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# Enterprise Data Management

**Building core competencies to unlock data-driven business opportunities and the potential for competitive advantage**

IN COOPERATION WITH

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## Business Priorities for the Industrial Enterprise

To maintain and sustain competitive advantage, industrial enterprises must continuously adapt their business model to changing market requirements, regulatory frameworks, and to the advancement of technological innovation.

**Market requirements** materialize mainly in customer demands which are continuously evolving. At present, environmental requirements gain importance in addition to price and quality. Automotive OEMs, for example, do not only define a price range for an electric component (such as a window lifter), but also set a target for the product carbon footprint, i.e. the amount of greenhouse gases emitted to the atmosphere during the production and transportation of a certain product. Being able to quantify the product carbon footprint in a detailed and transparent way allows for differentiation from the competition.

The number and scope of **regulatory provisions** is increasing due to the growing importance of environmental and societal conditions under which an industrial enterprise operates. Prominent examples comprise the *Supply Chain Act*[1], which entered into force on 1 January 2023, and the European regulation of the data economy in the single market (such as the *Data Governance Act* and the *Data Act*)[2].

**Technological innovation** is one of the most powerful sources of competitive advantage, in particular for enterprises in highly developed countries with high labor cost, in which competition on costs is usually not an option. Technological innovation materializes in various forms and entails product innovation as well as service innovation and, recently, innovation from data. It has long been common knowledge that profit margins of service businesses outperform those of traditional product-centric businesses and that being seen as a technology company can also have a positive impact on market capitalization (see Tesla, Zalando). Today, artificial intelligence and data are the resources of digital services which generate highest growth rates[3].

The question of how the industrial enterprise must react on these changes has long been investigated in management science. A prominent example is *Michael E. Porters* work on the **Five Forces** determining corporate strategy and the related analysis of competitive advantage[4]. In recent years, **Dynamic Capabilities** emerged as a theoretical framework to explain the successful adaption of enterprises to changing environments, in other words to purposefully adapt an organization's resource base[5].

> Dynamic capabilities allow industrial enterprises to continuously re-arrange their resource base to sustain the competitive advantage.

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1 See https://www.bmas.de/EN/Europe-and-the-World/International/Supply-Chain-Act/supply-chain-act.html [accessed on 26 May 2024].

2 Data regulation in Europe is one pillar—next to the establishment of data spaces—of the European Data Strategy; see https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-data-strategy_en [accessed on 3 June 2024].

3 See for example an analysis performed by Die Deutsche Wirtschaft on future growth markets: https://die-deutsche-wirtschaft.de/trend-und-wachstumsfelder/ [accessed on 26 May 2024].

4 See Porter, M.E.: *Competitive Strategy.* Free Press, 1986; Porter, M. E.: *Competitive Advantage.* Free Press, 1998.

5 Teece, D. J.; Pisano, G.; Shuen, A.: Dynamic capabilities and strategic management. In: *Strategic Management Journal* 18 (1997) 7, p. 509-533. NB: Dynamic capabilities are a special form of organizational capabilities which – in general terms – allow for making use of an organization's resource base. The so-called Resource-Based View of an enterprise is a theoretical framework in management science used to determine the strategic resources a firm can exploit to achieve sustainable competitive advantage, see Barney, J.: Firm Resources and Sustained Competitive Advantage. In: *Journal of Management* 17 (1991) 1, pp. 99-120.


## The Role of Data for Competitive Advantage

Following the resource-based view of an industrial enterprise, data is considered a strategic resource for competitive advantage. In this view, the data resource of an enterprise generates strategic value in three different forms:

**Data-driven processes:** Data is a necessary resource for efficient and effective business and manufacturing processes, hence for operational excellence. Process performance requires the capability to use and analyze internal and external data of increasing volume, volatility, and versatility. For instance, predictive quality approaches for manufacturing exploit machine learning and data lake techniques to optimize process quality in real-time.

