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Committee Manager: **Corrie Charles Mr.**

TC251 2021 N741 - AHG4 Final Report

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Information Management & Decision-Making Criteria

Ad-Hoc Group 4 Report	Final

Contents

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 251, *Asset Management*, Ad Hoc Group 4, *Information Management & Decision-Making Criteria*.

Any feedback or questions on this document should be directed to the Convenor of Ad Hoc Group 4 through the national standards bodies. A complete listing of these bodies can be found at www.iso.org/members.html.

Executive Summary

Ad-Hoc Group 4 (AHG4) was formed in August 2020 to focus on PIP001 and present a recommendation to the Chairman's Advisory Group (CAG) to TC251 at the May 2021 plenary session. AHG4 reframed the mission statement to focus on understanding guidance related to specification, collection, management, and analysis of data supporting asset management decision-making in the larger context of organizational objectives.

The work done by AHG03 was valuable to setting the direction and boundaries for AHG04. AHG03's findings are particularly relevant with respect to the mandatory elements identified under Inputs within the proposed CIPO process framework for asset management DM. The inputs of interest to AHG4 were Data and Information and Knowledge. AHG4's approach was to start with reviewing the existing set of ISO 55000 standard from the perspective of five key themes. These themes are:

1. Creating Data for Asset Management DM
2. Classifying Data Based on Purpose, Quality and Format
3. Extracting Information from Data relevant to asset management DM
4. Managing Lifecycle of the Data
5. Sharing Secure Information at an Enterprise Scale

Each theme was linked to one or more specific 'mission statement' elements to ensure standards are being reviewed in the context of the intended mission – *Specification, Collection, Analysis, and Management of Data/Information*.

This analysis coupled with a broad scan of the other standards relevant to Data & Information in Asset Management Decision-Making yielded key findings as follows –

1. Data/Information is a key enabler for asset management
2. Data/Information strategy should provide a framework for lifecycle management of information
3. ISO 55000 Series provide 'What' but there are other Standards that can be referred for guidance on the 'How' to manage Data/Information for Asset Management
4. Many different information models exist relating to built assets. The range of standards and the impact of existing approaches means that any attempt in the ISO 55k series to specify specific approaches to information models and classifications may end up detrimental to the overall usefulness of the standards due to limits of applicability and relevance
5. Digitization of all data and information, digitalization of business processes and automation of many tasks and activities which were previously performed by humans has the potential to significantly enhance productivity and economic growth. However, to fully realize these benefits would require an enterprise-wide Digital Transformation Program with candidate technologies evaluated for their potential benefits, through-life costs, risks and the change management effort needed to implement and sustain the new ways of working

Based on the above findings, AHG4 proposes the following recommendations –

1. Update existing ISO 55000 Series of Standards with appropriate update to clauses clarifying data and information related information or referencing to relevant applicable standards from other TCs like ISO 19650 or ISO 8000.
2. Summarize AHG4 Findings & Recommendations in TC251 Articles. Several topics for these articles are presented in this report.
3. Continuance of AHG4 for an additional period of six months after the plenary to properly manage the effort required to produce the articles.
4. Maintain TC 251's ongoing collaboration with other TCs focusing on Data/Information

Information Management & Decision-Making Criteria

1   Mission Statement

The mission statement of Ad Hoc Group 4 (AHG4) is stated as follows –

> *Understand guidance related to __specification, collection, management, and analysis__ of data supporting asset management decision-making in the larger context of organizational objectives.*

2   Historical Context

During the virtual plenary in June 2020, it was decided that an Ad-hoc group needs to be created to focus on elevating the work required to be done for advancing the objectives of PIP001. As a result, Ad hoc Group 04 was created in August 2020 with an explicit goal of presenting a final report to the CAG by the next plenary meeting scheduled to be held virtually/in-person during the Summer of 2021.

The list of current members (23 Total spanning 11 countries) of AHG04 are shown in the table below –

Figure 2-1 AHG04 Membership Roster

Role	Member Name	Country
Convenor	Iyer, Shiv	United States
Consultee	Albrice, David	Canada
Drafting Panel Member	Alford, Karen	United Kingdom
Consultee	Alkema, B.	Netherlands
Drafting Panel Member	Androls, Mattias	Sweden
Consultee	Barratt, Ashley	United Kingdom
Consultee	Bevans, Caitlin	United States
Consultee	Corrie, Charles	United Kingdom
Consultee	Davies, Rhys	United Kingdom
Consultee	Hadjioannou, Andreas	Cyprus
Consultee	Hortensius, Dick	Netherlands
Drafting Panel Member	Khan, Imad	Canada
Consultee	Lachmann, Katharina	Germany
Drafting Panel Member	Lafioune, Nawel	Canada
Drafting Panel Member	Levin, Norberto	Argentina
Consultee	McLean, Scotty	Canada
Consultee	Noda, Takaaki	Japan
Drafting Panel Member	Patrício, Hugo	Portugal
Drafting Panel Member	Roth, Cyril	Germany
Drafting Panel Member	Schwarzenbach, Julian	United Kingdom
Drafting Panel Member	Shetty, Navil	United Kingdom
Drafting Panel Member	Sidawi, Sam	Canada
Drafting Panel Member	van Herpt, R.J.C.	Netherlands

Several Experts in AHG4 have links to other TCs (59/184) and relevant global initiatives on Data/Information thereby providing a wider influence on this work.

The work done by AHG03 was valuable to setting the direction and boundaries for AHG04. AHG03 researched which elements to include in the following three areas – a) sources of influence (decision-making (DM) criteria identification), b) DM mechanism, and c) DM application. Furthermore, they classified the elements as either '*mandatory*' or '*recommended*' linking them into a process framework to make it more practical and less conceptual.

AHG03's findings are particularly relevant with respect to the mandatory elements identified under Inputs within the CIPO process framework for asset management DM (*See Appendix A for details on AHG03 findings*). The inputs of interest to AHG04 are:

Data and Information - availability and quality naturally have an impact on processes that can be used for decision-making. However, while guidance should acknowledge the desire for 'fact-based' decisions, it should also recognise unavoidable uncertainties, such as represented by Resnikoff's Conundrum (loosely paraphrased as 'the most useful data to support decision-making is the evidence we least wish to observe' e.g. in justifying a planned intervention, we would really like to know what would happen, and when, if we do not intervene – the 'road untaken').

