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Abstract

Effective metadata management is one of the key enablers of information and knowledge management. Over more than two decades, enterprise metadata management technology has evolved to facilitate a consistent and efficient capture, maintenance, and delivery of metadata across the organisation. Academic research into challenges that organisations face when implementing this type of information system is limited. The paper explores common metadata conceptions, and places metadata in the context of the data-information-knowledge hierarchy. Based on a review of the existing literature on metadata, and an exploratory expert study, the authors propose a unified metadata typology that can help organisations clarify and focus their metadata efforts, and frame future research. The paper also investigates technology capabilities and current issues hindering metadata management initiatives.

Keywords

Metadata, Metadata Management, Enterprise Information Management, Knowledge Management, Enterprise Systems, Meta-data

INTRODUCTION

Metadata are important information assets that, when properly managed, enable efficient and effective access to and use of enterprise data, processes and systems. Organisations should not underestimate the crucial role of metadata in various types of enterprise systems and related initiatives such as business intelligence, knowledge management, information governance, and enterprise architecture management.

The strategic purpose of metadata is to improve an information asset's usability. This improvement can be demonstrated by making the activities in the information asset's life cycle more efficient (easier, simpler, less resource-intensive, faster, cheaper) and more reliable (lower risk, higher quality). Gartner emphasises that "metadata unlocks the value of data" (Beyer et al. 2010 p. 2). Typically, metadata represent definitions and descriptions of the content, quality, condition or other characteristics of data.

The focus of existing scholarly research into metadata lies in the cataloguing and semantic web domains (Greenberg 2005; Sicilia and Lytras 2009), however, only limited academic research is available on how organisations implement enterprise metadata management systems. This research paper lays foundations for a larger research project toward an enterprise metadata management framework.

Shankaranarayanan & Even (2006) suggest more research is needed to understand and justify the value of metadata management in the enterprise context. Apart from various technical considerations (Sen 2004), metadata also have an important role in dynamic decision environments through their manifestation as quality and provenance metadata (Shankaranarayanan et al. 2006). Having added the role of definitional and navigational metadata, Foshay et al. (2007) posit the overall importance of end-user metadata quality in user acceptance of business intelligence and data warehousing technology. A lessons-learned approach (Gabriel et al. 2010) may also help demonstrate the value of metadata by identifying metadata categories that cause common issues in data warehousing environments.

The remainder of the paper first reviews the related work on metadata and metadata management, and positions these concepts within the context of the data-information-knowledge hierarchy and information management, respectively. The section thereafter introduces research design and empirical data collection from a panel of 16 international metadata management experts on the topics of metadata typologies, issues and technology capabilities. Then, the paper presents and discusses results of the analysis. The concluding section summarises the paper, discusses its contribution and suggests future research opportunities.

BACKGROUND

The term metadata was pioneered by Jack E. Myers in 1969 for use with his MetaModel product line and later in 1986 Meyers' firm The Metadata Company registered METADATA® as a U.S. trademark (Greenberg 2005 p. 19). The term was quickly endorsed in computer science and in 1995 following the introduction of the Dublin Core Element Set it also spread into library and information science (Caplan 2003 p. 2).

The popular definition of metadata as "data about data" is concise but at the same time it is too indistinct and simplistic (Kim 2005) to be practical. In 1999, a summary report of the task force on metadata from a division of the American Library Association introduced metadata as "structured, encoded data that describe characteristics of information-bearing entities to aid in the identification, discovery, assessment, and management of the described entities" (CC:DA 1999). ISO and IEC defined metadata simply as "data that defines and describes other data" (ISO/IEC 2004 p. 4). NISO describes metadata as "structured information that describes, explains, locates, or otherwise makes it easier to retrieve, use, or manage an information resource" (NISO 2004 p. 1). In the enterprise metadata management domain, Marco (2000) provided a more specific definition:

> *Meta data is all physical data (contained in software and other media) and knowledge (contained in employees and various media) from inside and outside an organization, including information about the physical data, technical and business processes, rules and constraints of the data, and structures of the data used by a corporation.*

Such a variety of definitions demonstrates the multiplicity of facets related to the concept of metadata that is due to its use by diverse communities of researchers and practitioners.