**Data-driven products and services:** Data is a mandatory resource for many product-service-systems. Smart maintenance services, for example, use process and condition data from manufacturing processes to optimize maintenance and replacement activities for industrial assets (such as welding robots).

**Data products:** Recently, data has evolved into product themselves. Data products combine IT, legal and business aspects to enable the democratization and sharing of data, both within companies and across entire data ecosystems. At this, data marketplaces are evolving as novel type of data platform besides data lakes and data catalogs.

In addition to the strategic value of data for individual companies and entire ecosystems, governmental actors have also recognized the importance of data from an economic and political perspective. With the rise of geopolitical tensions, different economic areas in the world put **data regulation** into effect. Similarly to Europe (see above), the Chinese government has identified data as the fifth production factor and recently established the National Data Bureau to be "responsible for advancing the development of data-related fundamental institutions, coordinating the integration, sharing, development and application of data resources"[6].

> Data is a strategic resource for industrial enterprises.

## Business Benefits of Data Resource Management

If data is considered a resource for enterprises (in particular a strategic one) it is obvious that it must be managed as any other strategic resource in the enterprise. **Management practices** have been deployed for decades to manage all sorts of enterprise resources (such as products and materials, industrial assets, employees, intellectual property).

The foundations for quality management, for instance, were laid in the first decades of the 20th century when industrial manufacturing was organized in a variety of individual tasks. The distribution and specialization of work, first introduced by *Frederick W. Taylor* into the US automotive industry, allowed for paradigm shift in productivity and efficiency of industrial manufacturing[7].

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[6] See https://news.cgtn.com/news/2023-10-25/China-inaugurates-national-data-bureau-1obqU3dvBks/index.html [accessed on 26 May 2024].

[7] See Taylor, F. W.: Shop Management. In: *Transactions* 28 (1903), pp. 1337-1480.

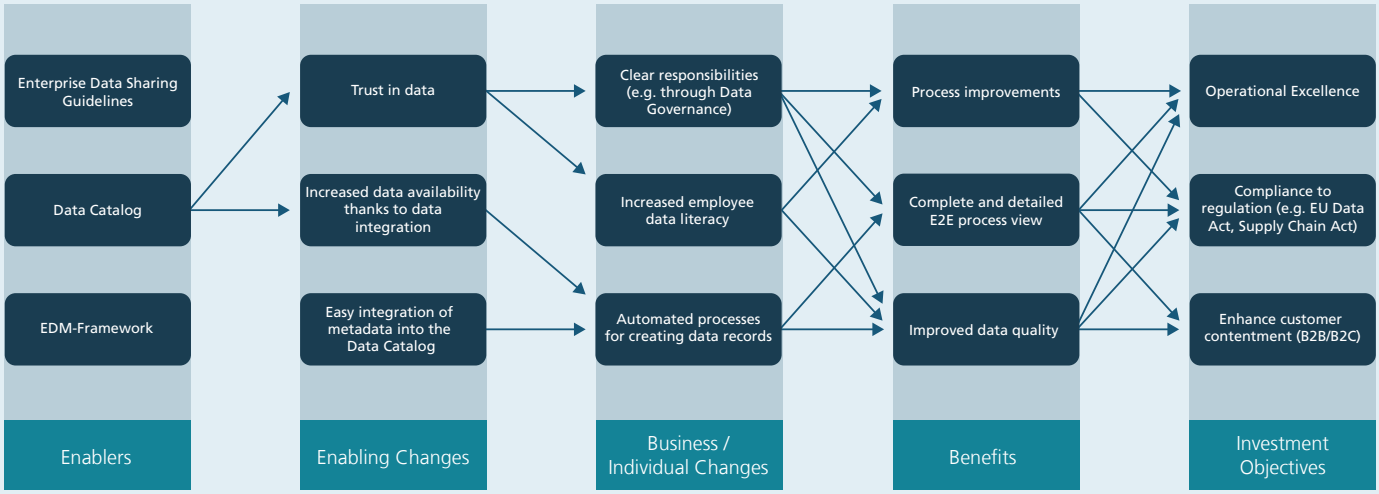


Figure 1: Benefit Dependency Network for Data Catalogs

Management practices must be applied to enterprises resources to acquire, use, and dispose/renew them in an optimal way, measured according to cost, time, and quality.

