Handling the Complexity of Tool Selection Processes – Simulation Data Management in the Automotive Supplier Industry

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Abstract: Both the number and the complexity of numerical mechanical simulations are constantly increasing. This leads to increasing quantities and higher interconnectedness of the resulting data objects. In order to manage the emerging complexity and to enable new concepts such as the digital twin, it is therefore necessary to have a future-proof simulation data management system (SDM system) in place. This paper illustrates how the complexity of IT landscapes for simulation data management can be handled by an approach for model-based IT architectures (MBITA®). The matrix-based approach helps to analyze the current collaboration processes and derive the requirements for a future SDM tool. The approach is used in a case study from the automotive supplier industry, leading to a basis for a systematic and traceable tool and vendor selection.

Keywords: IT Architectures, MDM, Process Modelling

1 Introduction

1.1 Motivation and Goals

Both the number and the complexity of mechanical simulations (e.g. finite element analyses, computational fluid dynamics, multi-body Simulations, 1D simulations, etc.) are constantly increasing (Schlenkrich, 2015; Roehrle et al., 2012). This leads to increasing quantities and higher interconnectedness of the resulting data. To enable new concepts such as the digital twin, future-proof simulation data management systems (SDM systems) are therefore necessary.

These systems are specialized in establishing a continuous and (as far as possible) automated process chain from model building to simulation and reporting of the results. An SDM implementation has the potential to increase efficiency (Krastel, 2021).

Given the complexity of modern IT landscapes, a structured IT architecture management is necessary in order to enable the full potential of an SDM system. This paper shows a combination of methods from structural complexity management and model-based engineering to ensure traceability in tool selection and implementation processes. This gives the possibility to trace elements from activities in the product development and simulation processes via tools in the current landscape and pain points in today's everyday work to features and requirements for a new tool.

1.2 Description of the Case Study

Magna's powertrain group is an operating unit of Magna International and a long-term premier supplier for the global automotive industry with full capability in game-changing powertrain design, development, testing and manufacturing. In addition to producing transmission systems and drivetrain systems, they also provide metal-forming as well as engineering services.

The case study in the automotive supplier industry the afore mentioned approach was applied in had the goal to implement a data management system to manage the data of the various simulation departments worldwide.

In order to introduce such a system, it was essential to thoroughly analyze the current CAE processes as well as IT landscape in order to come up with a profound list of requirements for a new system. The paper shows the process, the applied approach, as well as the results of the case study.

2 State of the Art and Applied Methods

2.1 Simulation Data Management

While product data management (PDM) and product lifecyle manamgent (PLM) systems are wide spread in the automotive and the automotive supplier industry, simulation data management is often done manually or via PDM or PLM systems.

However, for the successful use of PDM systems in the simulation domain, the existing simulation models of the respective model description languages must be integrated without loss of information. Due to the large number of languages used, the approach of implementing a product data model for all languages is associated with a high level of effort, since a separate adaptation of the PDM system is necessary for each model description language. (Krastel, 2002)

Therefore, a dedicated simulation data management system is necessary, which becomes a prerequisite for future developments like the digital twin (Schweiger-Recksiek et al., 2020). However, their implementation is not common practice as of today, even though many companies are now aware of the potential offered by a cross-domain, integrated simulation data management and a stronger integration of simulation data into PDM/PLM processes (Krastel & Tabbert, 2005). Figure 1 gives a Schematic View on Simulation Data Management in the Product Lifecycle according to Charles & Eynard (2005).

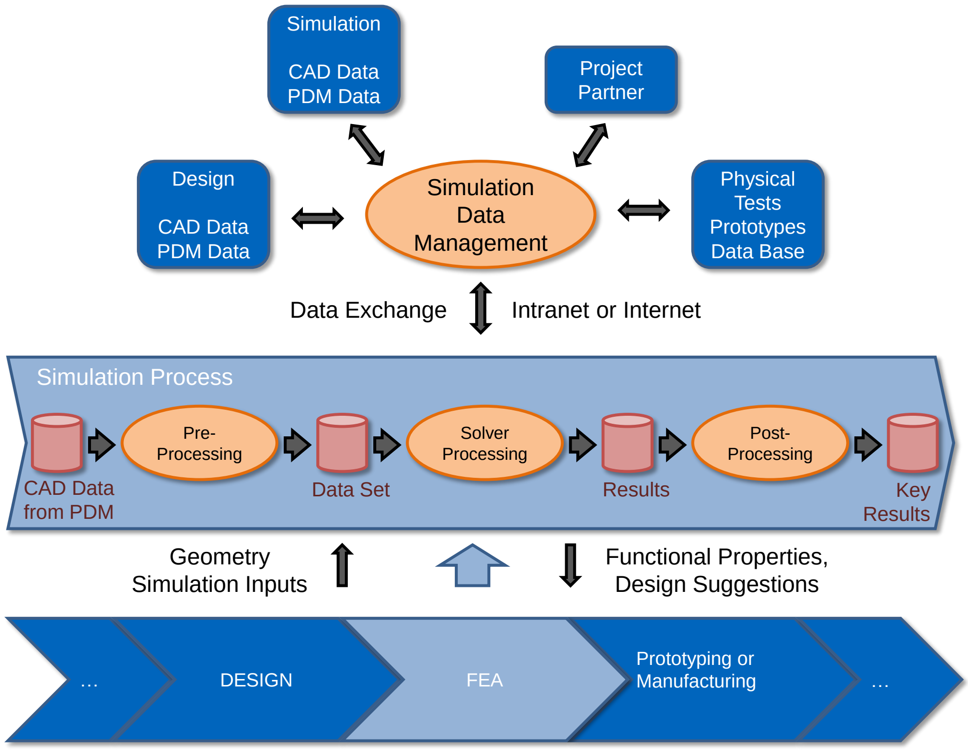

Figure 1. Schematic View on Simulation Data Management in the Product Lifecycle according to Charles & Eynard (2005)

In Summary, SDM includes all methods, processes, and tools that are important for the simulation and calculation as well as the activities and interfaces that are necessary to integrate CAE in the overall product development process.