> *Without an adequate definition of metadata and an understanding of the role of metadata as a resource, enterprises will find it virtually impossible to treat information as an asset.* (Beyer 2009 p. 1)

Gartner research proposes to establish a harmonised definition compatible with other industry organisations and posits metadata as "information that describes various facets of an information asset to improve its usability throughout its life cycle" (Beyer et al. 2010 p. 3).

Metadata in the context of the DIKW hierarchy

The New Shorter Oxford English Dictionary defines the prefix meta- as "1 Denoting a nature of a higher order or more fundamental kind" (Brown 1993 p. 1753). In information science, the Data-to-Information-to-Knowledge-to-Wisdom (DIKW) hierarchy offers an important contextual framework of higher-order concepts that can demonstrate the role of metadata. Although the hierarchy's fitness as one of the canons of information science has recently been criticised (Frické 2008), these criticisms will not be addressed in this paper as the authors believe that, if slightly modified, it is still a valuable reference model. The recent appearance of research into the origins and representations of DIKW by Rowley (2007 p. 166) may indicate that the enquiry of its foundation, representation and soundness is ongoing. Rowley located early mentions of DIKW in the influential works of Cleveland (1982), Zeleny (1987), and Ackoff (1989). Cleveland's article further referenced a poem by T.S.Eliot (1934) whereby the following couplet of verses from the opening chorus is often attributed to be the origin of the hierarchy:

> *Where is the wisdom we have lost in knowledge?*
> *Where is the knowledge we have lost in information?*

A noteworthy addition to Rowley's research would be the following excerpt by Robert Lee (1845 p. 237):

> *Information is not knowledge, much less is it wisdom ... We must exercise reflection upon facts - information must be digested. Then only is it turned into that knowledge which is the vital fluid of man's spirit, and from which wisdom draws her nourishment.*

Over time, authors have developed numerous DIKW hierarchy or pyramid representations and there is no consensus on the definitions of the constituent elements (Faucher et al. 2008; Rowley 2007; Zins 2007a). Table 1 displays some of the early as well as more recent abbreviated definitions of DIKW.

Table 1: DIKW definitions by selected authors

Zeleny (1987, 2008)	**Debons et al.** (1988)	**Ackoff** (1989)	**Zins** (2007b p. 349)
Taxonomy of Knowledge (1987) **DIKWE Cycle** (2008)	**Knowledge Spectrum Knowledge System**	**Hierarchy of types (of content of the human mind)**	**D-I-K-M phenomena of information science (ad hoc definitions)**
Data: *know nothing*	*symbols organized according to rules and conventions*	*symbols that represent properties of objects, events and their environments*	*symbols that represent empirical perceptions*
Information:	*state of awareness given*	*useable processed data,*	*symbols that represent*

know what	*physical representation*	*answers to who, what, where, when and how many*	*empirical knowledge*
Knowledge: *know how*	*cognitive state beyond awareness or organized record of human experience*	*know-how*	*symbols that represent thoughts, which one justifiably believes to be true*
Additional elements			
Wisdom *know why* Enlightenment *know yourself*	Symbols *signs representing events* Wisdom *application of knowledge as contained in human judgement*	Understanding Wisdom	Message *symbols that represent any meaningful content*

In the knowledge management domain, Faucher et al. (2008) describe meta layers that correspond to their DIKW transition-understanding functions of meta-data (M1), meta-information (M2) and meta-knowledge (M3). In Figure 1 we present these concepts integrated within our DIKW hierarchy representation. The downward arrow represents the process of instantiation, effectively enabling loops in the transitions. These contextually shifting abstraction levels contribute to the complexity of core concepts in the discipline of information systems.

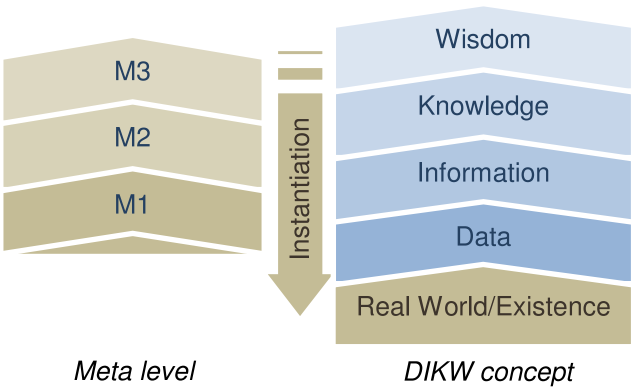

Figure 1: Meta levels and the DIKW model

Metadata management

In order to position metadata management in the enterprise context the authors refer to the functional framework in Table 2 published by the Data Management Association (DAMA). Within this framework metadata management as one of ten data management functions covers "planning, implementation and control activities to enable easy access to high quality, integrated meta data" (Mosley 2008 p. 11). It also supports most of the other data management functions.

