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How Does Digitization Succeed in the Municipal Water Sector? The WaterExe4.0 Meta-Study Identifies Barriers as well as Success Factors, and Reveals Expectations for the Future

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Abstract: Water is increasingly taking center stage when it comes to coping with climate change. Especially in urban areas, negative consequences from heavy rainfall events and prolonged dry periods are rising worldwide. In the past, the various tasks of urban water management were performed by different departments that often did not cooperate with each other (water supply, wastewater disposal, green space irrigation, etc.), as the required water supply was not a question of available water volumes. This is already changing with climate change, in some cases even dramatically. More and more, it is necessary to consider how to distribute available water resources in urban areas, especially during dry periods, since wastewater treatment is also becoming more complex and costly. In the future, urban water management will examine water use in terms of its various objectives, and will need to provide alternative water resources for these different purposes (groundwater, river water, storm water, treated wastewater, etc.). The necessary technological interconnection requires intelligent digital systems. Furthermore, the water industry must also play its role in global CO₂ reduction and make its procedural treatment processes more efficient; this will also only succeed with adequate digital systems. Although digitization has experienced an enormous surge in development over the last five years and numerous solutions are available to address the challenges described previously, there is still a large gap between the scope of offerings and their implementation. Researchers at Hof University of Applied Sciences have investigated the reasons for this imbalance as part of WaterExe4.0, the first meta-study on digitization in the German-speaking water industry, funded by the German Federal Ministry of Education and Research. Only 11% of roughly 700 identified products, projects and studies relate to real applications. For example, the surveyed experts of the water sector stated that everyday problems are considered too little or hardly at all in new solutions, which greatly overburdens users. Furthermore, they see no adequate possibility for a systematic analysis of new ideas to identify significant obstacles and to find the best way to start and implement a digitization project. The results from four methodologically different sub-surveys (literature and market research, survey, expert interviews and workshops) provide a reliable overview of the current situation in the German-speaking water industry and its expectations for the future. The results are also transferable to other countries.

Keywords: smart water; success factors; digitization; sustainability

1. Introduction

In the last five years, digitization activities in the German-speaking water industry have multiplied, and digitization has become a core topic [1–3]. Internationally, rapidly increasing developments can be observed in the areas of product development and solution offerings [4]. Nevertheless, the persistence of public clients is also evident in digitalization topics, even though this behavior has been known for decades. New things are only hesitantly accepted and put into practice. Overall, however, there is a conspicuous lack of

scientific studies on the dynamics of water innovation, both nationally [5] and internationally [4], although an urgent need for water innovation is becoming increasingly clear. The increase in funding sources indicates a broad recognition of this need. Examples in Europe include the Horizon 2020 program (for research, development and innovation activities), the Structural Funds, LIFE 2014–2020 (the EU funding instrument for environment and climate action) and special grants for researchers throughout the European Research Council to conduct basic research. Unfortunately, financial investment in the water sector lags far behind sectors such as energy [6]. In Germany, there are currently not many research programs or R&D competitions that exclusively address innovations in the water sector. It is not only in Germany that the water sector is considered less innovative than other sectors, with innovation indicators suggesting that far less is invested in research and development (R&D) in the water sector than in other sectors [7], as the water sector is dominated globally by a pattern of innovation that follows the natural progression of sectors dominated by providers [4]. Municipal organizations dominate, and less willingness to innovate or even a rejection of change is the consequence [8].

Although the German-speaking public water industry will have a greater willingness to innovate than the general public sector (because of required technology) [9], the water industry still lacks the necessary implementation momentum [5]. For example, the advantages of digitization are not being optimally exploited in order to more effectively meet the challenges of climate change. Already in 2018–2020, two major research projects on digitization in the German-speaking water industry, SMADIWA [10] and KOMMUNAL 4.0 [11], identified considerable non-technical reservations on the municipal side regarding the increasing number of digitization developments. In the vast majority of projects examined within the meta-study the focus was on technical feasibility, solution development and application goals (e.g., [12–14]). User-oriented topics dealt almost exclusively with hints on usability, the unification/standardization of data and structures, application-related settings at the software level (e.g., [15–17]) or with legal issues in some cases (e.g., [18,19]). Only the topic of cybersecurity was considered intensively from both a technical and an application perspective (e.g., [20,21]). Occasionally, the aspects of education and added value of data were also subjects of some investigations [22,23]. Internationally, too, it is now recognized that a sole focus on technology is not enough [24,25]. Although global research on smart water solutions is accelerating to meet industry and government demand [26–28], the conceptual, technical and practical gaps between providers and customers are still not sufficiently closed [29]. Here, there is a particular lack of solutions that can be integrated into everyday working life and do not present additional barriers [30].

A scientific investigation of the framework conditions underlying this strategy or a scientific verification of the positive effects has not yet been carried out. The WaterExe4.0 meta-study was the first to systematically investigate the state of digitization technology in the German-speaking water sector.

2. Materials and Methods

Within the framework of WaterExe4.0, a systematized analysis of the digitization of municipal water management in Germany, Austria and Switzerland was carried out. The scientific work comprised four methodological sections:

1. Literature and market research;
2. Online survey;
3. Expert interviews;
4. User workshops.

In the first methodological part, nearly 700 projects, products, complete solutions, services and studies were identified and subsequently analyzed. For this purpose, extensive literature and market research was carried out. All German-speaking universities and colleges that had planned, started or completed research projects on the topic of digitization in the water industry between 2015 and 2021 were contacted. In addition, internet research and the evaluation of company advertisements in trade journals on available products

and solutions from industrial companies (cyber physical machines, sensors, software solutions, AI systems, etc.) were part of these works. As a third pillar, a literature and internet search of realized digitalization projects in the municipal sector was conducted. If the publicly available information was not sufficiently informative, the companies and municipalities were contacted and asked for further information; in individual cases, personal communication with project managers also took place. All results were assigned to different aspects and categories, which are summarized in Table 1. Some of these aspects and categories were already defined in the planning phase of the investigations as a result of preliminary research. Further aspects and categories were defined after the study results were presented, as these could be derived from the content of the identified digitization elements (projects, products, systems and studies).

Table 1. Aspects and categories for the evaluation of the identified digitization elements.

Areas of Application	Application Maturity	Digitization Concept	Practical Relevance
Wastewater disposal	Idea/concept	Digital technology	Benefit/effect
Drinking water	Development/demonstration phase	Business model method data analysis	Relevance
Water bodies	Test phase/prototype	Data use	Transferability
Rainwater	Market-ready/continuous operation	Degree of networking	Suitability as best practice
Process water/domestic water			
Sludge treatment			

For practical application, three key elements which have an implementation perspective could be identified for the digitization of the water management complex [31]:

- Digital information base for decision support systems in water management (digitization of maps, databases available via application programming interface (API), etc.);
- Digitization of production—“smart” infrastructure, robot structures, equipment with artificial intelligence (AI), analytics, satellites and drones, distribution systems, transport, water supply and sanitation, etc. Analytics and big data—analytics platforms for all sectors of the water industry: water content prediction, negative impacts of water, water consumption, transboundary and climate risks;
- Digitization of distribution—traceability of a resource from “source to consumer” based on blockchain technologies, exchange for the distribution of water resources and ecosystem services.

The considerable amount of identified products, projects, studies and other digitization elements required a clear classification structure, especially for future extended analysis. For this purpose, the terms commonly used in the field of digitalization were combined with the common terms from IT/automation in the water industry (see Figure 1). On this basis, the detailed technological structuring of all 698 identified individual elements was carried out.

In the online survey conducted in parallel, in which around 120 industry representatives took part, various aspects of digitization in the water industry were addressed. In addition to asking about existing experience with digitization projects, the survey asked in particular about success factors and obstacles experienced, and specifically about non-technical influencing parameters that survey participants were able to identify or derive from their project experience. They were also asked in which areas digitization should shape the future and what benefits are expected from digitization projects. Since digitization also has to be increasingly sustainable, they were asked for their personal assessment of the role of sustainability in future digitization projects (sustainability has been studied in water management for more than two decades [32–34]). The online survey was primarily designed as a quantitative survey, but allowed participants to add their own thoughts to the quantitative questions. This made it possible to identify further digitization projects that had not previously been reported publicly. Furthermore, aspects of digitization were

seen that had either not been addressed at all or only marginally in previous research. A strict separation of qualitative and quantitative methods is also evaluated critically in empirical social research. Here, the danger is seen in too strong a demarcation, that the full potential that each individual method can provide for answering concrete questions can remain unused [35].

