

ОБЩЕСТВЕНИ КОМУНИКАЦИИ И ИНФОРМАЦИОННИ НАУКИ
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**DESIGN-ORIENTED RESEARCH AS A METHOD FOR THE DEVELOPMENT
OF PROCESS-ORIENTED INFORMATION MANAGEMENT SYSTEMS**

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Abstract: *This paper examines the suitability of Design Science Research (DSR) as a methodological framework for the development of process-oriented information management systems (PIMS) for the analysis, evaluation and design of industrial processes. The starting point is the assumption that the conventional standard methods used in practice for the development of information management systems (IMS) do not meet scientific requirements regarding systematicity and transferability. The study shows that DSR is particularly well-suited as a scientific framework for the systematic development of PIMS. To this end, a DSR-oriented approach is described that combines top-down decomposition and bottom-up specification, whilst systematically integrating system boundaries, constraints, influencing factors and target variables. PIMS enable the capture of industrial processes, the process-oriented structuring of data, and the generation of synthetic data. This allows for a reduction in operational trials and a shortening of innovation cycles. Triangulated validation based on literature findings and model studies further strengthens the traceability, validity and transferability of the developed solution.*

Keywords: *Design Science Research; Process Modulation; Information Management Systems; Synthetic Data; Validation*

INTRODUCTION

In an increasingly dynamic economic world, companies are faced with rising demands for efficiency, quality, flexibility and sustainability. To remain competitive, they must continuously optimize their industrial processes. The systematic analysis and evaluation of technical processes is therefore becoming increasingly important. Particularly in the case of complex industrial processes, it is necessary to capture, link and evaluate relevant information in a structured manner. Process-oriented information management systems (PIMS) offer a suitable approach for this, as they map industrial processes in their essential contexts and enable the systematic consideration of relevant influencing factors (cf. Biethahn et al. 2004, p. 18). In daily industrial practice, however, the development of such systems is often based on established standard methods, such as VDI 5600. According to Kletti (2015, p. 27), these standardized or experience-based methods are primarily geared towards practical application. Although these approaches generally yield good, practical solutions, from a scientific perspective, they exhibit shortcomings in terms of methodological rigor, traceability and general transferability. This is particularly true when complex process relationships need to be modelled, different influencing factors have to be integrated, and robust statements regarding the effects of process changes are required. Against this background, the research question arises as to what extent Design Science Research (DSR) is suitable as a scientifically sound methodological framework for the development of PIMS in a systematic, traceable and transferable manner. DSR aims to systematically develop artefacts relevant to practice and evaluate them under scientifically sound conditions. This approach combines scientific knowledge acquisition and application orientation in a unique way and therefore appears suitable for both providing a methodological foundation for the development of PIMS and meeting the requirements of industrial practice. This paper examines the suitability of the DSR approach for the development of PIMS for the analysis, evaluation and optimization of industrial processes. At its core is a DSR-based approach that combines a top-down decomposition of complex processes with a bottom-up specification, whilst systematically taking into account system boundaries, boundary conditions, influencing factors and target variables.

The aim of this paper is to present a methodologically robust development framework for PIMS and thereby contribute to the scientific foundation of their design and application in an industrial context.

RESEARCH METHODOLOGY

Methodologically, the work is based on two interlinked components. Firstly, a qualitative literature review is conducted to establish the theoretical foundations of key terms such as information management, information management systems, PIMS and DSR, as well as to identify established concepts of system modelling, evaluation and validation. Secondly, field observations are used to identify practice-relevant requirements for the structuring of industrial processes, the definition of system boundaries and the consideration of influencing factors. By linking these two components, the suitability of DSR as a methodological framework for the development of PIMS is to be established.

RESULTS

Information management and information management systems

According to Krcmar, information management (IM) aims to “make the best possible use of information as a resource in line with the organization’s objectives” (cf. Krcmar 2015, p. 10). Biethahn et al. (2004, pp. 25–26) describe information management as “the systematic, method-driven planning, steering, monitoring and management of all information-related activities”. This also includes the collection, recording, processing, storage and provision of information, as well as the design of the organizational structures required for this (cf. Biethahn et al. 2004, p.28). No uniform definition of the term ‘information management system’ (IMS) could be found in the relevant specialist literature. Biethahn et al. (2004, p. 10) define it as “a system for meeting all relevant information needs, particularly within the context of operational decision-making processes” (Biethahn et al. 2004, p. 10).

