Theses of Doctoral (PhD) Dissertation

Gábor István Vajda

Budapest
2025

John Von Neumann University Doctoral School of
Management and Business Administration

INTEGRATION OF THE DIGITALIZED PERFORMANCE EVALUATION MODEL INTO THE CONTROLLING SYSTEM

Gábor István Vajda

BUDAPEST
2025

Doctoral School

Name:	John Von Neumann University Doctoral School of Management and Business Administration
Discipline:	Management and Business Administration
Head:	Prof. Dr. Judit Oláh DSc Professor / Correspondent member of the MTA John Von Neumann University Doctoral School of Management and Business Administration
Sub-programme:	Finance and Financial Digitalisation
Supervisor(s):	Prof. Dr. Zoltán Zéman PhD Professor / PhD John Von Neumann University Doctoral School of Management and Business Administration

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Approval of Head of Department Approval of Supervisor

CONTENT

ANTECEDENTS AND OBJECTIVES OF THE WORK

The development of technology and the availability of its results have opened a new era in corporate digitalization. Technologies previously only available to a narrower range of large companies are now also available to small and medium-sized enterprises. This process was also aided by the price reduction experienced in the technology field and the spread of open source technologies and solutions. The advent of Industry 4.0 has enabled the development of a theoretical operational model for digitized, data-driven manufacturing enterprises, the outcomes of which have subsequently been adopted across various other industries. The growing corporate demand for digital solutions, along with the continuous development of theory and technology, has resulted in a digital competition where each element mutually catalyzes the growth of the other. The degree of maturity, quality and ability to produce results of individual solutions vary significantly. Nevertheless, it is clear to companies that digitalization cannot be avoided (MACHKOUR - ABRIANE 2021) and its results are visible in corporate practice. As a result, almost every organization now has some kind of footprint in the digital space and is paying strategic attention to developing the organization's digital capabilities and solutions. The COVID-19 pandemic has also acted as a catalyst for the digitalization process.

The spread of digital solutions has resulted in wide-ranging changes in the everyday operations of companies. Research supports that the digital transformation of organizations is more than the introduction of isolated IT target solutions (TABRIZI et al. 2019). These solutions affect the operation of the entire organization, including the organizational structure, learning ability, mode of operation, corporate innovation, and also affect the operation of the business ecosystems surrounding the companies (KUUSISTO 2017). In other words, digital transformation entails the reinterpretation and optimization of business processes and the modification of current corporate practices (ROSS et al. 2017). In parallel, data and data utilization have increasingly become central issues, whereby data has become a production resource (LYPAK et al. 2018). As digital competition intensifies, the development of digital capabilities has become one of the criteria for corporate success and has become a critical competitive factor (BOIKOVA at al. 2021). Despite the successes, several studies confirm that a significant portion of digital transformations does not meet the original objectives (TABRIZI et al. 2019), one of the reasons being the maintenance of traditional corporate practices after the transformation.

Controlling is connected to all areas of corporate operations and evaluates and presents corporate operations to management through its specific vision. This creates a kind of bridge between core operations and the managerial mindset.

Therefore, a significant change affecting almost any area of the organization, such as digital transformation, also affects the operation of the controlling system. In contrast, practice shows that digital changes within the field of controlling either do not occur or happen very slowly. It is important to emphasize that in organizations or organizational units that have undergone digital transformation, managerial needs change. The changed needs can be traced back to faster and more efficient management work that appears as a requirement of digital competition. This requires faster, more accurate, more efficient, and broader data-based planning, data collection, analysis, and decision-making work from the controlling system.

The relevance of my research lies in the significance of corporate digital transformation and its impact on the controlling system. Practical experiences and publications confirm that in many digital transformation projects, integration of related areas - such as controlling - is either not addressed or is implemented only with delay. These resulting effects impair the performance of these related areas, including the controlling system. Therefore, I consider it important to research how these impacts can be identified, demonstrated, and what measures are necessary In my doctoral dissertation, I examine the effect of corporate digitalization on controlling and, through the changed digital demand system, I identify the problem areas and create a conceptual model for comparing and evaluating the level of digitalization of the company and controlling. In this context, I also formulate generalized statements and suggestions for the theoretical expansion of the controlling system's foundations.

In the foundation phase of my research, I determined that no comprehensive research has yet been conducted on the joint measurement and comparison of the level of corporate digitalization and the level of controlling digitalization and their mutual impact. Based on this, in my dissertation, I propose a solution to this measurement task by developing a conceptual model, for which I define the following research objectives:

1. Overview of current and relevant scientific results:
    a. To explore the most important characteristics of digitalization and, as a part of it data asset management and its impact on organisations, and to compare the most significant maturity models dealing with the field.
    b. To examine controlling practices, performance measurement, and their connection to digitalization as described in the literature.

2. To reveal the characteristics and specific features of corporate and controlling digitalization by analyzing case studies:
    a. To analyze, through concrete cases, the key characteristics and aspects of corporate and controlling digitalization - including data asset management - and the practices of their measurement and evaluation.
    b. To highlight the main characteristics and shortcomings of controlling work proccesses from the perspective of digital organisational operation through specific cases.

3. Development of a unified conceptual model suitable for measuring, evaluating, and comparing the level of corporate and controlling digitalization:
    a. To define the metrics, structure, development steps, and application conditions of the unified conceptual model through the analysis of the identified case.
    b. To develop the method, steps and mathematical apparatus for evaluating the unified conceptual model from a management perspective.

4. Formulation of generalized conclusions and proposals for the theoretical development of the controlling system in a digital direction:
    a. To determine at which points it is necessary to supplement and expand the fundamental principles and objectives of the controlling system as a consequence of digitalization.
    b. To formulate those additions which support the integration of the theoretical controlling workflow into the company's digital operational practices and processes.

1 MATERIAL AND METHODS

As the data collection method for my research, I used a qualitative case study method. In organizational research and in the exploration of how organizations operate, the qualitative case study method is among the most frequently applied approaches (BRYMAN 1992). Several researchers, such as YIN (1994) dentify the primary function of this method as the foundation and development of new theories. In my dissertation, the case studies are specific companies and their digital activities. My goal in selecting the cases was to make the digital activities of the companies and their impact on the given organizations significant. The background of the case analysis was created by my professional expertise in the field and my personal working relationship with the companies.

When conducting qualitative case studies, iterative data collection must be carried out to a depth sufficient to obtain all information necessary to understand the case and to achieve the research objectives (GLASER - STRAUSS 1967). In my case, I defined this level of understanding at the point where the corporate and controlling digitalization status, maturity, and/or the application methods of KPIs related to their measurement were undertsood. I based the case studies on a review of available documents. Then, I collected the necessary information using semi-structured in-depth interviews. The interview subjects were:

- Managers of the examined company who were involved in the digital transformation and in the formulation of strategy and vision,
- Managers and experts responsible for the operation of the examined digital field,
- Experts and managers familiar with the controlling activities of the examined company,
- Leaders and experts of the digital field who use the controlling tools.