Knowledge - analyse and translate data/information to insight (see Figure 2 -2).
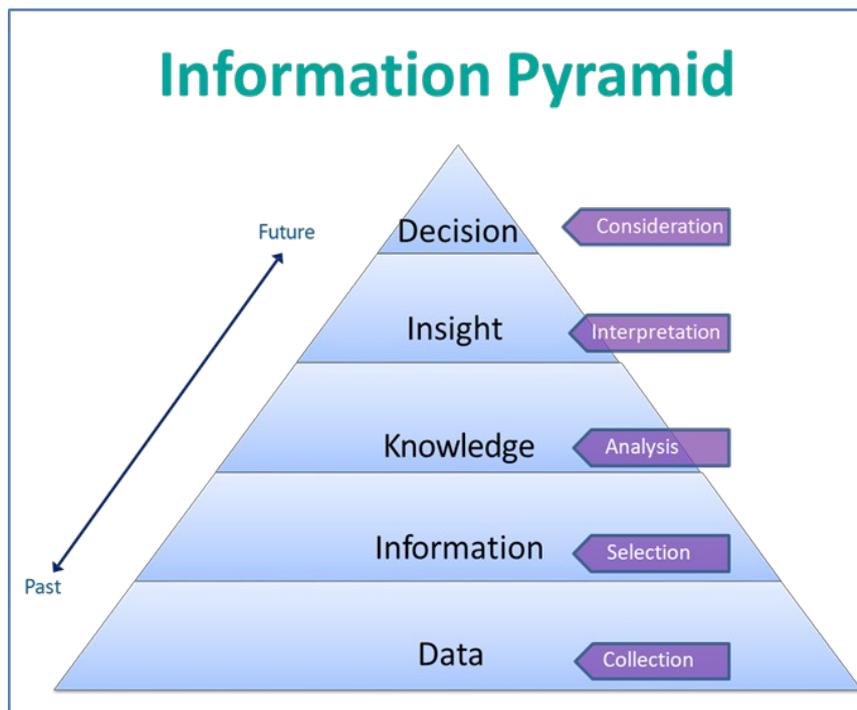

Figure 2-2 Information Pyramid

Since AHG03 handled the asset management DM process framework and outlined the elements to be considered, AHG04's initial goal and objective needed adjustment to align with AHG03's findings and recommendations.

3   Approach

At the outset, AHG04 initiated efforts by scoping and refining the mission statement factoring in the AHG03 final report findings. During this process the team refined the mission statement to emphasize various data facets in support of asset management DM. The initial and refined mission statements are outlined in Figure 3 -3.
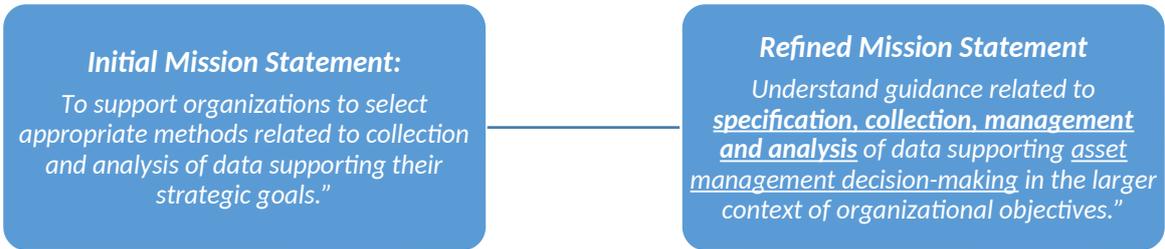

Initial Mission Statement:

To support organizations to select appropriate methods related to collection and analysis of data supporting their strategic goals."

Refined Mission Statement

Understand guidance related to *specification, collection, management and analysis* *of data supporting* *asset management decision-making in the larger context of organizational objectives."*

Figure 3-3 AHG04 Initial and Refined Mission Statement

The refined problem statement focuses on all aspects of the data life cycle while limiting the scope to supporting asset management DM.

Next, the group reviewed all the ISO 55000 series (00, 01, 02, and 10) standards against five key themes to identify possible gaps, issues, and improvement areas. These themes are:

6. Creating Data for Asset Management DM
7. Classifying Data Based on Purpose, Quality and Format
8. Extracting Information from Data relevant to asset management DM
9. Managing Lifecycle of the Data
10. Sharing Secure Information at an Enterprise Scale

Each theme was linked to one or more specific 'mission statement' elements to ensure standards are being reviewed in the context of the intended mission – *Specification, Collection, Analysis, and Management of Data/Information*. The process was to first determine what guidance language was available in the current set of standards against each of the five themes. If guidance was available, the next step was to determine if there were gaps with respect to the desired level of guidance under a given theme. The gaps were recorded and relevant recommendations (modify, refer out to existing standard, etc.) were developed. Detailed description of the gaps can be found in Section on Findings. The example below illustrates the process.

Themes	Sub-Theme	Problem Statement Element	ISO Standard	Clause	Description/Gap	How best addressed?
Creating Data for AM Decision-Making		Specification, Collection	0		Repeated statements about the importance of asset data/ information to asset management outcomes, but scope of document means that the 'what' and the 'how' are not covered. Does not refer to BIM or reference the ISO 19650 series.	Needs references to BIM and the ISO 19650 series
			1	6.2.1	Para 2 covers various organizational requirements but does not mention data/information.	Include minor addition to the current list
				7.6.2-3	7.6.2 Specifies creating and updating information & 7.6.3 specifies control of documented information. Approaches to achieve this are not defined.	Include notes to refer out to ISO 19650 series and ISO 8000-61