2.2 Enterprise Architecture Management

The approach of this case study, as presented in the next section, uses methods of enterprise architecture management (EAM) for the design of a suitable IT architecture (lowest bar in Figure 2). A holistic digitization strategy not only includes the digitization of products and production systems, but also processes, methods and the IT architecture. Enterprise architecture management is an analytical discipline that provides methods to comprehensively define, organize, standardize, and document an organization's structure and interrelationships in terms of certain critical business domains (physical, organizational, technical, etc.). It serves to capture the relationships and interfaces between domain elements as described by their processes, functions, applications, events, data, and employed technologies. (Dedić, N., 2021)

While only partially intended disruptive forces often influence business visions, EAM enables the holistic and collaborative steering of decision-making processes towards the development of a future-proof enterprise architecture at all levels. (Gartner, 2022)

Through a combination of top-down and bottom-up strategy elements EAM methods make it possible to reconcile the requirements of the various business levels with the system and IT infrastructure-side capabilities. Figure 2 shows the EAM architecture pyramid (adapted from Dern, 2006).

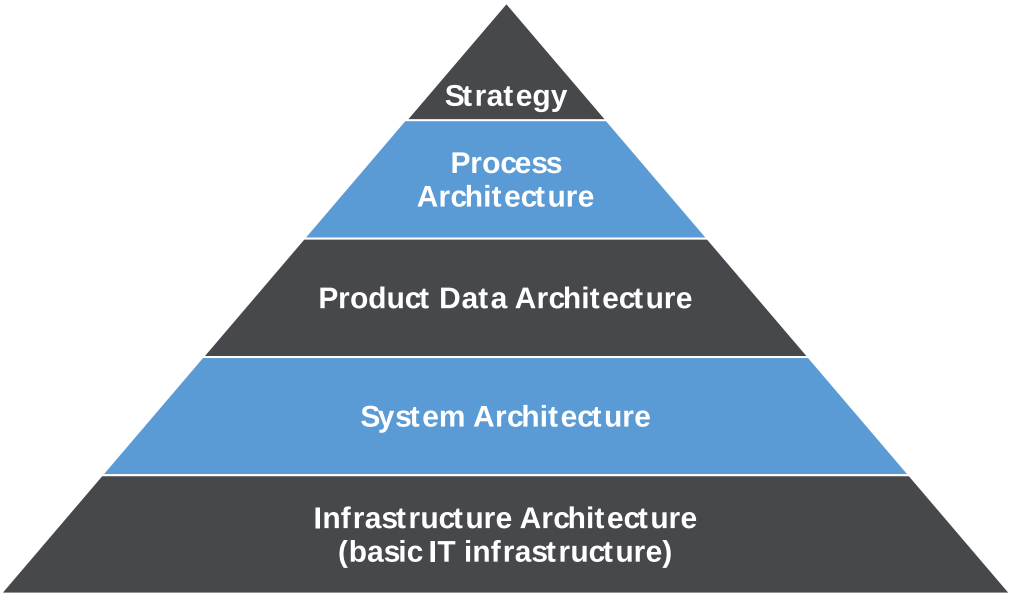

Figure 2. Architecture Pyramid (adapted from Dern, 2006)

2.3 Structural Complexity Management

Modern product development processes are often complex systems consisting of various subsystems or rather domains (Lindemann et al., 2009; Eppinger and Browning, 2012). In order to understand and manage this complexity, it can be helpful to model the entire system. This requires that various domains of interest as products and people as well as relations between the elements of the domains are considered (Browning, 2001).

For modeling the relations between diverse elements of a subsystem, the Design Structure Matrix (DSM) of Steward (1981) is a widely used method. The DSM depicts direct dependencies between elements of the same domain. The Domain Mapping Matrix (DMM) is used for direct dependencies between the elements of two different domains. To visualize both direct dependencies within a single domain as well as across different domains in one matrix, Maurer developed the Multiple Domain Matrix (MDM) (Lindemann et al., 2009).

Methods of structural complexity management also include graph-based methods next to the matrix-based methods described in the previous paragraph. Both of them have proven beneficial for the improvement of engineering information flows and collaboration structures (Schweigert-Recksiek & Lindemann, 2020, Schweigert-Recksiek, 2022).

3 The Approach – Model-Based IT Architectures

Model-based approaches have long been applied in the development of products and production systems. The application of model-based principles also enables the direct link to value creation processes, their information and IT systems in the field of EAM. In this way, the traceability of decisions that require a change in the IT technological framework of a company can be raised to a new level.

As a registered trademark of :em engineering methods AG, MBITA® brings the existing IT application landscape into an overarching End2End process context. MBITA® focuses on the areas of product data architecture and system architecture, at the interface of which requirements from value-creating business processes must be translated into the necessary capabilities of an IT architecture. However, this does not happen without influences and dependencies on the part of corporate strategy and process architecture as well as the basic IT infrastructure. Figure 3 shows the building block approach for IT architecture definition of MBITA®.