The fundamental goal of my modeling work is to create a conceptual model that can be used to explore and analyze the digital differences of the entire company and the controlling area. To do this, I formulate the following model building concept: A general conceptual model (ODM) suitable for measuring the digitalization level of the entire organization and a conceptual model (CDM) suitable for measuring the digitalization level taking into account the specialties of controlling must be built. The common part of the two models creates the basis for creating a unified digital conceptual model (UDM), which is suitable for measuring both areas and thus comparing them.

I define the steps of the model building process as follows:

1. Summary of case studies, analysis of the content of the collected KPIs.

2. Development of intermediate models, during which I define the organizational digitalization (ODM) and controlling digitalization (CDM) models. In my dissertation, the role of these models is exclusively to analyze, standardize, consolidate, categorize, and structure the collected KPIs into a hierarchy, and to present them as partial results. Therefore, when developing intermediate models, I strived to define the widest possible set of KPIs, covering as many areas as possible. The two models thus created provide a transparent and comprehensive picture of the theoretical measurement options of both the corporate digitalization and the controlling digitalization levels and provide the background for further analyses. In my dissertation, no measurements are made with the intermediate models, therefore the model steps, evaluation methods and mathematical apparatuses necessary for their application are not described.

3. The KPIs included in the intermediate models (ODM, CDM) are analyzed and it is determined which KPIs can be interpreted for the operation and functions of the entire company and the controlling area. In the following steps, I only examine the intersection of the metrics of the two intermediate models thus determined.

4. Development of the structure of the comparative unified conceptual model (UDM) of digital capability based on the narrowed KPI set defined in step 3. In this regard, I create the structure of the UDM and organize the KPIs into a model hierarchy. Then, I perform the content standardization and consolidation of the KPIs selected from the intermediate models.

5. Elaboration of the steps of building the UDM conceptual model and definition of the model evaluation method based on fuzzy logic as a method and as an evaluation tool system. As part of this, I define a method capable of comparing the digital level and digital capabilities of the company and the controlling function.

6. Based on the literature, case studies and the results of the model creation process, determine at which points the fundamental principles and workflow of the controlling system need to be supplemented from a digital perspective. Furthermore, the connection between the additions and the UDM model must be determined.

2 RESULTS AND DISCUSSION

2.1 Presentation of case studies

2.1.1 Case Study 1 – Analysis of a commercial and service company with a digital sales channel

The main profile of the Hungarian-owned company examined in the research case study is the spare parts trading and the provision of related service activities, which operate as independent profit centers. The company has been present on the Hungarian market for more than 20 years, and has undergone organic development during this period. As a result, it has now become one of the leading domestic companies in the spare parts trade. The company also engages in both domestic and international retail and wholesale activities. The product portfolio includes more than fifty thousand items, for the distribution of which the company holds direct, exclusive contracts with manufacturers. The background for service provision is ensured by their own employees and subcontractors. In the first ten years of its operation, the organization carried out its commercial activities exclusively through a store network, later through a telephone sales channel. After that, it developed the possibility of purchasing online through a digital channel. Thus, it has now become a typical hybrid operating company.

The organization only partially understands digitalization as a corporate transformation and its effects, which is why it is difficult to formulate a digital strategy. IT developments occur without a conscious strategy, on an ad hoc basis, and do not extend to examining or aligning related areas. In order to move forward, it is necessary to shape the digital mindset of the ownership group and management, and to enhance the preparedness of the professional staff. Although the organization's digital image and functionality on the market are not up to date, they still provide continuously increasing revenue through the digital channel. The integration of webshop capabilities and internal processes has only been partially resolved. The organization perceives this directly in its slow and cumbersome operation, the effects of which it primarily tries to mitigate with supplementary Excel-based functions.

I found that the expectations of digital business can only be partially met with controlling products. Due to its traditional financial closing processes and conservative approach, the controlling system cannot interpret the data and analysis needs of digital operations. The resulting problems are mainly clustered around issues of speed and quality. One part of these originate from the shortcomings of the organization's digital capabilities. The other part, however, can be found in the uncoordinated operation of the organization's digital operational processes and controlling processes. I identified the reason

for this in that the organization focused separately on the development of the digital presence in the market for a long time and did not develop the other organizational processes and capabilities related to this. As a result, the difference between the digital capabilities of the controlling system and the operational activites and their level grew significant. The organization could not recognize this process and the root causes independently. The identification of these can be considered a direct organizational benefit of my research.

The case highlights that the slower pace of transformation of the controlling system compared to the digital core activity and the different levels of digitalization can cause operational problems, which can also affect the digital core activity itself. Progress is expected from improving controlling methods, processes, IT solutions, human capabilities, and increasing the degree of automation.

During the analysis of the case, 19 KPIs related to the measurement of corporate digitalization and 13 KPIs related to the measurement of controlling digitalization were identified.

2.1.2 Case Study 2 – Adapting commercial bank controlling to digital operational processes via a data warehouse

This case study investigates the capabilities of one of the leading institutions in the Hungarian banking industry. The bank has a history of several decades in Hungary, during which it has undergone several transformations affecting its foundations. Thus, on the one hand, it builds on the traditional business processes, services and customer base of the past, and on the other hand, it is continuously expanding its product portfolio and customer base in the digital space. Its operations are supported by a branch network that provides nationwide coverage, but it has also already built up the range of basic digital banking services, which are continuously being expanded. In terms of services, it provides a full range of commercial banking services for both retail and corporate customers.

It can be stated that there is a significant difference between the digital capabilities, toolsets, and processes experienced in the bank's general operations and those characteristic of controlling. The general digital development of the organization, the use of modern systems, and the preparedness of the employees are not typical of controlling. Controlling does not exploit the potential of the digital solutions and tools available to it. I have identified the roots of this in the following:

- During the development of digital capabilities, the bank focused on enhancing its competitive capabilities and neglected the development and digitalization of central support functions - such as controlling -

that are important for business operations. This process gradually separated controlling from the main process of development and deepened the differences. Furthermore, controlling processes are not aligned with the bank's business and digital business processes, since the related processes were not redesigned during their development.

- The mindset and dynamism of digital business operations emphasized the importance of the depth and timeliness of data analysis, and the provision of daily and weekly control. This kind of approach is inherent to digital business operations, but it was not adopted by the controlling function. As a result, it has not become necessary to change the applied controlling methodology or expand digital capabilities, since the summary report packages related to closing can also be produced manually on Excel. However this aspect of digital business management has made the role of controlling products formal. Thus, controlling can only partially serve the needs of management and digital leadership.
- Due to the two points above, controlling did not develop the digital competencies of employees, so the differences in this area also continued to grow.

