsibilities	x	x		x				x		-	10
	Determine resource availabilities	x		x*			x		x	x	2	9
	Decide on evaluation & selection method	x	x	x*			x		x	x	2	11
	Determine evaluation categories		x	x*			x	x	x	x	3	14
	Determine the criteria's importance		x		x		x				4	6
	Define thresholds			x*					x		1	2
	Establish ITPPM policy	x		x*							7	9
P2	Identify IT project proposals	x	x	x*	x	x	x	x	x	x	10	10
	Define mandatory IT projects	x		x							2	3
P3	Check the IT project's eligibility			x					x		1	3
	IT project (re-)evaluation	x	x	x	x	x		x	x	x	6	20
	Discuss the results	x						x			8	3
	Top management involvement	x			x			x			1	3
	Final evaluation							x			-	2
P4	Define interdependencies			x	x		x		x	x	4	8
	DSS / optimization model usage			x							2	6
	Optimal IT portfolio			x	x						-	4
	Scenario & sensitivity analysis		x	x	x		x		x		2	3
P5	Discussion of the "optimal" results	x	x		x				x		8	4
	Prioritization/selection	x		x	x	x		x	x	x	3	18
	Authorization	x			x			x		x	1	5
	Portfolio adjustments	x		x				x	x	x	-	5
	Final IT portfolio composition	x	x	x							1	5
P7	Periodically review of IT portfolio	x			x	x		x	x	x	5	5
	Measures in case of deviation	x			x	x	x	x	x	x	5	5
P8	Performance measurement			x*				x	x	x	4	4
	Knowledge generation	x		x*				x		x	3	3
	Lessons learned	x						x			6	10

* Pre/post activates; not included in main ITPPM phases

According to literature and our results and findings, effective IT project evaluation, prioritization, and selection are critical activities in ITPPM. Combining quantitative and qualitative methods, we further identified commonly used IT project evaluation criteria and developed a holistic evaluation framework (Karrenbauer & Breitner, 2022a, 2022b), see Table 2. It provides an objective evaluation method for IT projects of different sizes and types and quantifies subjective estimations. It is possible to score each IT project using the integer one to five scale and determine a weighted average, i.e., the individual IT project's value contribution that allows a comparison. Companies and organizations can adapt the scale with organization-specific values. Our scale enables objective evaluations based on a predefined scale instead of unstructured evaluations influenced by personal perceptions.

Table 2. IT project evaluation framework (Karrenbauer & Breitner, 2022b)

(Sub-)Criteria		Score Value 1	Score Value 2	Score Value 3	Score Value 4	Score Value 5
Complexity	Involved business departments	numerous	many	several	individual	IT department specific
	Change management impact on teams/individuals	significant changes	considerable changes	isolated changes	minor changes	no changes
	Interrelation with other IT projects	numerous	many	several	individual	none
	Ease of implementation	very complex	complex	medium	simple	very simple
	IT architecture fit	significant customi-zations	considerable customizations	isolated customizations	minor cus-tomizations	no customizations
Efficiency	Investment recovery periods	very long	long	moderate	short	very short
	Long-term cost savings	no effects	barely noticeable	noticeable	considerable	highly significant
	Impact on growth rate	no effects	barely noticeable	noticeable	considerable	highly significant
	Employee performance improvement	none	barely noticeable	noticeable	considerable	highly significant
Risk	Risk profile	very high	high	moderate	low	very low
	Similar (un)successful past IT projects of leader/ team	in-experienced	little experienced	medium experienced	experienced	highly experienced
	Positive interrelation with other IT projects	none	barely noticeable	noticeable	considerable	highly significant
	Negative interrelation with other IT projects	highly significant	considerable	noticeable	barely noticeable	none
Strategy	Short-term business goals support	none	barely noticeable	noticeable	considerable	highly significant
	Long-term business goals support	none	barely noticeable	noticeable	considerable	highly significant
Urgency	Non-compliance with regulatory requirements	none existing	short-term disruptions	considerable disruptions	legal con-sequences	sanctions
	Needed to keep daily business processes running	no need	for few processes	for several processes	for many processes	for core processes
	Need for modernization	next 6+ years	next 5 years	next 4 years	next 3 years	next 2 years