Figure 3-4 Standards Gap Analysis Example

4 Findings

4.1 Data/Information needs to be viewed from the key theme perspective

Findings from the analysis of the ISO 55000 series against the key themes for this project are detailed in the table below:
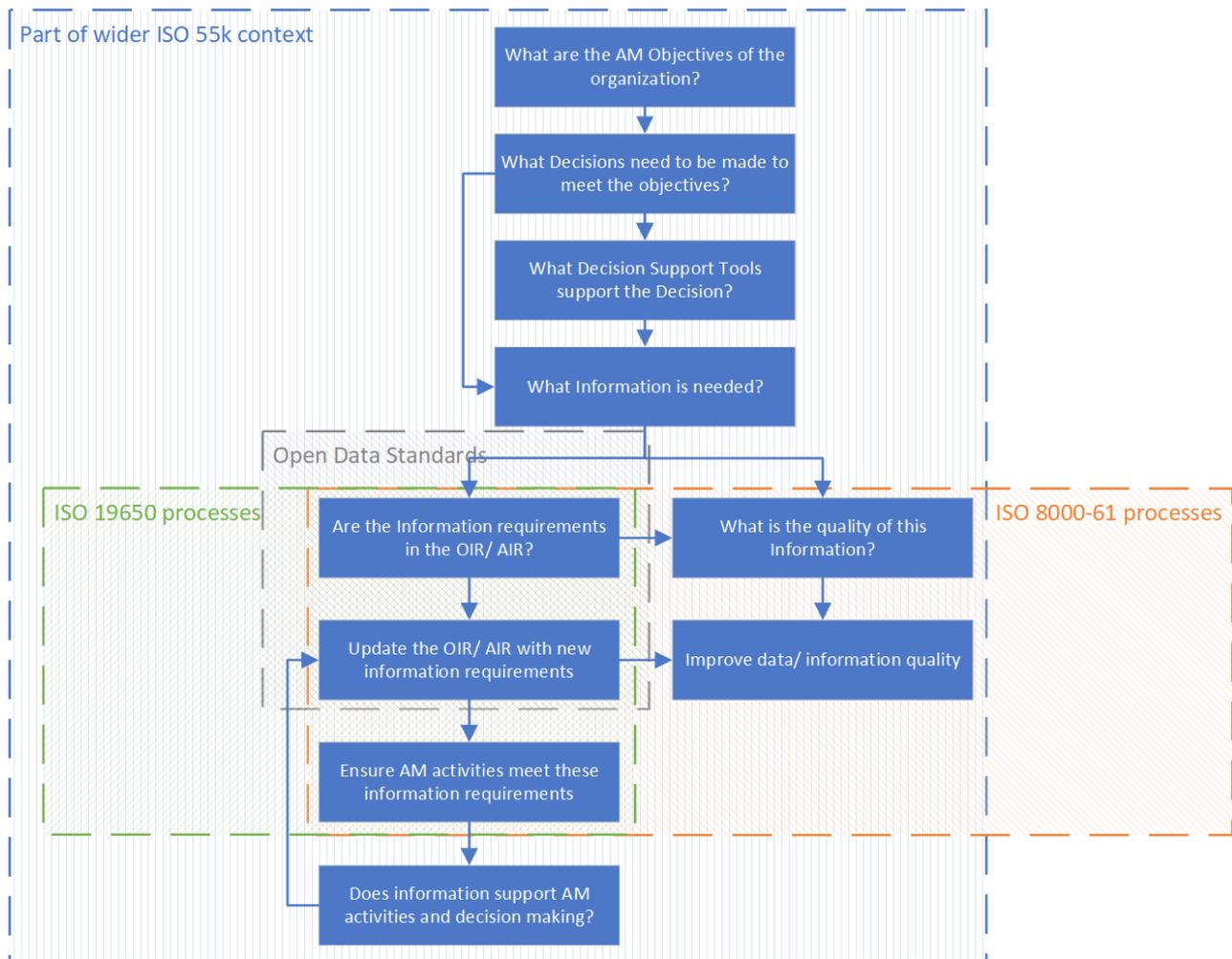
Table 4-1 Standards Current Gaps

ID	Theme	Standard	Clause(s)	Description/ Gap
1	Creating Data for AM Decision-Making	ISO 55000		Repeated statements about the importance of asset data/ information to asset management outcomes, but scope of document means that the 'what' and the 'how' are not covered. Does not refer to BIM or reference the ISO 19650 series.
2		ISO 55000	Various	Various references to decision making, that could be improved for clarity and consistency: 2.2 b) asset investment; 2.5.2 a) tools for organizational knowledge and decision making; 2.5.2 b) AMS provides inputs to decision making and organizational strategic planning; 2.5.2 b) long term and sustainable approach; 2.5.2 c) risk-based; 2.5.2 d) data integration leading to improved organizational decision making; 2.5.2 d) communications with employees and contractors; 2.5.3.2 influences of stakeholders; 4.2 asset management decision making; 6.2.2 a) decision making... to achieve asset management plan(s) and asset management objectives; 7.5 a) organizational decision making
3		ISO 55001	6.2.1	Para 2 covers various organizational requirements but does not mention data/information.
4		ISO 55001	7.6.2, 7.6.3	7.6.2 Specifies creating and updating information & 7.6.3 specifies control of documented information. Approaches to achieve this are not defined.
5	Classifying Data Based on Purpose, Quality, and Format	ISO 55001	7.5 b) and c)	Do not cross reference ISO 19650 series/BIM
6		ISO 55001	7.5 e)	Does not mention Data Quality
7		ISO 55002	4.1.3 g)	Does not refer to information quality while discussing 'information systems, information

ID	Theme	Standard	Clause(s)	Description/ Gap
				flows and decision-making processes'
8	Extracting Information from Data Relevant to AM Decision-Making	ISO 55001	7.5	Specifies requirements on information in general terms and does not have any mention on reqs for data collection and registration
9		ISO 55002	4.4	Does not refer to BIM or ISO 8000 series which cover approaches to information management
10		ISO 55002	7.5	Clause needs to be updated because whilst it makes reference to BIM/ISO 19650/8000 series this is only as Notes. ISO 8000 reference is only to Part 1
11	Managing Lifecycle of the Data that enables AM Decision-Making	ISO 55001	5.3	No roles or responsibilities described for data management experts in the organization
12		ISO 55001	9.1	Does not refer to the quality of information in the organization to support performance evaluation monitoring processes.
13		ISO 55001	9.3 c)	Does not refer to the monitoring of the quality of information used in review of information on asset performance.
14		ISO 55002	7.6	Refers to documented information but does not refer to the ISO 19650 BIM standards that also provide extensive guidance on it
15		ISO 55002	9.1.2.1	Does not mention monitoring the quality (performance) of information to support AM
16		ISO 55002	9.2	Does not mention quality of asset information as a key subject to be audited
17		ISO 55002	10.2	Does not mention data/information as a possible area of nonconformity
18		ISO 55002	Fig B-2	Does not mention how to extract data/information from service providers as they transition out
19		ISO 55010	5.3.3, 6.2, and 6.3	Does not refer to how data and info can be better managed
20	Sharing Secure Information at an Enterprise Scale	ISO 55001	8.3 c)	Refers to sharing of information and knowledge with outsourced parties but does not explicitly state approaches to achieve this securely. Also, no reference to internal sharing at enterprise

ID	Theme	Standard	Clause(s)	Description/ Gap
				scale
21	Definitions	ISO 55000	3.2	Missing definitions related to data such as asset data, asset information, asset register, data management
22	Bibliography	ISO 55001		No reference to ISO 19650 series or ISO 8000 series, particularly ISO 8000-61
23		ISO 55002		No reference to ISO 19650 series or ISO 8000 series, particularly ISO 8000-61
24		ISO 55010		No reference to ISO 19650 series or ISO 8000 series, particularly ISO 8000-61

Since several of the gaps identified above refer back to other standards where the gap in guidance has already been addressed, it is worthwhile to understand the linkages between these standards and ISO 55000 series. The relationship between ISO 55000 series, ISO 19650 series, ISO 8000-61 and Open Data Standards[1] is illustrated below:

[1] buildingSMART International

Asset management decisions are reliant on trusted data. Asset management data will reside in a number of places including external sources. Data is often created in a silo to support a discrete business outcome or process. When this data is brought together with other data, discrepancies emerge because it was not designed consistently or for the new purpose.