The information flow problems described and the resulting operational and management disruptions can be traced back to the differences in the levels of digital approach, method, process and tool use of the two areas. Therefore, a key research question is the measurement of digitalization differences between organizational units and the determination of these deviations. The case study also points out that the organization is unable to fully exploit the potential in its data.

During the analysis of the case, 26 KPIs related to the measurement of corporate digitalization and 23 KPIs related to the measurement of controlling digitalization were identified.

2.1.3 Case Study 3 – Analysis of the operation of a trading house established on digital foundations

The subject of the case study is a company that operates exclusively in the digital space. Its customers are typically individuals, but there are also business organizations, and their base is drawn from several international markets. Its product portfolio is broad and dynamically changes in line with market needs. In addition to food and products requiring special storage, it also includes a wide range of household and consumer goods, fashion, electronics, DIY, leisure and sports products. The owners previously gained significant experience in operating traditional store-based and mixed (store-based and digital) retail companies. This background encouraged them not to

expand the digital capabilities and product portfolio of their existing company, but to create a new business with purely digital retail capabilities.

The organization's fundamental approach is to utilize the possibilities offered by digital tools as broadly as possible in its daily practice. Its business and development plans related to this are well-founded, but the pace of development could not follow the original plans, one of the primary reasons being the the employees' lack of digital skills. Therefore, a systematic development program was developed, which includes the development of the tool system, the applied process methods and the human resources. A positive element was the implementation of a KPI measurement system focusing only on the most important issues for measuring digital capabilities, which made the progress and effectiveness of development transparent and traceable, while also supporting the formulation of plans for the next period in this direction.

The case carries the customer, data and technology focus characteristic of digitally born companies, as well as thinking in a borderless, international market. This digital awareness can be considered a positive example in domestic practice, as they are able to achieve their goals step by step with a method adapted to the Hungarian labor market and financing situation.

Controlling processes were an integral part of the company's digital operations from the initial planning stage, but their implementation was not complete at the start. The lesson of the case is that even with such centralization of digitalization and comprehensive planning, there may be differences during implementation. These differences can modify the achievement of the initial goals. In the context of the case, it was possible to analyze both adequately and inadequately digitalized workflows, data domains, and their associated functions within the controlling area. The differences between the two process groups were evident in the depth of the data and the extent of the resulting analyses, as well as in the proactivity and flexibility of the operation. It was established that the digitalization-centered approach to controlling facilitated the development and digitalization of the processes of the controlling system.

During the case study, 42 KPIs related to the measurement of corporate digitalization and 13 KPIs related to the measurement of controlling digitalization were identified.

2.1.4 Case Study 4 – Analysis of the measurement practice of a commercial bank with a self-developed data asset maturity model

The subject of the case is a commercial bank with an extensive network of subsidiaries, providing full-service banking services, whose role is clearly linked to the development of digital banking services, the implementation of its own innovations and IT development programs. Accordingly, the bank places special emphasis on the development of digital capabilities. One

manifestation of this is the use of modern IT tools, architectural solutions and technologies, in connection with which the bank has taken the initial steps to introduce cloud and AI technologies and applications. In addition to enhancing IT technological capabilities, the bank also allocates significant resources to the transformation of its internal operational processes in line with digitalization and to the continuous training of its employees. In parallel with the ongoing regulatory compliance-driven development projects, there is also focus on improving digital sales capabilities and customer journeys, with the aim of maintaining a high level of customer experience.

The bank's digital approach is closely linked to data centricity. In this regard, it has many years of experience in the fields of data warehousing, big data, central master data management systems and various business intelligence, data mining or individually developed target systems based on them. In addition, it also applies the metadata management, data governance and operational monitoring tools necessary for optimal operation. These solutions are also integral parts of the bank's internal business and customer service processes. The necessity for measurement emerged from the organization’s need to clearly and unambiguously present to management the most important capabilities related to data management and data asset governance. This would create the basis for the development of a multi-level data and digital development strategy and its review along with continuous measurements. It was set as a goal that the applied measurement method be usable at corporate, subsidiary, departmental, and organizational unit levels. Another objective was to ensure the comparability of the capabilities of stakeholders at each level.

During the analysis of the case, two data asset management maturity measurement methodologies were compared. In the first case, the bank used the data management maturity model of an international consulting firm. Then, recognizing its shortcomings, it developed its own methodology and evaluation practice.

The analysis of the case highlighted the limitations of the use of commercially available maturity models based purely on questionnaire data collection. The model used at the bank presented and described the current state according to its specific measurement and evaluation criteria, but this could not be linked to the bank's specific data management tasks and challenges, or to the formulation of data strategies at different levels. Therefore, its application did not bring the expected results. I identified the solution in changing the measurement principles and practice. The introduction of a measurement and evaluation methodology tailored to the bank’s situation and supplemented by expert input brought concrete results in the short term (within a six-month cycle).

n line with the research topic of the dissertation, I emphasize the importance of a model applied in practice being suitable for, or adaptable to, a specific measurement task, i.e. being sufficiently flexible and adoptable. In addition to the structure and tool system of this model, a key component is the related expert work.

The case study from a controlling perspective highlighted that the digital assessment of a controlling system with an extensive digital tool system is not clearly positive if the processes and data of the controlling system are not properly integrated, or the controlling approach and operation are rigid and do not fully align with the digital business model.

During the case analysis, 13 KPIs related to data asset management measurement were identified, which can be interpreted at the level of the entire organization or its individual units. Therefore, the identified KPIs have been applied in my research both at the corporate and organizational unit (controlling) levels.

2.1.5 Case Study 5 – Analysis of the digitalization measurement and evaluation criteria of an ICT sector company

The subject of the case study is an international multinational IT company and its Hungarian subsidiary. On the one hand, the global thinking of one of the representatives of the ICT sector in the field of digitalization can be learned, and on the other hand, a specific domestic practice can be analyzed. The company has its own innovation and product development background, which provides a continuously developing product portfolio. This includes hardware, software solutions and cloud-based services. Its products and services are sold through its own sales organization and partner network. In order to maintain high customer satisfaction, it also provides extensive support services for its products in addition to sales. Using the products and services it distributes, IT developments and digital transformations are carried out in a wide range of companies with different profiles. These projects are implemented by the customers either independently or with the help of an external company with specific knowledge, for which the subject of the case can provide implementation support and delivery services as needed.

The company is a committed representative of corporate and organizational digital innovation and its support. In addition to its own activities, it has numerous cooperation agreements with partners of various sizes and specializations, which in each case focus on expanding the range of opportunities provided to customers, improving the quality of service, and creating results on the customer side. In terms of customer base, there are individuals, small and medium-sized enterprises, large companies, foundations, and state organizations and institutions. Serving the industry- and

company-specific needs of this wide range of customers requires continuous and extensive information collection. It is important for the company to know the digitalization status of its customers, customer satisfaction with its products and services, and the opinions of its employees.

