IDENTIFICATION OF FACTORS INFLUENCING COST AND BENEFIT ASPECTS OF CROSS-COMPANY DATA EXCHANGE USING THE EXAMPLE OF THE STEEL INDUSTRY

Nikita Fjodorovs*, Alan Gütermann, Tobias Wagner
Institute for Industrial Management (FIR) at RWTH Aachen University,
Campus-Boulevard 55, 52074 Aachen, Germany

ABSTRACT

Purpose: In the last decade, enterprises realized the high value of data and learned to successfully utilize it for internal processes and business models, and they are trying to find more ways to acquire relevant data. Since enterprises are part of complex networks, the data from their partners and customers can also be beneficial: from adjusting the demand and supply to planning production and aligning capacities. One such example is adaptive process control: detailed material data from a supplier can be used to adjust process parameters in their production. This approach may be especially beneficial for the steel industry, as there is a possibility to adjust the material properties by changing the speed, force, or temperature in their own production processes. However, such an approach requires tight collaboration, e.g., regarding improving IT infrastructure, ensuring data acquisition and transfer and most importantly, the utilization of such data.
Approach: First, through literature research potential cost and benefit aspects regarding data exchange were identified. Second, conditions for the influence factors were defined. This determines which (qualitative) characteristics they must fulfil in order to be considered as such. On the one hand, there should be minimal overlaps of influence between the factors, and, on the other hand, the influencing factors should have a direct impact on the cost and benefit aspects. Finally, a qualitative analysis was conducted to determine the characteristics of the cost and benefit aspects under the influence of the factors.
Findings: 18 cost aspects in 6 categories as well as 14 benefit aspects in 3 categories were identified. 7 influence factors in 3 dimensions (strategy, technology, product) were determined. Additionally, an analysis, how each factor influences the cost and benefit aspects (only major influences will be described due to the page limit)
Originality/value: Cost-benefit-analysis is only useful on a specific use case. Trying to create a general analysis for a whole industry leads to high ranges for the cost and benefit aspects. The results of this paper help companies to understand, on which influence factors should they focus in order to either decrease costs or increase benefits of cross-company data exchange.

Keywords: Cross-company data exchange, intercompany data exchange, supply chain data management, cost-benefit-analysis, steel industry

Introduction

Data is becoming an increasingly important asset for manufacturing companies. Product and manufacturing-related data can be utilized to optimize decision-making, internal processes, reduce throughput times, and enhance product quality (Falck and Koenen, 2020; Brynjolfsson *et al.*, 2011). Moreover, data integration can contribute to the development of new products and services by acquiring knowledge about product usage and customizing products to meet individual customer requirements (Fritsch and Krotova, 2020).

Furthermore, data can be shared among different companies within a supply chain. Numerous research articles and studies have already explored successful cooperation in data sharing within supply chains, offering promising results. For instance, a study demonstrated that companies could reduce bullwhip effects by sharing demand signals or capacity (Erdebilli *et al.*, 2022). Successful implementation of functioning

supply chain tracking can lead to inventory capacity reductions up to 50 %, resulting in increased profits across the supply chain (Winterhoff *et al.*, 2016). Other studies suggest that data exchange with supply chain partners, along with the consideration of data from external sources, can enhance the resilience of a supply chain during disruptive events (Janßen *et al.*, 2022; Stich *et al.*, 2021).

A special case can be observed in the steel industry. It is possible to produce different types of final products from one semi-finished product thanks to the high adjustability of steel as a material. This adjustability is not only limited to the primal material creation (melting and solidification) but also extends throughout further production steps (e.g., rolling or heat treatment). Key parameters here mainly include the chemical composition, microstructure, and crystal lattice (Verein Deutscher Eisenhüttenleute, 1984). As a result, metal products go through a multi-step production chain from ore to semi-finished products, ultimately leading to the final product. Due to the complexity and cost of production, it is profitable to carry out the manufacturing process efficiently by specializing and producing large quantities. Therefore, the supply chain in the steel industry represents more of a process chain, involving several companies in the manufacturing of a final product. At each processing step, data is generated within individual companies, but during the transition between different companies, only a portion of this collected data is shared. For example, shared data on specific and detailed material properties can be used for adaptive process control – to set more suitable machine parameters to achieve better quality and reduce scrap.