Data has to be defined to be fit for all intended purposes. This involves detailing the business questions, the data needed to answer each question and establishing the required data quality parameters to satisfy these requirements. These are formalised within a data standard.

This approach establishes data standards across asset management, facilitates interoperability, improves knowledge about the primary source to reduce data holding within the AM estate. It also forms a framework for connecting data within a digital twin

4.2 Data/Information is a key enabler for asset management

In the management of physical assets, data/information relates to attributes such as cost, risk, performance, and service levels. Data/Information on these attributes are integral to the effective and efficient management of the lifecycle of physical assets. The data/information collected on the physical assets are only useful to the organization in as much as enabling the effective and efficient management of the assets to produce a product or deliver a service. This entity (data/information on cost, risk, performance, and service levels) cannot be bought or sold in open markets or in direct transactions (financial definition of value). Therefore, within the context of the application of ISO 55000 Standards to physical assets, Data/Information cannot be considered as an asset since it does not meet the necessary conditions of the current definition.

Data/information *is* (rather than *should be considered*) a significant enabler of asset management and thus should be *dealt with appropriately*. Organizations may choose to apply *relevant* asset management standards to *their* data/information in pursuit of effective and efficient management of *their* asset portfolio.

4.3 Data/Information strategy should provide a framework for lifecycle management of information

The following notes further elaborate on this finding -

1. An organisation needs a process to collate the **data requirements** and information across the enterprise. Further, sub-strategies on data and information down the value chain that rolls up to the enterprise asset management strategy also needs to be developed, however, standards from different perspectives and contexts may not readily align. Data/Information requirements at the asset level should feed into the overall asset information system requirements at the sub-system/system level which then feeds into the overall portfolio-level decision-making.
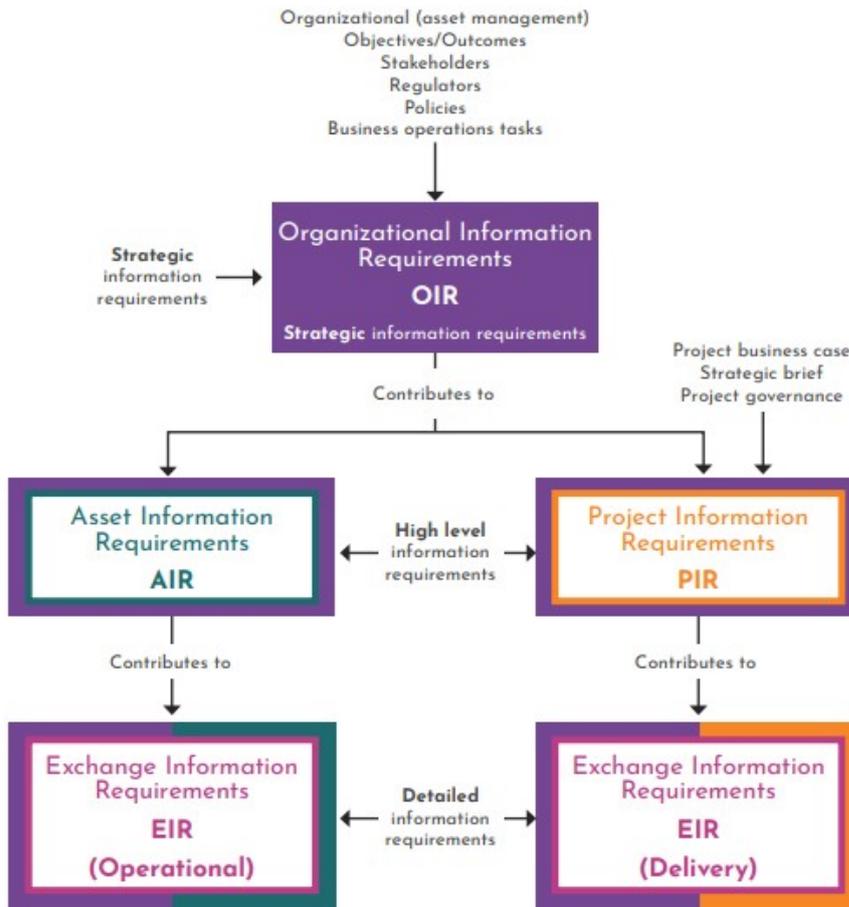
Figure 4-6 Relationship between different information requirements - From UK BIM Framework Guidance Part D
https://www.ukbimframework.org/wp-content/uploads/2021/02/Guidance-Part-D_Developing-information-requirements_Edition-2.pdf

2. Data/Information requirements should be linked to **Asset Management Business Capabilities**. Business capabilities may have social, environmental, financial, or other community developmental elements.
3. Organizations should understand and document the decisions they need to make, **understand the data/information requirements to support those decisions**, and how to acquire the data/information to meet the requirements.
4. **Data interoperability** addresses the ability of systems and services that create, exchange and consume data to have clear, shared expectations of the contents, context and meaning of that data. Organizations should invest resources in defining data interoperability standards so that information derived from such data meet the needs of the organization internally as well as externally if applicable.
5. **Data Security** is the prevention of unauthorized access, use, disruption, modification, or destruction of *data* in storage (on-premise or cloud). Whereas Information security is the prevention of unauthorized access, use, disruption, modification, or destruction of *information*. Data Security is a layer of information security and must be included in the Organization's Asset Information Business Architecture. ISO 19650-5 provides guidance on the wider challenges of information security in the built environment, particularly information on sensitive assets and/or sensitive information across complex supply chains.
6. Organizations need to focus on the **Data-to-Decisions** link while developing data requirements.
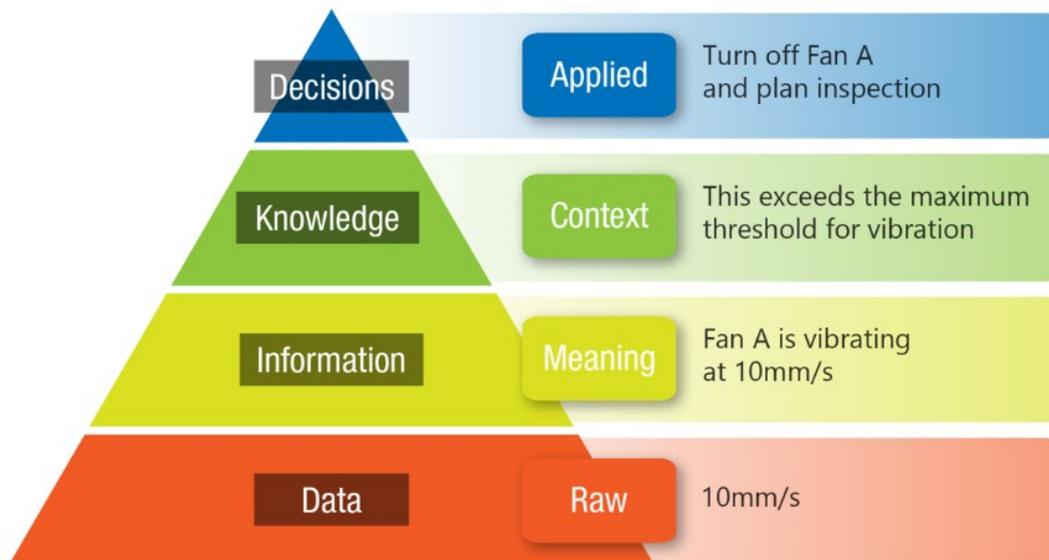
Figure 4-7 – Data-to-Decision Link w/ Example (Source: Asset Management Academy (AMA) Training Material)