The case study shows that an ICT company with an extensive range of activities continuously obtains data and information related to digitalization maturity and status from various sources during its activities for its clients and partners. From the company's unique service-provider perspective, these insights are directly utilized in product sales and project execution. Additionally, these data sources open up many indirect, theoretical opportunities for use in internal strategy building and the development of products and methodologies.

During the case study, I examine three major areas of information gathering related to digitalization and identify the KPIs related to the measurement of digitalization related to them:

- Measurements through employee surveys, 15 KPIs were identified.
- Measurement of the application of products and services, 3 KPIs were identified.
- Measurements related to the implementation of projects: 18 KPIs were identified.

From the perspective of my dissertation, I consider this ICT service provider viewpoint and the information derived from it to be of particular importance, as it provided insight not only into a measurement practice applied within one organization but also into a generally applied approach, methodology, and measurement framework that has already supported the digitalization efforts of multiple clients. The identified KPIs were applied in measurement tasks for entire organizations or their sub-units, and therefore I have incorporated them accordingly into the model developed in the context of my dissertation.

The evaluation of the case from a controlling perspective highlighted the risks of prolonged controlling digital transformation projects, the anomalies caused by parallel systems, and the resulting compliance and business management issues concerning the service level provided by controlling.

2.2 Summary of case studies, practical knowledge integration

As a result of the case analyses, I present summarizing conclusions along three thematic areas. These generalizing summaries provide background and explanation for the practical significance and role of the model defined as the research objective.

Generalizing, summary statements related to organizational digitalization:

1. Organizations recognize the importance of digitalization and its positive impact on their own organizations. They treat digitalization as a strategic area to be developed, and they formulate continuous, future development goals in this regard.
2. Organizations interpret corporate digitalization based on their specific situation, industry specialties, and IT capabilities.
3. Corporate digital operating modes, architectures, and technical solutions vary significantly even when the functions they perform are similar. This highlights the fact that similar digital goals can be achieved through multiple pathways and solutions.
4. Digital transformation cannot occur horizontally and vertically in all processes and areas of the entire organization at the same time. As a result, the consistency of previous processes is disrupted by new processes created during digitalization. Redesigning and adapting processes to digital operations is essential.

Generalizing, summarizing statements related to the digitalization and digital operation of controlling:

1. The corporate design, processes and approach of the controlling system, and the controllers' approach are typically not yet digitalization-centric.
2. The automation of controlling processes and the availability of digital tools i.e., the digital capabilities are generally at a lower level than those related to the company’s core activities. The prevailing practice mainly relies on office software tools, such as Excel.
3. The development of controlling digitalization represents a lower priority than the development of digital capabilities related to the organization's core activities.
4. The low level of digitalization and integration of controlling processes and its traditional approach are the reasons why controlling cannot fully serve the expectations of digital business management and digital corporate management. In my opinion, significant progress in this area can be expected from the development of controlling's approach, processes and tool system.

Generalizing, summarizing statements regarding the measurement of the level of digitalization and the applied KPIs:

1. Organizations develop the aspects of digitalization-related measurements based on their own priorities and focus points. They rely little on methods published by researchers, which is due to the diversity experienced in the field.

2. The consistency and similarities of corporate digitalization measurement methods and KPIs create the opportunity to create general metrics and groups of metrics from them.
3. The content of measurement practices and KPIs applicable to the controlling area and digital operations shows significant overlap. This enables the synthesis of measurement practices and KPIs by content and their inclusion in a common conceptual model. This makes it possible to achieve a uniform measurement and comparability of the digital level of the two fields.

2.3 Created models

2.3.1 Intermediate models

When developing the intermediate models, I created the structure and content of the models based on the analysis of the content similarities and differences of the digital perspectives revealed during the case studies, striving to provide the widest possible coverage of the different topics by describing their digital characteristics. By examining the measurement methods, practices, evaluation aspects, and specific KPIs mapped during the analysis of the collected information, identifying the synergistic content similarities between them and consolidating them, I defined the KPIs included in the intermediate models, and then classified them into the structure of the model. With this method, I created a model suitable for measuring the digital operation of corporate digitalization and controlling in two topics:

1. Organizational Digital Model (ODM) containing 107 KPIs
2. Controlling Digital Model (CDM) containing 76 KPIs

With the information summarized in the two models, I created the basic information base necessary for preparing the UDM model.

2.3.2 Unified Digital Conceptual Model (UDM)

The ODM and CDM models reflect the consolidation and integration of the tool systems used to measure the level of organizational and controlling digitalization examined separately in the case studies, but due to their differences, neither the ODM nor the CDM are independently suitable for the joint measurement and comparison of the levels of the digitalization of the entire organization and controlling. Therefore, by analyzing the content of the KPIs included in them and examining their interpretation for the entire organization or its digital component and controlling, I created the UDM conceptual model that is valid and applicable to both areas.

The application of the UDM enables the implementation of a complex organizational and controlling level digital performance evaluation system,

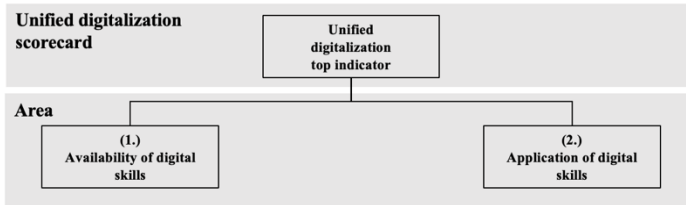
which allows for both separate and aggregated measurement across various aspects. The hierarchical structure of the model I developed supports detailed performance analysis along different digital aspects through simultaneous evaluation of measurements on both areas (corporate-level digital and controlling areas), and also enables comparison of the two areas through a unified digital performance indicator.

The theoretical foundation of the model's concept and methodology is based on fuzzy logic, which allows for the handling of the high level of subjectivity arising during evaluation. This results from the combined effect of several components, including the unclear definition of the concept of digitalization level, the lack of content standardization of the data required for the input of the measurements, and the ambiguity in interpreting the results obtained from the measurements. The evaluation of the model's outcomes is unique for each measurement, depending on the internal and external conditions of the given organization at a given point in time, prevailing priorities, and the current interpretation of relevant terms, in short, the context. Based on the above, I define the interpretation of the UDM model as follows:

> Due to the use of fuzzy logic, the goal of the UDM is not the precise determination of exact values. Instead, its clear objective is to demonstrate and assess the subjectivity of various inference steps during the digitalization level measurement process, thereby enabling a representation of the measurement results in a manner approximating human reasoning.

2.3.2.1 UDM Structure

Figure 1 shows the structural design of UDM. At the top of the structure is the Unified Digitalization Scorecard, which is composed of two main assessment areas - (1) availability of digital capabilities and (2) application of digital capabilities. The areas are further broken down into assessment perspectives and aspects. At the lowest level of the model hierarchy are the elementary KPIs. Aggregation is done starting from the elementary KPIs along the hierarchy through weight values. Figure 1 shows the entire model divided into three parts for easier overview.