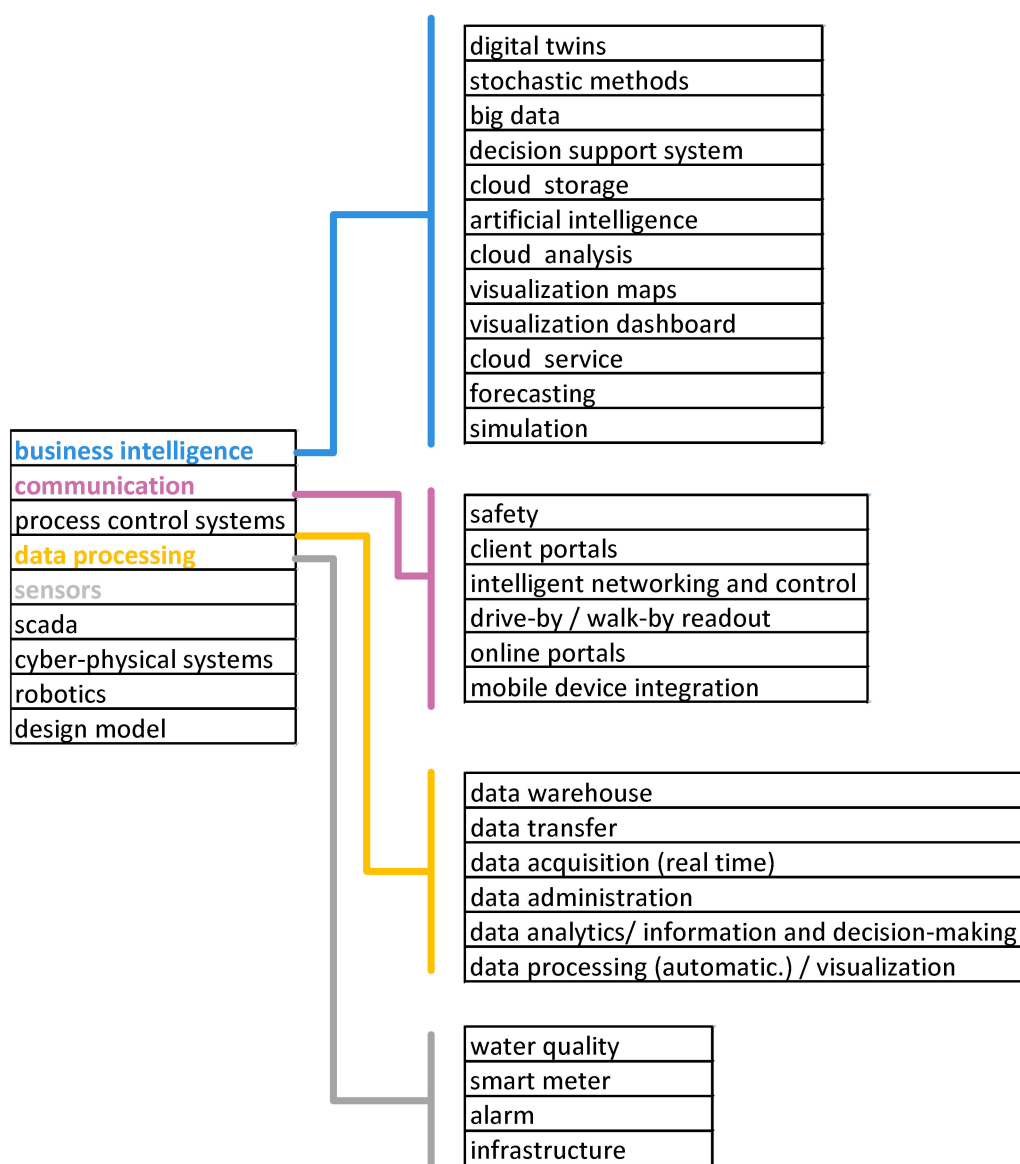


Figure 1. Structure of the category formation.

The quantitative portion of the responses was evaluated using state-of-the-art statistical methods. In addition to single- and multiple-choice options, scaling questions were also used so that survey participants could also make assessments in selected topic categories. This research methodology was used particularly where subjective assessments of positive or negative impact factors on the success of digitization projects have to be done. Classic technological research was limited to what was measurable, i.e., quantitative analysis and data evaluation. This is also confirmed by the identified research projects within WaterExe4.0. Modern and future-oriented technological research is increasingly incorporating social debates and consequential considerations [36].

In order to minimize the risk of an unintentional reduction in possible impact factors on the success of digitization projects through the type and content of the quantitative

questions, around 30 experts from the water industry were interviewed in addition to the possibility of entering free thoughts in the survey form. According to [37], experts are individuals who have specialized knowledge and experience on the particular research question and the associated contextual conditions, and who are expected to make a valuable contribution by answering the research question. The survey was designed using guided interviews [38], which on the one hand focused on personal experiences in digitization projects in the German-speaking water industry, and on the other hand allowed sufficient freedom for thoughts and hypotheses that went beyond this. The experts were selected according to the theoretical sampling model, which originates from the grounded theory methodology [39]. Care was taken to ensure that the selection of experts was neither purely theory-driven nor the result of subjective premises in advance as a defined top-down strategy. The expert selection was carried out as a data-driven bottom-up process in which the specific selection criteria were always related to the collected data material of the first method section in order to also be able to compare new findings from the research work with expert statements. The evaluation was based on a multilevel content analysis according to Mayring [40]. This analysis is category-based. Categories refer to aspects within texts or personal statements in order to bring the meaning of these aspects to the point. The related text analysis is thus limited to the chosen category system. Text contents that are not addressed by the categories or holistic impressions are not considered. Special models help to describe the procedure step by step. In WaterExe4.0, the model of qualitative content analysis was applied, which is characterized by strict regularity and systematics. In order to be able to make an additional quantitative comparison of survey participants and experts, the experts were asked to answer some quantitative scaling questions as a conclusion to the interviews. Here, too, the advantages of a combination of qualitative and quantitative survey methods were targeted, as was already the case with the online survey.

As a fourth research component, the results of several special workshops were analyzed on the topics of cost–benefit analysis in the water sector [41,42] and competence requirements.

3. Results and Discussion

3.1. From Sensor to Network Management—Technological Diversity vs. Implementation Barriers

The identified digitization elements (products, solutions and research projects) are proof of highly sophisticated technological development. Currently, the industry offers digital solutions for almost all areas of water supply and wastewater disposal. Their range varies from simple sensors via cyber-physical systems up to web-connected complete networking solutions (Figure 1).

About two-thirds of identified digitization elements are located at the business side. Research elements accounts for as much as a quarter. Only 11% are currently placed in the municipal water supply and wastewater disposal companies, which indicates an imbalance between supply and demand. Although more than 60% of the publicly presented digitization solutions can now be described as ready for the market (Figure 2), there has been a reluctance of procurement on the municipal side since the beginning of the digitization wave [10]. While companies are increasingly focusing on product development, municipalities tend to look for complete or system solutions. Of all industrial side identified digitization elements, 57% are products, but less than 5% are used as pure product solutions in municipalities. In addition, products are also part of projects on the municipal side, whose share is probably about max. 50% (estimation based on more than 200 interviews that one of the authors has done between 2016 and 2019 within the research project KOMMUNAL 4.0 [11]). The greatest convergence between supply and municipal demand was identified in digitization projects. Of all digitization elements, 8% can be attributed to studies carried out on the municipal side.

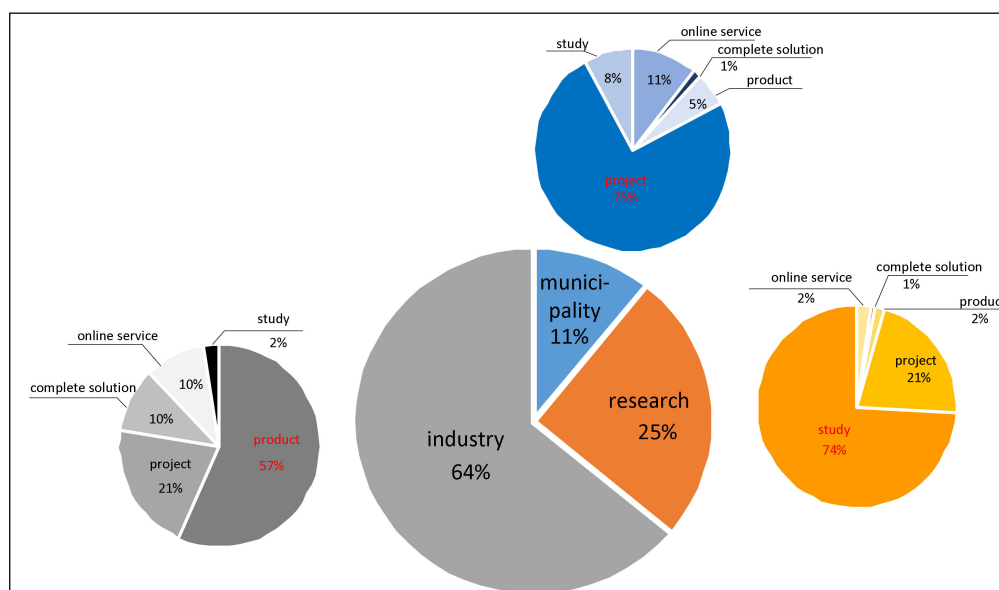


Figure 2. Distribution of the identified digitization elements ($n = 698$).