According to DAMA metadata management comprises the following activities: understand metadata requirements, define the metadata architecture, develop and maintain metadata standards, implement a managed metadata environment, create and maintain metadata, integrate metadata, manage metadata repositories, distribute and deliver metadata, and support metadata reporting and analysis (Mosley 2008).

Table 2: Metadata management within the DAMA framework (adapted from Mosley 2008)

Function	Scope summary
Data Architecture Mgmt.	Enterprise Data Modelling, Value Chain Analysis, Related Data Architecture
Data Development	Analysis, Data Modelling, Database Design, Implementation
Data Operations Mgmt.	Acquisition, Recovery, Tuning, Retention, Purging
Data Security Mgmt.	Standards, Classification, Administration, Authentication, Auditing
Reference & Master Data Mgmt.	External Codes, Internal Codes, Customer Data, Product Data, Dimension Mgmt.
Data Warehousing & BI Mgmt.	Architecture, Implementation, Training & Support, Monitoring & Tuning
Document & Content Mgmt.	Acquisition & Storage, Backup & Recovery, Content Mgmt., Retrieval, Retention
Metadata Mgmt.	Metadata Architecture, Integration, Control, Delivery
Data Quality Mgmt.	Specification, Analysis, Measurement, Improvement
Data Governance	Strategy, Organisation & Roles, Policies & Standards, Projects & Services, Issues
	Abbreviations: Mgmt.=Management, BI=Business Intelligence

Tools and technology, such as metadata repositories, registries, or warehouses, facilitate efficient and effective metadata management initiatives. This technology can also facilitate other related initiatives, as is shown in Table 3.

Table 3: Repositories used in other selected initiatives

Initiative	**Metadata technology**
Business Intelligence and Data Warehousing	Metadata repository, Data dictionary (Shankaranarayanan and Even 2004) Metadata warehouse (Sen 2004)
Knowledge Management	Knowledge repository (Alavi and Leidner 2001; Nevo and Chan 2007) Knowledge warehouse (Offsey 1997)
Enterprise Architecture Management	EA repository (Fischer et al. 2007)

Marco and Jennings (2004) introduced the concept of a managed metadata environment (MME) as "the architectural components, people and processes that are required to properly and systematically gather, retain and disseminate meta data throughout the enterprise". The six components that constitute a MME are displayed in Figure 2.

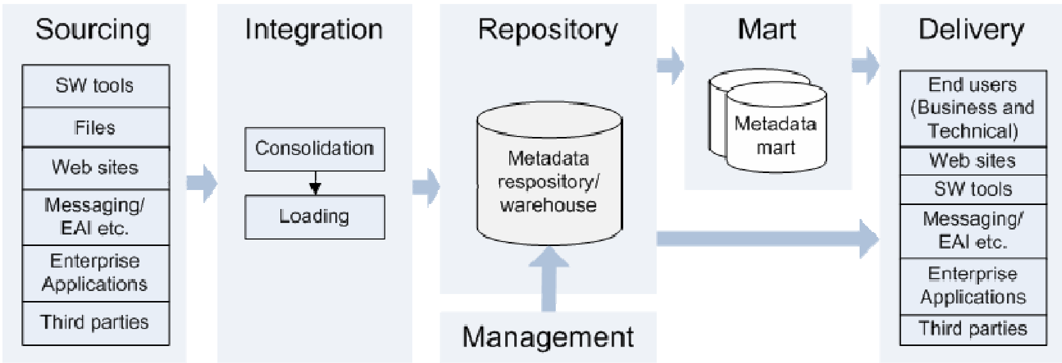

Figure 2: Managed metadata environment layers (adapted from Marco and Jennings 2004)

The authors argue that MMEs constitute a type of enterprise-wide information system. Since MMEs have not been given sufficient attention in academic research, this study as part of a larger research project attempts to contribute to filling the gap by identifying issues hindering metadata management initiatives, as well as investigating common metadata technology capability requirements.