7. Structured data is highly organized and formatted so that it is easily searchable in relational databases. Unstructured data has no predefined format or organization, making it much more difficult to collect, process and analyse. Unstructured data is completed by Structured data yielding useful insights. With the advent of **Industry 4.0 technologies**, management and use of both structured and unstructured data formats need to be carefully considered because they each need different types of data tools and methods for processing and analysis.

8. Organizations should maintain consistency in **data categorization and classification** to create structured metadata and connect it to other data. Also consider linking data classification to asset classification.

9. While sharing data, models, and analytics with end-users within and outside the organization, it should consider technologies that employ **high-level methods of accountability and lineage-tracing** to deliver trust and confidence to consumers.

10. Organizations must clearly define users, custodians, access permissions/rights through a data governance framework. ISO 8000-150 defines **roles and responsibilities relating to data quality** and is currently under revision.

11. Organizations should take a tiered approach to data storage. **Effective data storage system** should include a variety of solutions (on-premise, cloud, private cloud, others) depending on the usefulness of data and frequency of access.

12. **Data Acquisition and/or Procurement strategies** should be defined carefully after considering how the data will be collected, organized, and cleaned before it is routed to an appropriate tier of the data storage system. Externally procured/acquired data should comply with the OIR/AIR of the organisation. Therefore the Exchange Information Requirements (EIR) should be defined carefully to comply with the OIR/AIR and the specific context of the activity/ contract. This will help ensure that newly acquired data is validated independently and aligns with existing data sets and avoids future data migration/ data quality challenges.

13. **Data quality management processes** are aimed at achieving and maintaining appropriate levels of data quality. Data requirements enable data quality criteria to be agreed and may vary in level of detail based on the required use of the data. Organizations should define data quality thresholds and rules, perform regular data quality assessments, resolve significant data quality issues, and establish a data monitoring and control strategy that includes measurement and reporting of data quality. ISO 8000-61 provides a process reference model for data quality management

It is recommended that the key topics (highlighted in bold) addressed in the thirteen points above should be included in an organization's *Strategic Asset Management Plan (SAMP)* under *Data/Information Strategy* section or referenced out to a similar named stand-alone document.

4.4 ISO 55000 Series provide 'What' but there are other Standards that can be referred for guidance on the 'How' to manage Data/Information for Asset Management

From all HLS standards for management systems[2], ISO 55001 is the only one with a separate paragraph on Information requirements (section 7.5). Since asset management decisions should be based on information, this section requires organizations to specify the <u>attributes</u> and <u>quality requirements</u> of identified information and to specify how and when the information should be collected, analysed and evaluated. Exchange of information with stakeholders, including service providers, shall be considered when information requirements are specified.

ISO 55001 gives no further details on what connection this identified information might have with assets, asset types or asset systems.

ISO 55002 gives some more details in its section 7.5.2:

a) Identification and description.
   All examples that are given here refer to 'static asset data': data which will be available from the first day in use, which will remain the same during the lifetime of the asset.
b) Utilization.
   Although most assets will serve the same purpose and be utilized in the same manner during their lifetime and this characteristic may be seen as 'static asset data' as well, one must allow for the possibility that assets will get a new purpose at some point during the lifetime.
c) Criticality.
   This criterion is very much related to the asset utilization. Asset systems may be critical if in use for a business-critical process. Individual assets within such an asset system may or may not be critical, dependant on redundancy.
d) Performance.
   Information on performance of assets will demand 'dynamic asset data': this may be inspection data or sensor data.
e) Specific risk.
   Very much related to criticality and other risks.
f) Specific competence requirements
   Very much related to utilization, criticality, and other asset management activities.
g) Commercial information.
   This type of information is of a transactional kind.
h) Financial information.
   This type of information may be either transactional data, static data (e.g. acquisition cost, economic lifetime) or dynamic data (e.g. operating and maintenance costs).

All of the above considerations are about what the information should be about. It would be advisable to classify types of data, e.g.

- Static asset data
- Dynamic asset data
   - continuous (sensor data)
   - periodical
   - irregular (e.g. incidental failures of the asset)

For each class of data an organization should describe how this data will be structured, in what system it will be registered, which format will be used to enable exchange and with respect to details: whether the cost and effort of collecting, processing and maintaining a particular level of detail of data is worthwhile.

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[2] Check done for ISO's 9001, 14001, 22301, 27001, 41001 and 50001

Static asset data is usually registered in an asset register. If particular dynamic asset data is linked to this static asset data, one could call this an <u>asset data management system</u>, for which specific commercially available software can be used. Prior to selecting such an asset data management system, the requirements for the system must be defined in relation to the asset management decision criteria. Storage of asset data is only useful if the data is analysed, put in perspective and presented as information which leads to knowledge on which decisions can be based. There is no point in registering asset data which no one will ever want to retrieve.

More can be said on <u>how</u> static asset data should be structured:

First, a coding system with unique codes for each asset is essential for proper identification of assets. This is needed to prevent mistakes like maintaining or removing the wrong asset and to be able to link dynamic asset data to the right asset. The organization should consider labelling/tagging of assets to be able to identify individual assets. Asset owners with mobile assets are most likely to tag their assets but tagging of static assets (e.g. building installations) will be found useful too if several assets of the same asset type are present in one location.

Then, the decomposition of asset systems into separately identifiable assets should be well thought through. Possible considerations are:

a) the wish to report compliancy with regulations at the finest granularity at which lifecycle decisions are made at the organization
b) limitation of quantity of assets, e.g. square metres of floor space, kilometres of road length, etc. for assets which are not easily registered as number of items
c) performance measurement of separately identifiable assets or asset components

If we accept that the ISO 55000 series provides little guidance about how to organise/ manage data/ information for asset management, then the approach to providing clear approaches and requirements could either be to expand the ISO 55000 series to include such content, or to identify whether other standards already provide such definition. Fortunately, such approaches are already defined in both the ISO 19650 series and the ISO 8000 series, particularly ISO 8000-61 and provide broad definition of the activities required to support ISO 55000 series.

