Beyond Data Quality: Data Excellence Challenges from an Enterprise, Research and City Perspective

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Abstract: Researchers and practitioners widely agree on data quality as one of the major goals of data management. However, data management departments in enterprises and organisations increasingly realise needs for data availability, compliance, operational excellence with regard to the domain and other data-challenges. In raised case studies in the enterprise, research and city domain, challenges regarding data availability, operational integration, compliance and quality of data management processes are analysed. Based on the concept of data quality, this paper argues for a similar concept with a broader scope for assessing an organisation's data suitability. Based on literature and case studies this paper proposes a definition of the term data excellence as the capability of an organisation to reach its operational goals by ensuring the availability and integration of suitable, transparent and compliant high quality data.

1 INTRODUCTION

In recent years, the concept of data quality (DQ) has become a crucial goal for data and digitalisation experts in research as well as practice. DQ, defined as fitness for use by data consumers (Wang and Strong, 1996), is the major goal organisations pursue when launching DQ initiatives and establishing data management departments. However, insufficient DQ is not the only shortcoming they deal with:

(1) Operational excellence issues, defined as issues hindering the "execution of the business strategy more consistently and reliably than the competition" (Soto, 2013), often arise.

(2) Regarding legal issues, data-related non-compliance e.g. to the EU General Data Protection Regulation (European Comission, 2016) or to Basel III [1] for banks can lead to significant financial penalties or even cause criminal liability.

(3) Insufficient process quality issues are not directly measured by DQ, but have an indirect impact e.g. on the DQ dimension believability (Piro, 2014).

There are various organisations aiming to shape their future using existing or newly collected data. In the digital economy, the paradigm industry 4.0 draws a vision of fully wired shop floors producing intelligent products. Experts recommend adequate DQ, policies, culture change and a single source information system architecture to enterprises (Schuh et al., 2017). In research, Open Science is a basic principle that targets maximum access to scientific knowledge for research, society and economy. Smart City projects aim at creating or improving new data-based services for citizens (Saujot and Erard, 2015).

When discussing organisational data challenges, some essential definitions are needed. Master data are the fundamental data of an organisation with a low change-frequency (Otto et al., 2011). Metadata are information on data which can be subdivided in three subcategories: (1) descriptive metadata for identification purposes, (2) structural metadata on structure, attributes and versioning as well as (3) administrative metadata for methodological and technical aspects related to data creation as well as access rights (Zeng, 2004).

If an organisation strives to elaborate its ability of dealing with data, it needs to hold and manage it in a structured way. As data has been turned into value

[1]Recommendations on banking laws and regulations issued by the Basel Committee on Banking Supervision

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for particular resorts or departments, it should be included as a new data domain[2]. However, employees often think and work in their resort silos and use independent non-integrated data sources. From a solution perspective, data management concepts and methods address such issues and propose to implement data cleansing (Maletic and Marcus, 2005), master data management (Otto et al., 2011; Scheuch et al., 2012), data quality management (Otto and Österle, 2016; Morbey, 2011) as well as data governance techniques (Otto et al., 2011; Otto and Österle, 2016). However, from a problem perspective, no framework is able to explain or measure existing challenges beyond DQ.

This paper examines organisational data excellence by means of the very different organisation types enterprise, research institute and city administration. The following section initially explains our mixed methods approach, which is then followed by a brief literature review. The section on domain cases provides more thorough insights in enterprises, research institutes and cities facing data challenges. Before drawing conclusions and attempting an outlook, the subsequent analysis derives a deeper understanding of data excellence and provides a preliminary definition.

2 METHOD

As a basis for this paper, we conducted a comprehensive literature review which revealed the research gap of few existing frameworks for analysing and categorising organisational data challenges, especially for non-DQ issues. Four different challenge dimensions related to data were identified from literature, own project experience and case study results:

- Operational excellence (including internal compliance and standards)
- Legal challenges (obligations anchored within laws, external compliance)
- Data management process quality (data management maturity)
- Data quality (fitness for use by data consumers)

Further, we conducted a cross project analysis regarding data challenges relying on selected case studies available at our institute. In order to cover organisations with diverse purposes, we were able to group the case studies according to their characteristics into three domain cases: enterprises, research institutes and cities.