When establishing cross-company data exchange mechanisms, a relevant and crucial challenge is that economic incentives are not immediately apparent. The measurement of the net benefits (benefits minus costs) of the utilization of internal data is easier in comparison to the implementation of cross company data exchange. The net benefit of data exchange depends on multiple parties and initially means higher effort for the data producer. For example, sharing data only provides a benefit if it is used by the data recipient, but the costs or effort on collecting the data lies on the data producer. Furthermore, the protection of a company's own data against misuse, unauthorized viewing or use, modification, or falsification is also a risk for the data producer (Rückert *et al.*, 2021).

This paper aims to present the influence factors that have an impact on costs and benefits of cross-company data exchange and to describe their characteristics. This creates transparency of dependencies and approach the possibility of integrating cross-company data exchange into investment calculations and thus create a higher incentive for its introduction.

Approach

To achieve the aim of the paper, three main research steps were made. In the first step, relevant cost and benefit aspects were identified. For the identification of the aspects a systematic literature research according to Levy and Ellis, 2006, was conducted. Following search string was used: (“inter-company” OR “cross-company” OR “supply chain”) AND (“(data OR information) exchange” OR “(data OR information) transfer” OR “(data OR information) management” OR “(data OR information) collaboration”) AND (“benefits” OR “costs” OR “cost benefit analysis” OR “motivation” OR “implementation”); in following academic data bases: Elsevier (ScienceDirect), ProQuest (ABI/INFORM), JSTOR, Scopus, GoogleScholar, Researchgate. After the reviewing the identified papers, in this paper five especially relevant papers with detailed overview of possible cost and benefit aspects regarding data exchange are presented. To complete the list of relevant cost and benefit aspects separate research for possible aspects as well as a workshop with representatives from steel industry according to Niederberger und Wassermann, 2015, were conducted.

To evaluate how the identified cost and benefit aspects can be affected (decrease of increase), it is important to understand which situational and company-specific factors can influence the aspects. For this purpose, in the second step possible influence factors were identified, defined, and clustered. Based on systems (Ulrich and Hill, 1976) and model (Stachowiak, 1973) theory the requirements for the influence factors were defined. A valid influence factor must have a logical and direct influence on the expression of

at least one of the cost or benefit aspect as well as the influence of the factor must be undependable from other factors (they may, however, influence the same aspects).
In the final and concluding step, the influences of the factors on the cost and benefit aspects are qualitatively determined. For this purpose, all characteristics (if any) of the individual cost and benefit aspects are defined for each influence factor. However, this is limited to purely correlative and qualitative relationships. In the case of a positive correlation, the aspect increases as the influence factor increases; in the case of a negative correlation, the aspect decreases. If the cost or benefit aspect does not correlate with the influence factor, the value remains constant as the influence factor increases or decreases.

State of the art

During the research five especially relevant papers regarding cost-benefit-analysis of data exchange in supply chains were identified. All these papers focus on the evaluation of added value through increased data availability. Rückert *et al.*, 2021, and Gelhaar *et al.*, 2023, examine cross-company data exchange using the example of milling and within the framework of Catena-X respectively. Cheng and Westman, 2020, and King and Shrems, 1987, explore general benefits of digitalization or implementation of IT systems. Zipfel *et al.* 2021 have identified, that information is not being shared between supply chain partners, so they developed a method for quantifying the value of information to create incentives for companies to exchange information for short-term production control.

These papers have two crucial common aspects. First, they prove that data or information sharing in a supply chain is beneficial and that the benefits outweigh the invested costs. Second, the precise determination of the final benefits is only achievable based on specific examples. Across various industries or companies within an industry, these benefits can only be described at an abstract level. This idea is also supported by Flyvbjerg und Bester, 2021, as the authors assert that cost-benefit analyses without a specific case reference lack precision and validity because of many simplifications and assumptions.

Through this research a comprehensive list of possible cost and benefit aspects was developed. However, it was noticed that the used cost and benefit aspects in every paper were not consistent. In order to create a comprehensive list of all relevant aspects further research for possible cost and benefit aspects as well as a workshop with representatives from the steel industry was conducted. The results are be presented in the chapter Findings.