Reliable information and appropriate tools contribute to more informed decisions while portfolio information visualizations support decision-making quality (Osuszek & Ledzianowski, 2020). However, many ITPPM tools lack accessibility and transparency, and decision parameters and processes are often unknown or difficult to understand (Karrenbauer et al., 2023a). This black box prevents an effective analysis of critical thresholds and influencing decision parameters. Relying on DSR with existing knowledge and expert insights, we deduced a value-driven optimization model in Karrenbauer and Breitner (2023) and implemented it in a decision support system (DSS) prototype in MATLAB. It supports the IT portfolio's evaluation, selection, and scheduling while it considers interdependencies, resource restrictions, and further constraints. Our

results and findings guide IT portfolio decision-makers and enable more informed, transparent, objective, and value-driven decisions.

The applicability of ITPPM processes, tools, and models depends on the organizational IT maturity (Kock et al., 2020). Using a structured and holistic method to develop a maturity model (Becker et al., 2009), we developed and evaluated a comprehensive maturity model for ITPPM processes (Schulte et al., 2023). Table 3 shows an excerpt of the whole maturity model. In general, ITPPM processes can be classified within five maturity levels using the criteria IT portfolio management, IT project requirements, interface representation, quality management and documentation, process participants, integrated systems, and their corresponding sub-criteria. Our results and findings enable companies and organizations to classify their ITPPM process and deduce value-driven and value-creating improvements considering the organizational strategy and objectives. An application enables to derive a transformation roadmap, make informed decisions, and rationalize resource allocations.

Table 3. ITPPM maturity model (excerpt) (Schulte et al., 2023)

	IT portfolio management				
	Business processes	**Governance**	**Strategy alignment**	**Benefits**	**Approvals**
Level 1	None	None	None	Not seen by management	Ad hoc uncoordinated IT project approvals
Level 2	Defined, but workarounds exist	No standards	No rational investment decisions	Productivity gaps due to insufficient task automation	Uncoordinated IT project approvals
Level 3	Defined, but it may be still inefficient in some places	Defined standards	Specific strategic criteria developed	Clearer vision and overview of projects is set in place which allows better decision-making management	Approval process defined and shared with all departments and followed in most cases
Level 4	Defined and basically lived	Fully comprehensive governance structure	Prioritization on the basis of key figures and criteria aligned with strategy	Management sees benefits of an ITPPM process and understands the entire ITPPM process including participants	Portfolio composition based on an overall balance of risk, profit, return on investment, impact on project competition and on-time project delivery, including value creation
Level 5	Fully mature and considers different project types	Still a fully comprehensive governance structure	ITPPM process continuously optimized due to the structure and actively lived	All participants and stakeholders follow the ITPPM process as they recognize the efficiency	IT portfolio selection based on a clear, rigorous and formal optimization approach

Generally, companies and organizations tend to use tools for single project management only (Besner & Hobbs, 2008). Thereby, ITPPM tools support portfolio-related activities and support strategic decisions to accomplish more successful IT projects. Existing ITPPM tools differ in their functionalities and scope which make decisions for a suitable tool difficult (Killen et al., 2020; Kock et al., 2020). In Karrenbauer et al. (2023a), we classified existing literature and

60 real-world ITPPM tools, developed a taxonomy, and deduced five archetypes. We identified 20 dimensions and 51 characteristics to classify ITPPM tools (Kock et al., 2020). We used the taxonomy to deduce five archetypical patterns and evaluate its applicability (Kundisch et al., 2021). Identified clusters expand a taxonomy's knowledge and its descriptive nature (Möller et al., 2021). They include IT portfolio overview tools with predefined or customizable parameters, customizable evaluation and analysis tools with and without data extraction, and "in-between" IT portfolio evaluation and analysis tools. With our results and findings, we synthesized scientific and practical knowledge and contribute to the ITPPM tool knowledge base. We structure the ITPPM tool market and support practitioners to choose a suitable ITPPM tool.