In the field of research, three-quarters of identified digitization elements are studies. Only 2% of the accessible projects involve concrete product developments. R&D activities for industrial product developments with scientific institutions could not be recorded. About one-fifth of digitization elements deal with complex solutions, which have a predominantly project character.

Approx. 60% of the digitization elements are in the water supply and wastewater disposal sectors. The application fields of water, rainwater and industrial water are roughly equally distributed. A digitization solution development for sewage sludge treatment is rare (Figure 3).

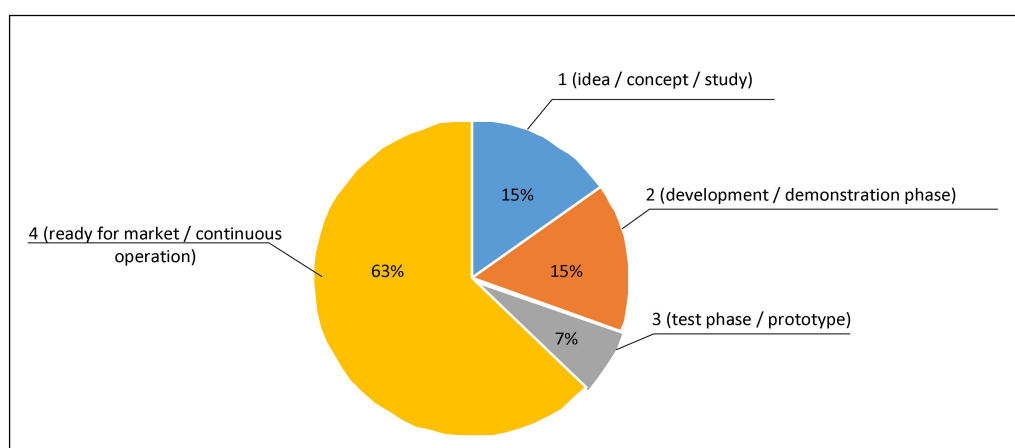


Figure 3. Development status of identified digitization elements ($n = 698$).

The results of the study from the perspective of analysis by technology type are shown in Figure 4. All results were divided into four subcategories. The largest number can be classified as “business intelligence” (43%, $n = 300$). Within this sub-category, the majority of the solutions could be classified as “simulation” (23%), “forecasting” (17%) and “cloud service” (16%). The second place was taken by the category “communication” (21%, $n = 143$). Within this sub-category, the largest numbers were “mobile device integration” (33%), “drive-by/walk-by readout” (22%) and “Intelligent networking and control” (19%). In the sub-category “data processing”, the area of “data analytics” is predominant. In the

sub-category “sensors”, the majority of solutions were found for “smart meters” (40%). On the one hand, the subdivision into various subcategories shows the diversity of the solutions available to date; on the other hand, it also reveals that the area of artificial intelligence is still not very well-developed. The current subdivision also allows an evaluation of the development speed of individual aspects/topics or technologies in future studies.

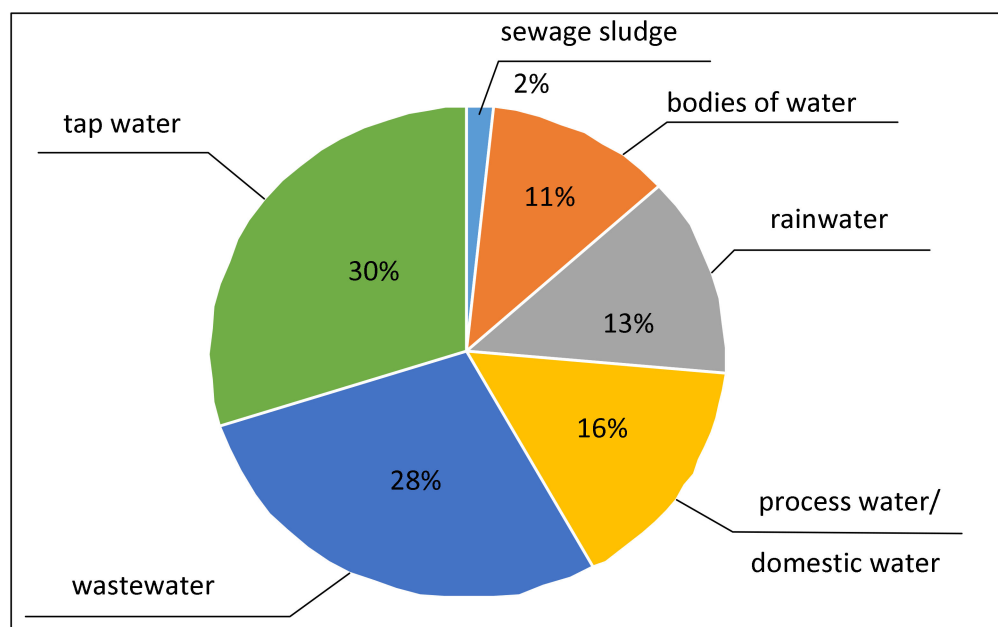


Figure 4. Application areas of identified digitization elements ($n = 698$).

The limited project time frame did not allow for the full complexity of the meta-analysis (see Figure 5) to be fully reflected and the type of digital technology to clearly be assigned. This mainly results in partly unclear information content. Due to the users' predominant need for complete solutions, this effort did not seem justified in the project, but should be taken into account in future research.

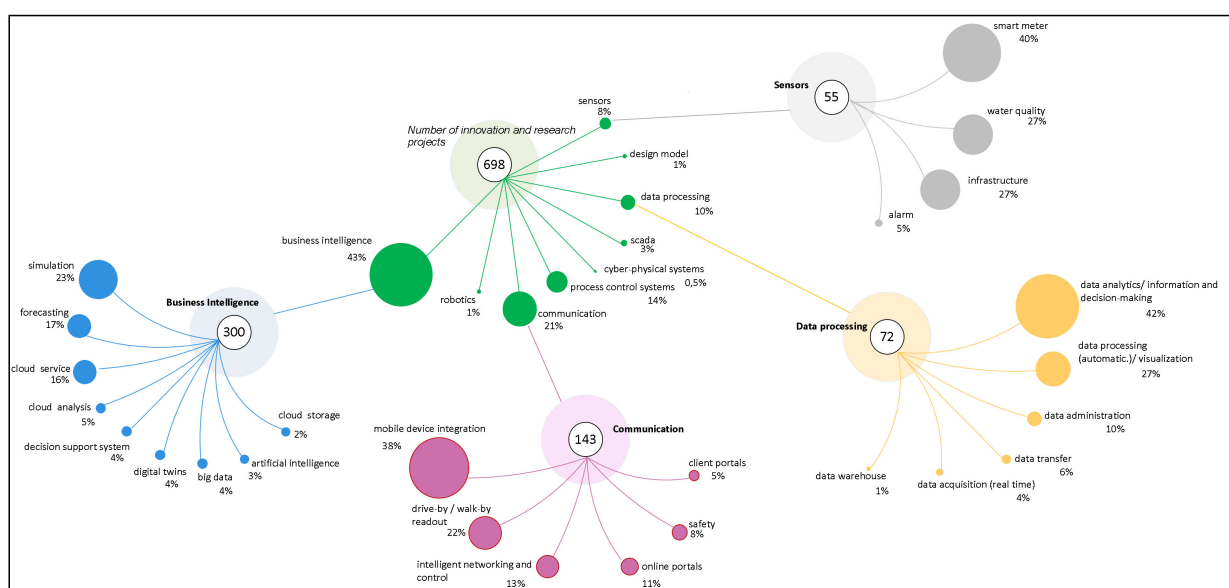


Figure 5. Technological distribution of identified digitization elements ($n = 698$).

The categories assigned were closely connected to each other. For example, “Internet of Things” is closely related to “communication”, and “neurotechnology and artificial intelligence” is to many types of data processing. It has to be noted that several categorical items could be used within a subcategory for a separate digital solution or for a group of technological parts.

3.2. Where the Water Industry Is Stuck When It Comes to Digitization

Previous studies have already pointed out that industrial development is far ahead of municipal demand [10,43–45]. Therefore, the quantitative survey and qualitative expert interviews served to find out the reasons for the existing discrepancy between supply and demand as well as which obstacles play the biggest role in the projects (Table 2)—indications of this have already been identified in the KOMMUNAL 4.0 research project [11].

Table 2. Requested barriers in digitization projects ($n = 91$).