RESEARCH DESIGN

This qualitative exploratory study aims to investigate common conceptions and types of metadata, issues of enterprise metadata management and a set of capabilities typically required of metadata management tools. The study's results will qualify toward building the analysis theory type (Gregor 2006).

Following a literature review on metadata and metadata management, an expert study covering two rounds equivalent to phase one of the Delphi method (Okoli and Pawlowski 2004) was designed to answer the following research questions:

RQ1: What metadata types do data management experts discern?

RQ2: Which issues hinder metadata management initiatives?

RQ3: Which capabilities should enterprise metadata management technology support?

The underlying inquiry method has been selected as a basis for this study due to its features of expert anonymity, controlled feedback and consensual outcome (Dalkey 1969). The Delphi method does not require a statistically valid sample size and the consensual outcome is unique to the specific panel and context at hand. It is particularly suitable in situations where subjective opinions are to be elicited and the personal contact may be limited due to time and cost constraints. The method has been applied in numerous settings for forecasting, issue identification/prioritisation, and concept/framework development (Okoli and Pawlowski 2004). Recent noteworthy applications include studies to define information science (Zins 2007b), and knowledge management system scope and requirements (Nevo and Chan 2007). The approach taken in this study is similar to that of Zins' (2007a) whereby results are evaluated qualitatively based on the interpretation of feedback gathered in the second round.

RESEARCH METHOD

Selection of participants

In order to identify suitable expert candidates to be invited to participate in the study, the researchers first reviewed publication records in metadata management and related areas. Additionally, any referral by already identified experts was reviewed on the merit of experience, and if qualified, added to the candidates list.

Since academic and practitioner viewpoints may differ, as reflected in the IS research and practice literature (Lee et al. 1999) the researchers decided to include available academic as well as practice literature in the search for publishing experts. A total of 41 experts in the fields of data and metadata management, data governance and data quality based on their publishing record were invited to participate in the study.

Study administration

The questionnaires were administered electronically. In order to facilitate participants' response effort the participants were given an option to either answer the study questions off-line and email their responses back to the researchers or answer the questions using an online questionnaire. The online questionnaire was developed in LimeSurvey v1.86 (www.limesurvey.org). All participants except for one opted to use the online web questionnaire method to respond. In total, 16 valid responses were received.

Analysis method

Responses to the introductory question on metadata definitions to elucidate the conceptual stand across the panel were parsed using a grammatical framework of subject, predicate, object and complement. Any missing elements in the responses were substituted with silent elements. Such structured representation of the metadata definition statements facilitated a cross-statement comparison analysis.

For the main three research questions, the open-format responses received from the 16 respondents in each of the questions were separated into individual statements. These statements were then compared to each other to form representative concept categories. These categories were further clustered into the main succinct themes. Through discussion within the research team the authors arrived at a consensus on the individual categories and theme areas. In the follow-up round these preliminary findings were then presented to the panel of experts for their individual critique. Based on experts' comments the researchers then made amendments to the final findings.

Participants' profile

The participants' expertise stems from one or more of the following roles: Academic/Researcher, Data Management Consultant, Metadata Manager, Data/Systems Architect/Developer, and Metadata Management Product Manager/Developer. Geographically, the experts represent primarily North America and Europe, however, experts from Israel and Australia participated as well. Table 7 in the Appendix lists the actual demographic statistics collected from 13 members of the panel (three participants did not respond to the demographic questions).

The length of relevant expertise in Table 7 indicates 11 (84.6%) panel members have been involved with metadata management for 10 or more years in total, and the remaining two experts (15.4%) have 2 to 10 years of involvement with metadata management in total. Eleven (84.5%) experts indicated they have experience with large organizations (500 or more employees) and five (38.5%) experts have worked with small and medium-size organizations (less than 500 employees). The panel's experience by sectors demographic shows that four major sectors of Industry, Education and Academia, Government, and Non-profit were represented on the panel with the most common being the Industry sector (quoted by 11 experts) and the least common being the Non-profit sector (quoted by 4 experts).

