GRID MODERNIZATION LABORATORY CONSORTIUM
U.S. Department of Energy

A Qualitative and Quantitative Approach for Measuring Interoperability

DRAFT

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Summary

The US Department of Energy's Grid Modernization Initiative identified interoperability as an important quality for enabling new technology deployments. This resulted in the creation of a Grid Modernization Laboratory Consortium foundational project on interoperability. The mission of this work is to promote a common understanding of the meaning and characteristics of interoperability, in terms of the quality of integrating devices and systems and the discipline to improve the process of successfully integrating these components as business models and information technology evolves over time. An element of this project is to articulate important characteristics of interoperability as a way to measure the state of interoperability in specific technology deployment domains, such as substation automation, or the integration of "grid edge" technologies, such as electric vehicle charging, photovoltaic systems, and load flexibility from buildings automation. This document describes an interoperability maturity model (IMM) as a tool to measure the state of integrating the information and communications technology aspects of intelligent devices and systems to coordinate their operation with the rest of the electric power system. The use of the tool also points out challenges and areas for improvement to more easily and reliably achieve interoperability.

Stated succinctly, interoperability is "the ability of two or more systems or components to exchange information and to use the information that has been exchanged." (ISO 2010) The electric power system continues the trend of embracing advancements in information and communication technology along with the rest of industry and our society. The vision of a modern energy grid is of a complex system of physical systems overlaid with a hyper-connected system of cyber systems that integrates grid operations with end-use business processes and social objectives to achieve ever greater scales of performance efficiency under conditions that must adapt to short-term disturbances and long-term trends. A transformational aspect of this vision of the future electric system is the coordinated operation of distributed energy resources, which include generation, storage, and responsive load, with the electric delivery system infrastructure for greater efficiency, reliability, and resiliency.

The IMM described in this document is a tool that is used as part of a strategy to develop roadmaps for advancing interoperability in technology integration domains. The roadmap process engages the communities (or ecosystems) of organizations involved smart technology deployments. A companion to the IMM in this strategy is a proposed roadmap development process, which is described in the Interoperability Roadmap Methodology document. The roadmaps developed using this methodology are intended help each ecosystem to articulate a vision of interoperability as well as prioritized steps to move toward it. This document identifies a list of 35 interoperability criteria, which are grouped into 6 categories, for quantifying the state of interoperability in a technology integration domain. The audience for this document are those stakeholders in technology integration domains who may apply these criteria to measure interoperability within a specific area, and for people interested in learning more about the details of the model.

Acknowledgments

This works rests on a foundation of smart grid interoperability-related work established by the GridWise® Architecture Council over the past dozen years and by work done by the Smart Grid Interoperability Panel under the guidance of the U.S. National Institute of Standards and Technology. The vision for interoperability and plan for a strategic engagement with stakeholders follows from recent efforts funded by the U.S. Department of Energy to advance interoperability for connected buildings.

The authors wish to acknowledge the help and guidance received from their U.S. Department of Energy managers, Marina Sofos and Christopher Irwin, in developing the plan for this document and encouraging outreach to relevant stakeholders. The authors' appreciation extends to their industry partners on this project, including Ron Bernstein, Dave Hardin, Austin Montgomery, and Matthew Butkovic. In addition, the authors recognize their Grid Modernization Lab Consortium liaisons to related grid modernization projects, including Jeffery Taft, Benjamin Kroposki, Robert Pratt, Liang Min, Ted Bohn, and Tom Rizy.

The model described in this document is an integral part of the interoperability roadmap methodology and the authors wish to acknowledge the help and guidance received from members of that team including Ron Melton, Maurice Martin, Steve Widergren, and Keith Hardy.

Lastly, this work's value is determined by the participation of the broad grid modernization stakeholder community. Without stakeholder input and idea exchange at project review meetings and stakeholder engagement sessions, the ability of this material to influence the transformation of the electric system will vanish.

Acronyms and Abbreviations

CMMI	Capability Maturity Model Integration
EV	electric vehicle
GMLC	Grid Modernization Lab Consortium
GWAC	GridWise® Architecture Council
IEA	International Energy Agency's
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMM	Interoperability Maturity Model
ISO	International Organization for Standardization
mph	mile(s) per hour
NIST	National Institute of Standards and Technology
ROI	return on investment
SGIP	Smart Grid Interoperability Panel
TOGAF	The Open Group Architecture Framework
V2G	Vehicle to Grid

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1.0 Introduction

Interoperability as a concept is fairly simple, yet it is a topic that is often misunderstood. To improve interoperability, it is first necessary to converge on a common understanding about what interoperability is, and who benefits from improved interoperability. This document addresses these challenges and introduces a method for measuring interoperability. There is another document (DOE 2017B) that describes the overall methodology including stakeholder engagement and roadmap development.

The objective of this work is to introduce and promote the use of interoperability criteria to aid in creating more cost-effective integration of a wide variety of devices and systems (both inside and outside of the energy sector) that need to interoperate. A key goal of interoperability is to reduce costs associated with integration. This necessitates a definition for integration in this context. In this document integration is a process that occurs after a decision to acquire systems and components has been made. Integration covers planning for what changes need to be made to the devices, systems, and their interfaces; making those changes; and all other steps leading up to the initial successful operation of the system. Improved interoperability reduces the integration burden, ideally to zero.

ISO/IEC/IEEE Standard 24765 (ISO/IEC/IEEE 2010) states that interoperability is, “The ability of two or more systems or components to exchange information and to use the information that has been exchanged.” For the purposes of this document, the scope of interoperability is concerned with the exchange of information at interfaces. It is said that a chain is only as strong as its weakest link and the same is true of the interoperability value chain. If information cannot be exchanged, interoperability does not exist. If the information cannot be used, interoperability does not exist. If the people benefiting from interoperation across an interface do not understand the information, they can still benefit from the use of the information but doing so involves something else understanding it for them. If the information is not understood, interoperability does not exist.