Classic Factors	Arithmetic Mean	Variance	Standard Deviation
5 = great importance; 1 = less importance; and 0 = no importance			
Generous time budget	2.84	1.83	1.35
Sufficient financial budget	3.51	1.66	1.29
Communication across departments	3.63	2.06	1.44
Competence of the project manager	3.97	1.37	1.17
Staff competence	4.00	1.19	1.09
Expertise from specialists	3.68	1.59	1.26
Orientation towards available best practices	3.02	1.89	1.38
Exchange with third parties who already have experience	3.25	2.35	1.53
Further training offers	2.31	2.18	1.48
Ø	3.36		

Particularly in the public sector, which includes the water sector in the broader sense, the development of digitization is proving extremely difficult. While proponents claim that even a small amount of data can significantly increase the efficiency of administrative processes, opponents of digitization are fearful of surveillance and the loss of privacy [46]. Somewhere between these extreme poles, digitization projects will settle. Where exactly each individual project will end up is not visible to most of those affected at the outset, leading to rejection or strong reluctance [47,48].

The main obstacle is seen in the lack of staff among the interviewed, closely followed by an unexpected high overall effort. In a certain distance, the lack of internal competences and insufficient funding are also mentioned.

Furthermore, the survey participants were allowed to name further, very individual obstacles (see Table 3). These included typical factors such as fear of change or insufficient involvement of employees, as well as technical aspects such as unresolved IT security and a lack of standardized interfaces. However, a lack of time to sufficiently deal with the existing digital possibilities due to their complexity or the priority of everyday tasks prevent many from starting a digital project. A lack of time could be defused if the practical benefits of digital offers and the relationship between benefit and price become visible very early. Furthermore, it would help if providers show more engagement to respect the needs of the municipal side and provide more individual advice.

Looking at the factors that were positively evaluated in the project, in the end it is the own staff competencies and reasonably successful internal communication that, with the support of external experts, have ultimately made projects a success.

Table 3. Freely expressed obstacles in digitization projects ($n = 91$).

Obstacles	Arithmetic Mean	Variance	Standard Deviation
5 = great importance; 1 = less importance; and 0 = no importance			
Lack of financing	2.52	3.96	1.99
No sufficient financing	2.74	3.05	1.75
Total expenditure greater than expected	3.36	1.70	1.31
Lack of internal competencies	2.85	2.13	1.46
Lack of external competencies	2.52	2.21	1.49
Lack of staff	3.53	1.85	1.36
Lack of IT security	2.30	1.75	1.32
Inadequate legislation	1.83	2.93	1.71
Lack of best practices	2.27	1.44	1.56
Missing guidelines and implementation aids	2.32	2.39	1.55
No suitable further training opportunities	1.92	2.36	1.54
Ø	2.56		

Regarding success factors, the respondents were allowed again to name their individual success factors. These range from needs-based digitization, clear project goals, practical relevance, an internal understanding of digitization and confidence in the matter to clear benefits such as simplification of processes and structures, acceleration of processes and improvement of transparency. The interviewed experts also mentioned similar factors and place particular emphasis on benefits which are not visible in many places:

“Uncomplicated use”

“Showing how projects are actually implemented in practice”.

“Does it make sense? is the question we ask ourselves. If something analogue already doesn’t meet today’s requirements in terms of sustainability, realisation time, benefits, it doesn’t make sense when it’s digitally enhanced”.

“Digitization is a means to an end, the focus is on solving problems”.

“In principle, the most important factor was always the integration of all employees concerned. From the cooperation, processes and needs could be analysed as quickly as possible and implemented using the best practice method”.

“What can the organisation (still) achieve?”

“Finding relevant use cases. After all, digitization should not be an end in itself, but should bring benefits and solve problems”.

“The most important thing is the practical benefit of a project. This must not be imposed, but must be supported by all participants. Different understanding of goals and contents endanger a project. In the application phase, the user himself must be able to operate it. Otherwise, the value of a project is lost”.

The survey also asked about the benefits users expect from digitization solutions, as shown in Table 4. The most important thing for survey participants was information transparency, closely followed by an increase in process efficiency and location-independent data access. However, improvement in time efficiency in daily work was also one important wish for digitization solutions.

Table 4. Expected benefits from digitization projects ($n = 88$).

Benefits	Arithmetic Mean	Variance	Standard Deviation
5 = great importance; 1 = less importance; and 0 = no importance			
Time efficiency	3.91	1.51	1.23
Cost efficiency	3.63	1.51	1.23
Process efficiency	4.23	1.08	1.04
Transparency of information	4.25	1.16	1.08
Data access from anywhere	3.98	1.73	1.31
Knowledge retention and transfer	3.51	2.06	1.44
Security of supply and disposal	3.42	2.97	1.44
Showing that you are up to date	2.39	2.16	1.47
Making work easier for employees	3.73	1.38	1.17
Danger detection/alerting	3.77	1.83	1.35
Future-proofing	3.99	1.58	1.26
Ø	3.71		

Looking at the average value of the arithmetic mean of success factors, the significance of obstacles and the benefits of digitization solutions show that the benefits have the highest significance of the three aspects with an average value of the arithmetic mean of 3,71 (out of a maximum of 5). At 3,36, the barriers (Table 2) are currently much more important than the experienced success factors, which have a value of 2,56. Some of the results correspond with a survey done in 2017 about the German water industry [49].

Additionally, the survey participants were once again allowed to name the individual aspects by which they recognize and evaluate the success of a digitization project (Table 5).

Table 5. Freely named success factors ($n = 99$).

Success-Generating Factor	Nominations
Opportunities to Drive Digitization Forward	
Pilot projects/best practice	3
Generational change/cultural change/readiness for change	2
Change in cooperation	1
Develop management level	
Engaging and listening to staff	4
Common database of all sectors	3
Further Success Factors	
Competence/know-how	3
Willingness of employees to participate	1
Readiness of clients	1
Recognizable added value	15
User-friendliness/user-oriented	7
Resources (time and money)	3
Project planning	1
Communication of projects	2
IT security	4
Key person (CEO/responsible person)	2
Be able to present quick successes	1
Transparency	5
Acceptance (MA and people)	10
Economic aspects	1

Table 5. *Cont.*

Success-Generating Factor	Nominations
Opportunities to Drive Digitization Forward	
Connectivity/networkability	1
Interfaces	1
Overall strategy	4
Suitable (external) partners	2
Preserve the tried and tested	2
Education/training	2
Data basis/inventory data	4
Promising Technologies/Solutions of the Future	
Create standard	2
IoT	1
Automatic maintenance/predictive maintenance	2
Intelligent data analysis	1
AI	1
Sensors/data acquisition	2
Central collection of all data	1
Reasons for the Need of Digitization	
Regulatory requirement to be able to present data as quickly as possible	2
Skills of the Project Manager/Project Team	
Availability for customers	1

The survey shows a heterogeneous distribution of industry participants with different responsibilities and digitization expertise. Since 30 experts from Germany, Austria and Switzerland were interviewed parallel to the survey, a direct comparison of the expert statements and the survey results could be made (Table 6) in order to identify any deviations between experts and “normal” users.

Table 6. Comparison of expert testimonies and survey results.

Online Survey	Expert Interview	Frequency Nomination	Proportion %
Recognizable added value		15	15.15
	Recognizable added value	11	8.53
Acceptance by users/staff		10	10.10
	Acceptance by users/staff	11	8.53
User-friendliness/user-oriented		7	7.07
	Pilot projects/best practice	8	6.20
Transparency		5	5.05
	Key person	7	5.43
Overall strategy		4	4.04
	Overall strategy	7	5.43

Surprisingly, the comparison shows a high degree of agreement in the five most frequently mentioned aspects of success. The two most frequently mentioned factors are identical for both groups, these being that “high added value” must result from a digitization solution and that it is imperative to achieve a “high acceptance among users/staff”. Both factors show a clear gap to the following factors, which highlights their importance as a success factor for digitization projects in the water industry. There is also further agreement on rank 5, with the need for an overarching strategy.

In earlier research projects [44,45], industry participants repeatedly pointed out that there are no flagship projects or tools that can be used to adequately calculate possible

digitization solutions and evaluate them regarding the own expected benefits. The consequence of this lack is that potential digitization solutions are not procured in the first place, or that the necessary resources are calculated incorrectly. The interviewed experts identified this aspect also as one of the greatest inhibiting factors in digitization projects. Therefore, in addition to the conducted survey and expert interviews, four intensive workshops were offered on the topics of “cost-benefit analysis” and “required staff competences” in relation to successful digitization projects. In addition to the results from the discussions, which could be recorded in detail through double moderation, the participants were also surveyed. Table 7 shows the results of the survey, which was completed by nine of sixteen participants. The participants felt rather uncertain or insufficiently informed both in terms of safe cost calculation and in relation to the assessment of the required competences of their staff. The development of suitable staff competences in relation to planned digitization projects is assessed as necessary. The determination of comprehensive costs that arise with a digitization project is also rated as very important.

Table 7. Participant survey intensive workshop ($n = 9$).

