Using Process Simulation to Assess the Effect of Data Format Standardization in Collaborative Processes

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***Abstract*— Data quality plays an important role in the context of collaborative engineering and virtual enterprise. Drawing on business process management perspective, this paper attempts to gain deeper understanding of data format standardization in B2B processes by using process simulation methodology on data drawn from a large industrial project situated in automotive industry. Analysis results of this process from the virtual engineering domain show that implementation of the data format standard does have a positive effect on business process performance in terms of process costs and execution time not only for the main manufacturing enterprise but also for its suppliers. These findings have implications for data quality and standardization initiatives illustrating the use of simulation technique for process performance evaluation.**

Keywords- Data in supply chain collaboration, data management, business process simulation.

I. Introduction

Process changes that are induced by re-engineering activities of process elements like activity, data or organizational structure are difficult to assess without implementing the process in real life. Simulation tools can support this assessment by providing first insights into the new process. Complex simulation scenarios require high amounts of data on the process details as well as on business process environment. Using business process modeling and simulation software enables process documentation that contains process details as well as subsequent process simulation based on the documented process flow and included information on process logic and tasks. This analysis technique is applied here to assess the effects that are induced by the introduction of a format standard for data interchange and documentation on process performance within a collaborative process in automotive industry.

Being the foundation of business to business (B2B) communication, data needs to be managed towards several aspects. In 1999 a survey performed by NIST (National Institute of Standards and Technology) revealed that the economic cost of bad data exchange processes in the US automotive industry is $1 billion per year [7]. Similar studies with similar results have been conducted in Japan and Germany [16]. This problem can be approached from two angles: considering intrinsic or extrinsic aspects related to data exchange process. Intrinsic aspects cover data content and its structure, whereas extrinsic aspects relate to issues appearing during data translation [2].

Here, intrinsic aspects of data exchange in the context of collaborative engineering are put in focus. Simulation-based design tools in manufacturing context make it possible to analyze the behavior of complex products without constructing their physical prototypes. Manufactured parts can be virtually tested so that design and tolerance problems are detected in an early phase saving costs and time. This virtual prototyping can simulate a crash test with a virtual car and analyze dynamic behavior of mechanical parts.

Two main simulation types can be distinguished [2]: Discrete event simulation and geometric (continuous) simulation. A case study from the second type situated in the context of a major German car manufacturer is analyzed in this paper. Heterogeneous simulation and design software as well as accordant data standards in the context of virtual engineering cause interoperability problems as well as process performance drawbacks within the considered supply chain. A consortium containing a major German car manufacturer as well as involved simulation partners was founded to develop a continuous simulation process to eliminate the mentioned drawbacks.

One of the most important measures to achieve the goal of a continuous simulation process is the development of a data format standard that supports data transaction requirements in automotive industry with the focus on the virtual prototyping process. As the common format an XML-based data format was developed and implemented throughout the process of virtual prototyping. To perform data exchange a central information system has been envisaged. Selecting XML as the data interchange syntax provides for enough freedom in structuring geometric data, at the same time ensuring that different proprietary standards can be made interoperable. XML is an open data format recommended by [17] for all communications between the elements in a mediator-based system that allows platform- and system-independent encoding and integration of semi-structured data. Benefits of this standardization effort are expected on the output and process levels [19] supporting efficient and safe task execution [9]. Data is considered as the lowest level of abstraction resulting from measurement, that is storable in documents, i.e. semantically structured files, and processable using specific syntax.

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There is relatively little research activity in this domain, thus to close this gap, the guiding research question of the paper is focused on how to assess the impact of data format standardization in virtual prototyping on the process level. As the actual roll-out of the process is cost-intensive and requires re-structuring of the processes of the involved actors this question is addressed using the process simulation method. Furthermore, simulation allows creating “before” (as-is) and “after” (to-be) scenarios.