Heinrich, Riedl and Stelzer (2014, pp. 4–7) also do not provide a straightforward definition, but make it clear that information systems can perform both technical and organizational functions. They support IM by structuring information flows and automating certain tasks. The terms IM and IMS are closely interlinked; consequently, a clear distinction between the two terms often appears neither feasible nor meaningful in practice. Whilst traditional IMS ensure the supply of information, PIMS are geared towards supporting all operational processes along the value chain. The focus here is on the systematic recording, analysis and optimization of manufacturing processes based on integrated and process-oriented information flows. PIMS enable a holistic view of processes and their interdependencies by consolidating information from various sources and making it available in a process-oriented manner. These systems can be adapted to specific process requirements and support change through dynamic modelling.

A key feature is the use of synthetic data, which can be generated through model-based simulation without affecting operational activities. This ensures that updated information is available at an early stage and forms the basis for well-founded, data-driven decisions. PIMS thus enable detailed analyses and evaluations of changes to industrial processes and are, therefore, an essential component of process optimization. Particularly where processes consist of modularly structured processes and sub-processes, an inadequately integrated IM frequently leads to inconsistencies. Data is stored in silos, key performance indicators are interpreted without regard to system boundaries, and whilst optimization measures may have a local effect, they sometimes impair the overall system. PIMS address this gap by not only collecting or managing information, but also consistently embedding it within a process-oriented context, thereby enabling a holistic view of partial and sub-processes. Their central task is to analyze the effects of changes in process variables in a targeted manner and to simulate different scenarios.

A key factor in the successful implementation of a PIMS is consistent process structuring. The foundation for this is provided by a combination of top-down and bottom-up approaches, with the system approach serving as the methodological backbone. Target variables are defined as measur-

able, process-relevant parameters that are influenced by input variables and are to be maintained or adjusted through control within a defined framework. They serve as a reference for evaluating system performance. The illustration in Figure 1 depicts a conveyor belt process and simultaneously demonstrates why the process-oriented perspective is of central importance. Electrical energy acts as an input variable, belt transport as a target variable, whilst waste heat generated by friction acts as an output variable. Furthermore, the kinetic energy of the belt movement can in turn act as an input variable for downstream processes. This simple example alone demonstrates that process variables cannot be interpreted in isolation, but occur in chains and feedback loops that must be visualized and accounted for within a PIMS. For more complex systems, the system approach developed by Biethahn, Mucksch and Ruf (2004, pp. 25–26), which views the overall system as the interplay of various partial processes and their mutual relationships. Processes whose further decomposition yields no new insights are defined as sub-processes. Of particular importance here are the interfaces between partial and sub-processes, as they determine the nature of the interaction, whether substance-related or informational, and influence the boundary conditions of the process structure. Following this logic, partial and sub-processes with a significant influence on the overall system should be treated as essential partial processes and given priority. They may be aggregated for the sake of simplicity in the analysis, provided that no relevant causal relationships are lost in the process.

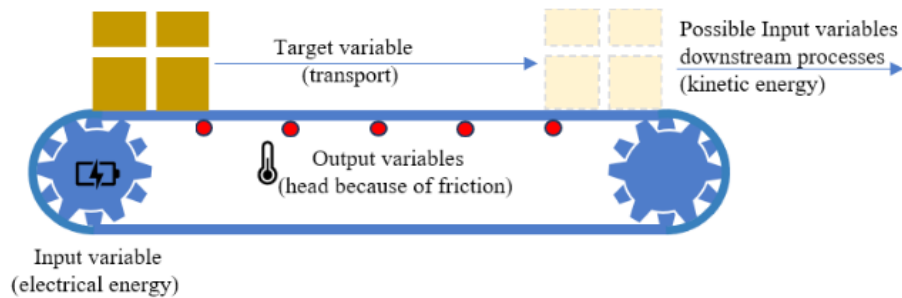


Fig. 1. Conveyor belt process for illustrative purposes (source: own illustration)