On an IT project level, skilled and experienced IT project managers contribute to successful IT project completion (Adzmi & Hassan, 2018; Gheni et al., 2017; Trigo & Varajão, 2020). However, the recruitment and selection of suitable and qualified IT project managers is difficult (Ahsan et al., 2013). In Karrenbauer et al. (2023c), we first classified and evaluated IT project manager job advertisements and then deduced archetypes. We used them to develop a decision tree as a decision support framework for IT project manager recruitment. Based on four questions, the framework recommends which benefits and requirements a job advertisement for an IT project manager should highlight. Our results and findings identify key requirements and corporate benefits for IT project manager positions. The decision framework supports the entire recruitment process, assists to create targeted job advertisements to attract suitable candidates, supports conducting interviews, and the final candidate selection.

The research field of IDSA in HEI includes six scientific publications. Digital assistants resulting from the digital transformation enable to address the need for more individual study support and counseling. IDSA provide ubiquitous online access to automate first-level support and study-specific and individual guidance. In our research, we performed a long-term project to design, develop, and evaluate an IDSA in HEI. ADR-oriented, with different participants from research and practice, we iteratively designed, developed, evaluated, and adapted an IDSA prototype and derived guidelines. In the beginning, part of the ADR team performed 28 expert interviews with lecturers from different disciplines and HEI stakeholders and an additional quantitative student survey (n = 570). During our research process, we analyzed the interview transcripts and student survey results from different perspectives, triangulated them, and used them for our results and findings, supplemented by various literature reviews.

We identified (non-)functionalities of IDSA to get an overview of the status quo in König et al. (2020) and Karrenbauer et al. (2021), based on literature reviews, market searches, qualitative, and quantitative analyses. Regarding the non-functionalities, we identified nine dimensions with 26 characteristics. For example, DSA differ in their communication mode, intelligence,

authorization, and privacy protection. Further, we identified several functionalities and structured them along the three student lifecycle phases before study, during study, and after study (Sprenger et al., 2010). For the before study phase, an IDSA encompasses functionalities, including self-assessments with study recommendations. Regarding the phase during study, IDSA offer functionalities to support the scheduling of classes and exams or major and institution suggestions. Concerning the after study phase, IDSA are mainly used to provide alumni activities with links to a list of graduates. Our results and findings structure commonly used IDSA (non-)functionalities and serve as a knowledge base for IDSA development and introduction.

Next, we deduced CSF and challenges for IDSA in König et al. (2023a) using mixed methods. We structured our results within the six IS success dimensions of DeLone and McLean (2016). CSF and challenges in the dimension system quality and maturity include ease of use, data privacy, and security. The dimension information quality encompasses, inter alia, reliable and unique information and the possibility to integrate existing data. Skilled personnel and answer quality are assigned to the service quality dimension. The dimension user satisfaction includes, for example, positive experiences and involvement with an IDSA. Further, an IDSA's possibility for learning enhancement and added value of the functionalities influence its net impact. Self-regulation and defined target groups are critical for the intention to use dimension. Our results and findings benefit IDSA system developers and vendors, contribute to integrate IDSA knowledge within the IS success model, and advance the theoretical understanding in this field.