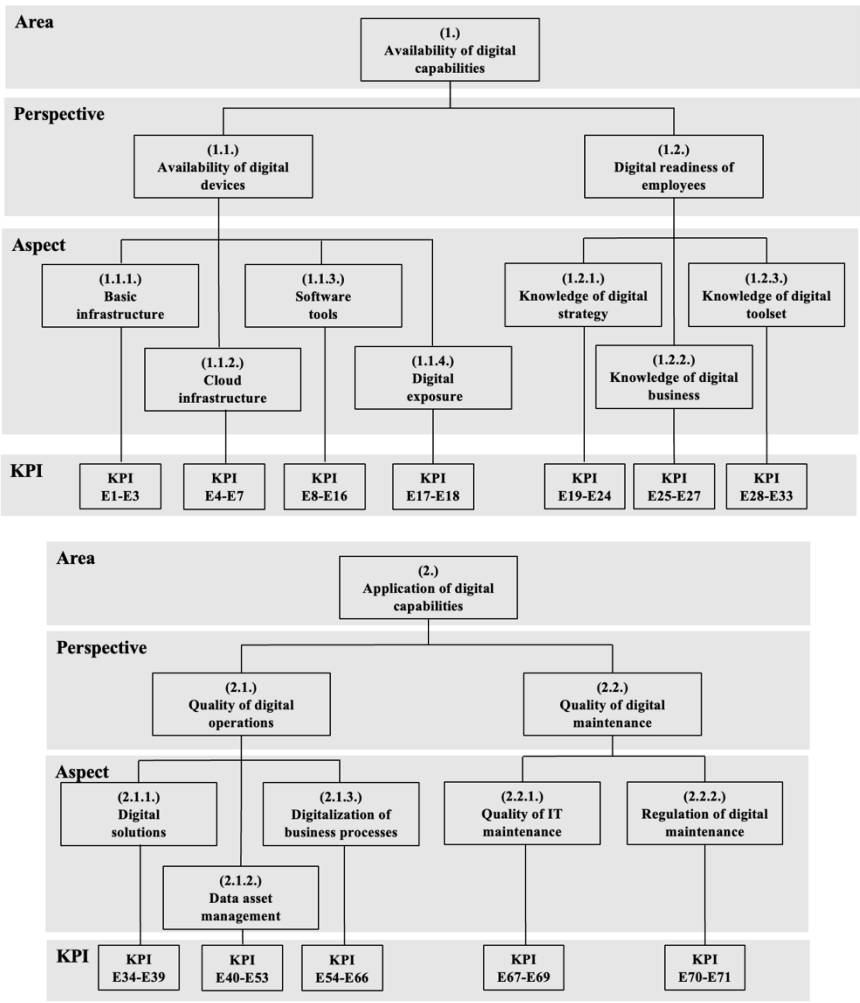


Figure 1: Structure of the Unified Digital Conceptual Model (UDM)
Source: own editing

2.3.2.2 Conditions of the UDM conceptual model

Based on the analysis of the literature and case studies, I came to the conclusion that there is no exact answer to the question of what constitutes acceptable, good or excellent digitalization, and there cannot be, because the context and the characteristics of the given case fundamentally influence the answer to the question. Therefore, to make the question answerable, I chose a methodological and mathematical apparatus that is suitable for representing and evaluating such uncertain, vague measurement sets. Accordingly, I created the methodological and evaluation background of my model by applying Fuzzy logic.

Fuzzy logic works with fuzzy sets, which means that deciding whether something belongs or does not belong to a predefined set cannot be described by a clear characteristic function, but rather different membership functions must be applied. These membership functions, interpreted on the entire set, illustrate the values belonging to a previously, appropriately given linguistic variable, classification category (ZADEH 1978). The relevance and applicability of the fuzzy method and concept in the context of my dissertation lies in the the fact that the boundaries of the concepts of "digital maturity" and "digitalization level" used in the evaluation are not sharp, but blurred.

The components of the model I developed, including the structure of the model, its metrics, aggregates, target value, weight value and fuzzy category definition methods, are included as recommendations. The reason for this is, on the one hand, that there is no uniform conceptual and measurement system accepted by the scientific community for the implementation of digitalization level measurements, and on the other hand, that the characteristics of measurements carried out in different situations and contexts can be radically different. Therefore, every organization and digital level measurement should be considered a unique environment containing a high degree of subjectivity. Consequently, the components of the model must be adaptable to the given measurement situation.

2.3.2.3 Steps of UDM

In order to make the digitalization of the entire company (or its digital business) and its controlling area measurable and comparable with the UDM conceptual model, I must first define its scope, operation, steps and interpret them precisely for both areas within a single case. Accordingly, I define the measurement scope of the model as follows:

a. Company-level scope. In this case, data collection and model interpretation apply either to the entire company or to its digital business area. The controlling area must be excluded from the measurement scope.
b. Controlling scope. In this case, the scope means the totality of those performing controlling activities within the organization. This can be a centralized controlling organizational unit or a set of controllers present in multiple units within the organization.

Each step of the model must be implemented according to the interpretation of the scopes. In the following, I will describe the task and content of each step, specifying the necessary conditions and methods.

Step 1: selecting the UDM model metrics to be applied, collecting the data necessary for the model to operate.

From among the KPIs (E1–E71) situated at the elementary level of the UDM model, those must be selected which will be included in the measurement. The most important aspect of the selection is which KPIs best represent the digitalization of the given organization, and are therefore suitable for describing the digital level and measuring digital performance. The condition for the operation of the UDM model is that each aspect or viewpoint is represented by at least one KPI. The input data required to calculate the actual values of the indicators must be collected separately for both interpretation scopes. Then, based on these, the individual elementary-level actual KPIs must be calculated separately for both scopes.

The measurement results expressed by the indicators are presented as percentages relative to a predefined target value. This unified description of the indicators enables the standardized expression of measurement results. These calculations take place during the construction of the model, using the collected factual input data and the target values defined through expert judgment. The definition of the target values is based on the subjective expert opinion of a designated expert group, where experts assign a target value to each indicator. The final target value is the arithmetic mean of the target values defined by the experts, with outlier values excluded. The method for identifying outliers is also decided by the expert team. Providing target values is a prerequisite for the model's operation, and the target values may not be zero.

Step 2: selection of different-level aggregates that match the characteristics of the organization along the UDM structure.

In this step, the structure of the UDM model shown in Figure 1 must be adjusted according to the characteristics of the given measurement task. The UDM model must always be built by calculating the KPI aggregates according to the structure. The model aggregation method is the weighted average calculation.

Step 3: assigning weight values to the indicators and the aggregates formed from them using subjective expert opinion.