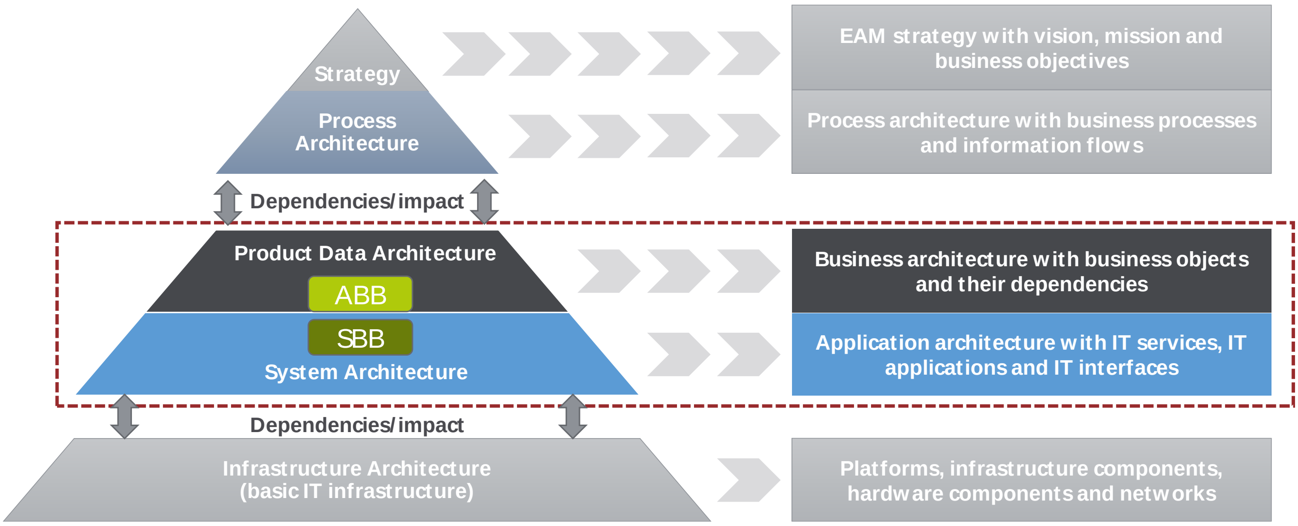

Figure 3. Building Block Approach for IT architecture definition

The principle of a comprehensive information repository and various views on the same data reduces the complexity of IT application landscapes and avoids redundancies. The MBITA® model is a customizable template and extends typical EAM approaches by the overarching process context as well as in-depth information about the data used in it as well as its formats (cf. Figure 4). With this additional information, it is possible for a company not only to find a suitable software solution that meets the defined IT requirements. MBITA® directly identifies required interfaces to other areas and processes, so that the use case of a specific domain is fulfilled, but also a solution that fits seamlessly and traceably into the enterprise architecture together with its interfaces.

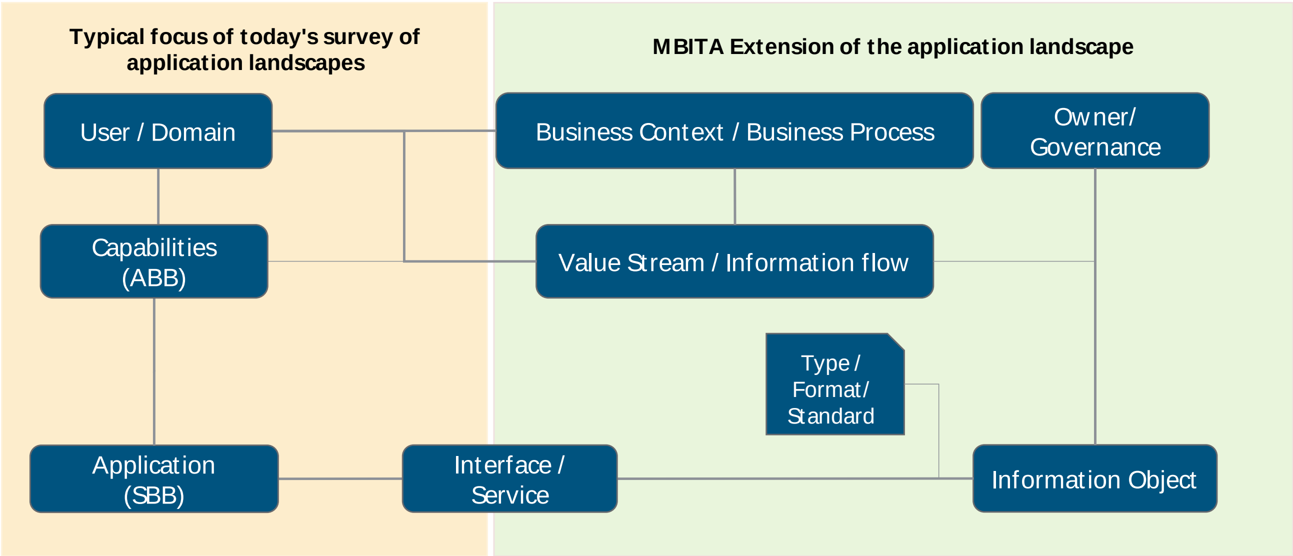

Figure 4. Elements of the Information Architecture

4 Application in the Case Study

4.1 Overview of the Analysis and Tool Selection Process

With the goal of building a solid foundation for the tool selection and vendor decision, the MBITA approach, as described in section 3, was applied to the case study (cf. Figure 5). **As-is processes** were recorded in interviews to link **activities**, **stakeholders**, and **tools** with **pain points**. These pain points were grouped to **fields of action** before these fields of action were mapped to typical **capabilities** of SDM systems. Based on an analysis of the current and desired SDM capabilities of the client's IT infrastructure and the **use cases** of different stakeholder groups, **features** were derived, against which a shortlist of possible tools was evaluated. After this evaluation, the use cases were grouped and **user stories** were formulated out of the use cases. The sum of user stories formed the so-called **story book** that served as input and script for the vendor presentations.