It is not only the people who build and use interfaces that benefit from improved interoperability, it is also the people who use goods and services that are enabled by those interfaces. Thus the stakeholders for interoperability are very broad. The concepts are general and can be applied anywhere but tools and approaches may vary with organizational scope and coupling: company, consortia, community, industry, state, domain, etc.

Many stakeholders may look at interoperability and ask “how much will improving interoperability save me?” To improve interoperability, money needs to be spent. Thus, to invest in interoperability, the benefits need to be quantified, the alternatives evaluated[1], and the steps (and costs) for improving interoperability need to be understood. It is also necessary to know from what point the improvements are starting and where the gaps exist between the current state and improved interoperability. Without value, there is no driver for an organization to move up the interoperability curve, so it is necessary to quantify both the benefits and costs of doing so.

This document presents the relevant concepts for specifying criteria that support a grid modernization strategic vision for interoperability. It focuses on the ways to assess levels of interoperability. The assessment of interoperability needs to clearly show the relationship to interoperability and provide the necessary data to create a roadmap for how to improve interoperability. A key point to understand is that interoperability has several crucial elements, any of which may have areas for improvement.

[1] 1) update an old system; 2) integrate to develop a bridging mechanism to extend the useful life of an existing system, while enabling interoperability with new/different systems; and 3) replace legacy systems that do not meet the criteria set for approaches1 or 2.

To measure interoperability, it is helpful to focus on specific areas based on the objectives of the members of the ecosystem that are initiating interoperability advancement. The measurement tool is based on, and developed from, the GridWise® Architecture Council's (GWAC's) Beta release of its Interoperability Maturity Model (GWAC 2011). As such, it represents an evolution of that approach.

The IMM in a Nutshell

- A tool designed to measure interoperability.
- Identifies gaps between current and desired levels of interoperability.
- Helps make integration easier, cheaper, and more cost-effective
- The IMM can be applied to
  - integration interests within the electricity delivery system, including transmission and distribution automation systems, energy management systems, and energy market systems
  - integration interests within distributed energy resource technology domains, for example: electric vehicles, photovoltaic systems, and buildings automation
  - integration between the electrical grid and distributed energy resource technology domains
- Applied as a tool in the process to create a roadmap for interoperability improvement
  - Before measuring interoperability, some high-level questions are asked.
  - After discussing/answering the high-level questions several interoperability criteria are used to assess current interoperability maturity.
  - Interoperability criteria are grouped into six categories and each category (and each criterion) has five levels of maturity.
  - The criteria selected for review depend on one or more categories selected for measurement.
  - The category and criteria are the standards by which different aspects of interoperability are assessed.
  - The gaps between current and desired levels of interoperability are used to create a roadmap that is aligned with the goals, drivers, and milestones identified by the stakeholders.

1.1 Target Domains

The IMM applies to the integration of devices and systems in various technology domains (technology domains are the domains identified in the frameworks of the Topic 1.2.1 Grid Architecture work, the National Institute of Standards and Technology/Smart Grid Interoperability Panel (NIST/SGIP 2014) framework, and Institute of Electrical and Electronics Engineers (IEEE) Standard 2030 (IEEE 2011): bulk generation, transmission, distribution, customer, markets, control and operations, and, electric service providers). The IMM is part of an overall roadmap methodology (DOE 2017B) that can be leveraged in ways such that strategic plans (roadmaps) can be developed for stakeholder communities to address interoperability gaps.

The first step in improving interoperability is to identify a target domain or domains. Interfaces between systems and components may be both inter- and intra-domain. Many key interfaces are between domains.

Once a domain for applying the IMM has been selected, it is necessary to decide whether to apply the whole IMM or part of it. The choice of what parts (categories) to use may be driven by known interoperability deficiencies or specific drivers that cause the stakeholder(s) to prioritize one category over another. To facilitate this, the IMM has interoperability criteria that are used to determine interoperability maturity and these criteria are divided into several categories.

1.2 Categories for Organizing Evaluation Criteria

The categories used within the IMM for the grouping of interoperability criteria are based on those used in GWAC's Beta IMM which not only used the traditional layers (technical, informational, organizational) of GWAC's interoperability framework (see Figure 1.1) but also grouped cross-cutting issues[2] together to create three groups of cross-cutting issues. These groups of cross-cutting issues were introduced by GWAC to help organize issues where the impact on interoperability could be prioritized and establish agreement on specific directions for resolution to advance the cause for interoperability. As such, they provide an excellent foundation for defining categories for interoperability criteria.

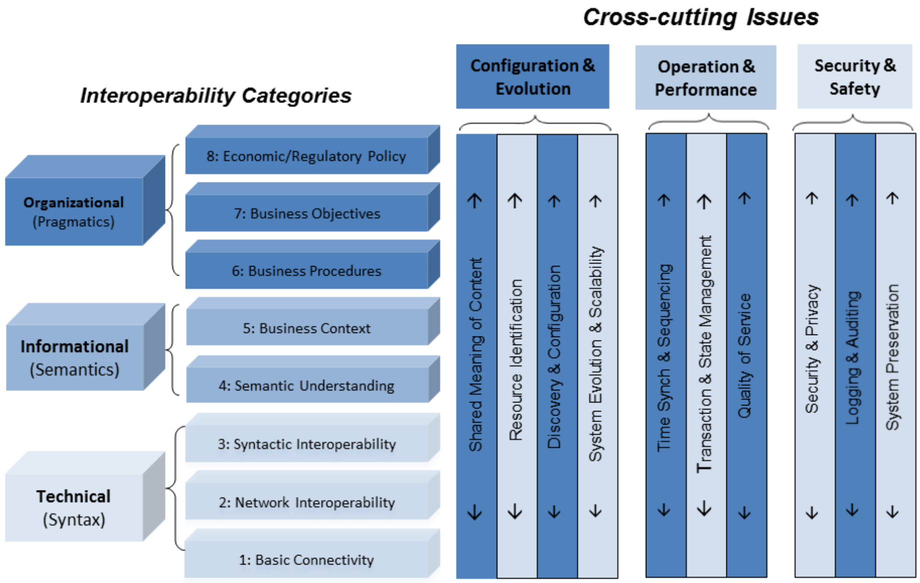

Figure 1.1. GWAC Interoperability Context-Setting Framework[3]