(1) In the context of enterprises, case studies of data governance projects and related triggering challenges within four DAX 30-enterprises[3] were observed. In addition to four semi-structured interviews with external data governance consultants, project experience lead to the presented results.

(2) For research institutes, a single case study covers the status quo in an institute of the German Fraunhofer Gesellschaft with about 600 employees. By means of 19 half-standardized interviews with leading personal, scientific employees and service team staff, we were able to gain insights into current techniques of handling research data.

(3) Major problems in city departments were identified in a workshop with 15 scientific employees working in various research and consultancy projects. Another workshop with ten international strategic officials and smart city leaders from European cities and companies confirmed and enhanced our information collection.

Next, we assigned all empirically identified challenges to one of these categories and enhanced them with further empirical findings if applicable (cf. tables 1–3 in chapter 4). Then we extracted main challenges from one or more empirical issue. Next, we derived aspects in other dimensions if applicable, following own data management experience. Finally, in a cross-domain analysis empirical issues and derived aspects were clustered and assigned to the 4 challenge dimensions. All items then were added to a bullet list, tagged with the domain case they stem from and enhanced with sources from the literature review confirming the observed issue. All challenges considered as strongly evident in all three domain cases were added to the final bullet list presented in section 5.

3 RELATED WORK

Wang et al. (1998) describe DQ as "information delivered [as] a total product: it includes all the attributes that in combination meet the information consumer's expectation" (Wang, 1998). Others define DQ as the "suitability to fulfil determined requirements" (Paskaleva et al., 2017) or as "a measure for the suitability of data for certain requirements in the business processes, where it is used" (Otto and Österle, 2016). However, few scientific approaches exist describing further organisational data characteristics beyond quality such as compliance, availibility for operational excellence and process quality.

[2]Examples for data domains are product data (enterprise), interview data (research) or ground water level data (city).

[3]30 major German companies listed in the Deutscher Aktienindex (German stock index)

Pentek et al. (2017) suggest data excellence as "the impact of data management on the data itself, first and foremost with regard to data quality [...], but also with regard to additional data related aspects, such as data compliance, data security and privacy" (Pentek et al., 2017). Although data governance is already identified as a possible solution for tackling data excellence challenges, many approaches avoid the initial step of identifying fundamental problems and providing a classification framework. Otto provides a literature-based overview on goals of data governance. He identifies compliance with legal requirements as the most frequent trigger (Otto, 2011).

The term DQ is furthermore widely understood as a concept containing several dimensions. Morbey distinguishes the non-machine measurable criteria retrievability and normative consistency from the machine-measurable criteria horizontal completeness, syntactical correctness, consistency, accuracy, freedom of repetition, integrity and vertical completeness (Morbey, 2011, p. 26–27). According to the most common approach there are 15 DQ criteria, divided into the four categories Intrinsic DQ, Contextual DQ, Representational DQ and Accessibility DQ (Wang and Strong, 1996).

According to Piro et al. (2014), most of the aforementioned 15 dimensions by Wang and Strong (1996) are objectively valuable by direct measurement or objective checklists. The dimension believability for instance is objectively valuable as it is of higher value when an organizational data management process is established (Piro, 2014). Thus, data management process quality is a constituent of DQ but formulates different requirements. High process quality thereby has a direct impact on DQ (Glowalla and Sunyaev, 2013). For the measurement of data management process quality maturity models can by applied. They mostly provide a quantitative maturity index in combination with expert recommendations on organisational steps for achieving the next respective level (Mosley, 2008; Otto and Österle, 2016; Pentek et al., 2017).

Turning to other data challenges, Morbey (2011) identifies data owners, and not the DQ team, in charge of content accuracy investigations (Morbey, 2011, p. 28–30). Also, not all domain needs regarding data are transferable to computer measurable criteria (Piro, 2014).

The concept of operational excellence, understood as "the consequence of an enterprise-wide practice of ideal behaviours based on the correct principles" (Rusev and Salonitis, 2016), is a common framework for ideal business performance across all domains. Compliance requires the observance of "rules and regulations imposed by any regulatory bodies to which a firm is subject" (Edwards and Wolfe, 2005). For organizations, it embodies the influence of the law in operational activity and includes internal business policies designed to counteract against possible quality losses and to achieve operational excellence. With an ideal compliance management function, whenever a new regulatory requirement is enacted, an enterprise is capable of predicting its impact on operational processes. The concept of compliance management consists of the functions risk minimization, harm reduction, liability obligation, and corporate efficiency increase (Wecker and Ohl, 2013).