Question	Average Value	Median
How well informed do you feel about assessment methodology of competences related to digitization. (1 = not at all, 5 = very detailed)	2.3	2
How important is the competence assessment of your employees in relation to digitization for you? (1 = very low, 5 = very high)	3.0	3
What role does the exact fit of your employees' competences play in relation to a successful digitization project? (1 = no role, 5 = important role)	3.4	3
What role does knowledge of all relevant costs play for you when deciding for or against a digitization project? (1 = no role, 5 = important role)	3.1	3
How confident do you feel in being able to capture all the costs to be considered for a digitization project? (1 = very uncertain, 5 = very certain)	2.6	3
How do you assess the information currently available to determine the costs to be considered for a digitization project? (1 = there is no available offer for this, 5 = very good offer available)	2.8	2
What value would it have for you if the recording and individual assessment of all costs to be considered for a digitization project were offered by a new system? (1 = no importance, 5 = very high importance)	3.6	4

The congruence with practice is also confirmed by the results of the “Digitalisation Index Water Management” [50]. In the best case, use cases for the necessity of digital possibilities are recognized by the employees themselves, if they are at the same time sufficiently familiarized with digital possibilities and trained in the ability to make competent assessments. Promoting this or taking it sufficiently into account in the development of digitization projects not only a significant influence on the motivation of involved staff, but also on the probability of success of digitization projects.

3.3. The Role of Cost and Competence Analysis for Digitization

Cost and competence analysis as a result of the aforementioned workshops turned out to be essential as one of the results of the other three method components when it comes to improving the evaluation of digital projects for municipal users. The respondents and interviewees considered the availability of an easy-to-use and target-oriented evaluation

tool to compare their own digitization ideas with the solutions available on the market and obtain a meaningful cost–benefit analysis as a result to be a future success factor.

3.4. Water Management of the Future—What Direction Does It Go?

Despite the criticism of digitization, which has still been the case for the last five years [11,45], today there is a clear difference in the water industry: the WaterExe4.0 study has shown that there is hardly anybody in the German-speaking water industry who does not deal with the topic of digitization. For almost all respondents and interviewees the consequences of experiences of the last five years and the deduction for the future are nearly identical. It does not play a significant role whether the respondents have their own practical experience with digitization or whether they are dealing with the topic in any analytical way.

While only the expert interviews specifically asked about future expectations, the participants in the survey named various aspects of the future when freely naming success factors, which are listed in Table 8.

Table 8. Sustainability aspects in future digitization projects ($n = 85$).

Aspects of Sustainability in Future Digitization Projects	Nominations
Economic factor predominates	2
Sustainability and digitization processes do not go together	1
Social factor predominates (employees)	1
Sustainability has been gaining importance for years	2
Digitization supports sustainability	8
Sustainability cannot be guaranteed for every project	5
Efficiency is the real driver	3
Sustainability is taken into account in decisions	3
Circular economy	3
Sustainability increases the acceptance of the project	2
Persuasion through data leads to sustainability	1
Sustainability is the solution to many challenges	5
Local conditions determine the weighting of the three factors	1
Standard projects prevent sustainability	1

The topic of sustainability as one of the central political topics for the future [51] was surveyed separately (Figure 6, Table 8). It can be seen that more than 70% of the respondents rate the importance of sustainability in future digitization projects as “very important” or “important”. The most common view is that digitization generally supports sustainability in water management, but also provides a solution to many other challenges. However, it is also expected that sustainability aspects cannot be considered in every digitization project.

For the interviewed experts, the staff that municipal organizations need or must train in digitization projects have first priority in the future. In addition, it is of central importance that digitization solutions demonstrate a clear added value (benefit) in relation to the individual situation of each organization. Technologically, the experts see the topics of cloud application, automatic maintenance/predictive maintenance, IT security and AI as the focus of future developments and applications (Table 9). This view to the future coincides with the EU’s “Digital Goals 2030” [52]. The topics of human resources and AI in particular must be seen in context. Due to the increase in available data (big data), there is the opportunity to obtain assessable data for almost all areas of operational water management and to design processes and workflows more efficiently, more targeted and more benefit-oriented. However, AI-based systems will not be able to carry out the necessary data processing and data analyses completely autonomously in the foreseeable future, so additional personnel will be necessary for increasing use. On the other hand, users in the water industry also want corresponding transparency of internal processes in digital systems, which will also limit the use of AI variants [53].

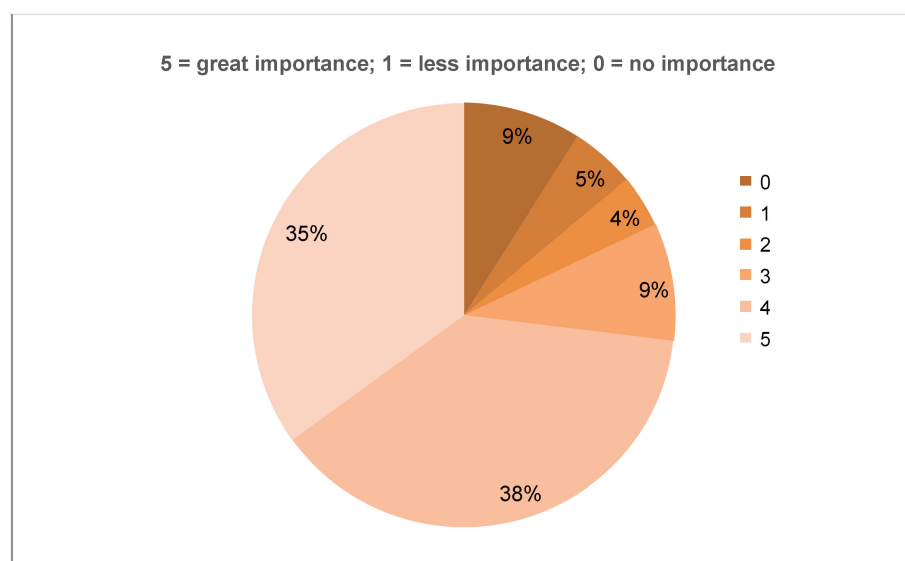


Figure 6. Importance of sustainability in future digitization projects ($n = 85$).

Table 9. Future topics named by experts in relation to digitization ($n = 64$).

Future Success-Generating Factor	Nominations
Promising Technologies/Solutions of the Future	
Cloud	5
Creating standards	4
Internet of things (IoT)	3
Automatic maintenance/predictive maintenance	6
Cyber-security	6
Control via smartphone	1
Building information modeling (BIM)	3
Geographical information system (GIS)	1
Intelligent data analysis	3
Use of webcams/image processing	2
Precipitation forecasts	2
Event-related sewer network operation	3
Digital twin	2
AI	5
Central data management	3
Open source	1
Sensors/data acquisition	2
Smart meter	1
Simulation	1
Modeling	1
Interfaces	1
Hormone elimination in wastewater	1
Summary of all data	2
Operating assistants for plants	1
Data availability	1
Uniting different systems and processes	1
Digitization of customer management	1
Digital services	1

Other future topics relate to the integration of water management as part of a smart city and the consideration of sustainability.

In the end, very extensive data material was collected and evaluated in WaterExe 4.0. It allows, for the first time, scientifically validated statements on the status of digitization in the German-speaking municipal water management sector.

3.5. WaterExe4.0 in the International Context

Many articles in different journals deal with a variety of new technologies or methodological approaches that address the digitization of the water sector [54–60]. Some articles have already been cited as sources in the previous sections. Nearly all articles agree that water and wastewater systems in urban areas must be prepared for the digital age. Digitization promises significant benefits for all users and providers, but also for society as a whole. As shown in WaterExe4.0 for the German-speaking region, the authors also see considerable challenges to be mastered in the international context, for example in the areas of data protection and cyber security. Even in international publications, the aspects to be considered are not limited to technologies alone. In contrast to the WaterExe4.0 study, the central and multi-layered role of research is increasingly emphasized [61–65].

Additionally, not addressed was the special role of digitization when it comes to the design, introduction and implementation of integrated water management. This topic plays an important role internationally in funding projects and concept analyses [66]. In view of increasing water shortages, which are now also affecting individual regions in German-speaking countries, the topic of wastewater reuse or irrigation [67] is increasingly being discussed as a building block of integrated industrial water management. Although it has been known for a long time, especially in German regions such as Berlin and Brandenburg or in parts of Lower Saxony [68], that precipitation is declining and that more and more irrigation in agriculture has become required, these application areas of the water sector have not yet been focused on in digitization projects.

Another aspect that is increasingly discussed internationally is the topic of aquaculture, which only has a niche existence in the German-speaking world (Hof University of Applied Sciences has its own research group dealing with this topic [69]). Here, too, digitization now plays an important role when it comes to maintaining water quality and the necessary waste/water treatment [70,71].