It is worth noting that the three layers (organizational, informational, and technical) are also used by The Open Group Architecture Framework (TOGAF) and others for grouping interoperability requirements.[4] Many people focus on the lower portion of the interoperability stack when trying to create interoperable applications, which makes the physical connection and exchange of data possible but ignores (or takes for granted[5]) the broader integration with business objectives and policy setting that are represented by the upper layers of Figure 1.1. For this reason, the cross-cutting issues

[2] These issues are relevant to more than one interoperability category of the framework and as such they reflect real-world challenges that need to be addressed.

[3] GridWise Architecture Council. 2008. GridWise Interoperability Context-setting Framework, v1.1, 52 pp.

[4] TOGAF V9, Section 29.2

[5] For exchanges within a single organization business/policy may not be in question.

categories present a compelling opportunity for evangelizing interoperability because they apply across all the layers and describe topics as opposed to conceptual layers. This may make them more tractable for organizations that are looking to implement changes to help improve interoperability.

For the IMM the evaluation criteria are categorized as follows:

- **Configuration & Evolution**
  These criteria address topics related to vocabularies, concepts, and definitions across multiple communities and companies. This means that all resources need to be unambiguously defined to avoid clashes between identification systems. This is important over time as new automation components enter and leave the system because resource identification is essential for discovery and configuration. This also provides the ability to upgrade (evolve) over time and to scale without affecting interoperability.
- **Security & Safety**
  These criteria[6] are concerned with aligning security policies and maintaining a balance of the tension between minimizing exposure to threats while supporting performance and usability. This includes the capability to troubleshoot and debug problems that span disparate system boundaries, while placing the integrity and safe operation of the electric power system above the health of any single automation component.
- **Operation & Performance**
  These criteria focus on synchronicity and quality of service, as well as operational concerns. Operational concerns may include concerns such as maintaining integrity and consistency during fault conditions that disrupt normal operations and ensuring that distributed processes can meet expected interaction performance and reliability requirements.
- **Organizational**
  These criteria represent the pragmatic aspects of interoperability. They represent the policy and business drivers for interactions. Interoperability is driven by the need for businesses (or business automation components) to share information and requires agreement on the business process integration that is expected to take place across an interface.
- **Informational**
  These criteria emphasize the semantic aspects of interoperability. They focus on what information is being exchanged and its meaning and they focus on both human and device recognizable information. At this level, it is important to describe how entities are related to each other, including relations to similar entities across domains and any constraints that may exist.
- **Technical**
  These criteria address the syntax, format, delivery, confirmation/validation, and integrity of the information. They focus on how information is represented within a message exchange and on the communications medium. They focus on the digital exchange of data between systems, encoding, protocols, and ensuring that each interacting party is aligned.

In addition, several criteria identified focused more on the culture changes and collaboration activities that are required to help drive interoperability improvements and that reflect stakeholder maturity with respect to interoperability. These additional criteria reflect the participation of organizations in efforts to improve interoperability in general, not just specific interfaces. Instead of creating an additional category for these “community criteria” each community criterion was categorized as belonging to one or more of the other six categories. Thus, when using the IMM a number of the

[6] Both cyber and physical security and safety requirements need to be addressed and validated.

criteria used for measuring interoperability maturity would come from those community requirements in so far as they were relevant to the selected categories. This is depicted in Figure 1.2.

Figure 1.2. Categories for IMM Criteria

1.3 Structure of this Document

This document describes an IMM for measuring interoperability for grid modernization beginning with background material on measuring interoperability and characteristics of interoperability (Section 2.0). Next, the criteria to be used for measuring interoperability are introduced (Section 3.0). Then, this document discusses domains, or areas to which the model can be applied in order to measure interoperability (Section 4.0).

Building on the explanation of the structure of the interoperability maturity model, the document provides a simplistic example of applying the IMM to a fictional case to show how it is used (Section 6.0). The remaining sections of the document are Appendices that provide more detail about Interoperability Maturity Levels by Category (Appendix A), Interoperability Maturity Levels by Criteria (Appendix B), how to score the results after the IMM has been applied (Appendix C), and an overview of how the IMM fits into the interoperability roadmap methodology (Appendix D).

2.0 Measuring Interoperability

An essential part of stating clear evaluation criteria is defining when requirements are met and what will be used to assess success and gaps. While the criteria describe attributes that support interoperable systems and components, it is the lack of desired interoperability traits that are often being measured. Some criteria, such as the existence of policies and conformance to standards, can be measured by conformance, but other criteria can be measured by lack of conformance. For instance, error handling may be poorly specified. If an error has occurred and caused a problem, then this can be measured but the impact may not be measurable until the error has occurred; there is an opportunity for measurement of "non-interoperability." In some ways, this can be likened to a doctor's visit. You might appear to be healthy but disease or injury can be identified and cured. A mathematical analogy is measuring the probability of an occurrence by calculating the probability of it not happening and then subtracting that result from one.

The use of the roadmap methodology seeks to ensure that these criteria can be verified to be improving interoperability and therefore they need to be measurable in pragmatic terms once they are applied.