The determination of weights plays a key role in the operation of the model, as due to the conceptual nature of the model, this method allows the model to be tuned to the organization's characteristics through KPIs and aggregates. Consequently, constant weight values should not be applied during measurements, but should be determined separately for each organization and measurement situation.

In the model, the aggregation method is weighted KPI calculation, where a given level of aggregation is represented by the weighted average of the underlying elements (KPIs or aggregates). Accordingly, weights must be

assigned to both the KPIs on the 1st elementary level and the aggregates on the 2nd, 3rd, and 4th levels. The weights are determined using subjective expert opinions via a questionnaire method. The weights modify the percentage ratio of the difference between the actual and target values of the individual indicators, and in doing so, influence the entire vertical structure of the model. As a result, determining the weights fundamentally affects the model's operation and outcomes.

Step 4: Evaluation of the metrics and the aggregates formed from them using an evaluation procedure based on fuzzy logic.

The prerequisite for beginning the evaluation is the creation of fuzzy categories based on subjective expert opinion. To define the categories, I developed a questionnaire based method in which two values must be assigned to each indicator for each category (linguistic value):

- a: the minimum value of the given indicator for the given category,
- c: the maximum value of the given indicator for the given category.

The simple arithmetic average of the **a** and **c** values appearing in the completed questionnaires per fuzzy category defines the two characteristic points of the fuzzy function that describe the category: minimum (a) and maximum (c). To calculate the third characteristic point (b) of the fuzzy function, I applied the simple arithmetic average of the minimum and maximum values of the given fuzzy category.

For the standardized norm (1SN) evaluation of indicators and aggregates along their target values, and for the calculation of the σ target-to-actual ratio for a given KPI, the following calculation must be performed.

$$\sigma_i = KPI_{E_i} = \frac{KPI_{E_{i(t)}}}{KPI_{E_{i(c)}}}$$

where, KPI_{E_i}: standardized target-to-actual ratio, $KPI_{E_{i(t)}}$: actual value of the indicator, $KPI_{E_{i(c)}}$: target value of the indicator as determined through expert judgment.

The result of the operations is always a ratio between 0 and 1, which is suitable for evaluation along fuzzy categories.

$$\sigma_i = \mathrm{U} \rightarrow [0,1]$$

where, σ: target-to-actual ratio, i: index of the examined element. When analyzing KPIs at the elementary level, the value of σ represents a specific target-to-actual ratio. For aggregated indicators, the value of σ represents an aggregate of target-to-actual values. Thus, the model does not assign separate target values to the aggregation levels.

The calculated σ_i ratios must be evaluated along the following five fuzzy function classes (linguistic categories):

$$T_i = \begin{cases} extremely\ low, & if\ \sigma_i < c_1 \\ low, & if\ \sigma_i \in]a_2; c_2[\\ medium, & if\ \sigma_i \in]a_3; c_3[\\ high, & if\ \sigma_i \in]a_4; c_4[\\ extremely\ high, & if\ \sigma_i > a_5 \end{cases}$$

Based on the theory of fuzzy logic, the specific values of σ_i are grouped according to the defined classes, which represent a membership according to T_i. In this way, concrete numerical values are replaced by linguistic concepts that represent the level of digitalization.

The membership function categories, defined by overlapping fuzzy functions, illustrate the uncertainty and vagueness in the evaluation process, which are supported by expert opinion. Figure 2 illustrates the membership according to the 1 Standard Norm (1SN), where the overlaps between the functions and the category subsets differ from one another. As a result, during the evaluation when assigning linguistic elements to the KPIs or aggregates the boundaries of the intervals defined by the membership functions also influence the process in addition to the standardized norm.

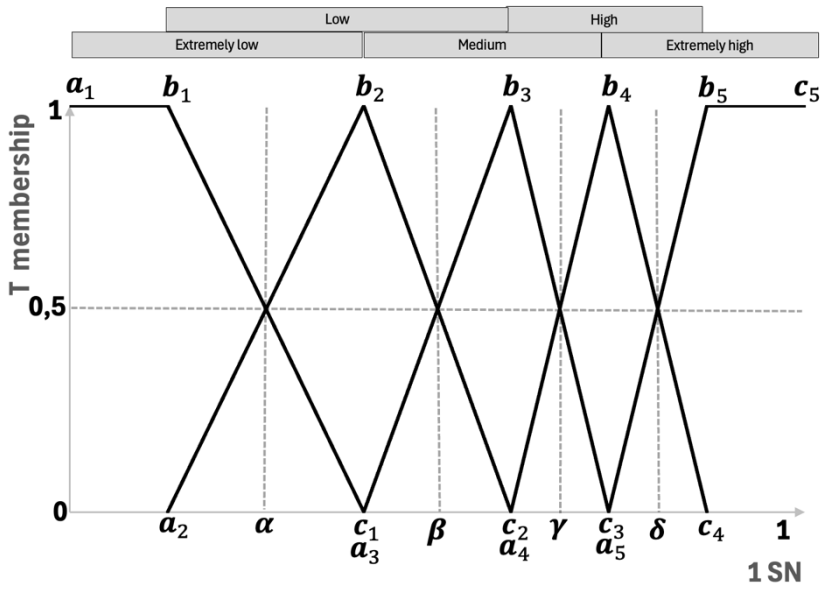


Figure 2: Membership function (1SN)
Source: own editing

The individual fuzzy membership functions explain the extent to which the target value-fact ratios belong to a category. Moving up or down from the

intersection points (α, β, γ, δ) on the function image, it is visible which category membership described by which function section in the "fuzzy" overlapping section of two functions contributes to the assessment and explanation of the given target value-fact ratio.

Step 5: creating a peak indicator at the top of the model that represents its content with a value.

The digital peak indicators must be created for both scopes, along the aggregation levels according to the UDM structure. This aggregate at the top of the model contains the appropriately weighted effect of all digital viewpoints, aspects, and elementary-level KPIs formulated in the UDM. Accordingly, this indicator, or its representation substituted with a linguistic value, is capable of expressing the level of digitalization and digital maturity within the given scope through a single value.

Step 6: Comparison of UDM model results measured in corporate and controlling scopes

The purpose of the evaluation is to determine the level of digital maturity in the corporate and controlling areas (scopes), and to identify and characterize the differences in digital development between these areas.

The management perspective of the evaluation in this case means that, in terms of the individual KPIs and aggregates, the fuzzy linguistic values based on the 1SN standardized norm are compared, abstracted from their specific numerical values. By evaluating these, the characteristic differences between the corporate level (or a specific digital area) and controlling can be identified. By analyzing the deviations, it becomes possible to highlight the root causes of problems and operational malfunctions that result from the differing levels of digital maturity in the two areas. In this way, the areas requiring development and the intervention points can also be determined.