Table 4. IDSA guidelines for HEI decision-makers (adapted from König et al., 2023b)

Guidelines		
1. Framework	1.1	Check HEI IT and IS for maturity, choose one LMS that all stakeholders use, and ensure top HEI management commitment to support openness.
	1.2.	Carefully determine all target groups.
	1.3.	Build a team for core tasks depending on the fields of expertise.
	1.4.	Define specific, attractive, and reachable goals of an IDSA.
2. Project Management	2.1.	Build a team of mainly experienced software developers.
	2.2	Choose one environment and (virtual) place, if possible, and use hybrid/agile project management methods.
3. Content	3.1.	Consider internal data and privacy protection challenges and barriers.
	3.2.	Ensure efficient and visible IT project management also for content.
	3.3.	Create an easily useable and inviting, up-to-date design, including mobile devices.
	3.4.	Ensure user-centered IDSA development.
	3.5.	Have testers of all target groups reliably available.
	3.6.	Pay attention to appropriate and user-oriented language.
	3.7.	Ensure that content is structured in a pedagogically efficient way.
	3.8.	Redefine and enrich target groups, if necessary.
	3.9.	Build a team for all content tasks depending on the fields of expertise.
	3.10.	Redefine specific, attractive, and reachable goals of an IDSA.
4. Team selection	4.1.	Group members must have time capacity, professional competence, and social competencies.
5. Team development	5.1.	The desired performance and synergy effects can be achieved by supporting team development.
6. Marketing	6.1.	Begin marketing efforts, both internally and externally, at an early stage.
	6.2.	Top management – the board of directors – must be involved as soon as possible.
7. (Team) Communication	7.1.	A good mix of online and face-to-face meetings strengthens team communication.
8. Student habits	8.1.	Ensure that students are well organized in their virtual support environment.

Based on the CSF, we developed requirements for IDSA functionalities, its design, and implementation and implemented and evaluated a prototype in an iterative process (Karrenbauer et al., 2023b; König et al., 2023b). We aggregated identified requirements into seven groups: functionalities, contact options, data-based responsiveness and individuality, well-tested system, marketing strategies, data protection, and usability, all with several sub-requirements. Based on these, a prototype within several iterations was developed within the project team. More than 1,700 students tested the prototype and gave feedback. Relying on this, we modified existing functionalities and introduced new ones. Based on our gained knowledge during the design and development process, we abstracted general guidelines for an IDSA design and development, see Table 4. In general, our results and findings contribute insights and knowledge about IDSA in HEI and provide requirements and guidelines for the design, implementation, and adaption of IDSA for researchers and practitioners.

One functionality within the IDSA included open educational resources (OER) and inter-university exchange network (IUTEN) recommendations. In König et al. (2021), we deduced requirements and incentives for OER usage and IUTEN participation based on expert interviews. We identified, for example, the OERs' preparation, content relevance, and need to be target group focused as relevant for OER usage. Regarding incentives to participate in IUTEN, we identified performance certification, the availability of a technical framework, and a balanced distribution as essential. Using these results, we developed two incentive models to encourage lecturers to engage in IUTEN collaborations and produce and use OER. Our incentive models provide opportunities for HEI to improve OER usage and IUTEN participation. They contribute knowledge on how to implement measures to enhance collaboration and usage.

Based on the results and findings and limitations of the 12 papers, this dissertation discusses a further research agenda for ITPPM and IDSA in HEI. It includes 13 general research directions with explicit research topics. In the ITPPM field, further research can analyze cultural influences on ITPPM, our artifacts' proof of use and proof of value, and the expansion of our optimization model and DSS prototype. In IDSA research, it is possible to further investigate the long-term effects of our IDSA, its acceptance and trust, and privacy-related topics. We provide scientific contributions and extend the ITPPM and IDSA knowledge base. Practitioners can use our results and findings of the ITPPM research to increase transparency in their ITPPM decisions, contribute to strategy, and reduce failures. The IDSA research serves as a knowledge base for decision-makers in HEI when introducing an IDSA. The derived research agendas address further research directions and topics in the two important research fields. They can be a foundation for initiating discussions and conducting tailored research in the continuously changing ITPPM and HEI environment.