Interoperability is one of the benefits of using standards. The interoperability benefits of adopting standards accrue because a standards-compliant system can operate with a wider variety of other such systems—systems that have adopted the same conventions. Thus, an important consideration is to create a framework of interoperability criteria that can be mapped to standards in each domain, rather than creating competing standards. The IMM is designed so that the same criteria can be satisfied by different standards, and these standards may be domain-specific.

2.1 Characteristics

A criterion needs to exhibit several additional characteristics as well as being measurable to be considered a "good" criterion. Good criteria[1] should have the following characteristics:

- **Traceable**: Criteria should be traceable back to a goal and be attributable to an authoritative source. This is most important for functional criteria but the interoperability criteria specified in this document can, in many cases, be linked to a specific standard, report, paper, or another source.
- **Unambiguous**: The wording of each criterion should be considered from different stakeholder perspectives to consider whether it can be interpreted in multiple ways. Vague, general statements are to be avoided.
- **Measurable**: The implementation of criteria can be assessed quantitatively or qualitatively. Where the measurement is qualitative, guidelines should be provided to create consistency between assessments.
- **Testable**: Functional criteria must be testable to demonstrate that they have been satisfied.
- **Consistent**: Criteria must be consistent with each other; no criterion should conflict with any other criterion. Criteria that have questionable feasibility should be analyzed and, if necessary, be eliminated.

[1] There are many references for developing requirements, including IBM Rational RequisitePro, Carnegie Mellon University, MITRE Systems Engineering Guide, The Engineering Design of Systems Models and Methods (Wiley).

- **Uniquely identified**: Uniquely identifying each criterion is essential if criteria are to be traceable and able to be tested. Uniqueness also helps in referring to requirements in a clear and consistent fashion.
- **Design-free**: A criterion reflects "what" the system shall accomplish, while the design reflects "how" the criterion shall be implemented. Given the broad applicability of interoperability criteria to multiple domains, criteria should not be domain-specific; thus, it is important that no design-specific criteria are present.
- **Independent**: Criteria should be independent of each other so they can be assessed without impact from other criteria.
- **Negotiable**: Understanding the business drivers and context mandates flexibility. For instance, it may be possible for a criterion to be met using different standards in different domains.

2.2 Interoperability Criteria

The interoperability criteria for use with the IMM are listed in Table 2.1

Table 2.1. Interoperability Maturity Criteria

Ref	Statement	Category
01	The accommodation and migration path for integration between legacy and new components and systems shall be described.	Configuration & Evolution
02	Organizational capability to revise and extend interface capabilities over time (versioning) while accommodating connections to previous versions of the interface shall be supported.	Configuration & Evolution
03	The way regional and organizational differences are supported shall be described.	Configuration & Evolution
04	Configuration methods to negotiate options or modes of operation including the support for user overrides shall be described.	Configuration & Evolution
05	The capability to scale the integration of many components or systems over time without disrupting overall system operation shall be supported.	Configuration & Evolution
06	The ability of overall system operation and quality of service to continue without disruption as parties enter or leave the system shall be supported.	Configuration & Evolution
07	Unambiguous resource identification and its management shall be described.	Configuration & Evolution
08	Resource discovery methods for supporting configuration shall be described.	Configuration & Evolution
09	The requirements and mechanisms for auditing and logging exchanges of information shall be described.	Safety & Security
10	Privacy policies shall be defined, maintained, and aligned among the parties of interoperating systems.	Safety & Security
11	Security policies shall be defined, maintained, and aligned among the parties of interoperating systems.	Safety & Security
12	Failure mode policies shall be defined, maintained, and aligned among the parties of the interoperating systems to support the safety and health of individuals and the overall system.	Safety & Security
13	Performance and reliability requirements shall be defined.	Operation & Performance
14	The way errors in exchanged data are handled shall be specified. Interface definitions may need to specify their error-handling expectations.	Operation & Performance
15	Time order dependency and sequencing (synchronization) for interactions shall be specified.	Operation & Performance
16	Transactions and state management capability for interactions shall be specified.	Operation & Performance
17	Compatible business processes and procedures shall exist across interface boundaries.	Organizational
18	Where an interface is used to conduct business within a jurisdiction or across different jurisdictions, it shall comply with all required technical, economic and regulatory policies.	Organizational
19	Information models relevant for the interface shall be formally defined using standard information modeling languages.	Informational

Ref	Statement	Category
20	Information exchange relevant to the business context that is derived from information models (i.e., ontologies) shall be specified.	Informational
21	Where the information exchanged derives from multiple information models, the capability to link data from different ontologies shall be supported.	Informational
22	The structure, format, and management of the communication transport for all information exchanged shall be specified.	Technical
23	The informational and organizational categories in an interface definition specification shall be independent from the technical categories.	Technical
24	Stakeholders shall reference openly available standards, specifications, or agreed-upon conventions in interface definitions.	Community
25	Stakeholders shall participate in development of interoperability standards efforts consistent with their businesses.	Community
26	Stakeholders shall support interoperability test and certification efforts and have clear incentives for participation.	Community
27	Stakeholders shall actively identify and share lessons learned and best practices resulting from interoperability improvements.	Community
28	Stakeholders shall periodically review refinements and extensions to interface definitions.	Community
29	Stakeholders shall not compromise security or privacy requirements through efforts to improve interoperability.	Community
30	Stakeholders shall manage the balance between information exchange transparency and privacy agreements across the interface.	Community
31	Stakeholders shall manage the balance between usability and security in interface definitions.	Community
32	Purchasers of connected technology shall specify interoperability performance language in relevant procurement contracts.	Community
33	To sustain interoperability improvement, the creation of an interoperability culture is required using education and marketing, such as material expressing the return on investment of interoperability.	Community
34	Stakeholders shall work to specify existing, mainstream, modern information exchange technologies that fit their business objectives and maximize the longevity of interface definitions.	Community
35	Stakeholders shall not create a new standard where a suitable standard already exists.	Community

2.3 Domains

Domains define the integration ecosystems to which stakeholders choose to apply the roadmap methodology and hence the IMM. Categories within the IMM reflect the specific aspects of interoperability that can be measured. High-level domains (as described in Section 1.1) can be summarized by the conceptual diagram developed by NIST and shown below in Figure 2.1. However, the word domain has also been applied to integration ecosystems for buildings, electric vehicles and PV integration. These are all areas where interoperability can be improved. These “domains” do not fit nicely into Figure 2.1 and each could arguably be placed in more than one of the NIST domains.