Findings

In this chapter, the core findings of the research are presented. First, a short overview of possible cost and benefit factors regarding cross company data exchange in the steel industry is presented. The overview of these factors gives an insight into the expected costs and benefits when companies intend to exchange data in a supply chain. However, the focus of this paper lies on the description of influence factors and their influence regarding these aspects. This description helps companies to define, which of the aspects can they influence based on their maturity or abilities in the presented dimensions.

Overview of cost aspects

As shown in Figure 5, a total of 15 cost aspects were identified from six different categories that must be considered when implementing cross-company data exchange. These categories allow a simple allocation of costs to the respective tasks and topics.

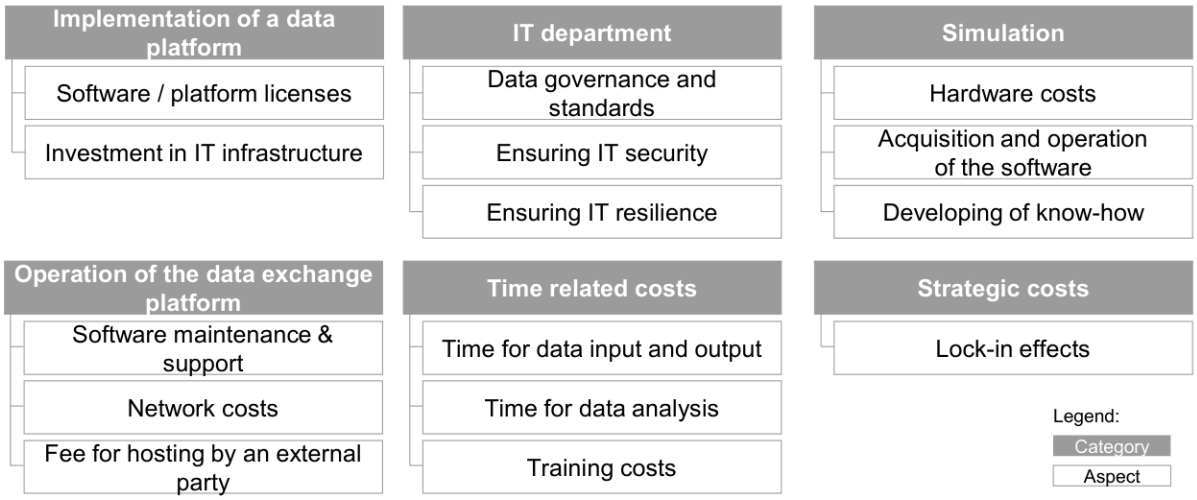

Figure 5: Overview of relevant cost aspects for cross-company data exchange

Overview of benefit factors

A total of 14 benefit aspects were identified from three different categories that have an impact on the added value of cross-company data exchange (see Figure 6).

Figure 6: Overview of relevant cost aspects for cross-company data exchange

Overview of dimensions and influence factors

This section introduces and defines the dimensions and associated factors. The influence on the factors on the previously introduced aspects is then presented. The dimension **Strategic Capabilities** of a company are the characteristics that determine the company's ability to develop and maintain a long-term orientation and competitive advantage. This dimension contains the influence factors **Market Power**, **Resource Availability** and **Transaction Quantity**.

Market Power refers to the ability of a company to influence price and other economic conditions in a given market. This can be caused by its size, market share, product differentiation or competitive advantages. The underlying scenarios for different market positions are defined through different market forms according to the number of suppliers and demanders, e.g. monopol/monopson or oligopol/oligopson (Stackelberg, 1934). Table 6 presents the infulence of high market power.

	Category	Aspect	Influence
Benefits	Quantitative	Time savings	Increasing
	Quantitative	Efficiency increase	Increasing
	Quantitative / Qualitative	Quality increase	Increasing
	Qualitative	Customer satisfaction	Decreasing
Costs	IT department	Data governance and standards	Decreasing
	Time related costs	Time for data entry/ output	Decreasing
	Time related costs	Time for data analysis	Decreasing
	Strategic costs	Lock-in effects	Decreasing

Table 6: Influence of the increasing factor Market Power (dimension Strategic Capabilities) on costs and benefits of a cross-company data exchange

Resource Availability reflects the company's ability to provide internally available resources (especially on a short notice). Internal resources can be divided into material, non-material and personnel resources. Material resources are for example physical resources like machinery. The term of non-material resources encompasses for example the characteristics technology, know-how as well as reputation. Examples of personnel resources include staff, work experience and deployment flexibility. Table 7 presents the influence of an increasing resorce avaiability concerning costs and benefits.