3.6. Multi-Criteria Approach

Based on the results of preliminary studies as well as their own professional experience, the authors were aware that innovation decisions are usually based on multi-criteria decisions. This was therefore also to be expected in the context of digitalization in water management. It was therefore not surprising that the free expression of opinions in the expert interviews in particular made the multi-layered nature of decision-making processes clear. Thus, the WaterExe4.0 study identified a variety of factors that can be decisive for the success of digitization projects. The information provided by the participants in the online survey and the experts interviewed is based on personal and thus subjective assessments, highly dependent on the individual circumstances of the respective project. The funded work of WaterExe4.0 did not provide any further analysis; this is to be carried out in future follow-up projects. Nevertheless, a first simple estimate of a multi-criteria analysis was made to evaluate the partly very heterogeneous criteria in a more structured way. Therefore, all quantitative queries as well as qualitative-free statements were checked for consistency of content. Since the aim of the study was to identify decisive success factors, only the success factors named by the study participants were analyzed for further multi-criteria evaluation. Thus, according to Table 10, a total of 19 success criteria could be identified, which all study participants agreed to be relevant. In order to take into account the importance of the expert statements, the number of mentions was multiplied by a factor of two (one mention = two points) and the mentions of the participants in the online survey were given a simple rating (one mention = one point). This increase in the rating of the expert statements was necessary because it could be assumed that the knowledge and experience of the experts was partly many times higher than that of the participants in the online survey.

Table 10. Success factors mentioned by all survey participants.

Success Factors Mentioned by Participants from Online Survey and by Experts	Online Survey Ratings	Expert Ratings	Total Ratings
Opportunities to Drive Digitization Forward			
Pilot projects/best practice	3	16	19
Generational change/cultural change/readiness for change	2	6	8
Change in cooperation	1	4	5
Developing the management level	1	4	5
Engaging and listening to staff	4	4	8
Common database for all areas	3	2	5
Success Factors in Digitization Projects			
Competence/know-how	3	8	11
Willingness of employees	1	8	9
Recognizable added value	15	22	37
Resources (time and money)	3	10	13
IT security	4	10	14
Key person (CEO/responsible person)	2	14	16
Transparency	5	2	7
Acceptance (staff and people)	10	22	32
Economic aspects	1	4	5
Connectivity/networkability	1	2	3
Interfaces	1	2	3
Overall strategy	4	14	18
Suitable (external) partners	2	10	12
Promising Technologies/Solutions of the Future			
IoT	1	2	3

Particular attention should be paid to the criteria “Recognizable added value” with 37 points and “Acceptance (staff and people)” with 32 points. With a significant distance, the criteria “Pilot projects/best practice”, with 19 points, “Overall strategy”, with 18 points and “Key person (CEO/responsible person)”, with 16 points, must also be considered. The simplified multi-criteria evaluation carried out confirms the importance of non-technical criteria described at the beginning as essential success factors for digitization in water management.

3.7. Reflection of Results

The study has shown that only a small number of the diverse research ideas, numerous products and solutions have been implemented in the municipal water sector. The main reason for this implementation deficit, according to the respondents and interviewed experts, is the difficulty of transferring solution offers to respective individual tasks. There is also a fundamental lack of comprehensible best practices. In addition, too little attention is paid to the challenges of everyday work, which means an enormous additional burden for employees at the start of digitization projects. Here, the survey participants wish to see a better integration of digitization projects into the workflow of everyday work. The focus of a digitization project must be the employee and not only the technical solution. On the one hand, in most cases there is not enough employee involvement. On the other hand, the focus must be on the assigned role of employees in a digitization project, as they are the strongest drivers (or the biggest obstacle) of successful projects, according to the survey participants. In the absence of sufficiently qualified employees, projects encounter numerous and varied difficulties, and the desired success fails. Projects also do not work without qualified employees. Nevertheless, the survey participants associate digitization with the hope to master future challenges in a better way, such as, e.g., climate change, and to make everyday work easier for employees.

Comparing the results of the study with international research studies, numerous overlaps in the success factors and obstacles in digitization projects can be found. Non-technical aspects also receive a great deal of attention internationally, as was emphasized by the respondents in the WaterExe4.0 study and identified as lacking in German-speaking areas.

4. Conclusions

For the first time, it was possible to identify sufficiently precisely described success factors and obstacles that can promote or slow down digitization in the water industry, especially on the user side. Due to the requests from potential users of digital solutions in water management to get support in digitization projects due to the lack of guides and working aids, which were sent to the researchers at Hof University of Applied Sciences before the start of the project, the study results are to become part of such guides and working aids. In addition, some of the previously described research gaps could be closed in the approach.

What are the consequences of the study? What does research have to change? What is the future path of the industry to bring more digitization solutions into municipal infrastructures? Additionally, what is the role of municipal clients within these challenges? The clear message of the survey and expert interviews is that people are the central success factor in digitization projects. Contrary to modern Industry 4.0 factories, water supply and wastewater disposal is not a clearly linear definable process. Without well-trained, motivated people who think for themselves, digitization in the water industry is neither possible nor feasible, either today or in the future. All thought experiments and technological developments for further digitization, including AI, are only able to automate a part of water management, and require the additional participation of operating personnel. Neither the wastewater volume nor the drinking water supply represent ideal, fully describable and thus predictable systems. Looking only at the input variable of precipitation, reliable predictions are not possible in the near future to manage water infrastructures based solely on data and machines. In any case, the use of digital systems is becoming more and more necessary. The number and complexity of future challenges in water management are continuously increasing, especially due to the consequences of climate change, so good decisions and effective process flows require more and more data in addition to the evaluation of their results. It is therefore the joint task of industry, science and municipal users to find the optimal balance between necessary technology systems and motivated operating personnel. WaterExe4.0 has shown that digitization in the water industry is on the right track, but people still need to be more involved. At the same time, it is necessary for the user side to be more open-minded in order to participate actively in the development process. In particular, previously unspoken expectations on the municipal side need to be more strongly and clearly communicated; it is not enough to hear about them within scientific surveys. Industrial companies and researchers have to combine new solution developments much better with the challenges of daily work. The main players in the municipal water industry must talk to each other to recommend or reject technical solutions. Another point derived from the workshops was that the current generation of municipal leaders prefers face-to-face meetings to make judgments, not the internet [72]. Therefore, they want early dialog with researchers and industry and do not want to make their statement only when a specific solution is installed and adaption results are needed for a great effort. In addition, it became clear in the study that the benefits of a digital solution must be highlighted much more strongly, not only in a general way, but also specifically for individual cases. If this benefit is not presented to the user in all clarity and depth, it will be difficult to achieve sufficient acceptance and thus project implementation.

With WaterExe4.0, a comprehensive and valuable database has been created for German-speaking regions with regard to the digitization of the water industry. In addition to a well-founded overview of application areas, application breadths and depths as well as used technologies, the conducted surveys and interviews provided comprehensive information on success factors and possible obstacles. Based on the desire of potential

users in the water sector for support aids and guidelines in the phase of the selection and introduction of digital solutions, results can be used to create these desired aids. Although new data will be constantly identified and entered into the database as part of the study, the result of the project is a snapshot. The innovation dynamics of digitization continue to increase in the water sector. Even if the development dynamics in the water sector are not as intensive as in other industries, there will be a significant increase in solution variants and in the applications of complex systems, such as AI. Climate change must be seen as a strong driver for digital developments. A large part of the effects of climate change has a direct or indirect impact on the earth's water balance. Humans and technology should be combined together in the best way possible to preserve the most important food on earth: water!