The aspect of long-term archiving is becoming more and more important, as "historical" media from the beginning of the digital age are not easily readable any more (Ferle and Spath, 2012).

4 DOMAIN CASES

The following subsections present domain-specific thematic introductions describing the organisation's characteristics and purpose, what operational excellence means to them as well as current developments and legal requirements. Empirical results (highlighted in grey) and derived data management implications within the previously introduced challenge dimensions are presented in table 1–3.

4.1 Enterprises

In contrary to research institutes and cities, enterprises stand out due to their organisation type. While all three consist of several different departments, enterprises nevertheless are viewed as more homogeneous and act in accordance to the joint objective of providing services, infrastructure or products.

In today's information society, high quality data are the most important raw materials for operational excellence and thus the economic success of an enterprise. The volume of data which permanently increases triggers completely new challenges among enterprises. While so far, they have only focused on efficiency and ability to compete, today and in the future, networking and collaboration of enterprises and organisations are of greater importance also with regard to economic profit.

With the fourth industrial revolution, corporate and manufacturing decisions will be increasingly based on results from data analytics. Industry 4.0 experts recommend data governance structures in order to overcome management, compliance as well as operational challenges (Schuh et al., 2017).

The empirical results of four case studies described in table 1 were the main causes for an implementation of data governance organisations in each of the globally operating DAX 30 companies in the automotive, bank, chemistry and energy sector. Analysed cases may be a good representation for the situation of large corporations. However, they do not reflect small and medium enterprises playing a key part in many economies.

Specific legal regulations for enterprises demand contract transparency as well as explicitly data governance, IT infrastructure and risk data reports in order to ensure an accurate risk management. There was only one case study in which other then legal challenges were the main trigger for subsequently realizing a data governance function. Double data entries and inaccurate data as well as inefficient steering and regulatory risks were further main challenges.

4.2 Research Institutes

Departments and researchers within research institutes often complete their tasks independently. For the single researcher, freedom of action is crucial.

Digitalisation and globalisation lead to far-reaching changes in the field of science. Currently, a paradigm shift towards Open Science is in progress, representing a new approach based on cooperative work (European Commission, 2016). In institutes, currently often cross-department collaboration plays a minor role, as is not necessary for fulfilling operational project objectives. In future, operational excellence will imply the digital interchange of data, ideas and results. For reaching out the data's full economic potential, research data have to be managed and described in ways that make them FAIR (findable, accessible, interoperable and reusable) (Wilkinson and other, 2016).

Due to the wide range of discipline-specific research data and corresponding requirements for methodology, research design and interpretation, it is not possible to define universal criteria for operational excellence. The subject communities themselves must negotiate whether criteria are fulfilled or not (Kindling, 2013). As established for scientific publications, peer-review processes as well as a professional citation practice based on citation indexes could evolve for data, as soon as detailed documentation and good practice collection and archiving methods exist as pre-

Table 1: Enterprise Data Excellence Challenges (empirics and theoretical derivations).

Main Challenges	**Operational Excellence Challenges**	**Legal Challenges**	**Data Management Process Challenges**	**Data Quality Challenges**
Unreliable contract data	Lack in transparency whether contract contents have been entered and approved correctly (automotive OEM[i] procurement)	AO, HGB, IFRS 2015 and 2016[ii] demand for contract transparency	Unclear responsibilities, no clear contract master data creation processes	Inconsistent contract details (especially believability, completeness, concise representation)
No reliable risk management	No identification of business risks from bank data	BCBS 239[iii] and MaRisk[iv] demand data governance & IT infrastructure, aggregation and report of risk data	Unclear and unreliable data management processes (bank)	Low data quality in all dimensions
Insufficient business performance	Insufficient performance in procurement and sales	Dangerous goods remain at customs office[v]	No data governance as basis for clear data ownership	No reliable supplier and customer master data (chemical company)
Regulatory risks	Inefficient steering, risks for inaccurate cable excavations, customer complaints (grid operator)	Regulatory risks regarding network performance and maintenance	No clear responsibilities	Double data entries, accuracy

[i] Original equipment manufacturer [ii] German tax code (AO §97 (1), §147), German commercial code (HGB §238, §242), Int. Financial Reporting Standards 2015 and 2016 [iii] Basel Committee on Banking Supervision's standard number 239 [iv] Minimum requirements for risk management by the German Federal Financial Supervisory Authority sources [v] German Gefahrgutbeförderungsgesetz (Hazardous Goods Transportation Act)

requisites (OECD, 2007). Both, the German Research Foundation (DFG) (DFG, 2015) and the OECD (OECD, 2007) consider institutions and research associations responsible for defining professional standards for the management of research data.