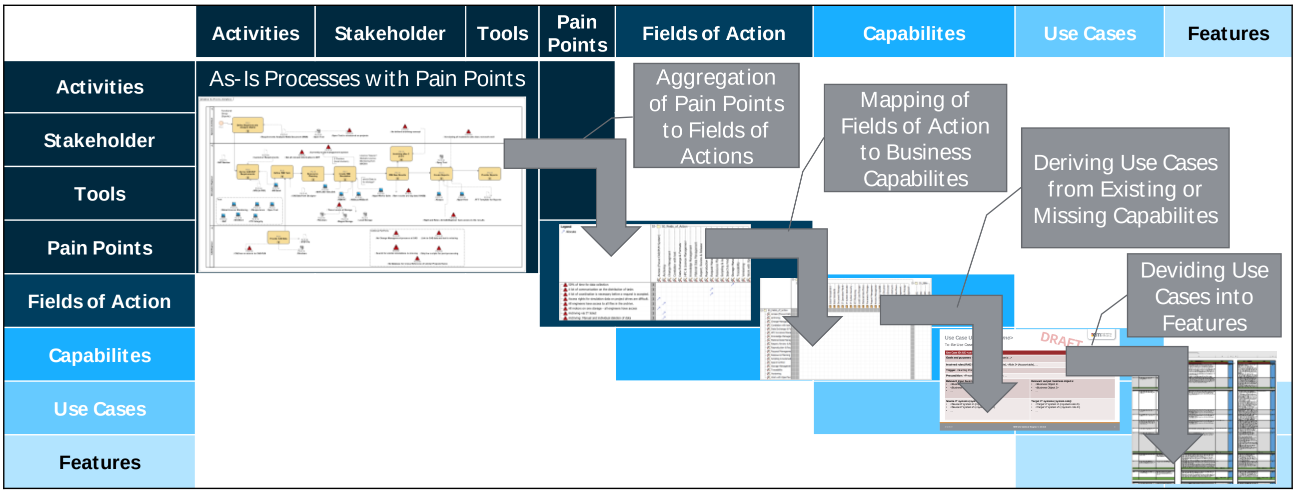

Figure 5. Matrix-based Connection of System Elements

As the analysis of the current processes was modelled in a central repository (cf. next section), a complete traceability from activities stakeholders, tools, and features was possible. As a result, when evaluating the features of different SDM systems, the impact of not fully fulfilled requirements concerning certain features could be analyzed directly.

The following sections describe the different phases of the tool selection process in more detail.

4.2 Phase 1: Process Modelling

In the first phase of the analysis, workshops with simulation engineers and managers from different locations were performed. The goal of the workshops was to identify the current way of work of the stakeholders. The different activities, the relevant IT tools and data repositories, as well as the current pain points were documented in ten process models. Figure 6 shows an example of a process model out of the domain of finite element analysis. Due to confidentiality reasons, the details are blurred. Activities (yellow boxes), tools (blue icons), and pain points (red triangles) are still visible, though.