It is important to understand that data typically has no direct business benefit but rather enables business benefits through a network of effect mechanisms.

Figure 1 shows the **Benefit Dependency Network**[8] for Data Catalogs, which are typically implemented to handle metadata as Single Source of Truth (SSOT) and to enhance data quality throughout the enterprise's departments. The viewgraph shows that implementing a Data Catalog has no direct impact on investment objectives but instead leads to organizational and business changes that in return lead to business benefits.

Furthermore, the viewgraph shows that there is no monocausal relationship between data resource management activities and instruments on the one hand and desired strategic enterprise goals on the other. Enterprises must understand that the impact of data resource management becomes effective through a complex network of causal effect mechanisms.

As data is not a tangible resource but an immaterial one, it behaves differently than materials. The nature of data as a resource has long been studied. Among the foundational characteristics of data goods are[9]:

- **Data is non-rivalrous,** i.e. its use by one user does not prevent its use by another user. Data can be shared/re-used multiple times without diminishing the value of the individual use. In fact, one could argue the value of data actually increases with the number of uses.
- **Data is not depreciated when used,** i.e. there is no wear and tear as with physical goods.
- **Data depreciates over time** if not maintained, as data is a representation of reality. If the data is not updated as reality evolves, the value of the data diminishes.
- **Data is a credence or even experience good,** i.e. the full value of data can only be assessed after its consumption. However, managing data as a transparent product improves this situation and leads to less waste and faster development life cycles.

Even though data is of different nature than physical goods, transfer of management practices such as Total Quality Management and Lean Management to the data resource are useful and beneficial for the industrial enterprise[10].

The enabling nature of data resource management is also the reason for the continuous legitimation need. Costs are very transparent because they can directly be allocated to individual data resource management activities, instruments, and systems. The benefits, however, materialize in a variety of different processes and products and, thus, are "invisible".

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8 The Benefit Dependency Network was developed in the 1990s at Cranfield University in the UK as a benefit management methodology. See Peppard, J.; Ward, J.; Daniel, E.: Managing the realization of business benefits from IT investments. In: *MIS Quarterly Executive* 6 (2007) 1.

9 See Moody, D.; Walsh, P.: Measuring The Value Of Information: An Asset Valuation Approach. In: *Proceedings of the European Conference on Information Systems (ECIS)* 1999.

10 See e.g. Otto, B.: Quality and Value of the Data Resource in Large Enterprises. In: *Information Systems Management* 32 (2015) 3, pp. 234-251.

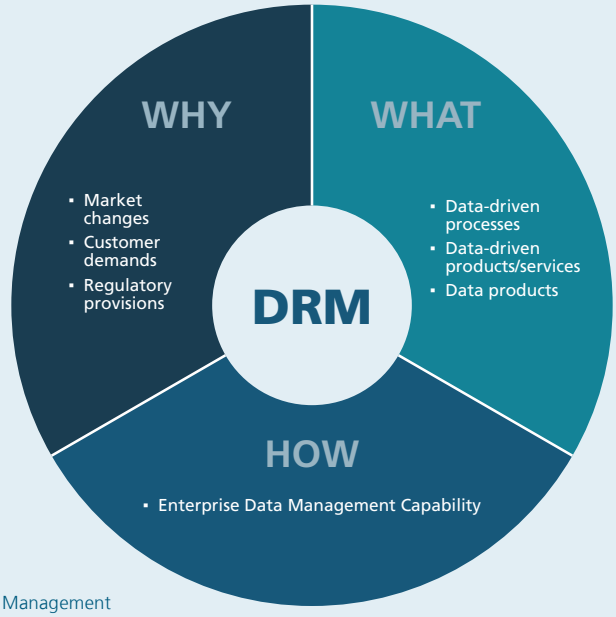


Figure 2: Why, how, what for Data Resource Management

The *Golden Circle* approach[11] can be used to illustrate why Data Resource Management is needed in the industrial enterprise, how it influences the strategic position of the enterprise, and what needs to be done to manage the data resource (see Figure 2).