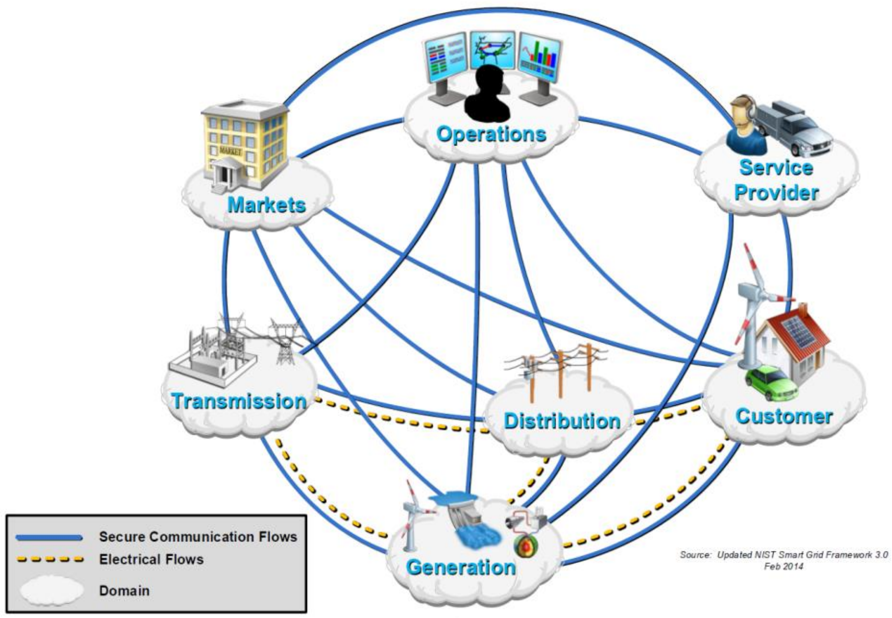

Figure 2.1. NIST Conceptual Domains

The process for applying the IMM is described within the interoperability roadmap methodology and starts by selecting an integration ecosystem domain. In the end, we will need to select domains where there is a sustainable congregation of stakeholders to support ecosystems of products and services. These can form in technical societies, business consortia, or combinations of groups that give form to a community of people, businesses, and practices.

Understanding and measuring the current level of interoperability maturity is most helpful when a target level of maturity attainment has been established. As an analogy, a driver may be traveling 45 mph in a car. Is that good? If this occurs in a 30 mph zone, then it is not good. If this occurs in a 55 mph limit is it good? That depends. If travel time is to be minimized then it is probably not good. If the car is moving with the flow of traffic then it might be good. The point here is that it is necessary to have a good understanding of the scope, context, and current level of interoperability maturity and the goals being sought to put together a plan for how to make improvements.

2.4 Applying the IMM Tool

The steps for applying the IMM are described in the interoperability roadmap methodology, but as a part of applying the IMM, it is necessary for the evaluation team to understand what differentiates the levels of maturity for each category and what each category covers.

The levels used in the IMM are based on the Capability Maturity Model Integration (CMMI) (CMMI 2010). This is the same system that was used by GWAC for the Beta[1] release of the IMM, which described the levels of maturity for different areas as shown in Table 2.2 (GWAC 2011B).

Table 2.2. Interoperability Maturity Levels from GWAC's IMM

GridWise Architecture Council Interoperability Maturity Model		Maturity Characteristics			
		Community / Governance	Documentation	Integration	Test / Certification
Maturity Level Statements	Level 5 Optimizing	Managed by a community quality improvement process	Adopts and open community standard	Integration metrics used for improvement of the standard	Test processes are regularly reviewed and improved
	Level 4 Quantitatively Managed	Processes ensure currency and operation	References community standard w/o customization	Integration metrics are defined and measurements collected. Reference implementations exist	Community test processes demonstrate interoperability. Members claim interoperable performance
	Level 3 Defined	Managed by community agreement	References community standard w/ some customization	Integration repeatable w/ predictable effort	Tests exist for community w/ certification. Members claim compliance to standard
	Level 2 Managed	Managed by project agreement	Documented in a project specification	Integration is repeatable w/ customization expected	Testing to plan w/ results captured
	Level 1 Initial	Management is ad hoc	Documentation is ad hoc	Integration is a unique experience	Testing is ad hoc

By looking at each level of maturity for each category the evaluation team can make an informed decision about which categories are of most interest for interoperability improvement. Within the categories there are the individual criteria, each of which also has five levels of descriptions that can be used to assess interoperability maturity on a more specific basis. The scope of each category was described earlier in Section 1.2 and is extended in Appendix A to include a brief description of interoperability for each of the interoperability levels for each category. The objective here is to provide examples such that the level of subjectivity can be reduced when it comes to making

[1] For the beta IMM developed by GWAC the maturity characteristics (community/governance, documentation, integration, test/certification) were used to create a matrix of maturity characteristics and maturity level statements to provide guidance in assessing the maturity for each metric. This approach has been simplified for the current IMM.

assessments about the level of interoperability maturity. However, there will often be a degree of ambiguity and this will require continuing refinement of the model.