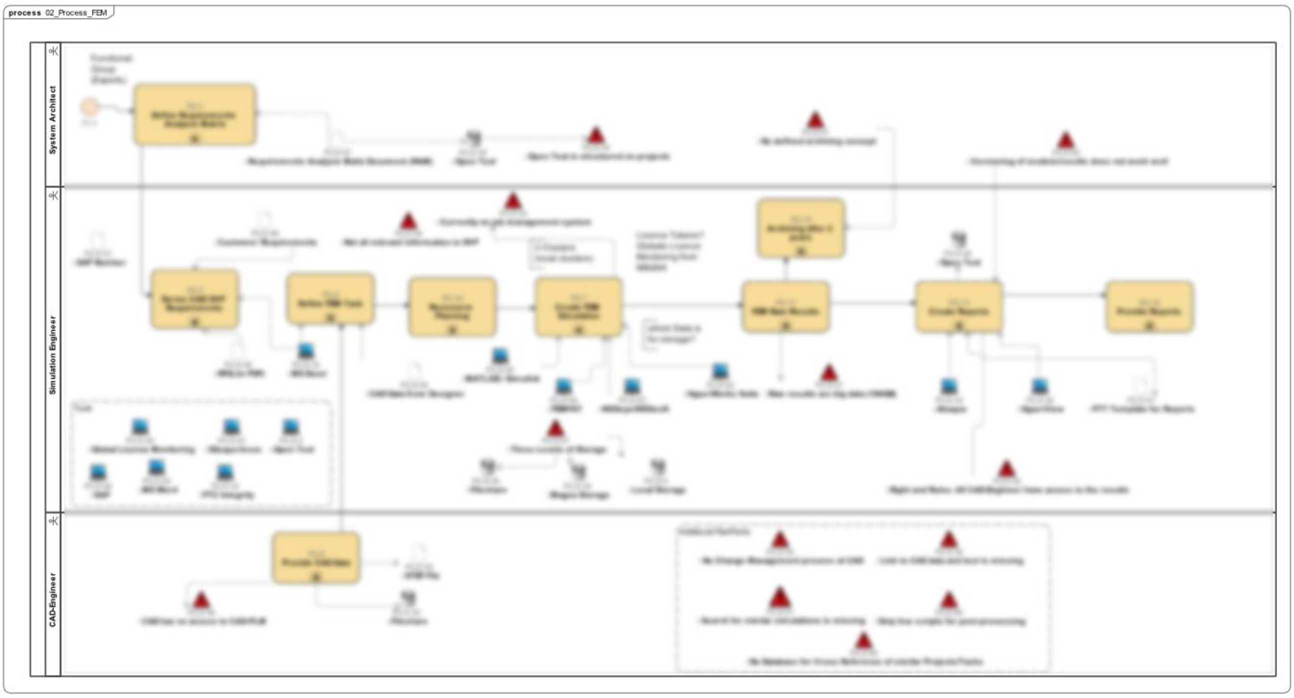

Figure 6. Example of the FEM Process (as-is) with Related Pain Points and Tools

The process analysis with in total 24 simulation engineers and managers resulted in 130 pain points in the current as-is processes. Figure 7 shows the Multiple Domain Matrix (MDM) of the process in Figure 6 with the relations between the domains activities, tools, information objects, data storages, and pain points.

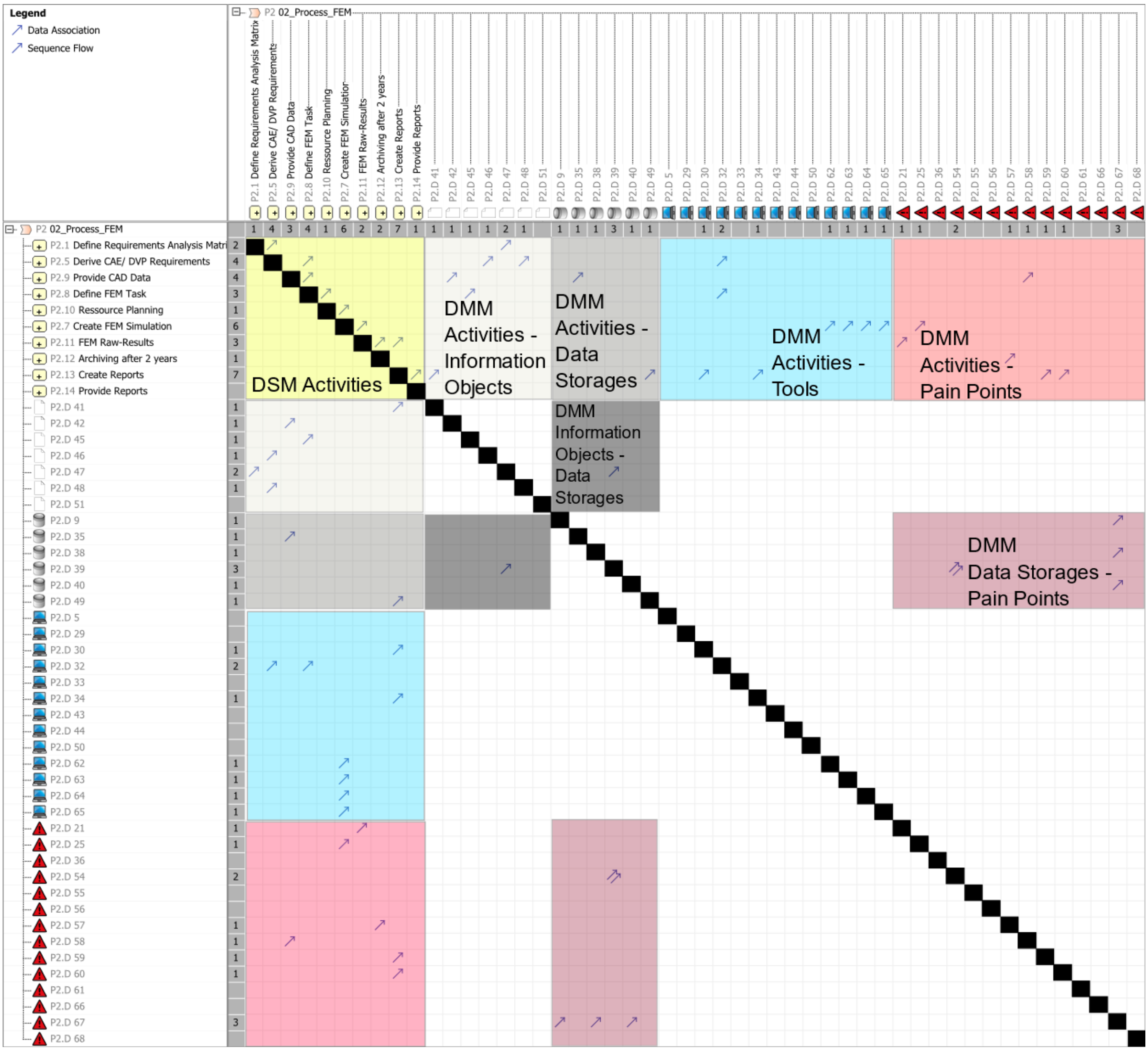

Figure 7. MDM of Activities, Information Objects, Data Storages, Tools and Pain Points of the FEM Process

The MDM is symmetric, which means that relations are displayed above and below the diagonal. As the information flow was not analyzed in detail, no information about the relations between information objects exits. The corresponding DSM of information objects is empty.