Using the method of process simulation with time and cost related indicators on the as-is and to-be process that includes integration of the common data format, the question of the direction of the effect induced by data format standardization is addressed. The results show positive changes in the process performance measured using process simulation. This effect is referred here to the data format standardization. Although, these results might be expectable, only little scientific evidence on this matter exists. Furthermore, these results can be used by managers of collaborative processes to promote data standardization in the particular environment.

The reminder of the paper is structured as follows. In Section II related work on the effects of data standardization as well as simulation in business process management context is presented. Section III describes the case study in focus as well as the process under analysis. In Section IV the applied research method as well as the simulation set-up is described. Analysis results are presented and discussed in Section V. Conclusion and outlook finish the paper.

II. Related Work

The effect of electronic data interchange (EDI) as paperless transmission of business documents between trading partners has been extensively covered in research. MacKay [6] defines EDI as “paperless transmission of business documents between trading partner application systems, via a computer and communications network, in a standard message format”. Survey-based research by MacKay [6] showed that the component sector in automotive industry did experienced benefits from EDI adoption being among others: improved relations with trading partners, improved data accuracy as well as increased productivity. Keller et al. [12] showed that external collaboration, i.e. collaboration between supply chain actors, does not directly improve logistical effectiveness, measured in costs. Nevertheless, their research shows that collaboration with external supply chain entities influences increased internal collaboration, which in turn improves logistical service. Rajgopal and Abdumalek [1] use a case-based approach to demonstrate how lean manufacturing tools can help process industry to obtain better overall financial and operational control. Therefore, they apply the value steam mapping (a simulation method by Rother and Shook [10]) on snapshot data such as inventory levels before each process, process cycle times, number of workers, and changeover times. They also use “before” and “after” scenarios as well as value stream mapping in order to demonstrate potential benefits of lean manufacturing tools.

In the research area of business process management, business process simulation has been widely used for business process re-engineering [5], [15], [4] as well as organizational design [3] and quality assessment [18] among other domains.

Business process simulation has gained a lot of attention in the context of business process re-engineering in 1990ies as a tool to support managerial decision and illustrate potential effects of a newly designed business process without significant financial effort. Business process simulation aims at assisting the process of modeling and analyzing organizational structures. Use of simulation in the context of business process re-engineering is based on the approach to computer-aided analysis expressed by [11]. Being an operational research technique simulation has a major advantage as it allows experimentation with any element of a business system [3] being used in order to measure, understand, and predict the metrics of process improvement and quality [5] and to explore the effects introduced IT-support on the process performance.

III. PROCESS CONTEXT AND DESCRIPTION

The goal of this paper is to use a case-based approach to demonstrate how data format standardization influences process performance. Here, the virtual prototyping process of a major German car manufacturer is analyzed. Since some of the information is confidential, the company is referred to as Construction throughout this paper.

In the context of automotive manufacturing numerous actors are involved in the cooperative and digitalized development and manufacture planning composing a virtual or extended enterprise. Figure 1 shows the general architecture for the IT-supported processes during the product creation. Multiple actors are involved and different IT-support levels are needed to bring a (manufacturing) product to life. Here, the process of virtual prototyping of car parts consisting of the subprocesses: forming, joining, drying and crashing is considered.

The sub-processes are performed by different actors that use different Computer Aided Engineering (CAE)-systems and data formats. Only after all the sub-processes are successfully performed and functionality of the parts is given, the parts can be built. Therefore, the process considered here is centered at data generation and transmission. The sub-processes are organized in a way that their sequence and thus generated data is crucial for the subsequent step. Without the data following sub-processes cannot be executed. The as-is process is shown in figure 2. Due to the heterogeneous architectures of the cooperation partners the prototyping process is currently time and cost consuming.