To ensure that PIMS do not become “unrealistic models”, a precise system definition is required. Terms such as boundary conditions, constraints, influencing factors and system boundaries, which are frequently used in information and control engineering, must therefore be clearly defined in the context of the selected process for the PIMS. Boundary conditions are to be understood as specifications or constraints that significantly influence the execution of a process or the design of a system. Typical boundary conditions are technical parameters such as temperature ranges, cycle times or physical system boundaries. Compliance with these is generally a prerequisite for a system to achieve its objectives. Influencing factors, by contrast, are described as dynamic variables that alter internal or external variables and can affect or modulate the process. Unlike static boundary conditions, they can change in response to alterations in the process flow, which is why a clear distinction between and consideration of both elements is essential for modelling and evaluation within the framework of a PIMS. Finally, system boundaries define the transition between the system under consideration and its environment, and determine which sub-processes, objects or data flows within the overall process are taken into account or are considered external influences. The targeted selection of system boundaries is regarded as a prerequisite for the transparency and consistency of process-oriented information management systems.

The conveyor belt example in Figure 1 also illustrates the practical significance of this distinction. Technical specifications of the drive motors may define a speed range as a boundary condition, whilst safety requirements without protective devices further restrict usage within this boundary condition as an influencing factor. The system under consideration comprises internal components such as motors, control systems, sensors, power supply and waste heat, whilst external elements such as material supply or onward transport lie outside the system boundary. For PIMS,

this results in the clear design requirement that the artefact must not only map process variables but also explicitly indicate which boundaries, boundary conditions and influencing factors apply, as otherwise simulations and evaluations cannot be interpreted and the risk of drawing incorrect conclusions increases.

Another key component of PIMS is the ability to generate synthetic data and thereby expand decision-making scope without necessarily having to carry out real operational trials immediately. The framework states that a PIMS developed using top-down and bottom-up approaches can serve as the basis for generating synthetic data. Synthetic data is also referred to as surrogate data and is generally not produced by measurement, but as the result of an algorithmic generation process. One way to generate synthetic data is through the targeted modification of existing data. The conveyor belt shown in Figure 1 can once again be used to illustrate this. A certain amount of electrical energy is required to move a mass from point A to point B. If additional or heavier packages are added, the energy requirement increases, and the mass being moved thus becomes a significant factor directly linked to energy consumption. It is precisely here that the added value of a PIMS becomes apparent compared to a purely physical analysis. Because although the laws of physics are well known, practical decisions (e.g. package sizes, load cases, operating modes) cannot be derived from physics alone. Rather, they require process-related analyses that take into account boundary conditions such as motor characteristics, friction coefficients and material properties in order to be able to model non-linear behavior as well. A PIMS does not necessarily have to be designed as a comprehensive software platform. A diagram comparing the motor characteristic curve and mass-dependent friction, and interpreting the overlap region as the optimal process range, already provides synthetic information about the load ranges within which the process can be considered optimal. At the same time, it can be deduced from this whether friction reduction or motor optimisation promises greater energy savings.

The Design Sciences Research Method

The Design Sciences Research (DSR) method, or the Design Sciences paradigm, as Hevner sometimes refers to DSR in his publications, has its origins in engineering (Hevner et al. 2004, p.76). According to Hevner et al. (2004, p. 76), DSR is a fundamental problem-solving paradigm that aims to create innovations, also referred to as an outcome or artefact. A deliberately designed and evaluable outcome that solves a specific problem whilst generating transferable design knowledge. According to Hevner et al. (2004, p. 76), ideas, practices, technical skills and products that enable the analysis, implementation, management and use of information systems to be carried out effectively and efficiently can also constitute artefacts. However, Hever et al. (2004, p. 76) explicitly point out that such artefacts are not exempt from the laws of nature. “Creation must always be based on existing core theories, which are applied, modified and expanded through the researchers’ experience, creativity, intuition and problem-solving skills” (Hever et al. 2004, p. 76). Weber, in particular, points out that the Design Sciences Research method is particularly suited to applied technical tasks, as this research approach combines practical utility with scientific rigor (Weber 2022, p. 102). Thus, the method of Design-oriented research, as described by Weber (2022, pp. 101–114), Benner-Wickner, Kneuper, Schlömer (2020, pp. 1–10), Hevner, Park, March, Ram (2004, pp. 75–105), and Österle, Becker, Frank, and Hess (2004, pp. 1–11), could represent a possible approach to the development of a PIMS. Hevner et al. (2004, pp. 101–114) first established guiding principles for the proper use of DSR in their paper “Design Sciences Research in Information Systems Research”. Österle et al. (2010, pp. 1–11) recommend the four-stage knowledge process shown in Figure 2 for application-oriented research.