Where levels of maturity can be judged to be improving based on the increasing numbers of interface implementations for systems and components that conform to the criteria, there needs to be a way of quantifying this. For example, the maturity statements for the criterion above use the terms “some,” “most,” “many,” and “all.” These terms are used to graduate responses into different levels. Within the IMM process these terms are mapped to specific quantifications as shown in Figure 2.2.

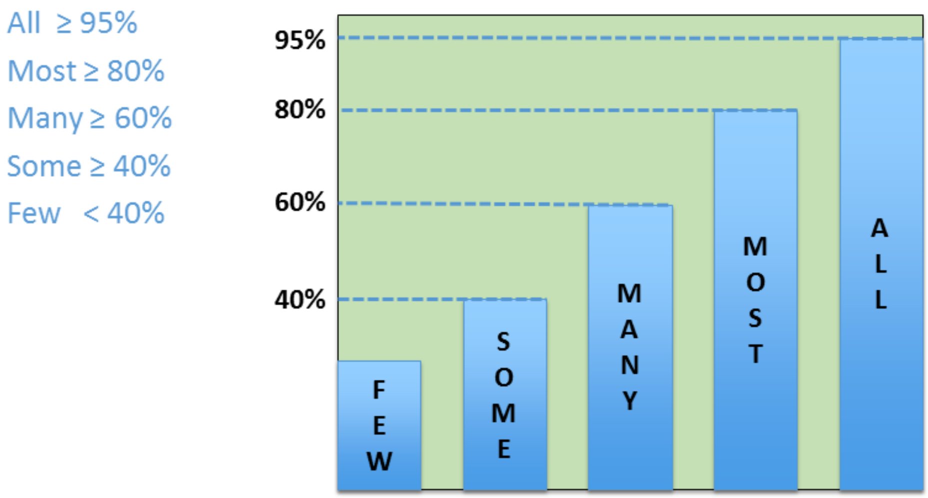

Figure 2.2. Using Common Terms to Quantify Responses

2.4.1 Calculating a Maturity Score

The level of interoperability maturity is determined by the documented evidence that supports satisfying the criterion. For measurement against a target level this means that each criterion is either ***performed*** or ***not performed*** for the level being measured against.

After assessing each criterion within a category, the score for the category is then determined to be ***achieved*** when all practices are performed, ***partially achieved*** when some practices are performed, and ***not achieved*** when no practices are performed.

3.0 Applying the IMM to Electronic Vehicle (EV) Integration

The following short, hypothetical example shows how the IMM is applied to the technology scenario of electric vehicle (EV) integration. This covers the way EVs are integrated into distribution control and load forecasting and into customer behavior and charging habits.

Applying the IMM is only one step in the roadmap methodology (DOE 2017b) depicted below in Figure 3.1. Before the IMM is used there are many preceding and concurrent steps that involve stakeholder tasks. Determining the current baseline level of interoperability maturity for the domain under consideration comes within the Planning and Preparation phase. The development of the roadmap itself does not occur until Phase 3. Once the current level of maturity and future vision have both been determined, the large amounts of information that has been gathered can be compiled into a compelling, rational sequence of activities that demonstrate the steps to achieve the desired maturity level.

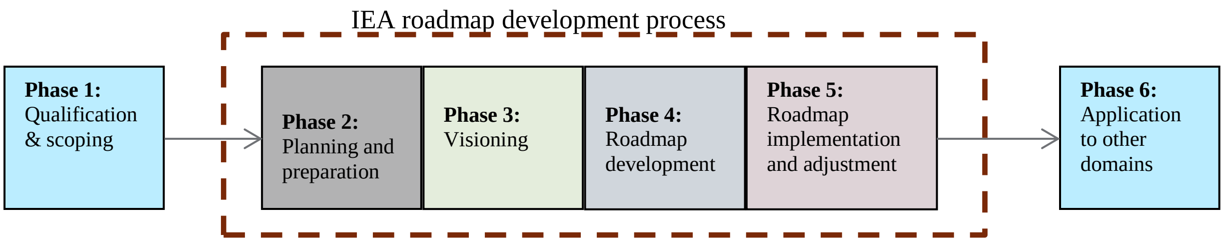

Figure 3.1. The Roadmap Methodology

The questions in this section are intended to probe into the problems and concerns of the area where the IMM is to be applied. The intent of probing is to help the people providing information to the assessor to think about the broader aspects of the area, and to help the assessor by providing contextual information that they might otherwise be unaware of and thus help facilitate clarifying discussions when applying specific criteria from the IMM.

Measuring interoperability maturity involves looking for evidence that practices (capability or integration) are being performed and, where they are not (to the level desired), creating a list of gaps so that the steps to reach the desired level of interoperability can be planned.

To "warm up" the participants it is good to start with a dozen broad questions about the state of interoperability. These questions should be introduced in a conversational forum and the discussion should be allowed to digress sometimes. Answering the questions gives the reviewer and the participants a broad common understanding of the current state of interoperability and how it is seen, and the process may yield some useful insights that can then be used to tease out details and clarify issues when evaluating specific criteria.

This activity is intended to help the people providing information to the assess to think about the broader aspects of the area, and to help the assessor by providing contextual information that they might otherwise be unaware of, and thus help with clarifying discussions when applying specific criteria from the IMM.

For a self-assessment it would also be beneficial to start with a group discussion using some of these questions to make sure that all stakeholders have a common understanding of the current situation, especially in situations where a complex community ecosystem exists. These questions also provide the benefits of a simple "tool" for a quick and dirty assessment. If consensus is not reached during discussions or if there is disagreement on direction, then the roadmap methodology should be checked for next steps. Areas of strong debate should be carefully explored when reviewing interoperability criteria related to those areas.