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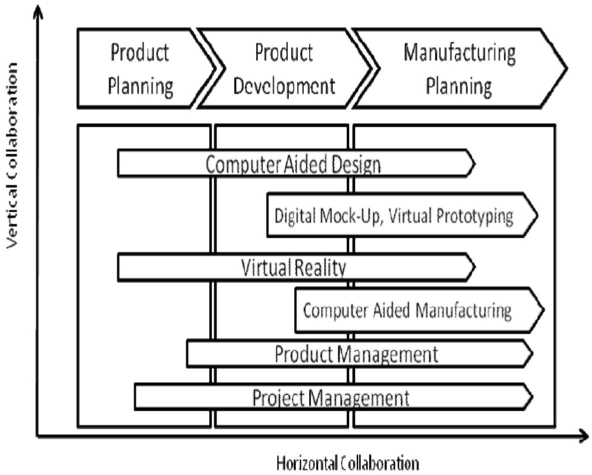

Figure 1. IT-support during the product creation process [13]

To overcome the mentioned shortcomings, process actors built a consortium to develop a continuous simulation process that will be based on a data format standard, i.e. common data definitions, representation, and structures. This initiative is based on the expectation that this standard will allow a more robust process as well as diminish the effort of data transformation, i.e., the time and costs expenses. Thus, the main goal of the consortium is to integrate heterogeneous software and enterprise architecture and enable a continuous simulation chain from the concept to the product. As standard language for data structuring and transmission XML has been chosen and the process flow has been subsequently adapted to the emerged changes. Figure 4 shows the envisaged to-be process that includes the data management system(s) that supports collaboration and data exchange between process actors.

The process is situated in the automotive industry and describes prototype simulation within a construction process. Main actor is the car manufacturer (Construction). Parts (virtually) designed by the Construction need to be (virtually) tested in numerous scenarios to identify their fit and possible quality drawbacks before being sent for actual realization. Thus, the process contains four simulation sub-processes (see figure 2): forming, joining, drying and crashing. These simulations are performed by different simulation partners (abstracted in the collapsed pool: simulation). Only when data from all simulations is derived and approved, the simulation process can end and the parts can be sent for physical construction.

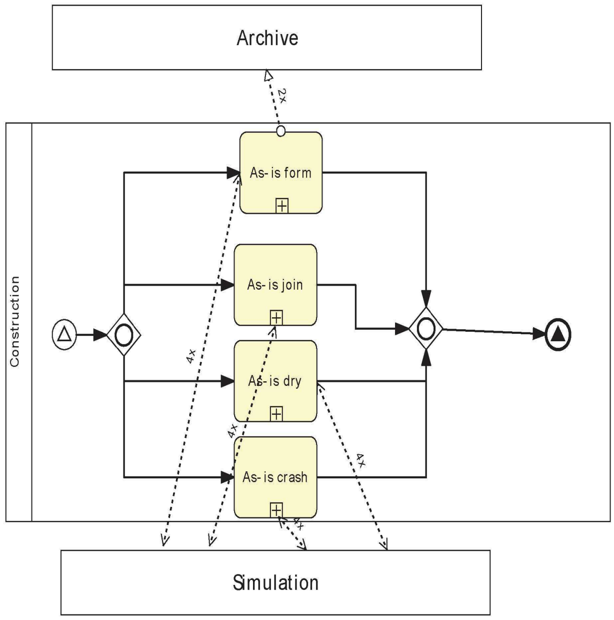

Figure 2. As-is process: generalized cooperation view

Figure 2 shows the cooperation activities between process actors, i.e., as-is simulation process from the abstract view point. Figure 3 shows an example of an as-is sub-process, here: drying, on a detailed process level.

The sub-processes are structured in a similar way. First the part has to be designed by the Construction and a contract with the simulation partner has to be negotiated. Then, Construction collects the data needed for simulation and sends this data to the accordant partner. The partner has to evaluate data for their completeness and correctness. If the data is not sufficiently elaborated, the partner sends the data back to Construction for re-work. Re-worked or complete initial data are then preprocessed, simulated and post-processed by simulation partner and the results are sent to the Construction. Construction receives the results, evaluates them according to the test goals and disseminates them to further partners involved in the subsequential manufacturing activities.