The **analysis process** focuses on the systematic investigation of a practical problem and its application context in order to derive relevant requirements for the development of a suitable artefact.

The **design process**, which builds on this, comprises the targeted conception and development of this artefact based on the identified problem and the derived requirements.

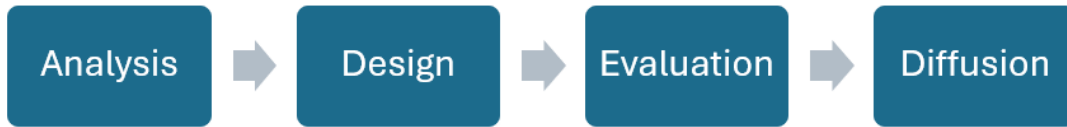


Fig. 2. Four-stage process according to Österle et al. (2010: 1–11), own illustration

The **evaluation process** then serves to systematically assess the developed artefact in terms of its suitability, effectiveness and achievement of objectives within the respective application context.

Finally, the **diffusion process** describes the preparation, communication and dissemination of the findings obtained, as well as the developed artefact, to relevant stakeholders in academia and practice.

Benner-Wickner et al. (2020, pp. 1–10) combine the guideline-based approach of Hevner et al. (2020, pp. 1–11) with the four-phase knowledge-generation process of Österle et al. (2020, pp. 1–11) and reinterpret both approaches, particularly in the context of applied research projects. The guiding principles further developed on this basis are summarised in Table 1 and classified with regard to the development of a PIMS.

Table 1. Guiding principles of Hevner et al. (2004, pp. 101–114) interpreted by Benner-Wickner et al. (2010, pp. 1–11), (own representation)

General guiding principles for DSR	Guiding principles relevant to the development of a PIMS
“Artefact design: DSR aims to produce a tangible result (artefact) and must achieve practical utility. This can be a method, a model or a product (Benner-Wickner et al. 2020, p. 5)”.	The PIMS itself is the artefact.
“Problem relevance: The result must solve an existing and current practical problem (Benner-Wickner et al. 2020, p. 5)”	Process changes or process optimisations to be investigated, for example, by using synthetic data
“Design evaluation: Whether the result solves the problem must be evaluated methodologically (Benner-Wickner et al. 2020, p. 5)”.	The literature describes various evaluation methods. In industrial engineering, case-based evaluation methods are frequently used, but these must meet the requirements of scientific quality criteria.
Research contributions: “In addition to solving the practical problem through the artefact, a contribution of general validity must also be made (Benner-Wickner et al. 2020, p. 5)”.	For PIMS, this implies that research hypotheses should be formulated as generally as possible and should not have a direct reference to a specific case study, unless this has relevance beyond the individual case.
Research rigor: When developing and evaluating the results, established methods from the literature must be applied correctly. Deviations from this are permissible if the deviation itself is the subject of the contribution (Benner-Wickner et al. 2020, p. 5).	For the development of a PIMS, this means that development and evaluation must be based on established methods from the literature. Deviations are only permissible if they are justified and themselves make a scientific contribution.
“Design as an optimization problem: Using Design Science Research, the result is developed incrementally in the search for the ‘perfect’ solution that meets all the framework conditions (Benner-Wickner et al. 2020, p.5)”.	The PIMS to be developed must be designed to be modular and expandable, so that new sub-processes can be integrated and existing ones re-evaluated in the event of changed boundary conditions.
“Publication suitability: The research contribution must be made accessible to the specialist audience (Benner-Wickner et al. 2020, p. 5)”.	As with any scientific work, publications are a mandatory component.