	Category	Aspect	Influence
Benefits	Quantitative/ Qualitative	Synergies	Increasing
	Qualitative	Innovation	Increasing
Costs	Implementation	Software maintenance & support	Decreasing
	IT department	Ensuring IT security	Decreasing
	IT department	Ensuring IT resilience	Decreasing
	Simulation	Acquisition and operation of the software	Decreasing
	Simulation	Developing of know-how	Decreasing
	Time related costs	Training costs	Decreasing

Table 7: Influence of the increasing factor Resource Availability (dimension Strategic Capabilities) on costs and benefits of a cross-company data exchange

The influence factor **Transaction Quantity** refers to the number of transactions which take place in a business relationship. This factor can be used to analyse the relationship between business partners as it offers insights in intensity and duration of the data exchange. Two possible scenarios could be a short- and a long-term oriented partnership. For example, the higher the transaction quantity, the more synergies can be achieved, and the fixed costs can be distributed on more transactions. The impact of this factor on the costs and benefits is shown in Table 8.

	Category	Aspect	Influence
Benefits	Quantitative	Time savings	Increasing
	Quantitative	Efficiency increase	Increasing
	Quantitative	Quality increase	Increasing
	Quantitative / Qualitative	Synergies	Increasing
	Qualitative	Customer Satisfaction	Increasing
Costs	Operation of the data exchange platform	Variable costs	Increasing
	Strategic costs	Lock-in effects	Increasing

Table 8: Influence of the increasing factor Transaction Quality (dimension Strategic Capabilities) on costs and benefits of a cross-company data exchange

The dimension **Technical Capabilities** of a company refer to the technical characteristics which relate to the company´s technical infrastructure and (informational technology and communications) systems. Influence factors of this dimension are the **Digitalization Maturity Level** and **Simulation Expertise**.

The **Digitalization Maturity Level** can be assessed based on various factors such as resources, information systems, organization, and company culture. It describes the progress of a company´s digitalization. The "Industry 4.0 Maturity Index" is used to separate the digitalization maturity level into six steps (Schuh *et al.*, 2020). There exists a relationship between the level of digitalization maturity and cost and benefit aspects. Table 9 shows that an increasing level of digitalization maturity has a positive impact on costs and benefits. Higher digital maturity level of a company means that some investments in digitalization were already made, and some relevant data may be already acquired; then sharing this data through already existing infrastructure will mean little cost simultaneously providing high benefits in return.

	Category	**Aspect**	**Influence**
Benefits	Quantitative	Time savings	Increasing
	Quantitative	Quality increase	Increasing
	Quantitative / Qualitative	Synergies	Increasing
	Qualitative	Innovation	Increasing
Costs	Implementation	Investment in IT infrastructure costs	Decreasing
	IT department	Data governance and standards	Decreasing
	Simulation	All expenses	Decreasing
	Time related costs	Time for data analysis	Decreasing

Table 9: Influence of the increasing factor Digitalization Maturity Level (dimension Technical Capabilities) on costs and benefits of a cross-company data exchange

Simulation Expertise refers to the knowledge within the company that is necessary to conduct and interpret simulations. Simulations are computer models or virtual prototypes utilized to analyse the performance, behaviour or characteristics of processes or products. This allows for cost savings in real processes. The ability to utilize comprehensive material data (e.g., digital twin) in simulation models is crucial for adaptive process control in the scope of this paper.