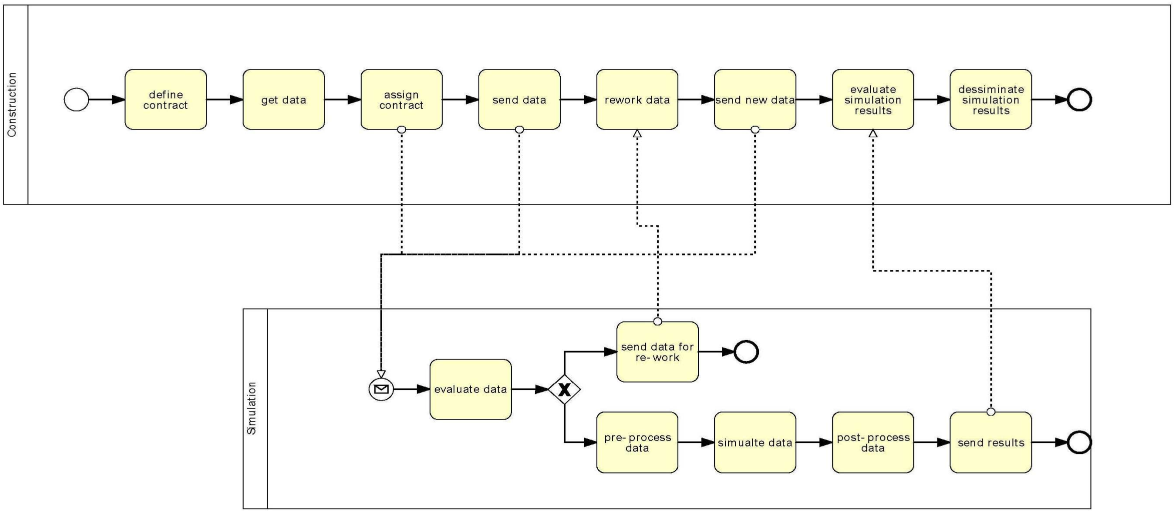

Figure 3. As-is process: sub-process (simplilfied)

As mentioned above, the as-is process provides potentials for performance enhancement that are addressed by the new data format standard. The re-engineered business process includes information systems that manage and convert incoming data into the defined format. Therefore, the process structure is changed to accommodate data management support and conversion efforts. In the process model these changes are visible through the addition of an extra pool called information systems (IS) that includes three application systems supporting cooperation in and execution of the process. Figure 4 shows the abstract view on the re-engineered to-be process.

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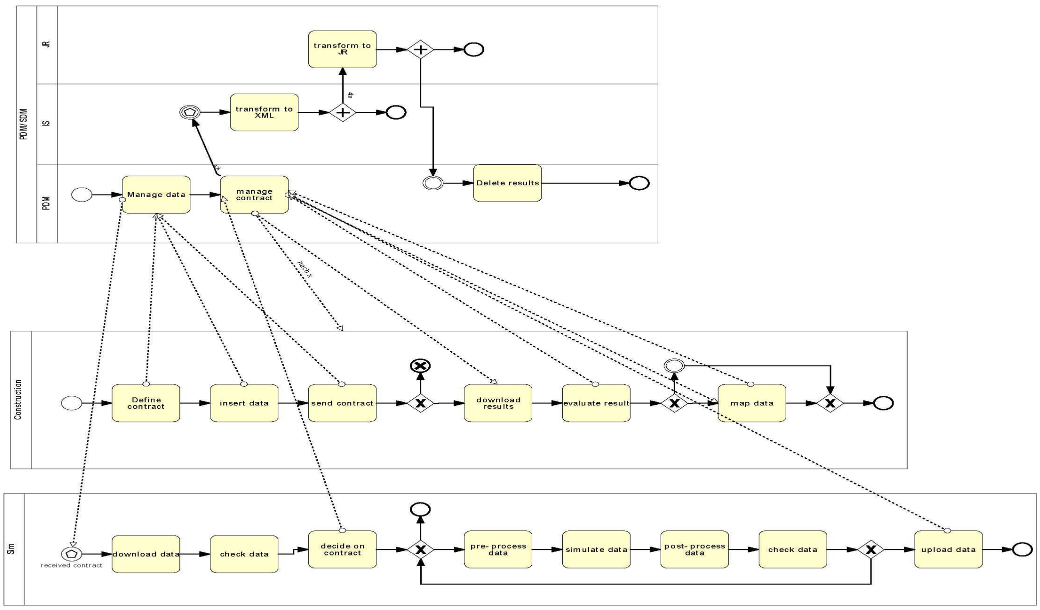

Figure 4. To-be process: abstract view

Using these “before” and “after” scenarios process performance change is now analyzed towards the effect of data format standardization.