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References

1. Randhahn, A.; Kerbusch, J.; Gaaß, M.; Richter, D. Digitalisierung—Segen oder Fluch für den Klimaschutz. In *Klima*; Springer: Berlin, Germany, 2020; pp. 180–194.
2. Kröhling, A. Digitalisierung—Technik für eine nachhaltige Gesellschaft. In *CSR und Digitalisierung*; Springer: Berlin, Germany, 2017; pp. 23–49.
3. Balogun, A.L.; Marks, D.; Sharma, R.; Shekhar, H.; Balmes, C.; Maheng, D.; Arshad, A.; Salehi, P. Assessing the potentials of digitalization as a tool for climate change adaptation and sustainable development in urban centres. In *Sustainable Cities and Society*; Elsevier: Amsterdam, The Netherlands, 2020.
4. Wehn, U.; Montalvo, C. Exploring the dynamics of water innovation: Foundations for water innovation studies. *J. Clean. Prod.* **2018**, *171*, S1–S19. [CrossRef]
5. Müller-Czygan, G.; Wimmer, M.; Wagner, C.; Tarsyuk, V. WaterExe4.0—Results of the first meta-study on digitization in the water industry in the German-speaking region. Proceedings of the Eu-ropean Wastewater Management Conference 2021, 28–29 September 2021 at Birmingham/Online. Available online: www.ewwmconference.com (accessed on 5 May 2021).
6. Ajami, N.K.; Thompson, B.H., Jr.; David, G.V. *The Path to Water Innovation*; Stanford Woods Institute for Environment: Stanford, CA, USA, 2014.
7. Ipektsidis, B.; Remotti, L.A.; Rumpf, G.; Spanos, Y.; Soderquist, K.; Vonortas, N.; Damvakeraki, T.; Montalvo, C.; Bulavskaya, T.; Dröes, M.; et al. *R&D Investments and Structural Change in Sectors, Report to the General Directorate of Research and Innovation*; Eur. Comm. Bruss: Brussels, Belgium, 2016.
8. Kuipers, B.S.; Higgs, M.; Kickert, W.; Tummers, L.; Grandia, J.; Van der Voet, J. The management of change in public organizations: A literature review. *Public Adm.* **2014**, *92*, 1–20. [CrossRef]
9. Norbert, T.; Ritz, A. Das Innovationsmanagement zur Neuausrichtung öffentlicher Institutionen. In *Public Management*; Springer: Wiesbaden, Germany, 2017; pp. 117–164.
10. Wybrands, M. Literaturanalyse von Anwendungsfällen, Technologien und Datenquellen im Kontext Wasserinfrastruktur in Smart Cities. In *Smart Cities/Smart Regions—Technische Wirtschaftliche und Gesellschaftliche Innovationen*; Springer: Wiesbaden, Germany, 2019; pp. 69–83.
11. Müller-Czygan, G. *KOMMUNAL 4.0—Produkte und Lösungen für eine Durchgängige IT- und IoT-Kommunikation für die Wasserwirtschaft. gwf Praxisbuch Wasser 4.0*; Vulkan-Verlag: Essen, Germany, 2018.
12. von Ditfurth, H. Towards Smart Water—Die Zukunft der deutschen Wasserwirtschaft in einer vernetzten Welt. In *Smart City—Made in Germany*; Springer: Wiesbaden, Germany, 2020; pp. 351–361.
13. Malewski, C.; Spies, K.-H. TaMIS—Ein Baustein zur Digitalisierung für das Risikomanagement an Talsperren. In *Wasserbauwerke im Bestand-Sanierung, Umbau, Ersatzneubau und Rückbau*; conference transcript; Dresdner Wasserbaukolloquium: Dresden, Germany, 2018; pp. 221–227.

14. Hahne, L.; Abecker, A.; Bruns, J.; Jolk, C.; Wiggett, J. Integriertes Water Governance Support System am Beispiel des Olifants Flusseinzugsgebietes (Südafrika). In *Umweltinformationssysteme—Wie verändert die Digitalisierung unsere Gesellschaft?* Springer: Wiesbaden, Germany, 2021; pp. 89–103.
15. Gahr, A.; Wazinski, P.; Andreas, N. Water Management 4.0 in the Bitterfeld-Wolfen Chemical Park. In *Chemie Ingenieur Technik*; Wiley-VCH: Weinheim, Germany, 2019; pp. 1375–1381.
16. Keilholz, P.; Spinnreker-Czichon, D.; Huttner, P.; Augstein, A.; Borsdorff, D.; Erdle, K.; Ahlers, S.; Deubel, A. Bewässerung 4.0: Ein möglicher Ansatz zur weiteren Optimierung der Bewässerung. *Korrespondenz Wasserwirtschaft: Boden*, Germany, 2019; pp. 510–517.
17. Schüttrumpf, H. Smart Hydraulic Structures-Wohin führt uns der Weg. In *Interdisziplinärer Wasserbau im digitalen Wandel*; Selbstverlag der Technischen Universität Dresden: Dresden, Germany, 2020; pp. 3–10.
18. Saßl, C. Das Wasserrecht im Informationszeitalter—Neue Rechtsfragen des modernen Informations- und Entscheidungsmanagements für wasserwirtschaftliche Daseinsvorsorge und ökologischen Gewässerschutz. In *Deutsches Verwaltungsblatt*; Wolters Kluwer Deutschland: Kölle, Germany, 2016; pp. 896–898.
19. Weber, K. Rechtliche Aspekte der Digitalisierung in der Siedlungswasserwirtschaft. In *Österreichische Wasser-Und Abfallwirtschaft*; Springer Science & Business Media: Berlin, Germany, 2019; pp. 369–373.
20. Zimmermann, M.; Schramm, E.; Ebert, B. Siedlungswasserwirtschaft im Zeitalter der Digitalisierung: Cybersicherheit als Achillesferse. *TATuP-Zeitschrift für Technikfolgenabschätzung in Theorie und Praxis* **2020**, *29*, 37–43. [[CrossRef](#)]
21. Rasekh, A.; Hassanzadeh, A.; Mulchandani, S.; Modi, S.; Banks, M.K. Smart water networks and cyber security. *J. Water Resour. Plan. Manag.* **2016**, *142*, 01816004.
22. Oelmann, M.; Czichy, C.; Beele, R. *Smart Water Teil 3—Wie die Digitalisierung die Anforderungen an die akademische Ausbildung verändert*; Energie | Wasser-Praxis: Bonn, Germany, 2018; pp. 2–9.
23. Hormann, L.; Stuhl, S. The Value of Data for the German Water-and Wastewater industry. In Proceedings of the 11th International Conference on Mangement, Enterprise and Benchmarking (MEB 2018), Budapest, Hungary, 27–28 April 2018.
24. Seetharaman, P.; Mathew, S.K.; Sein, M.K.; Tallamraju, R.B. Being (more) human in a digitized world. *Inf. Syst. Front.* **2020**, *22*, 529–532. [[CrossRef](#)] [[PubMed](#)]
25. Eigenstetter, M. Ensuring Trust in and Acceptance of Digitalization and Automation: Contributions of Human Factors and Ethics. In *Proceedings of the International Conference on Human-Computer Interaction, Copenhagen, Denmark, 19–24 July 2020*; Springer: Cham, Switzerland; pp. 254–266.
26. Mvulirwenande, S.; Wehn, U. Promoting Smart Water Systems in Developing Countries Through Innovation Partnerships: Evidence from VIA Water-Supported Projects in Africa. In *ICT for Smart Water Systems: Measurements and Data*; Springer: Wiesbaden, Germany, 2019.
27. Kim, K.G. Development of an integrated smart water grid model as a portfolio of climate smart cities. *J. Smart Cities* **2019**, *3*, 23–34.
28. Espinosa Apráez, B.; Lavrijsen, S. Exploring the regulatory challenges of a possible rollout of smart water meters in the Netherlands. *Competition and Regulation in Network Industries* **2018**, *19*, 159–179. [[CrossRef](#)]
29. Jiada, L.; Yang, X.; Sitzenfrei, R. Rethinking the framework of smart water system: A review. *Water* **2020**, *12*, 412.
30. Müller-Czygan, G. Industrie 4.0 in der Wasserwirtschaft. In *Innovation Race—Wegweisende Prinzipien für das Management von FuE-Projekten*; Dortans, P., Ed.; Murmann: Hamburg, Germany, 2021; pp. 160–177.
31. Merzlikina, Y.B. Digitalization of Water Sector: Problems and Possibilities. In Proceedings of the XV International Scientific-Practical Symposium and Exhibition «Clean Water of Russia», Ekaterinburg, Russia, 23–27 September 2019; pp. 155–160.
32. Owen, D.A.L. *Smart Water Technologies and Techniques: Data Capture and Analysis for Sustainable Water Management*; John Wiley & Sons: Hoboken, NJ, USA, 2018.
33. Kluge, T.; Libbe, J. *Transformationsmanagement für eine nachhaltige Wasserwirtschaft. Handreichung zur Realisierung neuartiger Infrastrukturlösungen im Bereich Wasser und Abwasser*; research report; Institut für sozial-ökologische Forschung–ISOE: Frankfurt, Germany, 2010.
34. Tauchmann, H.; Hafkesbrink, J.; Nisipeanu, P.; Thomzik, M.; Bäumer, A.; Brauer, A.; Schroll, M. *Innovationen für eine nachhaltige Wasserwirtschaft: Einflussfaktoren und Handlungsbedarf*; Springer: Berlin/Heidelberg, Germany, 2006.
35. Flick, U. Triangulation als Rahmen für die Verknüpfung qualitativer und quantitativer Forschung. In *Qualitative Forschung*; Springer: Wiesbaden, Germany, 2014; pp. 185–191.
36. Cuhls, K. *Methoden 4.4 der Prospektiven Technologiebetrachtung/Technikvorausschau*; Technikfolgenabschätzung: Handbuch für Wissenschaft und Praxis; Nomos Verlag: Mannheim, Germany, 2021; p. 321.
37. Gläser, J.; Laudel, G. *Experteninterviews und Qualitative Inhaltsanalyse: Als Instrumente Rekonstruierender Untersuchungen*; Springer: Berlin/Heidelberg, Germany, 2009.
38. Niebert, K.; Gropengießer, H. Leitfadengestützte Interviews. In *Methoden in der Naturwissenschaftsdidaktischen Forschung*; Springer: Berlin/Heidelberg, Germany, 2014; pp. 121–132.
39. Mey, G.; Ruppel, P.-S. *Qualitative Forschung Sozialpsychologie und Sozialtheorie*; Springer: Wiesbaden, Germany, 2018.
40. Mayring, P. Qualitative content analysis: Demarcation, varieties, developments. In *Forum Qualitative Sozialforschung/Forum: Qualitative Social Research*; Freie Universität Berlin: Berlin, Germany, 2019; Volume 20.