2.3.3 Controlling regulation and control model

As a summary of the case studies, I pointed out that a low-level digitalized controlling system organized on traditional bases cannot provide sufficiently accurate, fast, detailed data, information and analyses for digital business management and management. In our case, the low level of digitalization is not absolute, but a relative comparison to the level of corporate digital operations.

The design of the controlling system is structured around five core principles (goal orientation, bottleneck orientation, future orientation, cost orientation, and decision orientation). While these principles remain valid, their effective implementation is clearly dependent on how well they are embedded into the organization. My research has found that controlling practices are

fundamentally not digitalization-oriented, which hinders the alignment between the controlling system and the organization's digital processes and operations. Therefore, both the controlling system and the controllers themselves require development in this area.

To help develop future controlling systems and transform existing ones, I propose supplementing the goals formulated as five basic principles with a sixth goal as follows:

> Digitalization orientation: The controlling system must be designed to align with the digital maturity level of the organization. This means that controlling workflows should become an integral part of the organization's digital processes. The applied methods, technologies, digital tools, and controller competencies must be matched to the organization's digital level, thus ensuring the system can meet the organization's evolving demands.

To implement this in practice, the controlling system must be brought "closer" to the system of digital corporate operations, digital operating processes. I create the theoretical concept of this by supplementing the controlling regulatory circle, which is presented in Figure 3.

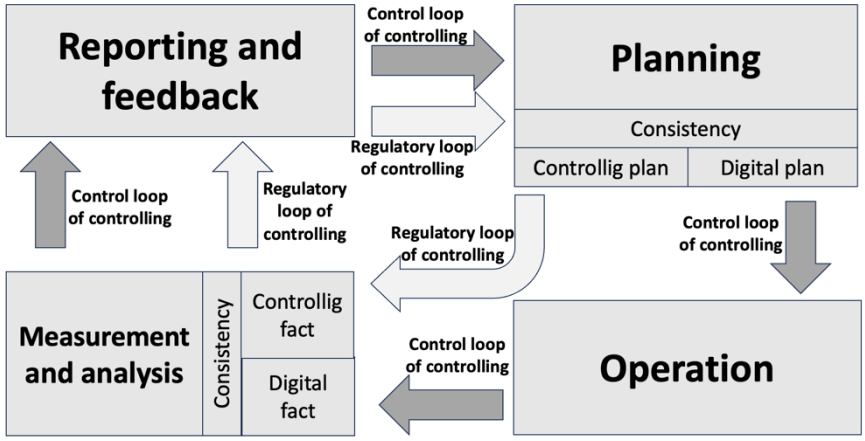


Figure 3: System of digital controlling regulation and control
Source: own editing

According to the proposed concept, during planning, detailed planning structures must be developed that match the depth and content of the digital operations. I refer to this as the digital plan. Each element of the digital plan must be consistent with the controlling plan, meaning one should be derivable from the other. This requires the development of a common organizational conceptual framework, the transformation of traditional planning processes, and an expansion of the controlling mindset. With this level of integration

between controlling and digital planning, it becomes possible to create a comprehensive plan that describes all aspects of business operations. The situation is similar during measurement and analysis. The recording of factual data is divided into two parts: on the one hand, the usual factual data of controlling are recorded, on the other hand, factual data describing the performance of the digital operation at an elementary level are obtained directly from the digital operational processes. Creating consistency between the two different resolution groups of plan and factual data is a prerequisite for digital controlling operations.

Keeping the plan and actual data consistent creates the theoretical possibility of including traditional and digital corporate operations in a common controlling system. The logical system structure shown in Figure 1 consists of two parallel processes and circles:

1. Controlling Regulation Loop: Its time cycle aligns with the corporate reporting cycle and it primarily controls the organization-level plans, including appropriately aggregated digital views. It is implemented through the redesign and digitalization of traditional controlling methods.
2. Controlling Control Loop: Its time cycle is aligned with the digital business and business management system and controls their processes. Digital business control is implemented through planning, measurement and feedback processes and data produced with appropriate dynamics within the controlling control circle. This circle has a significantly higher automation requirement, as the requirements system, speed and technological background of digital business create the possibility of creating data and event-driven functions and processes. This reduces the need for human intervention to a minimum, which in the future will be significant mainly in the definition of frameworks, operating rules, control parameters and not during operational implementation.

During the parallel operation of the two circles, the functions of planning, operational operation, measurement and analysis, as well as reporting and feedback are based on the same, conceptually uniform, consistent data content and data management methodology valid for both circles. In other words, the two circles form a single, integrated system, examined from the data, process and function sides.

A critical point in implementing this system is raising the digitalization level of the controlling system to match that of the overall company. This means enhancing digital capabilities and their practical application. The development process begins by identifying the differences between the two areas and

defining the areas to be improved based on these findings. The UDM conceptual model I developed provides a suitable solution for this, which can be adopted in a corporate environment.

3 CONCLUSIONS AND SUGGESTIONS

1. Consequences of the conceptual ambiguity of digitalization

There is no unified position within the scientific community regarding the concept of digitalization or the assessment of digital performance.

After reviewing the literature, I found that the number of different procedures and methodologies related to the measurement of digitalization or some of its sub-areas is significant. These approaches often overlap partially in terms of conceptual frameworks and measurement tools, yet despite this, they frequently contain considerable contradictions. This diversity of measurement approaches can be traced back to the lack of clarity surrounding the definition of digitalization. The subjective perspective of the models and methods is clearly linked to the authors' unique vision of digitalization, as well as the focus and field of study of their solution. This high degree of ambiguity and subjectivity complicates the practical application of digitalization related concepts and methods within corporate environments. Corporate applicability is further complicated by the uniqueness of corporate environments and the many digitalization-related specialties inherent in their operations.

The case studies I conducted revealed that companies typically do not apply one single, published measurement method when assessing digitalization, but rather measure the critical points that are interesting to them using unique measurement methodologies. Despite the many uncertain circumstances, it is important for the organization to be able to determine the characteristics of different aspects of digital operation and measure their performance.

2. Organizational effects and consequences resulting from the difference in the level of corporate and controlling digitalization

By directing the processes of planning, measurement, analysis, reporting, and feedback, controlling serves as one of the central functions within organizations and plays a critical role in supporting corporate decision-making. During my research, by analyzing several case studies, I highlighted that corporate digital transformation processes are often not complete. As a consequence, the digital development of individual functional areas does not progress uniformly. Thus, a t any given point in time, when examined by digital maturity, these areas may show significant differences. The organizational impact of this is significant and also applies to controlling.

The results of my research highlighted that the increase in the level of corporate digital operations changes the level of demand for digital areas and management. This primarily manifests itself in the need for faster and more accurate data and information that matches digital operations. Summarizing the insights from the case studies, it can be stated that in cases where the

digitalization of controlling significantly differed from the corporate level, controlling cannot or can only partially serve these changed needs. These caused cooperation problems and operational disruptions between organizational units.