IV. SIMULATION SET-UP

The main research method that was used here to assess the research question whether data format standardization has an impact on a collaborative business process performance was business process simulation. The choice of the research method allows assessing the effect of standardization on process performance and structure in different business domains as well as industries. The simulation set-up is briefly described here. Figures 2 and 3

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show the as-is process on the abstract level as well as an example of one of the sub-processes accordingly.

Two processes, as-is as well as the to-be process, have been simulated and their results were compared (see Table I). A case-based research methodology was chosen here with the aim to provide an example of practice and test the proposition that the supporting tools of process mapping and business process simulation can illustrate the effect of data standardization on the process performance. Although a single-site study has obvious limitations with respect to the generalizability of the findings, the case is not aimed at being representative, but rather exemplary. Thus, the researcher does not need to assume that the simulation results that were retrieved are exhaustively representative for all similar situations (same reasoning has been successfully applied in [14]).

To perform business process simulation of the described processes, they have been modeled according to interviews, workshops and documentation using Business Process Modeling Notation (BPMN) as well as enriched with detailed information on their organizational and temporal structure.

Derived information as well as the business processes have been modeled using Adonis® 2.01 community edition software. It is a business process analysis tool supporting business process management, specifically simulation and calculation of business performance indicators, such as human resources, process costs, etc. It allows business process modeling using BPMN, process analysis, simulation, evaluation as well as publishing and process automation with BPMN 2.0 XML.

To gain an insight on the effect of the introduced data format on the business process performance, the process has been modeled and simulated using two different scenarios.

In the first scenario, the as-is process as described in interviews, workshops and documentations has been represented. In the second scenario, data management system and accordant process adjustments due to the new data format have been modeled. The overall duration of the simulation was set to five years in working days with 8 hours per working day and 190 working days per year (excluding holidays and vacation time) for both scenarios. Activity costs were assigned according to the data elevated in interviews.

Hlupic [4] suggests a process for business process simulation that consists of the following phases that were also adopted in the presented research:

- Define modeling objectives;
- Decide on model boundaries;
- Collect and analyze data;
- Develop business process simulation model;
- Test model;
- Model experimentation;
- Analyze output;
- Provide business process change recommendations.

Hlupic [4] suggests this proceeding for evaluation and decision support. Thus, the last phase is omitted here as the goal of the research is not recommendatory but rather exploratory. The modeling objective here is to document a business process to perform scenario-based performance evaluation using business process simulation. The model boundaries are the process boundaries, including process actors and their processes involved in the virtual engineering in the given case study.

Data has been collected to define the process flow as well as performance characteristics such as time, costs and frequency of an activity. The simulation model used here, has been developed to include the process (logic and temporal) flow as well as execution times as defined by process workers in the as-is process. For the to-be scenario expert interviews were led with process workers, process managers and process owners to derive an estimate for realistic task times and costs. The to-be process has been modeled and simulated.

These results were presented to the interviewees to assess their feasibility. Simulation results of both scenarios as well as their comparison are described and discussed in the following section.

V. RESULTS

A. Simulation Results

Results of the process simulation are shown in Table I.

Process cycle time is elevated in days: hours: minutes: seconds format. Costs are expressed in money units (MU). Activity times are measured for one execution cycle (process cycle). Delta is computed in hours for the time metrics and as the difference in change between “before” and “after” metrics.

Process execution time represents the sum of activity times without consideration of their parallel execution, while process cycle duration represents the time for the actual process flow.