Developing these standards and approaches to a level of detail that is relevant to most contexts without being so specific that clauses are not relevant in many contexts is an ongoing challenge. The BIM community through supporting documentation for the ISO 19650 series continues to refine this supporting documentation to guide users across different contexts.

The ISO 19650 series is being developed by ISO/TC 59/SC 13/WG 13 and currently includes:

- ISO 19650-1:2018 - Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 1: Concepts and principles
- ISO 19650-2:2018 - Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 2: Delivery phase of the assets
- ISO 19650-3:2020 - Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 3: Operational phase of the assets
- ISO/CD 19650-4 - Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 4: Information exchange (under development)
- ISO 19650-5:2020 - Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling — Part 5: Security-minded approach to information management

Several of the people involved in development of these standards have asset management backgrounds, therefore, the resultant standards have been developed to be applicable in asset management contexts.

The ISO 8000 series is being developed by ISO/TC 184/SC 4/WG 13 and includes:

- ISO/TS 8000-1:2011 - Data quality — Part 1: Overview (under revision)
- ISO 8000-2:2020 - Data quality — Part 2: Vocabulary (regularly updated)
- ISO 8000-8:2015 - Data quality — Part 8: Information and data quality: Concepts and measuring
- ISO 8000-61:2016 - Data quality — Part 61: Data quality management: Process reference model

Parts 1, 2 and 8 have recently become *'horizontal deliverables'* due to their wide applicability to other standards. The process reference model in Part 61 is applicable in many industrial contexts including asset management.

In conclusion, the ISO 19650 series and the ISO 8000 series of standards, particularly ISO 8000-61, define most of the approaches needed to ensure information management activities support asset management activities.

5   Information Models

Many different information models exist relating to built assets. Some of these are as follows:

- ISO 10303 – Large family of standards covering representation and exchange of product manufacturing information
- ISO 12006-2 – Framework for classification of information. Note that this is just the specification of the approach with many national examples having been created, for example:
    - o   Omniclass in the USA
    - o   Uniclass in the UK
    - o   CoClass in Sweden
    - o   CCS in Denmark
    - o   Etc.
- ISO 12006-3 - Framework for object-oriented information. This is also known as BuildingSMART Data Dictionary or International Framework for Dictionaries (IFD) Library
- ISO 14224 – While originally Oil and gas reliability data, its asset hierarchy model identifying location levels and physical asset granularity levels has become a de-facto standard across the most diverse industries
- IEC 61968 – Series of standards relating to electrical distribution systems
- CIM – Common Information Model - Open standard for structured data that defines how managed elements in an IT environment are represented as a common set of objects and relationships between them. While originally developed for the electric power distribution industry, it is being applied extensively across industries.
- Plus other industry, sector or use specific examples

Additionally, work is ongoing across a range of initiatives to further define/ improve the approaches to information models, such as the Information Management Framework (IMF) being developed by the Centre for Digital Built Britain (CDBB) in the UK. Despite all these standards and activities, actual implementation by asset owners will vary across a range of bespoke and/or legacy approaches, therefore, even if a single unified information model could be agreed, it would take many years for this to be implemented universally, if possible.

This range of standards and the impact of existing approaches means that any attempt in the ISO 55k series to specify specific approaches to information models and classifications may end up detrimental to the overall usefulness of the standards due to limits of applicability and relevance. It is suggested that the current level of

specificity in the ISO 55k and ISO 19650 series of standards remains suitable to ensure widespread usability and applicability of these standards.

6   Application of Digital Technologies for Asset Management

The **Fourth Industrial Revolution** (or **Industry 4.0**) is a term that was first introduced in Germany in 2012 to refer to emerging technologies that allow greater degree of automation and interconnectedness. Over recent years many new technologies have emerged, and this trend is likely to continue. Digitization of all data and information, digitalization of business processes and automation of many tasks and activities which were previously performed by humans has the potential to significantly enhance productivity and economic growth. However, to fully realize these benefits would require an enterprise-wide Digital Transformation Program with candidate technologies evaluated for their potential benefits, through-life costs, risks and the change management effort needed to implement and sustain the new ways of working.

Figure 6-8 Industry 4.0 Technologies Amit Maniar, Industry 4.0 - Connecting Traditional Hardware to Internet, 2018

Although there is no universal agreement on what technologies constitute Industry 4.0, the technologies represented in Figure   6 -8 are commonly accepted as part of Industry 4.0. The application of Industry 4.0 technologies is radically transforming how business work and collaborate with their customers, stakeholders and ecosystem partners. The ==Figure   6 -9== below illustrates a range of potential applications of these technologies and how these are enhancing value-to-customers and the organizations adopting them.
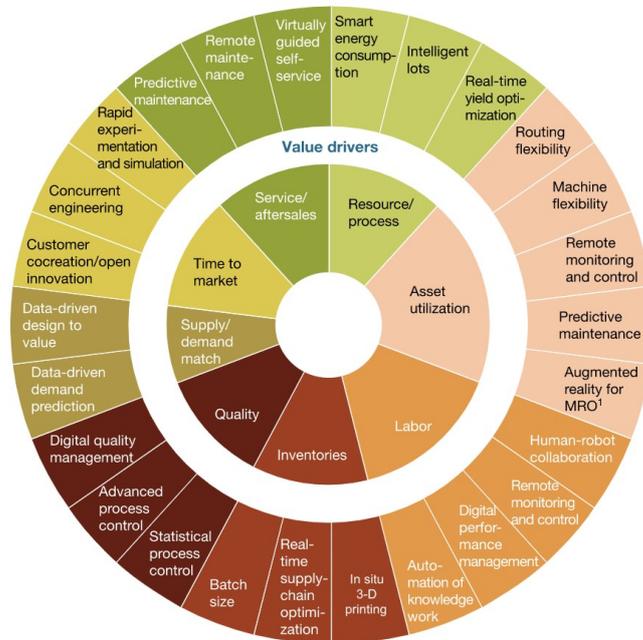

Figure 6-9 Applications of Industry 4.0 McKinsey & Partners, Manufacturing's Next Act, 2015

Together with the BIM approaches for structured management of data and information, the application of Industry 4.0 technologies is transforming asset management practices. The table below summarizes potential applications of some of the technologies to Asset Management.