FINDINGS AND DISCUSSION

Metadata conceptions and typology (RQ1)

In order to establish a common understanding of the concept of metadata the authors first asked the experts to briefly mention their preferred definitions of metadata. The dissected responses can be found in Table 8 in Appendix 2. Most of the panel's metadata definitions stated that metadata is usually *data* or *structured information*. They further define metadata as *describing* a) *Data*, b) *Information Object or Asset*, c) *System*. Finally, although the purpose mentioned in the metadata definitions varies, it often suggests gaining value from effective *use*, and *management* of the information objects.

The *data* versus *information* aspect of the subject element suggests the question of genus, i.e. whether metadata is just data or a matter of a higher order, such as information, or indeed a transitional function. The *structured* versus *unstructured* aspect of the subject element introduces the issue of metadata with or without an explicit internal structure. The object element in the definitions presents the issue of metadata scope. In the strictest sense metadata describe *data* only but the concept is often broadened to include metadata about any *information object*, such as a book, or even a *system*.

Following the above intensional definitions, the metadata types question (RQ1) was to elicit extensional definitions from the experts. The responses contained metadata types and typologies. In total 75 individual types were identified. The types were then grouped into categories and reconstituted into various typologies by relevant criteria. Across the individual metadata types the authors isolated four major foci as shown in Figure 3.

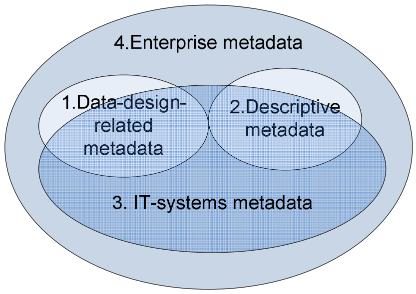

Figure 3: Metadata focus areas

Based on these focus areas, we discern two separate dimensions – the conceptual role (1 and 2) and the scope (3 and 4) of metadata types. We propose that metadata types can be classified into two distinct conceptual roles - prescriptive and descriptive as shown in Table 4.

Table 4: Two conceptual roles and respective metadata typologies based on the types nominated by the experts

Conceptual role	Metadata type examples	Role-specific typologies	Generic typologies
Prescriptive (ontological)	*Models (data models, business rules, process models,...), Classifications (taxonomies and reference data), and Definitions (glossaries, thesauri)*	*By vertical viewpoint:* • Conceptual, Logical, Physical *By horizontal viewpoint:* • Data, Process... *By Zachman's architecture framework cells* *By IS lifecycle phases:* • Requirements, Design...	*By user domain:* • Business • Technical *By underlying object's structure:* • Structured • Unstructured *By purpose:* • Descriptive • Administrative • Technical • Use&Usage
Descriptive (derivative)	*Quality metadata, Usage metadata, Audit trail, Annotations, Document and Content management metadata*		

The *Prescriptive* conceptual role is meant for metadata of an ontological nature such as controlled vocabularies, taxonomies, and database schemas that *can* be conceived prior to the instances they describe. The *Descriptive* conceptual role, on the other hand, is for metadata of a derivative nature, such as annotations, usage data, quality data, document and content management metadata, audit trails and other logs, that *cannot* be conceived prior to the existence of instances they describe.

The *Role-specific typologies* column in Table 4 includes typologies that fit within a single conceptual role. Metadata types representing columns, rows or cells of the Zachman (1987) framework, as well as artifacts created at and classified by different IS lifecycle phases, fit the prescriptive conceptual role. The *Generic typologies* column includes typologies transcending the *Prescriptive* and *Descriptive* classification. The *By user domain* typology classifies metadata by the targeted principal user perspective – *Business* or *Technical*. The *Unstructured* type contains metadata created for data of unspecific internal structure. Finally, the *By purpose* typology resembles classifications popular in the bibliographic community (cf. Gilliland 2008).

Issues in metadata management initiatives (RQ2)

A total of 55 individual statements were extracted from responses provided by the 16 expert participants. These 55 statements were compared to one another to identify 19 issue categories. These categories were then grouped together to identify seven issue areas. In the feedback round the experts provided comments which resulted in adding two new categories and regrouping some of the categories into four final issue themes as presented in Table 5.