Performance quotient is an additional metric that enables a better assessment of time and costs performance of the process. It is calculated as the quotient of costs and actual process execution time.

Simulation results show that process cycle duration of the to-be process is larger than in the as-is process. This is due to the fact that the goal of process re-engineering was to create a continuous process where the sub-processes are executed sequentially rather than parallel as it is the case in the as-is process. Nevertheless, execution time of the to-be process is by 19.59% shorter and costs by 17.83% lower than in the as-is process. This effect is also reflected in the sub-processes, suggesting that simulation partners also benefit from data format standardization. The performance quotient of the to-be process is more than 88% higher than for the as-is process indicating a more effective process flow.

TABLE I. RESULTS OF PROCESS SIMULATION

KPI	As-is process	To-be process	Delta(in%)
Process cycle duration	4d:00h:09min:20s	6d:01h 52min:47s	+ 55.12
Process execution time	38d:07h:26min:43s	32d:04h: 25min:22s	- 19.59

Process costs (MU)	25772	21176	-17.83
Performance quotient (MU/ cycle duration in h)	802	425	-88.41
Cycle time (costs): Join	1d:3h:45min:14s (5937)	1d:02h: 36min:04s (5453)	-11.9 (-8.88)
Cycle time (costs): Form	7h:38min:27s (3175)	7h:06min:59s (2899)	-8.03 (-9.52)
Cycle time (costs): Dry	4d:9min:20s (13076)	3d:48min:40s (10047)	-29.44 (-30.15)
Cycle time (costs): Crash	1d:28min:48s (3583)	6h:49min:26s (2828)	-25 (-26.7)

B. *Discussion of Results*

Business process simulation performed using business process modeling and simulation software was performed here to assess the effect of process element changes on process performance. Here, the context of virtual engineering, which relies on data management and exchange was analyzed. The goal of the to-be scenario was to design a continuous, sequential collaborative process for automotive parts simulation and thus to improve process performance. Therefore, a data standard was developed to make data exchange and its use of the CAE more efficient. Subsequentially, processes of the actors needed to be adjusted. As this is a costs- and time consuming transformation, its effect on process performance was measured using time and costs indicators in a process simulation.

Results in Table I show that the sequential flow of the process increased the process cycle duration by almost 50 per cent. Nevertheless, the other performance indicators such as process costs, process execution time as well as cycle times of the subprocesses were decreased resulting in a better performance quotient of the process.

In the context of collaborative processes implementation of a common standard can be difficult as process members need to adopt their IT- and business infrastructure. Using the simulation it is now possible to outline the time and cost related benefits for process participants, creating a common ground for discussion on the adaptation of the standard.

VI. Conclusion and Outlook

In this paper, the question has been addressed how data format standardization can affect process performance and structure. Business process simulation has been chosen as a method to assess performance changes in terms of time and costs. The results show that introducing a data format standard led to a continuous process flow that induced positive implications on process performance not only for the main manufacturing enterprise but also for the service partners.

Results of the business process simulation showed that the re-engineered to-be process provides a better performance quotient due to both number of activities and cost reductions. Cost and time benefits are also passed over to simulation partners. This positive development is supported by the subsequential analysis of quality measurements performed with the simulated parts from the as-is and to-be process as well as real-life parts. These results provide insights that are crucial for managing collaborative processes. They show that measurements performed on virtually simulated parts in the to-be engineering process are more precise and allow insights into characteristics of the constructed parts that were not possible using data derived in the as-is process [8]. These research results can be used to assess the need for data standardization initiatives. Thus, future work will include a more extensive research on product costs and quality changes due to the data format standardization.

Nevertheless, limitations of the presented research are obvious: only one process has been analyzed and only limited feedback from process management was collected. Also, the effects on the role distribution in the process as well as knowledge transfer that have been changed due to the changed standard need to be explored in the future research. Furthermore, future research need to include the analysis of the use of semantic technology such as RDF or OWL as they can provide an increased interoperability in collaborative processes and compare process performance difference to the performance gains induced by the use of XML documented here.

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