Table 6-2 Application of Digital Technologies to Asset Management

Digital Technology	Description	Asset Management Applications
Automated Data Collection	Several technologies such as drones, lidar, vehicle-mounted sensors/cameras, IoT sensors and other remote monitoring approaches for rapid or near real-time capture of data.	Automated, remote inspection and monitoring of assets, operations and environmental parameters to monitor how assets are performing and degrading with time.
Cloud-hosted Big Data Platform	Storage and management of data on a native or public cloud platform.	Integration of data to provide a "single version of truth" across all structured, unstructured and semi-structured data into a Data Lake.
Data Analytics technologies such as Machine Learning (ML) / Artificial	Machine learning (ML) refers to computer algorithms that improve automatically through experience and by the use of data. It is seen as a part	Data analytics technologies (AI/ML etc.) help to process large amounts of data from automated data collection technologies and support various Asset Management applications, including

Digital Technology	Description	Asset Management Applications
Intelligence (AI)	of artificial intelligence which refers to machines that mimic "cognitive" functions that humans associate with the human mind. Machine learning algorithms build a model based on sample data, known as "training data", in order to make predictions or decisions without being explicitly programmed to do so.	recognition of defects, deterioration modelling, predictive maintenance and optimizing operations and production.
Data Visualization (VR/AR)	Virtual reality (VR) is a simulated experience that can be similar to or completely different from the real world. Augmented reality (AR) is an interactive experience of a real-world environment where the objects in the real world are enhanced by computer-generated perceptual information, sometimes across multiple senses.	VR and AR can be used to simulate design, construction and operation of a future facility before it is built. It can also be used to train operators on how to operate or maintain a complex plant or a facility.
Data Sharing using Blockchain	A blockchain is a distributed ledger maintained by a network of computers, each of which independently validates changes to the ledger by other members.	The Blockchain technology can be used to share authenticated data and information securely and transparently across ecosystem partners. Monetization and selling sensitive data is likely to utilize blockchain technology.
Robotics	Robotics is an interdisciplinary field that integrates computer science and engineering. Robotics involves design, construction, operation, and use of robots. The goal of robotics is to design machines that can help and assist humans.	Robots are beginning to be used to automate asset inspection, maintenance and operations typically in remote, complex or hazardous environments.
Digital Twins	A digital representation of a physical asset/system and its context fully synchronized in time; and used to understand and simulate scenarios on the physical asset/system to	Digital twins of critical assets and asset systems can be used for design rehearsals and construction simulation for new assets or simulate and optimize several asset management, operations and maintenance activities. Often digital

Digital Technology	Description	Asset Management Applications
	support decision-making	twins utilize automated data capture technologies to maintain the status of the asset in real-time and AI/ML and other simulations tools combined with VR/AR visualization techniques.

7 Recommendations

AHG4 recommends the following action to the CAG –

7.1 Update existing ISO 55000 Series of Standards with suggested changes

We recommend that several suggested changes are considered for the existing ISO 55000 range of standards:

- ISO 55000
    - General - Provide suitable references and links to the ISO 19650 series of standards
    - General – Provide guidance on scope of decision making and the likely generic outcomes of asset related decisions
    - Clause 2.6 – Consider adding a reference to security in the list of management systems in para 1
    - Clause 3.2 – Missing definitions relating to asset data, asset information, asset register and data management
    - Annex A – Update Information Management to include TC251's understanding based on the AHG04 Final report
- ISO 55001
    - Clause 5.3 – Consider addition of roles and responsibilities for data management – may be covered in forthcoming update of ISO 8000-150
    - Clause 6.2.1 – Include addition to list in para 2 to mention data/information
    - Clause 7.5 – Consider additions relating to asset data collection and asset criticality
    - Clauses 7.5 b) and c) – Add minor additions to refer to ISO 19650 series
    - Clause 7.5 e) – Add minor addition to refer to quality of data and explain that this is an assessment of conformance to data requirements
    - Clause 7.6 – Include reference to ISO 19650 series
    - Clauses 7.6.2 and 7.6.3 – Include note/references to ISO 19650 series and ISO 8000-61 for explanation of how to deliver
    - Clause 8.3 c) – Refer to ISO 19650 series for guidance on sharing information with outsourced parties
    - Clause 9.1 - Include minor addition to require orgs to monitor the quality of data to support AM activities
    - Clause 9.3 c) - Include minor amendment to add reference to monitor the quality of information used for the review
    - Bibliography – No reference to ISO 19650 series or ISO 8000 series, particularly ISO 8000-61
- ISO 55002
    - Clause 4.1.3 g) – Add 'information quality' to this clause and explain that this is an assessment of conformance to requirements
    - Clause 4.4 – Include note(s) referring to ISO 19650 and ISO 8000 series
    - Clause 7.5 - Clause needs to be updated because it makes reference to BIM/ISO 19650/8000 series but only as Notes and ISO 8000 reference is only to Part 1

- o Clause 9.1.2.1 - Include explicit reference to monitoring information quality and refer to ISO 8000-61
- o Clause 9.2 - Include information and data management as subjects to be audited with reference to trigger events as described in ISO 19650-3
- o Clause 10.2 - Include explicit reference to monitoring info quality and refer to ISO 8000-61
- o Figure B-2 – Provide content to state how to extract data/ information from service providers as they transition out
- o Bibliography – No reference to ISO 19650 series or ISO 8000 series, particularly ISO 8000-61
- ISO 55010
  - o Clauses 5.3.3, 6.2, and 6.3 - Include note referring to ISO 19650/8000 series, particularly part 8000-61 to explain how to manage data and information
  - o Bibliography – No reference to ISO 19650 series or ISO 8000 series, particularly ISO 8000-61

7.2 Summarize AHG4 Findings & Recommendations in TC251 Articles

We recommend the following topics be considered for a series of articles or white papers because of the work done within AHG4. Experts within AHG4 should be involved in the writing and publishing of these articles. Topics may include:

1. AHG04 Final Report
2. Importance of Asset Data Quality in AM DM (link to ISO 8000)
3. Explain relationship between BIM and AM
4. Operationalizing BIM
5. Aligning Data across the life cycle of assets
6. How to link AIR and OIR to AM Decisions
7. Decision framework and how data/information will support it
8. considerations for asset managers on selecting asset data management software

We also recommend that TC251 publish a link to stand-alone publicly available resources related to Data/Information to benefit the asset management community at large. Some notable resources are as follows:

1. Data Over-view video https://www.youtube.com/watch?v=rE-9DWKieRs
2. Data Requirements Library https://www.youtube.com/watch?v=pklF-g_aUDo
3. CAD and Object Standards https://www.youtube.com/watch?v=P84nBTT0dMc

7.3 Maintain TC 251's ongoing collaboration with other TCs focusing on Data/Information

We recognize the importance of TC 251 collaborating with ISO/TC 184/SC4/WG13 - ISO 8000 and data quality, ISO/TC 59/SC13/WG13 – BIM to exchange understanding in the development of standards around data/information across the three TCs. Therefore, we recommend a collaboration strategy be developed for this purpose.

7.4 Continuance of AHG4

Although the central mission of AHG4 concludes with the development of this Final report, more work needs to be done to execute on recommendation stated in 7.2. To properly manage the effort required to produce the articles, we recommend the continuance of AHG4 for an additional period of six months after the plenary. Once the articles (a final list will be decided upon collectively by the group) have been published, AHG4 can be dissolved at a convenient time.