It is clear that both the general design principles of the DSR and the four-phase knowledge process can be applied to the development of a PIMS. Against this background, the DSR, as described by Benner-Wickner et al. (2020, pp. 1–10), can be regarded as a suitable methodological

framework for the development of a PIMS. The underlying logic of DSR corresponds to the central requirements of PIMS, such as the systematic structuring of complex problems, the goal-oriented design of an application-oriented artefact, its iterative further development, and the transparent evaluation of its effectiveness. DSR would thus enable a practice-oriented and, at the same time, scientifically sound conception of PIMS development.

Application of DSR to the development of a PIMS

If the four-phase DSR process, as shown in Figure 2, is applied to the development of a PIMS, a clearly structured procedural logic emerges. In the analysis phase, the PIMS to be developed is first situated as an artefact within the overall context of the development task. This involves identifying the underlying practical problem, assessing the state of the art, justifying the scientific and practical relevance, and defining the research object, research subject, and research aim. In addition, research hypotheses are formulated to ensure the traceability and subsequent verifiability of the research success. A further focus of the analysis phase is the establishment of a robust knowledge base. This comprises, on the one hand, the theoretical foundations of PIMS and, on the other hand, the subject-specific theoretical prerequisites of the use case. On this basis, key requirements for the PIMS are derived, particularly with regard to features, components, possible applications, boundary conditions, influencing factors, and input, output, and target variables of the relevant sub-processes. The analysis phase thus serves the function of both systematically structuring the problem domain and creating the conceptual prerequisites for the subsequent design of the artefact.

The design phase serves the systematic development of the PIMS as a solution-oriented artefact. In accordance with the DSR approach, the design does not take place in isolation, but is based on the requirements derived from the analysis and the results of the preceding literature review from the analysis phase. Methodologically, a top-down approach is combined with a bottom-up approach. First, the overall process is broken down into its essential partial processes in order to identify structural elements, interfaces and process-determining factors. Subsequently, the identified partial processes are gradually recombined into a consistent overall system. This development process involves identifying the essential partial processes, determining their boundary conditions, and evaluating and balancing them. The successive integration of the partial processes results in a quantifiable overall process that constitutes the actual PIMS. A key feature is that the system is not limited to the mere management of existing information, but, through the model-based linking of process-relevant variables, also enables the generation of synthetic data, thereby creating a basis for simulation, comparison and decision support.

The artefact design phase is followed by the evaluation phase, during which it is assessed whether the developed PIMS is suitable for addressing the identified practical problem in a methodologically sound manner. This phase of PIMS development may include, amongst other things, literature reviews, model studies, the actual creation of the PIMS, and its validation. In this phase, a relevant literature review no longer serves to build a general knowledge base, but rather to provide a sound basis of data and findings for the evaluation. This can be supplemented by model studies, which can be used to analyze selected aspects of the process under consideration in particular. The findings obtained from the literature review and model analyses are then integrated into the overall system to verify the validity of the PIMS.

Validation is hypothesis-driven and takes into account limiting and influencing factors. In this context, validation can be designed using a triangulation approach, whereby different sources of knowledge are systematically brought together and compared with one another. This ensures that the validity of the PIMS is not assessed from a single perspective, but is verified on the basis of several complementary approaches. In this way, it is examined whether the artefact allows for robust statements regarding the effects of process changes and thus meets the requirements of a scientifically sound and practically usable PIMS.

Finally, in the diffusion phase, consideration is given to the extent to which the research aim has been achieved, what further questions arise from the results, and what scientific and practical benefits the developed PIMS offers. This involves a critical assessment of the system both in the context of the specific case study and with regard to its transferability to other industrial process-

es. The result of the work is thus not merely an information system limited to a single case, but a referenceable model that can serve as a methodological basis for the development of further PIMS. In this sense, the diffusion phase fulfils the task of making the research contribution visible beyond the immediate application context and highlighting the relevance of the developed artefact for science and practice.