As the aim of the analysis was the preparation of a new simulation data management system, pain points related to data storages were of particular interest. Figure 8 shows the Domain Mapping Matrix of data storages and pain points. Pain point P2.D 67 reads as “Three different storage locations” as indicated by the relations to the three data storages. Such weaknesses in the IT landscape that prevent the creation of a single source of truth had to be eliminated in the following.

The DSM of the activities (upper right corner of the MDM in Figure 7) is already sequenced, as there are no relations below the diagonal. As a consequence, no feedback loops exist in the process.

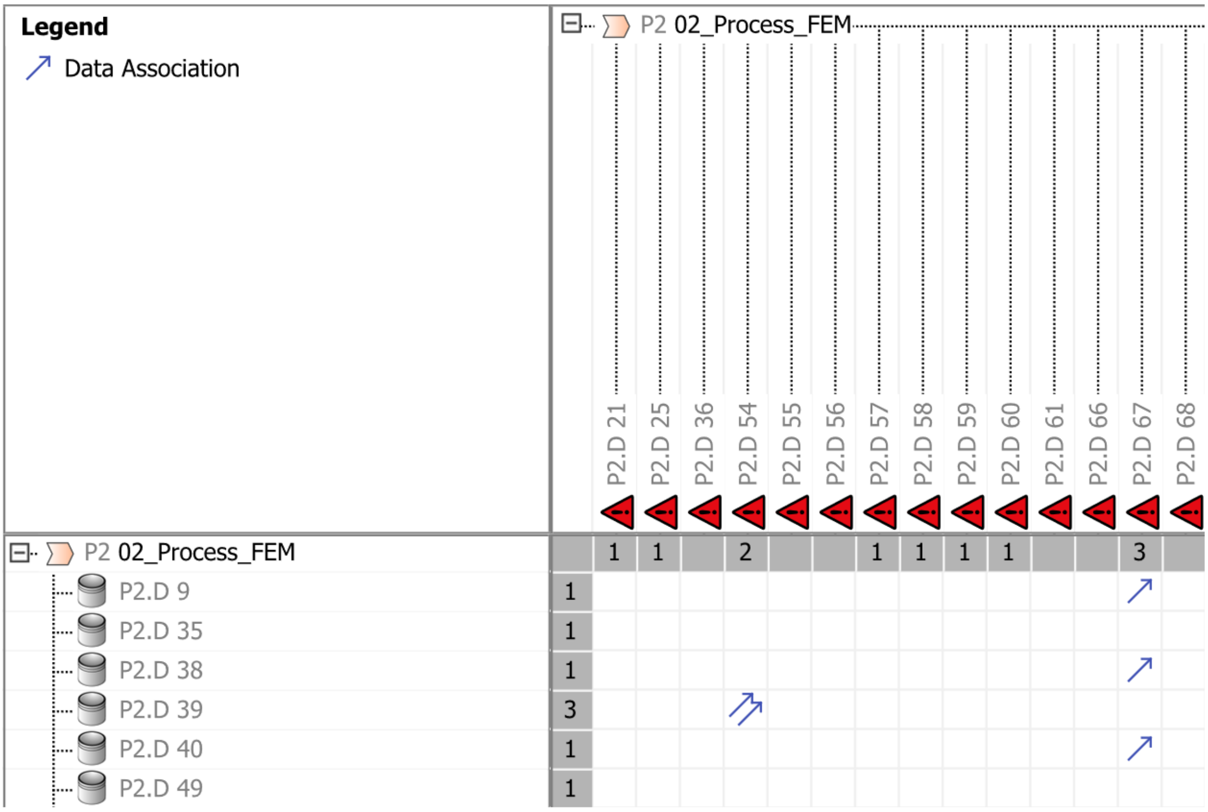

Figure 8. DMM of Data Storages and Pain Points

To analyze the pain points, they were grouped to fields of action. A set of typical fields of action in simulation processes based on experience of the involved consultants was supplemented by specific fields of action of the automotive supplier. Figure 9 shows an excerpt of the DMM between pain points and fields of action. Due to confidentiality reasons, the pain points are not explicitly shown.