Appendix A - Historical Context

At the 7th Plenary Meeting of the Technical Committee 251 on Asset Management (TC251) in Nanjing, China in May 2019, a Product Improvement Proposal (PIP001) titled "*Information Management and Decision-Making Criteria*" was forwarded to the Chairman's Advisory Group (CAG) by Mattias Androls (Sweden) and Ton Van Wingerden (Netherlands). The CAG accepted the proposal and assigned a team to work on researching the topic with an expectation of producing an article before the next plenary meeting to be held in Quito in November 2019. The original PIP001 is shown below:

This section is to be filled out by the TC 251 member(s) submitting the Product Improvement Proposal.:	
Title:	**Information management and decision-making criteria**
Output:	Article (to start with, likely guidance to follow)
Timeframe:	Strive for next TC251 meeting, depending on research and availability of TC/ experts
Priority:	High
Submitter:	Mattias Androls, Ton van Wingerden
Proposed Team:	Team lead: Bruce Hawkins, team members tbd
Objective:	To support organizations to select appropriate methods related to collection and analysis of data supporting their strategic goals.
Purpose:	Asset management is dependent on the availability, quality and alignment of data and information to support improved decision-making. Collection and analysis of data is not an end in itself, as a user we need to ensure that the collected data is relevant, useful and efficient. With all the data science attention and developments, asset management should provide leadership in this area. This project gives guidance to organizations by: Providing vision and objectives for data collection and analysis to support decision-making. Facilitating the discussion on the relationship of data science and asset management fundamentals. Articulating how a decision-making framework can drive structuring and management of data in order to ensure relevance, timeliness and quality.
Impact:	Audience: Interest of larger public, 'popular' current topic Information managers, those specifying information and knowledge needs of the organization (ISO55001 7.5 implementation) Reduce useless investments in information management by 10%
Process:	Collaboration/research Define scope first article decide upon other output Draft content Collect feedback of TC251 and perhaps collaborative parties Revise where appropriate

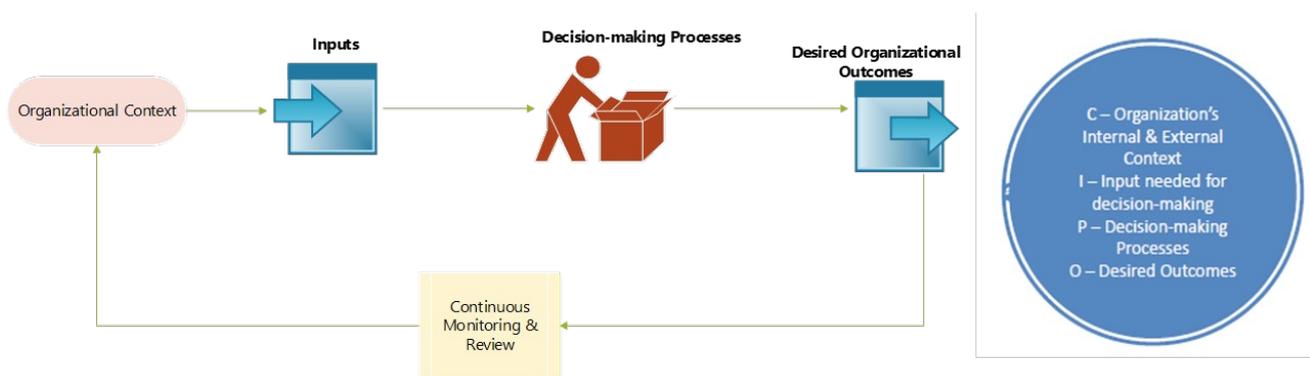|	Publish
Expertise & Resources	asset type managers/ experts (within TC251, liaisons, and other TC's) that are knowledgeable in data usage, data scientist, knowledge management competence
Notes:	TC184 Automation systems and integration SC4 industrial data, TC67 on ISO 14224 Petroleum, petrochemical and natural gas industries – collection and exchange of reliability and maintenance data for equipment, TC56 on IEC 60300-1 Dependability management, other committees appropriate for other asset types (research)

The work on this PIP did not proceed as expected during the time between the Nanjing and Quito plenaries. At the Quito meeting, TC251 recommended the formation of an ad hoc group (AHG03) to tackle several PIPs (PIP002, PIP004, PIP006, and PIP012) related to Asset Management Decision Making. Their focus was to develop guidance for decision-making processes, criteria and governance requirements to resolve conflicting objectives and deliver maximum overall value to stakeholders. One of the main goals of AHG03 was:

1. Develop (an approach to) Guidance for Asset Management Decision-Making (DM)
   a. Factor stakeholder needs into a multi-criteria model
   b. Process for decision-making: e.g. governance, consultation, business rules
   c. Decision-making framework (to prioritize and finance)

AHG03 submitted its final report to the CAG during the virtual plenary in June 2020. The work done by AHG03 was valuable to setting the direction and boundaries for PIP001. AHG03 researched which elements to include in the following three areas – a) sources of influence (DM criteria identification), b) DM mechanism, and c) DM application. Furthermore, they classified the elements as either '*mandatory*' or '*recommended*' linking them into a process framework to make it more practical and less conceptual.

Key findings from AHG03 are as follows –

1. There are varying types and levels of DM within the organization. Proposing guidelines for decision-making facilitates organizations to develop their own DM framework. Guidelines should focus on helping organizations identify key elements of a DM framework (The 'WHAT' and not the 'HOW') by using a business process-based approach. The CIPO (Context-Input-Process-Output) approach supported by PDCA (Plan-Do-Check-Act) was proposed as an overarching framework for developing the guidelines.

Asset Management Decision Making Process Framework

2. Organizational Context and Desired Outcomes are sources of influence on DM and should drive Processes and Inputs (CIPO)
3. The inputs and processes are key enablers in asset-management DM. Organizations must continually adjust their processes and inputs (PDCA) to:
    a. Accommodate constraints in their context and
    b. Match changing outcomes.
4. Mandatory Elements for Inputs are
    a. Decision Impact
    b. Decision Complexity
    c. Decision Urgency
    d. Human Factors
    e. Available **Data** & **Information**
    f. Knowledge
5. Mandatory Elements for Processes (based on core asset management principles) are
    a. Value-focussed
    b. Risk-based
    c. Proportionate
    d. DM criteria
    e. Sensitivity testing of uncertainties
    f. Transparent

6. Clarity is required in using the term - DM Criteria. DM Criteria are used by some to mean 'factors that affect a decision' akin to 'multi-criteria DM'. This is not the same as 'DM Criterion' (often a composite measure of the combination of factors such as 'IRR', 'B/C Ratio', or 'gross national happiness') that is the basis for making the FINAL decision.