Table 5: Issues in metadata management initiatives

Issue theme	Typical issue categories	Frequency
Executive mandate and business support	*Indirectness of the benefits*	9
	Lack of support and sponsorship from business management	7
	Unclear value articulation and justification	1
	Competing projects	1
Technology implementation and operation	*Scope and tool complexity (metadata types, sources, formats)*	3
	Inadequate tool features (usefulness)	3
	Tools complicated to use	3
	High cost of tools	2
	High cost of processes and staff	2
	Inefficiency of metadata generation	2
	Technology difficult to implement	1
	Interoperability, especially in legacy, local datasets	1
Organisational maturity	*Poor understanding of metadata aspects*	8
	Lack of established processes/governance	3
	Skill, knowledge and experience in metadata management	3
	Missing shared definitions	1
	Missing external standards	1
	Culture of knowledge-is-power	1
Metadata quality	*Low quality of metadata*	2
	Insufficient IT-sourced metadata	2
	Insufficient user-sourced metadata	1

The three most frequently mentioned themes among the issues were *Executive mandate and business support*, *Technology implementation and operation,* and *Organisational maturity*, which indicates that the panel perceives them as most critical. Of all the issue categories the following three were mentioned the most often: *Indirectness of the benefits*, *Poor understanding of metadata aspects*, and *Lack of support & sponsorship from business management*. The authors hypothesise that the lack of support and sponsorship from business management for metadata management initiatives may be caused by unclear value articulation which is further exacerbated by poor understanding of metadata aspects and the perceived indirectness of the benefits.

Technology capabilities (RQ3)

We dissected all responses into 68 individual capability statements. The statements were then clustered by similarity into categories and finally mapped to six high-level capability themes. In the feedback round the experts were agreeable to the results and the only amendment introduced was the *bi-directional* support. Table 6 shows the final list.

Table 6: Technology capabilities

Capability theme	Capability categories
Full metadata lifecycle	*Versioning and change control {5}; Capture/Harvesting/Population {3}; Update and manual entry {2}; Access control {1}*
User interface / Ease of use	*Easy to use for business and technical users {3}; Browser front-end {3}; Extensibility and Customisation of user interface {1}; Multilingual support {1}; Bi-directional edit support* [+] *{1}*
Robust search, analysis and reporting	*Reporting and documentation facilities {6}; Robust search facilities (including full-text search) {4}; Ad hoc query and analysis (including impact analysis) {2}; Lineage/provenance and mappings traceability {1}; Inter-model relationship traceability {1}; Audit trail {1}*
Metamodel	*Support for a wide range of metadata types {5}; Extensibility of metamodel {5}; Support for structured and unstructured data {1}*
Integration and Interoperability	*Integration with other tools through bridges {8}; Robust set of metadata sources {5}; Import and Export of external standards, schemas etc.{2}; Support standards (such as from W3C, OMG) {1}*
Other	*Alignment with information management requirements and maturity {3}; Performance and scalability {2}; Multi-environment support (as-is/to-be, dev/test/prod) {1}; Link or build reference data {1}*

Notes: The numbers in curly brackets denote the frequency of individual experts' statements in each category
[+] added from experts' feedback in the follow-up round

Although the frequencies of each capability mentioned by the experts do not reliably measure exact priorities of the individual categories, they do approximately indicate the level of interest in specific capabilities from the panel members. Within the *Full metadata lifecycle* theme, the *Versioning and change control* was the most frequently quoted capability category. The *Easy to use for business and technical users* and *Browser front-end* categories were most often mentioned in the *User interface* theme. In the *Robust search, analysis and reporting* theme, the most dominant categories were *Reporting and documentation facilities* and *Robust search facilities. Support for a wide range of metadata types* and *Extensibility of metamodel* were the most quoted within the *Metamodel* theme. In the *Integration and Interoperability* theme, *Integration with other tools through bridges* and support for *Robust set of metadata sources* were most often mentioned capabilities. Based on the overall positive feedback from the experts in the second round, authors suggest that the capabilities in Table 6 present a relevant set of technology requirements for metadata management initiatives.

CONCLUSION AND OUTLOOK

Although the concept of metadata is not new, it deserves more attention as data become pervasive at multiple organisational levels. An efficiently managed metadata environment can add value from operations to the strategic decision making levels.

Through the use of literature and empirical data from an international expert study the authors proposed two conceptual metadata roles, *prescriptive* and *descriptive*, incorporating common metadata typologies. Further, the authors proposed four major issue themes in regards to metadata management initiatives - *Executive mandate and business support*, *Technology implementation and operation*, *Organisational maturity*, and *Metadata quality*. Finally, the paper investigated technology capabilities in managed metadata environments. The findings represent a novel contribution to knowledge in the area of enterprise metadata management.