- Why do you want to improve interoperability?
- What problems has interoperability caused recently or in the past?
- What are the perceived barriers to interoperability today?
- What are the perceived barriers to increased levels of interoperability?
- What are the anticipated benefits from improving interoperability?
- What concerns do you have about the impacts of the current levels of interoperability?
- What key issues have driven interoperability cooperation with other organizations?
- What problems do you want to solve?
- What devices/systems need to be interoperable to solve the problems identified?
- What security issues does an interoperable ecosystem need to address?
- Are there any existing/mandated interoperability requirements that need to be considered?
- Are the current interface(s) focused on meeting minimum requirements, or looking ahead?
- Do your vendors/integrators fully understand the complexities and nuances of your working environment and the fundamental issues around data standards?
- Would you describe your approach to interoperability as ad hoc or managed? If managed, please describe the process and accountability.
- What additional data would be helpful to meet your goals and why is it not collected/shared/used today?
- What issues affect data collection and sharing today?

3.1 Measuring Current Interoperability Maturity

In this example, which shows how the IMM and interoperability roadmap methodology work together to create a roadmap, the evaluation team is an EV integration ecosystem which is assessing how and where to apply incentives or performance targets to create a highly interoperable environment for integrating EVs. Figure 3.2 shows the (fictional) overall interoperability maturity for EV integration within the state; the levels shown are for illustration purposes only. The dots represent maturity levels for the different interoperability categories, determined by applying the IMM. The interoperability categories are represented by the six columns, and the levels of interoperability maturity are represented by the rows in Figure 3.2. Level 1 at the bottom represents the lowest level of maturity and Level 5 at the top represents the highest level of maturity.

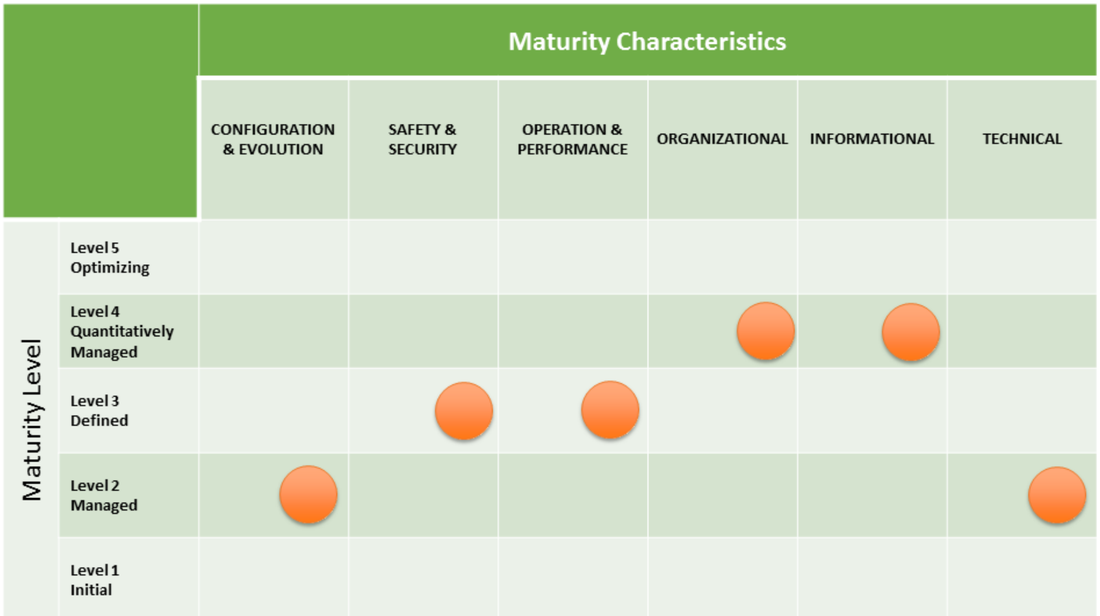

Figure 3.2. Example of Possible Current Interoperability Maturity for Electric Vehicle Integration

3.2 Articulating the Areas for Interoperability Improvement

Figure 3.3 shows the target interoperability levels for each category of interoperability maturity as obtained from the application of the roadmap methodology. The example is fictitious and is provided so that the process for how to address gaps between current and target levels of interoperability can be described. This then illustrates how the IMM can be used to articulate areas where interoperability improvement can be targeted by using the engagement process described in the interoperability roadmap methodology. For the example below, the rationale for the goals could have been as follows:

- **Configuration & Evolution**
  The ability to use configurability to support interoperability evolution is important, but the ability of an ecosystem to evolve is best served by establishing a good foundation; therefore, focusing on a good foundation was the goal for this category. Level 2 requires that vocabularies, concepts, and definitions are consistent among some systems and components. Implementation approaches follow guidelines but agreed-upon specifications or standards are not followed except in a few cases. Community specifications exist for ubiquitous definition and identification of resources but are only implemented by some systems and components.

- **Safety & Security**
  Safety and security are always important topics especially where interaction with the electricity grid is involved. Level 3 requires that the impacts of security, performance, and usability on each other are managed to agreed-upon specifications. Policies and specifications are aligned for most systems and components.

- **Operation & Performance**
  As more people consider purchasing EVs and as the population of EVs increases, more support for charging and Vehicle to Grid (V2G) capability will need to be implemented. This will require customer confidence, so it is very important that pilots and new programs work as expected to build upon not only the technological and business benefits but also customer confidence. Level 3 requires that the methods and specifications employed are based on community practices and policies and use

published standards. The specification of synchronicity, quality of service, and synchronization is consistent and repeatable. There is consistency for responding to fault conditions for most systems and components.