3. The current corporate practice of measuring the level of organizational and controlling digitalization is not uniform and is typically only partially suitable for identifying problems.

My primary conclusion from the evaluation of the case studies is that there is no uniform comprehensive measurement practice for measuring the level of organizational and controlling digitalization together and comparing them. As part of this, it can also be stated that the digital measurement tool system of corporate digitalization and individual business areas is not unified either.

Based on the overall picture emerging from the case studies, I concluded that organizations do not obtain a clear and complete picture of the level of digitalization that is also easily interpretable for management through the methods they apply. This makes it difficult to explore the connections between different processes and digital capabilities and to identify real problems and find solutions. The same applies to comparing the corporate digital level with the digital operations of controlling. The absence of targeted tools makes the exploration and analysis of this field more difficult.

4. Proposal for the application of the developed UDM conceptual model.

The application of the UDM model is highly recommended in cases where the controlling operation of partially or fully digitalized organizations shows phenomena that indicating that the digital level of controlling lags behind the organizational level. By analyzing the case studies, I concluded that these phenomena typically appear within the following topics:

- compliance with deadlines for controlling workflows and deliverables,
- responsiveness of controlling to specific business situations or ad-hoc requests,
- data depth of analyses and reports,
- data quality and accuracy of analyses and reports.

In addition, the model is also recommended when an organization is developing its digital capabilities or strategy, wishes to examine the effects of a digital transformation project on the organization and controlling, or seeks a clear situational analysis to support management decisions related to different levels of digitalization.

The UDM conceptual model provides a comprehensive methodological solution for addressing the proposed use cases. Furthermore, the results of the

model clarify the digitalization differences between the company and controlling, pointing out which digital metrics these can be traced back to.

5. Proposal for the further development of the UDM conceptual model.

The UDM conceptual model was optimized for the execution of a target task. I developed the structure, conditions and steps of the model in accordance with the requirements of this task. I propose the following directions for further development of this conceptual framework:

- expanding the range of indicators,
- enhancing the model's capabilities through the creation of new functions and refinement of existing ones,
- extending the model to other business areas.

6. Proposal for the practical application of the controlling regulatory and control system model and the introduction of the sixth controlling objective: digitalization orientation.

The purpose of the proposal is to help develop future controlling systems and the digital transformation of existing ones. As a first step, the mindset of controllers and the controlling system must be supplemented and brought closer to digital corporate practice. This can be effectively supported by expanding the five fundamental controlling objectives with a sixth, the objective of digitalization orientation, the definition of which I have defined and included in chapter 2.3.3. Such a fundamental objective and its publication and acceptance may have an attitude-shaping effect in the controller community, potentially catalyzing the necessary digital changes.

Systemic controlling problems can fundamentally be addressed by increasing the digital level of the controlling system and integrating it with the company's digital operations. This involves establishing a shared and consistent conceptual and data foundation, and building a unified, integrated system of processes and functions based on it. The model of the controlling digital regulation and control system, which provides the theoretical basis for this, is presented in chapter 3.3.3. At the beginning of the process, the current digital level of the company and controlling and its differences must be determined. The UDM conceptual model I have created can provide effective methodological support for this.

4 KEY FINDINGS AND NEW SCIENTIFIC RESULTS

1. Traditional controlling systems are unable or only partially able to meet the expectations placed upon them by digitalized organizations.

   Through my research, I have demonstrated that as the digital capabilities of organizations increase, their level of expectations toward controlling products and services also changes. This is due to the fact that digital transformation alters both the fundamental capabilities (such as speed, accuracy, data granularity, and flexibility) and the expectation levels of the transformed areas. As a result, controlling systems that have not undergone transformation can only partially meet the changed level of demand, which causes confusion between controlling and digital business areas.

2. Digital transformation disrupts the integrity between previous corporate processes and controlling processes, which results in a change in the scope of controlling.

   By analyzing case studies, I pointed out that organizations do not implement digital transformation in all organizational units at the same time. As a result, the digital capabilities of the areas involved in the transformation and those not involved differ from each other. I found that the digital transformation of controlling is implemented later and with lower priority compared to the digital business areas of the company. As a result, the previous processes of controlling no longer fit properly with the new digital business processes. This leads to operational and efficiency related issues between controlling and digital functions. I pointed out that in this situation, the controlling tasks and functions have been partially taken over by the digital areas. This, in turn, can trigger processes where the corporate role of controlling may decrease. To reverse the process, it is necessary to identify the digital differences and their causes, for which the application of the UDM model I developed can provide effective support. The digital transformation of controlling established in this way can restore the broken integrity of processes and increase the future tasks of controlling.

3. The UDM conceptual model suitable for comparing and evaluating the digital capabilites of digitalized organizations and controlling has been created.

   The model I created is a framework that can reveal the differences between corporate and controlling digitalization. The model expresses the level of digital capabilities as a ratio of the target value to the actual value of the metrics in a standardized way. Aggregated values derived from these KPIs compress the information into digital aspects,

perspectives, and areas along the hierarchical structure of the model. At the top of the model is a peak indicator representing the level of digitalization with a linguistic value. The evaluation method based on fuzzy logic enables the display of overlapping, subjective expert categories when assessing the level of digitalization. During the model evaluation, the digital organizational and controlling perspectives, dimensions, and KPIs expressed in linguistic descriptive categories are compared at each level. The evaluation of the metrics at the lowest model level explains the reasons for the differences at the higher levels, which can be used to determine the scope of the necessary management interventions and developments.

4. The concept of controlling digitalization orientation was formulated.

   Based on the case analyses, I determined that the controlling approach is not digitalization-centric, which hinders the digital transformation of controlling and cooperation with already digitalized areas. For this reason, I proposed extending the five traditionally recognized core principles of controlling (goal orientation, bottleneck orientation, future orientation, cost orientation, decision orientation) with a sixth principle: digitalization orientation:

   Digitalization orientation: the controlling system must be designed to align with the organization's level of digital maturity. This means that controlling processes must form an integral part of the organization's digital operations. The applied methods, technologies, tools, and the digital preparedness of controllers must correspond to the organization's digital level, thereby enabling the system to meet its evolving set of demands.

5. The theoretical concept of the controlling regulatory and control circle that fits the digital operation of the company was created.

   Based on the analysis of the differences between the corporate digital processes and the not yet digitized controlling processes, I developed the controlling and control circle shown in Figure 3. This defines two controlling processes running in parallel but with different frequencies, one fulfilling the traditional regulatory role, and the other performing a control function in support of the digital core operations. A The continuous maintenance of synchronicity and data consistency between the two forms the logical basis for the operation of the concept. A practical controlling system built on this logical basis can align with digital business operations or even with the principles of Industry 4.0 without compromising the traditional values and advantages of

controlling. The practical implementation of such a system can be based on the results derived from applying the UDM model I developed.

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