Since the beginning of the European Union's Research Programme H2020 in 2014, beneficiaries are obligated to make their research data available unless contrary to privacy, security or exploitation interests (European Comission, 2016).

The results presented in table 2 stem from an institute of the Fraunhofer Gesellschaft for applied research where scientists conduct research not only in projects commissioned e.g. by the government but also by clients from the industrial sector. The institute is quite heterogeneous regarding research fields and disciplines of employees. Therefore, the case may be a good representation for the Fraunhofer Gesellschaft as a whole (69 institutes, 25.000 employees). However, the widespread national and international research landscape is not reflected.

When taking the previously introduced new way of collaborative research as a measure of success, the illustrated main challenges internal exchange, data standards, awareness of legal requirements, shortage of incentives and methodological potentials arise. As e.g. funding bodies just begin to demand open data regulations from their beneficiaries, there is some time to go until the digitalisation and open data age reaches research practice. On the long term, research landscape can learn from enterprises that implement a higher maturity in data management.

4.3 Cities

Within city administration departments tasks are also completed independently. However, staff follows strict governmental guidelines. A city authority's purpose is to offer services to citizens or other administrative bodies. In contrary to enterprises, municipalities meet the structure of not a single but a conglomerate of organisations. This is based on the bureaucratic model (Weber and Weber, 1980) that ensures control and regulation of governmental bodies in order to

Table 2: Data Excellence Challenges at a Research Institute (empirics and theoretical derivations).

Main Challenges	**Operational Excellence Challenges**	**Legal Challenges**	**Data Management Process Challenges**	**Data Quality Challenges**
Internal competition	Not existing exchange post-usage hinders research excellence	–	Competitive thinking between scientists	Lack of accessibility for excellent research
No internal exchange	No efficient collaboration possible	–	Lack of communication between scientists within research field	Lack of representational data quality and accessibility data quality
Effort-benefit balance	Value for effort in metadata structure is not seen	–	Easy and low-effort processes for metadata standards are missing	Lack of representational and intrinsic data quality
Inattention on duties to funder	No provision of data to research community	Lack of knowledge on funder compliance	Not sufficient knowledge management	–
No process standards	Scientists collect their data in different ways	–	Lack of tools and processes guaranteeing more standardized collection of data	Insufficient standardization of data and meta data (representational data quality)
No data standards	There is no minimum standard for metadata and data storage	Ensure that institute /community standard complies to legal requirements	Lack of process for agreement of scientists and metadata standard coordination	Lack of representational consistency
Shortage of scientist development	Little methodological expertise	–	Provision of little methodological support in form of workshops/consultancy services	Lack of data quality in all dimensions

protect citizens.

The digital transformation at city administrations for a long time foremost took place in e-government topics and especially in Germany lacked of essential progress (Akkaya et al., 2011). Due to the increasing implementation of smart city projects, city governments are now facing the challenge of managing new and large amounts of data. In addition, in the smart city context, the sources of data are varied and owned by different stakeholders (Saujot and Erard, 2015). This challenges the administration as a whole as the usage of data in order to support city duties touches many different aspects. Operational excellence means providing services to citizens and make well-informed decisions. Currently the role of data in order to fulfil these goals increases as new available data allows for better performance. On the one hand, there are standards allowing different administrative bodies and different cities to exchange information (KoSIT, 2018). On the other hand, standards for the implementation of smart city solutions exist (DIN, 2017). Beyond that, there are recommendations on how to successfully carry out the transition towards digitalisation (BBSR, 2017).

However, "at the moment no [established] standard for administrative structures exists [..]. Many municipalities have troubles handling overlapping responsibilities because of a predominant and outdated silo mentality" (Pfau-Weller and Radecki, 2018). Regarding the availability of data, the European Commission requests the reuse of public sector information and the opening of governmental data (European Comission, 2003).