41. Thaler, T.; Seebauer, S.; Rogger, M.; Dworak, T.; Winkler, C. Erweiterung von Kosten-Nutzen-Analysen im Hochwassermanagement durch Berücksichtigung sozialer und psychologischer Verwundbarkeit. *Österreichische Wasser- und Abfallwirtschaft* **2021**, 1–7. [CrossRef]
42. Schwien, L. Erweiterung der Kosten-Nutzen-Analyse von Regenwasserbehandlungsanlagen um die Indikatoren Ökobilanz und Mikroklima. Doctoral Dissertation, Hochschule für Angewandte Wissenschaften Hamburg, Hamburg, Germany, 2021.
43. Holländer, R. *Chancen und Herausforderungen der Verknüpfungen der Systeme in der Wasserwirtschaft (Wasser 4.0)*; Dessau Umweltbundesamt: Dessau-Roßlau, Germany, 2019.
44. Müller-Czygan, G. *Smart Water—How to Master the Future Challenges of Water Management*; Chandrasekaran, P.T., Javaid, M.S., Sadiq, A., Eds.; Resoruces of Water 2020; IntechOpen: London, UK, 2020; pp. 19–33.
45. Schuster, O.; Wimmer, M. *Smarte digitale Transformation in der Wasserwirtschaft*; Hof University of Applied Sciences: Hof, Germany, 2018.
46. Klenk, T.; Nullmeier, F.; Wewer, G. Auf dem Weg zum digitalen Staat? Stand und Perspektiven der Digitalisierung in Staat und Verwaltung. In *Handbuch Digitalisierung in Staat und Verwaltung*; Springer: Berlin/Heidelberg, Germany, 2019; pp. 1–22.
47. Funke, D. *Innovation im Kontext der öffentlichen Verwaltung: Management von Hindernissen und Blockaden bei Veränderungen*; Diplomica Verlag: Hamburg, Germany, 2014.
48. Martini, M. Transformation der Verwaltung durch Digitalisierung. In *Verwaltungspraxis und Verwaltungswissenschaft*; Nomos Verlag: Mannheim, Germany, 2018; pp. 11–68.
49. Stoffels, M.; Ziemer, C. Digitalization in the process industries-Evidence from the German water in dustry. *J. Bus. Chem.* **2017**, 14.
50. Oelmann, M. Ergebnisse des Digitalisierungsindex. In *Energie Wasser Praxis*; Wirtschafts- und Verlagsgesellschaft Gas und Wasser mbH: Bonn, Germany, 2021.
51. Deutsche Nachhaltigkeitsstrategie-Weiterentwicklung 2021. Available online: <https://www.bundesregierung.de/resource/blob/998006/1873516/3d3b15cd92d0261e7a0bcd8f43b7839/2021-03-10-dns-2021-finale-langfassung-nicht-barrierefrei-data.pdf?download=1> (accessed on 1 November 2021).
52. Korrespondenz Abwasser. *EU-Kommission legt Digitalziele 2030 vor*; Korrespondenz Abwasser; Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e. V. (DWA): Hennef, Germany, 2021; p. 240.
53. Burrichter, B.; Quirnbach, M.; Oelmann, M.; Niemann, A. Künstliche Intelligenz in der Wasserwirtschaft. Korrespondenz Abwasser; Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e. V. (DWA): Hennef, Germany, 2021; pp. 94–101.
54. Blumensaat, F.; Leitão, J.P.; Ort, C.; Rieckermann, J.; Scheidegger, A.; Vanrolleghem, P.A.; Villez, K. How urban storm-and wastewater management prepares for emerging opportunities and threats: Digital transformation, ubiquitous sensing, new data sources, and beyond-a horizon scan. *Environ. Sci. Technol.* **2019**, 53, 8488–8498. [CrossRef] [PubMed]
55. Cepa, K.; Chen, H.H.; Laakso, T.; Nelimarkka, M. *Disrupting the Water Industry*; Aalto University's Multidisciplinary Institute of Digitalisation and Energy (MIDE): Espo, Finland, 2016; pp. 203–236.
56. Wehn, U.; Montalvo, C. Exploring the dynamics of water innovation. *J. Clean. Prod.* **2014**, 87, 3–6. [CrossRef]
57. Robles, T.; Alcarria, R.; de Andrés, D.M.; de la Cruz, M.N.; Calero, R.; Iglesias, S.; Lopez, M. An IoT based reference architecture for smart water management processes. *J. Wirel. Mob. Netw. Ubiquitous Comput. Dependable Appl.* **2015**, 6, 4–23.
58. Gupta, A.; Mishra, S.; Bokde, N.; Kulat, K. Need of smart water systems in India. *Int. J. Appl. Eng. Res.* **2016**, 11, 2216–2223.
59. Gourbesville, P. Key challenges for smart water. *Procedia Eng.* **2016**, 154, 11–18. [CrossRef]
60. Byeon, S.; Choi, G.; Maeng, S.; Gourbesville, P. Sustainable water distribution strategy with smart water grid. *Sustainability* **2015**, 7, 4240–4259. [CrossRef]
61. Moy de Vitry, M.; Schneider, M.Y.; Wani, O.F.; Manny, L.; Leitão, J.P.; Eggimann, S. Smart urban water systems: What could possibly go wrong? *Environ. Res. Lett.* **2019**, 14, 081001. [CrossRef]
62. Sprocati, R.; Blum, J.M. Digitization of the water sector-practical examples from around the world. In *Proceedings of the 13th Annual Water Research Conference: Danish Water Forum, Copenhagen, Denmark, 31 January 2019*; University of Copenhagen: Copenhagen, Denmark, 2019; p. 54.
63. Jiménez, B.; Asano, T. (Eds.) *Water Reuse: An International Survey of Current Practice, Issues and Needs*; IWA: London, UK, 2008.
64. National Research Council. *Water Reuse: Potential for Expanding the Nation's Water Supply through Reuse of Municipal Wastewater*; National Academies Press: Washington, DC, USA, 2012.
65. Angelakis, A.N.; Asano, T.; Bahri, A.; Jimenez, B.E.; Tchobanoglous, G. Water Reuse: From Ancient to Modern Times and the Future. *Front. Environ. Sci.* **2018**, 6, 26. [CrossRef]
66. Becker, D.; Jungfer, C.; Track, T. Integrated Industrial Water Management—Challenges, Solutions, and Future Priorities. *Chem. Ing. Tech.* **2019**, 91, 1367–1374. [CrossRef]
67. Fernández García, I.; Lecina, S.; Ruiz-Sánchez, M.C.; Vera, J.; Conejero, W.; Conesa, M.R.; Montesinos, P. Trends and challenges in irrigation scheduling in the semi-arid area of Spain. *Water* **2020**, 12, 785. [CrossRef]
68. Hartung, U. Extremwetterereignisse in der Landwirtschaft: Risikomanagement im Bundesländervergleich; Berichte über Landwirtschaft-Zeitschrift für Agrarpolitik und Landwirtschaft. *Bundesministerium für Ernährung und Landwirtschaft* **2020**, 98, 3.
69. Available online: <https://www.hof-university.de/forschung/institut-fuer-wasser-und-energiemanagement/forschungsbereiche/wassermanagement-mit-aquakultur.html> (accessed on 9 November 2021).

70. Lafont, M.; Dupont, S.; Cousin, P.; Vallauri, A.; Dupont, C. Back to the future: IoT to improve aquaculture: Real-time monitoring and algorithmic prediction of water parameters for aquaculture needs. In *Proceedings of the 2019 Global IoT Summit (GloTS), Aarhus, Denmark, 17–21 June 2019*; IEEE: Piscataway, NJ, USA; pp. 1–6.
71. Monteleone, S.; De Moraes, E.A.; Maia, R.F. Analysis of the variables that affect the intention to adopt Precision Agriculture for smart water management in Agriculture 4.0 context. In *Proceedings of the 2019 Global IoT Summit (GloTS), Aarhus, Denmark, 17–21 June 2019*; IEEE: Piscataway, NJ, USA, 2019; pp. 1–6.
72. Müller-Czygan, G. Empirical Study on the Significance of Learning Transfer and Implementation Factors in the Digitization Project KOMMUNAL 4.0 with Special Attention to the Interactions of Technology and Change Management. Master Thesis, Economic Psychology FOM University of Applied Science Münster, Essen, Germany, 2018.