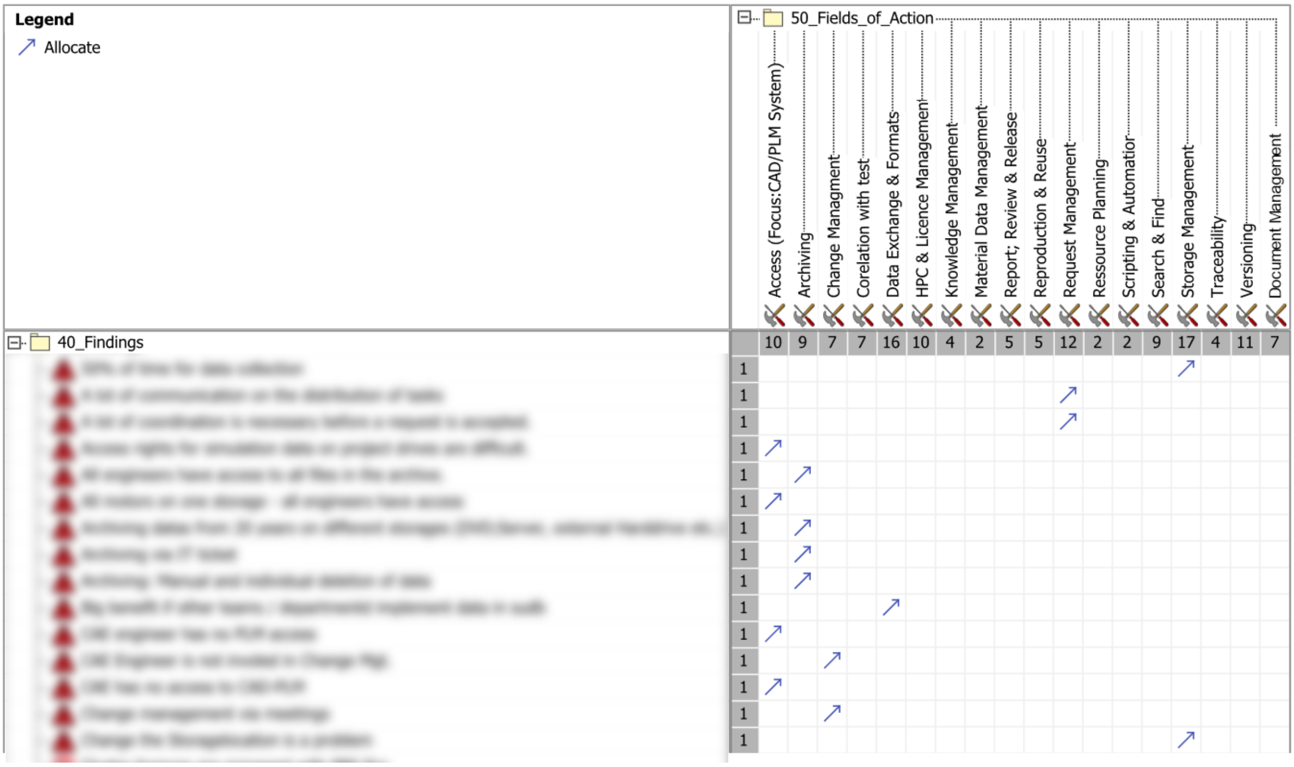

Figure 9. Mapping of Pain Points and Fields of Action (excerpt)

The initial situation was characterized by extreme heterogeneity: There was a high number of different simulation and data handling tools as well as different data storages. Moreover, structural heterogeneity complicated the tool selection process due to various, globally distributed locations of the employees as well as structural incompatibilities in processes and organizational structure due to various acquisitions in the past years. Last but not least, a diversity in the mindsets of the users, the used technologies, and diverging maturities (e.g. clusters/HPCs, cloud, tool landscape) were present to a significant degree. This resulted in very different levels of „SDM-readiness“ throughout the company. In many places, the functioning of the current systems dependent heavily on the long experience of a few stakeholders.

Additionally, various inhouse tools were in use. Some of them were highly sophisticated and essential for the work of the engineers. However, they had to be replaced in the long run due to the company’s IT strategy and security as well as issues with further development.

4.3 Phase 2: Analysis of SDM Capabilities

Figure 10 gives an overview of typical capability clusters that current SDM systems offer. They were derived from the experience of the involved consultants as well as market research. Behind each cluster are four to twelve capabilities. For example, the cluster “Core CAE Data Management” includes capabilities like “CAE Model Management”, “Parameter Management”, and “Simulation Variant Management”.

In a workshop, the current IT landscape was analyzed to see for each of the capabilities, whether they are already covered in the self-made tool that was to be replaced, in some other tool of the landscape or not covered at all yet.

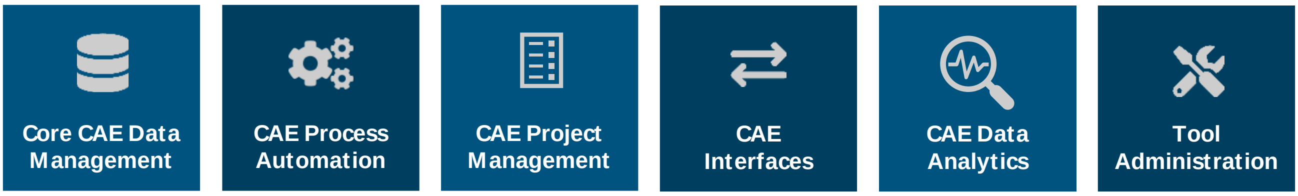

Figure 10. Overview SDM Capabilities Clusters

4.4 Phase 3: Deriving of Use Cases

To derive the use cases for a future SDM system as well as in order to rank them according to their importance, a hybrid approach was used. An online survey was used to gather the tools currently in practice (as a cross check to the process models of the first phase) as well as a ranking of typical SDM use cases before diving into company-specific use cases.

Based on the preceding analysis, drafts for to-be use cases were derived and discussed in multiple workshops with the respective stakeholders (cf. Figure 11). Five such use case workshops with a total number of 11 simulation engineers and managers were performed. This resulted in a total of 16 Use Cases from four different stakeholder groups.