The problems in city departments summarized in table 3 stem from a workshops with scientific employees and a workshop with strategic smart city leaders. The cases reflect the situation for European and international medium-size and big cities.

When taking a cross-city view, a lack of overview over existing data is a critical data challenge. The usage of different data types, standards, units or methods creates problems as well as the addition of smart city data to existing administrational data which necessitates cross-department data analysis and structured data management of the few valuable data set. Cities may also learn from enterprises regarding data management maturity.

Table 3: City Data Excellence Challenges (empirics and theoretical derivations).

Main Challenges	**Operational Excellence Challenges**	**Legal Challenges**	**Data Management Process Challenges**	**Data Quality Challenges**
No Data Distribution	Different responsible resorts (E.g. City Planning: Building of nature-based corridor)	Strict legal Limits for data exchange between departments	No central data access, no single data source (e.g. water pipe hinders tree planting)	Different data sources, no overview over existing data
Inattention of regulations	–	No implementation of regulations	–	–
No consistent handling of data	No cross-resort data analysis (use and mix existing data for better performance)	Heterogeneous usage regulations dependent on ownership and licensing	Effortful extraction of information, Distinct processes dependent on ownership	No concise representation and no accessability
Shortage of methodical knowledge	Unclear definition of methods (indicators, workshops)	–	Unclear standards and processes, uncoordinated collection of data	Data is wrong (Accuracy)
Old data	Data not operationally usable e.g. for safety and security issues	–	Irregular or non-structured data collection	Data is out-dated (Timeliness)
No data standards	Extra data processing effort (e.g. increase urban climate resilience)	–	No standard format defined or practically used	Different data format dependent on source and supplier (interpretability)
No process standards	Comparison of mobility data of different cities	–	Different standards, units, or methods in different cities	No concise representation, no interpretability

5 DATA EXCELLENCE

As different as the three analysed organization types may seem, they all share common data challenges that stand in the triangle of tension between strived operational excellence, restricting legal frameworks and enabling data management. Next to the data's quality, its compliance, organisational availability and operational integration is crucial. Also including non-DQ aspects in problem analysis is currently hardly supported by scientific frameworks. However, it is necessary as a crucial supplement to data management and data governance concepts addressing the solution view.

Some of the identified organisational challenges in the domain cases were clearly assignable to DQ. The other revealed challenges were not clearly related to previously described concepts. When aggregating challenges evident across all domain cases, the following major constituents of data excellence occur:

- **Operational excellence challenges**
  - Operational efficiency (Otto, 2011)
  - Exchange and collaboration
  - Data availability (Panian, 2010)
  - Operational integration and interoperability (Otto, 2011)
- **Legal challenges**
  - Operational legal requirements (Otto, 2011)
  - Awareness of regulations
- **Data management process quality challenges**
  - Clear responsibilities, processes and guidelines
  - Data transparency and auditability (Panian, 2010)
  - Central data acces
- **Data quality challenges** (Wang, 1998)
  - Intrinsic data quality
  - Accessibility
  - Contextual data quality
  - Representational data quality

Following the concept of operational excellence (Soto, 2013), we define data excellence as capability of an organisation to execute its strategy consistently and reliably with a suitable, transparent and compliant availability and integration of high quality data. The concepts compliance and operational excellence hereby are not part of data excellence, but reach its borders. In contrary, we regard data management and data governance as a possible solution to data excellence challenges.

6 CONCLUSION AND OUTLOOK

Regardless if deciders in organisations grasp for profit, scientific excellence or citizen's welfare, they all need to take new information from internal and external available data sources into account. Data excellence challenges such as data availability, operational integration, data transparency and awareness of regulations from an enterprise, research and city perspective were assigned to four challenge dimensions including DQ. In general, for data challenges in organisations two sides of the coin exist: the problem side and the solution side. While for the solution side well-settled concepts exist, the problem side beyond DQ and its criteria remained disregarded up to now. However, researchers and practitioners need to be able to assess an organisation's data suitability. This paper provides a first overview of data excellence as well as a preliminary definition.

Further research could do a structured literature review on non-DQ topics and examine data challenges on a more representative and broader empirical basis. Also, profound, sound and generally valid criteria are needed for non-DQ challenges. Coming to the organisations itself, departments on compliance, data management and operational departments need to cooperate more efficiently in order to address interlinked data challenges.

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