To maximize the business benefits of the data resource it must be managed as any other resource in the industrial enterprise.

## Enterprise Data Management

Enterprise Data Management is the organizational capability which ensures the data resource is managed in accordance with the strategic objective of the enterprise. Following the Golden Circle approach (see above) Enterprise Data Management responds to the question what must be established in the enterprise to seize the business opportunities of data.

The establishment of Enterprise Data Management, thus, is an organizational design task and requires consideration of three perspectives:

- The **capability** perspective (in a narrower) sense is concerned with identifying and establishing the organizational capabilities required for the effective and efficient management of the data resource[12].
- The **governance** perspective is concerned with what decisions must be taken by whom and where in the industrial enterprise. Thus, data governance is a decision-making framework for the best use of the data resource[13].
- The **dynamic** perspective considers the dynamic environment all organizational capabilities must be established in. It is therefore of utmost importance to continuously review and adopt Enterprise Data Management in terms of the individual capabilities and governance arrangement.

[11] The Golden Circle was introduced by Simon Sinek and is frequently used in management consulting and start-up companies. See https://simonsinek.com/golden-circle/ [accessed on 26 May 2024].

[12] First reference models for data management on an enterprise level were developed in the 1990s, for example the Data Management Body of Knowledge by DAMA (see https://www.dama.org/cpages/body-of-knowledge [accessed on 26 May 2024]). Scientifically grounded models were provided by the Competence Center Corporate Data Quality (see https://www.cdq.com/about/competence-center-corporate-data-quality [accessed on 26 May 2024]).

[13] See Khatri, V.; Brown, C.V.: Designing data governance. In: *Communications of the ACM* 53 (2010) 1, pp. 148-152; Otto, B.: A morphology of the organisation of data governance. In: *Proceedings of the European Conference in Information Systems (ECIS) 2011*.

| Business Engineering Layer | Enterprise Data Management Capability |
|---|---|
| Strategic Data Management | ■ Data Strategy<br>■ Data Culture<br>■ Data Governance<br>■ Data Accounting and Value Management<br>■ Data Product Management<br>■ Data Compliance |
| Data Value Chain Management | ■ Data Collection/Creation/Acquisition<br>■ Data Cataloguing<br>■ Data Storage<br>■ Data Distribution<br>■ Data Use<br>– Data Analytics and Artificial Intelligence<br>– Data-driven Products/Services/Processes<br>– Data Products<br>■ Data Sharing<br>■ Data Referencing<br>■ Data Maintenance/Curation |
| Data Foundation Management | ■ Data Architecture Management<br>■ Master Data Management<br>■ Data Security & Data Protection<br>■ Data Quality Management<br>■ Data Platform & Data Space Management |

Table 1: Enterprise Data Management Capabilities

The *Business Engineering* approach[14] developed at the *Institute for Information Management at the University of St. Gallen* is a functional tool to organize the different **Enterprise Data Management capabilities.** Table 1 shows all data management capabilities of enterprise-wide importance. An industrial enterprise, thus, must establish these capabilities to seize the competitive advantage potential of the data resources (see above).

Governance is not so much an instrument of control but rather one of coordination. Governance is needed to mediate the dysfunctionalities that are inherent in any organizational design (organizational structure, process organization). Finding the best governance arrangement is a complex task, in particular in multinational industrial enterprises.

The governance perspective on Enterprise Data Management is concerned with decision-making rights and accountabilities and responsibilities and their allocation in the organization. Finding the right **data governance** arrangement must balance the following dimensions:

- Design (e.g. setting data standards, API standards etc.) vs operations (e.g. performing data maintenance tasks)
- Central vs decentral units
- Business vs IT vs legal aspects

[14] See Österle, H.; Winter, R.: *Business Engineering: Auf dem Weg zum Unternehmen des Informationszeitalters,* 2nd ed. Springer, 2003.