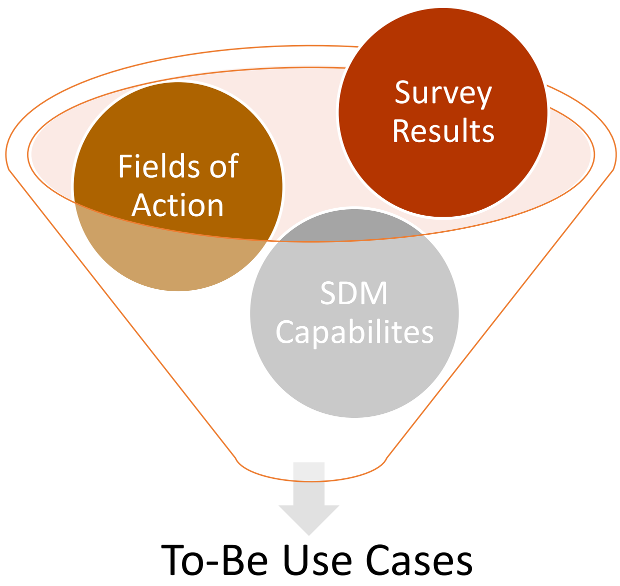

Figure 11. Deriving To-Be Use Cases from the Given Inputs

For the description of the use cases, their goals and purposes, the involved roles (according to the RACI method), the relevant business objects (input and output) as well as IT systems (source and target) were documented (cf. Figure 12). These one pagers were supplemented with the according activities that had to be performed to carry out the use case.

Use Case UC-2: Initiate Relevant Simulation Tasks and provide Meta Data — To-Be Use Case Description

Use Case ID: UC-2	Initiate Relevant Simulation Tasks and provide Meta Data
Goals and purposes: Create simulations tasks based on the output of the internal planning tool and provide the necessary meta data	
Involved roles (RACI label): DV Engineer (R), Component Responsible (C), Simulation Engineer (C), Project Team (A)	
Relevant input business objects: • Meta Data (transmission, vehicle, engine, housing number) • Internal standards towards quality • PDF (relevant data from Book of Requirements, e.g. external loads) • Step/Iges/JT/.CATPart (Geometry) • Input parameter (loads, etc.)	**Relevant output business objects:** • Simulation assignment
Source IT systems (system role): • Internal planning tool	**Target IT systems (system role):** • Internal SDM tool

Figure 12. Example-Use Case: UC2 – „Initiate the Relevant Simulation Tasks and Provide Meta Data”

4.5 Phase 4: Deriving of Features, User Stories and Activities

In order to fulfil the use cases of the stakeholders, features were formulated that the new SDM solution has to offer. 57 functional criteria were derived from the 16 use cases named above. These functional criteria were supplemented by requirements from IT and purchasing, leading to 22 IT criteria and 19 purchasing criteria respectively.

As no prioritization was regarded as necessary between the features, each of them was formulated in a “The SDM shall…” pattern. As an example, Feature 2.1 from Use Case 2 in Figure 12 reads as: “The SDM shall provide a list of standard simulations tasks.”

All 98 criteria (functional, IT, and purchasing) were sent to a shortlist of vendors for them to give statements about whether their software offers the features. Based on the analysis of their feedback, the shortlist was further reduced to define the final set of vendors, which was invited to give presentations of their SDM solution.

In order to make these vendor presentations comparable and focus on the most relevant aspects from the point of view of the stakeholders at the case study partner, user stories were formulated that served as a script for the vendor presentations. A user story combines multiple use cases in a logical order so that they add up to a typical situation the users will want to use the SDM in. Two user Stories were formulated. As an example, user story 1 comprises of use case 02 and five further use cases as shown in Figure 13.

US01	Perform a New Simulation Task (Initiation, Execution and Result Storage)

“As a **Simulation Coordinator** I would like to initiate a new simulation standard task in SDM, add a task description with requirements, carry out the resource planning and assign the task to a **Simulation Engineer**. This Engineer will search and add relevant meta data and ensure the traceability of the data. During the process, data from one simulation discipline is transferred to another (e.g. 1D to 3D). After the execution of the simulation, a report shall be generated and stored automatically, including meta data and key results. This forms the basis for a comparison with test results, When major steps of the workflow are completed (e.g. input data available, finalization and release of report), the SDM shall send an automatic notification to the relevant stakeholders.”

Figure 13. User Story 1 – “Perform a New Simulation Task”

Based on the two user stories, several vendor presentations were conducted. The analysis of the assessment of these presentation lead to the selection of a vendor for a following proof of concept. The details of this process as well as the selected vendor cannot be displayed here due to confidentiality reasons.

5 Conclusion

Limitations

As with most techniques of structural complexity management, one of the main limitations of the applied MBITA approach lies in the modelling effort that is necessary up front without direct benefit at the beginning of the project. The main benefits of this model-based approach can only be achieved in later stages, so that companies might refrain from starting the model-based selection process in the first place.

Contribution

The academic contribution of this paper lies in the transfer of matrix-based methods for structural complexity management in the area of IT Architectures via the MBITA approach as well as in the application of this approach on an industrial case study in a real-world environment. The example of a tool selection process for a simulation data management system shows the applicability of these methods

The industrial benefit of the MBITA approach used in this case study is a methodical and systematic way to guide tool selection processes and a solid foundation for a vendor decision. As the area of simulation data management is characterized by a myriad of different methods and authoring tools, such an approach has even more benefit.

Outlook

During the creation and review process of this paper, the vendor selection for a new SDM took part. The activities shown in section 4.5 served as a guidance for the vendor presentations that lead to a vendor decision. The repository with all the system elements named above (e.g. activities, tools, data storages, etc.) will play a major role in the planning of the proof of concept, which is the next step in the introduction of a new SDM system for Magna's power train group.

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