Practical implications of the study are manifold. The typology presented in Table 4 can be used to clarify terminology and facilitate communication across the organisation. It may also be used to inform and focus metadata management initiatives. The two proposed conceptual roles of metadata have the potential to help reconcile existing misunderstandings that often occur across communities of use. By addressing issues compiled in Table 5 metadata managers and consultants can improve their chances for success. The proposed metadata management tool capability set in Table 6 can be used by both, organisations in their tool selection criteria during the metadata management technology acquisition process, and by vendors to enhance their product offerings in this domain.

The rich empirical data received during this expert study were sufficient to arrive at the findings within two rounds of the brainstorming phase of the Delphi inquiry. Since the findings reported herein are parsimonious the authors decided not to introduce any ranking statistics that are frequently seen in studies adopting the Delphi process in a more holistic fashion. The authors plan to further validate the results and extend the research in the follow-up Delphi rounds toward proposing a critical-success-factor-based framework.

One of the features as well as limitations of the study at hand is the inclusion of experts' views only. Although their expertise is based on long-term experience with actual instances of data and metadata management systems, the study does not include end-user views. The authors therefore plan to verify and enhance the findings through a series of case studies exploring how organisations implement and practice metadata management.

As the findings suggest, the question of value justification for enterprise metadata management systems will need to be investigated further in future research. These meta-level information systems present a good opportunity to apply the existing theories within the information systems discipline.

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APPENDIX 1

Table 7: Expert panel demographic profile

Characteristic	**Frequency**	**%***	**Characteristic**	**Frequency**	**%***
Length of Relevant Expertise			***Experience by Industry Sectors*[+]**		
Less than 2 years	0	0.0	Commercial and Professional Services	6	46.2
2 to 5 years	1	7.7			
5 to 10 years	1	7.7	Consumer Products	4	30.8
10 or more years	11	84.6	Consumer Services	4	30.8
***Experience by Organization Size*[+]**			Energy & Materials	4	30.8
Less than 100 employees	1	7.7	Financials	8	61.5
100-499 employees	4	30.8	Health Care	6	46.2
500 or more employees	11	84.6	Information Technology	5	38.5
***Experience by Sectors*[+]**			Manufacturing, Construction and Trading of Capital Goods	5	38.5
Education and Academia	6	46.2			
Government	7	53.8	Telecommunication Services	6	46.2
Industry	11	84.6	Transportation	5	38.5
Non-profit	4	30.8	Utilities	2	15.4
Notes: * Percentage of 13 participants; [+] Multiple categories allowed to be selected					

APPENDIX 2

Table 8: Expert panel's metadata definitions

Subject	**Predicate**	**Object**	**Complement**
[Data]	Describe	Data elements	*Exclude: descriptive data about [actual matter]*
Structured information	Associated with	Information system or an object	*Purpose: discovery, description, use, management, and preservation*
Data	Describe	Data resource or collection thereof	

Data	Describe	Information and [system] assets	*Include: business concepts, requirements, design, physical implementation and operation of data, business processes, applications and technology*
Data	[Describe]	Data	*Include: content of data dictionaries, data models, data definitions, business rules related to data (validation, integrity rules), documents describing data designs Focus on: Design data, not descriptive data*
Data	[Describe]	Data	*Purpose: use data more effectively*
Supporting information	[being associated with]	[Information asset]	*Purpose: allows an enterprise to gain maximum value from the use of an information asset*
Contextual information	[being associated with]	Raw data	*Purpose: provide meaning Include: technical items and business definitions, calculations, algorithms, etc.*
Data	Describe	Information asset	*Purpose: to enable effective use and management*
Data	Describe	Other data	*Aspects: meaning, characteristics, and purpose*
Data	Describe	System and use of information	*Include: structure and workings*
Structured information	Characterize	Data	*Aspects: semantic, logical, physical*
			Include: definitions, descriptions, inter-relationships
Definition and specification	[being] above	“Real” level	*Include: documentation (requirements, design, implementation), project data...*
[Data]	[needed for]	[Data and process]	
[Data]	[being associated with]	Data content	*Purpose: provide context*

Notes: The square brackets denote silent elements and elements edited by researchers for clarity

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