CONCLUSIONS/DISCUSSION

If the structure and logic of the PIMS, as well as the rigorous approach of the DSR, are consistently followed, the DSR proves to be a methodologically suitable approach. This is particularly true as PIMS are not merely technical systems, but also perform organizational and decision-support functions. In contrast to non-process-oriented information management systems, which primarily serve to provide and manage information, PIMS specifically focus on process knowledge in order to analyze, evaluate and further develop complex industrial processes. In this respect, they are particularly concordant with the fundamental principle of DSR, according to which scientifically sound and at the same time practically relevant artefacts are developed to solve specific problems. A further key argument for the particular suitability of DSR lies in the fact that PIMS cannot be understood as purely technical applications, but rather as designed artefacts in which models, data structures, process logic, and decision-making mechanisms are systematically brought together. It is precisely this combination of design, application, and scientific reflection that aligns with the philosophy of DSR. The strength of the top-down and bottom-up approaches becomes clearly evident when applying the DSR approach to the development of a PIMS. The systematic decomposition of the overall process into relevant partial and sub-processes serves to enable the bottom-up approach to integrate real data, process variables and dependencies. It is only by combining both perspectives that a PIMS can realistically map the process logic and actual information flows of industrial systems. This iterative combination of theoretical modelling and practical design is characteristic of DSR in particular. The strength of PIMS is most evident in modularly structured process chains, in which technical, economic and organizational factors, among others, can be considered together. Here, PIMS enable a holistic analysis of process interrelationships as well as the use of synthetic data to investigate scenarios, conflicting objectives and the effects of change. In doing so, they provide a basis for well-founded decisions without relying on costly or high-risk real-world experiments. Precisely because DSR is geared towards the development of problem-oriented and application-specific artefacts, this research approach offers a particularly suitable framework for the development of such systems. Furthermore, DSR focuses not only on the design but also on the systematic evaluation of the artefact. This is of central importance for PIMS, as their scientific and practical viability depends significantly on the quality of the data basis, the validity of the underlying models, and the transparent consideration of system boundaries and influencing factors. Triangulation, in which, in particular, findings from the literature, model investigations and integrated system evaluations are systematically linked, corresponds to the DSR concept of a methodologically sound artefact evaluation. In this way, it is possible to rigorously verify whether the developed PIMS enables reliable statements about process changes and thus meets both scientific and practical requirements.

Overall, it becomes clear that DSR is not merely a viable but a particularly well-suited methodological framework for the development of PIMS. The strengths of DSR lie precisely in that combination of problem-solving, artefact design, scientific grounding and systematic evaluation which is constitutive of PIMS. PIMS can therefore be developed not only meaningfully but also particularly consistently within the framework of Design-oriented research. DSR should even be regarded as the ideal methodological approach for structuring PIMS, validating them in a transparent manner, and making them scientifically transferable beyond individual cases.

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ДИЗАЙН ОРИЕНТИРАНИ ИЗСЛЕДВАНИЯ КАТО МЕТОДОЛОГИЧЕСКА РАМКА ЗА РАЗРАБОТВАНЕ НА ПРОЦЕСНО ОРИЕНТИРАНИ СИСТЕМИ ЗА УПРАВЛЕНИЕ НА ИНФОРМАЦИЯТА

Резюме: В тази статия се разглежда приложимостта на Design Science Research (DSR) като методологична рамка за разработване на процесно ориентирани системи за управление на информацията (PIMS) за анализ, оценка и проектиране на индустриални процеси. Изходна точка е предположението, че конвенционалните методи, използвани в практиката за разработване на системи за управление на информацията (IMS), отговарят само в ограничена степен на научните изисквания по отношение на систематичността и приложимостта. Изследването показва, че DSR като научна рамка е особено подходяща за систематичното разработване на PIMS. За тази цел се описва подход, ориентиран към DSR, който комбинира разлагане от горе надолу и конкретизиране от долу нагоре, както и систематично интегрира системни граници, гранични условия, влияещи фактори и целеви величини. Разработените PIMS позволяват регистрирането на индустриални процеси, процесно ориентираното структуриране на данни, както и генерирането на синтетични данни. Така могат да се намалят експлоатационните изпитания и да се съкратят иновационните цикли. Триангулативната валидация въз основа на литературни данни и моделирани изследвания допълнително укрепва проследимостта, информативната стойност и приложимостта на разработеното решение.

Ключови думи: изследвания в областта на науката за проектирането; модулиране на процесите; системи за управление на информацията; синтетични данни; валидиране

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