While Enterprise Data Management must be continuously adjusted to internal and external dynamics (just as any other organizational capability), several recent developments stand out as drivers of change:

- **Data is a resource for AI.** AI and in particular foundation models have large potential for an S Curve Jump[15] both regarding traditional business operations and also innovative business scenarios. Apart from generative AI, model performance has peaked in the recent years. Hence, data-centric AI (more data and better data) is the way to go to foster AI innovation.[16]
- **Data is considered an economic good.** Even though there is (so far) not property right for data, it functions as a strategic resource (see above).
- **Data ecosystems emerge.** Many innovative business scenarios as well as business challenges cannot be addressed by one enterprise alone. Data ecosystems such as *Catena-X*[17] are multilateral forms of organization around data.
- **The boundaries between internal and external Enterprise Data Management blur.** Driven by ecosystems but also cloud transformation (which applies the same technology stack for both internal and external/shared business scenarios) there is a tendency towards a disappearance of differences between internal and external enterprise data management capabilities.
- **Data culture on the rise.** With the proliferation of easy-to-use tools, data democratization and data literacy are evolving which in return will confirm the well-known saying: "(Data) culture eats (data) strategy for breakfast."
- **The data value chain is a closed-loop cycle.** The value chain activities (see Table 1) do not form consecutive sequences but instead cycles. Data is used to provide smart maintenance services while the data from the maintenance tasks in return is new input to the data value chain.

Enterprise Data Management is the organizational capability concerned with the optimal management and use of the data resource. Its individual capabilities and governance arrangements must continuously be assessed and further developed to cope with internal and external changes.

## The State of Play in the Industrial Enterprise

The proficiency and maturity of the Enterprise Data Management capability in industrial enterprises has continuously grown over the last decades. Studies on the importance of data for business success have led to higher attention for managing the data resource on decision-making levels of companies.[18]

However, the overall maturity of Enterprise Data Management in Germany is characterized by significant room for improvement. According to the Data Readiness approach introduced by the DEMAND project[19], about 80 percent of the German companies are on one of the two lowest readiness levels.

The readiness model provides recommendations for climbing to higher maturity level and, thus, is a functional tool for companies to further advance their Enterprise Data Management capability.

Industrial enterprises should continuously assess the maturity of their Enterprise Data Management capability in order to advance the proficiency of managing data as a strategic resource and to maximize the data contribution to the company goals.

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15 The so-called S curve is model to analyze innovation life cycles and was introduced in the 1980s by *Richard N. Foster.* See Foster, R.N.: *Innovation: The Attacker's Advantage.* Summit Books, 1986.

16 See Jakubik, J.; Vössing, M.; Kühl, N. et al.: Data-Centric Artificial Intelligence. In: *Business & Information Systems Engineering* (2024). https://doi.org/10.1007/s12599-024-00857-8

17 See https://catena-x.net/en/ [accessed on 26 May 2024].

18 DalleMulle and Davenport coined the notion of offense and defense data management to emphasize the changed role of data for business success (cf. DalleMulle, L.; Davenport, T.: What's Your Data Strategy?. In: *Harvard Business Review* (2017)). More elaborated studies support the proposition of data evolving from a by-product of business process integration into a strategic business resource (see e.g. Legner, C.; Pentek, T.; Otto, B.: Accumulating Design Knowledge with Reference Models: Insights from 12 Years' Research into Data Management. In: *Journal of the Association for Information Systems* 21 (2020).

19 The DEMAND project was funded by the German Federal Ministry for Economic Affairs. The Data Readiness model identifies six readiness steps, namely (0) analog company, (1) digitized company, (2) digital-enabled company, (3) digital company, (4) digital network, and (5) digital ecosystem (see https://www.demand-projekt.de/paper/Gutachten_Readiness_Data_Economy.pdf [accessed on 26 May 2024]). Scientific project partners of the project consortium were Fraunhofer ISST and Institut der Deutschen Wirtschaft.

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