	Category	**Aspect**	**Influence**
Benefits	Quantitative	All factors	Increasing
Costs	Simulation	Acquisition and operation of the software	Decreasing
	Simulation	Acquisition and operation of the software	Decreasing
	Simulation	Developing of know-how	Decreasing

Table 10: Influence of the increasing factor Simulation Expertise (dimension Technical Capabilities) on costs and benefits of a cross-company data exchange

The dimension **Product Features** describe the qualitative or quantitative attributes of a product. This dimension includes the influence factors **Costs and Complexity of a Product** and **Criticality of a Product**. The **Costs of a Product** include all expenses incurred for its manufacturing, marketing, and distribution (Kirchner, 2020). **Product complexity** refers to the number and interaction of different components and processes required to manufacture or operate the product. On one hand, a higher complexity of a product implies higher production costs. On the other hand, investment in the digitisation of expensive products is more lucrative than for inexpensive products. For example, the usage of finite element method (FEM) simulations is standard for automotive industry for decades, whereas for packaging steels it is still a developing field (Köhl *et al.*, 2022). Table 11 shows how different costs change due to increasing product complexity.

	Category	Aspect	Influence
Benefits	Quantitative	Time savings	Increasing
	Quantitative	Quality increase	Increasing
	Quantitative	Energy savings	Increasing
Costs	IT department	Data governance and standards	Increasing
	IT department	Ensuring IT resilience	Increasing
	Simulation	Acquisition and operation of the software	Increasing
	Time related costs	All costs	Increasing

Table 11: Influence of the increasing factor Costs and Complexity of a Product (dimension Product Features) on costs and benefits of a cross-company data exchange

The second influence factor of this dimension is the **Criticality of the Product**. The criticality of a product or component refers to the significance or influence that a product has on the functioning of the final overall product at the end of the value chain. Components can be classified based on their criticality. For a non-essential component, like steel panels and covers, the criticality is typically low, whereas for a component, like a brake disc, quality and safety regarding requirements are high, resulting in an increase in importance of the product for the overall system or final product. The higher the criticality of a product, the higher are expectation towards its quality, stricter possible legal regulation, and higher possible fines or losses, if the quality is not ensured properly. In the case of a critical product, investments in systems that increase productivity and quality e.g., a manufacturing execution system or a coordinate measurement machine are high, however, also reasonable. Such investments can ensure that company collects and store vast amount of data in the production that can be also exchanged with supply chain partners thus creating synergy. The influence of this factor is presented in Table 12.

	Category	Aspect	Influence
Benefits	Quantitative	Time savings	Increasing
	Quantitative / Qualitative	Efficiency increase	Increasing
	Quantitative / Qualitative	Reduction of defective products	Decreasing
	Quantitative / Qualitative	Customer satisfaction	Increasing
Costs	IT department	Ensuring IT resilience	Increasing
	Simulation	Acquisition and operation of the software	Increasing
	Time related costs	All costs	Increasing

Table 12: Influence of the increasing factor Criticality of a Product (dimension Product Features) on costs and benefits of a cross-company data exchange

Summary
Due to the increasing value of data as an asset and the high potential benefits of its utilization ever more companies decide to implement various data-driven use cases, from improvement of internal processes and products to collaboration in supply chains and intercompany data sharing in order to increase possible benefits of the supply chain.

However, all digitalization projects and data-driven use cases have certain costs of implementation: direct monetary investments, personnel costs, and time as well as shifting the focus from daily business to digitalization projects. Therefore, enterprises must carefully approach such projects, picking the path of the best cost-benefit ratio. And for this, it is important to know what the potential benefits and upcoming costs are. Especially it is crucial for cross-company collaborations. This paper identifies the relevant cost and benefit aspects and corresponding influence factors for successful and effective data exchange in a supply chain using the example of the steel industry.

The overview of the cost and benefit aspects gives companies a comprehensive understanding of anticipated investments and possible benefits when planning cross company data exchange. It can be used of risk management of better investment planning. The overview of the influence factors and their specific influence on costs and benefits may help companies to assess their ability to leverage the potential of data exchange. By assessing own strategic and technical capabilities as well as product features companies can derive a suitable strategy to reduce costs and increase possible benefits, e.g., sharing the same investment costs between several digitalization projects or use cases.

For more precise research, companies engaged in intercompany data exchange projects (e.g., Gaia-X Funding Competition by BMWK) should be invited to participate in a long-term case study to quantify real costs and benefits over time. This would not only quantify the real costs and benefits, but also identify further implicit cost and benefit aspects.

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