- **Organizational**
  Organizational maturity is important, in terms of overall economic policy, regulations, business objectives and process maturity. This example contains examples of different types of interactions between community members and some variability will therefore be present. For improving EV integration it is not important for the whole community to have high interoperability maturity for everything, just those interfaces related to the EV integration. For community members that specialize in EV services high interoperability maturity will have much higher importance. Level 3 requires that policies and automation components are based on community specifications and policies with some customization.
- **Informational**
  The EV community considers it is necessary to have standards in place for information exchanges related to EVs. Standardizing information modeling early should provide more opportunity for innovation around services and hardware. Level 4 requires that the information model is managed in accordance with semantic models for most systems and components. Semantics are well defined and activity to define and link elements is organized. Relationships between semantic models are well described.
- **Technical**
  The EV community considers communications technology to still be evolving but would like to see some convergence. It has focused on semantics rather than technology because it considers technology to be still evolving and it is important for the technology layer be defined independent of the informational layers so that different communication technologies can support the same message definitions[1]. Level 2 requires that the syntax or format of the information represented within message exchanges is common for some systems and components but not based on published standards. Selection of hardware and software components is based on organizational guidelines with limited standardization.

[1] Interoperability Maturity criterion 23 addresses this point.

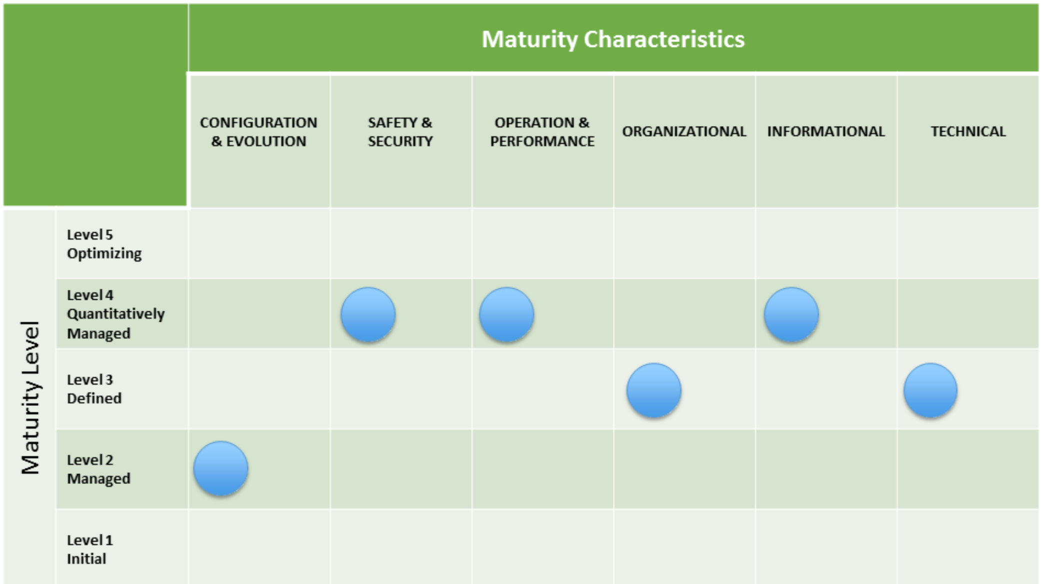

Figure 3.3. Example of Possible Interoperability Goals for Electric Vehicle Integration

3.3 Comparing Current and Target Levels of Interoperability

The objective of comparing the defined goals from the roadmap methodology with the maturity assessment is to develop a plan to address the gaps. By combining the target and current interoperability levels we arrive at Figure 3.4, which shows the differences between current and target levels. For the categories of Configuration & Evolution and Informational the target level has already been met. For the Organizational category, the current maturity level is at or above the target level but for Safety & Security and Operation & Performance the current level is below the target level.

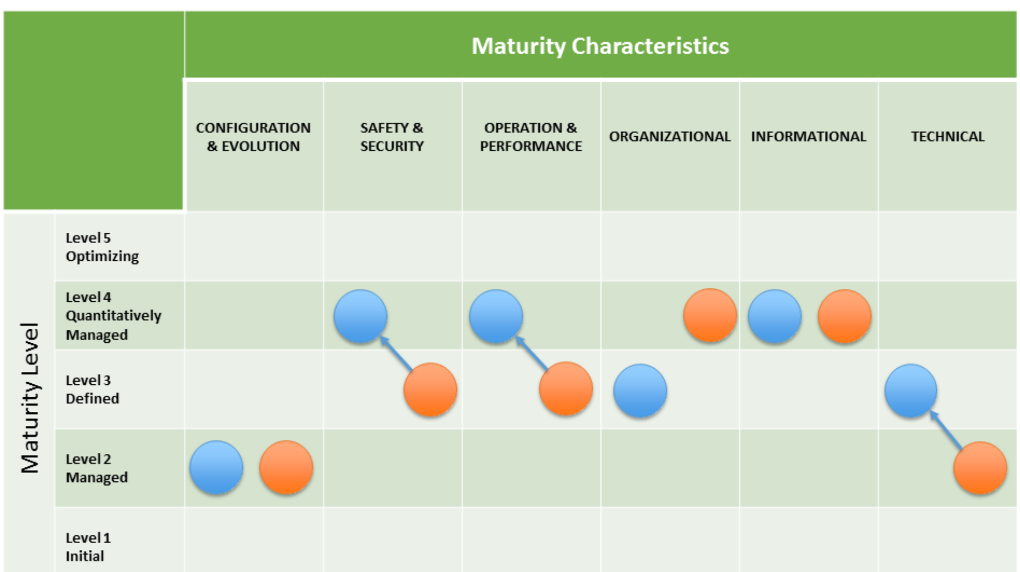

Figure 3.4. Example Gaps between Current and Target Interoperability Maturity

3.4 Selecting Areas for Maturity Improvement

The technology integration ecosystem determines that Operation & Performance is a critical area for EV integration and decides to tackle this category first. This includes creating a set of actions for inclusion in the roadmap to address the reasons for the scores that were below target.

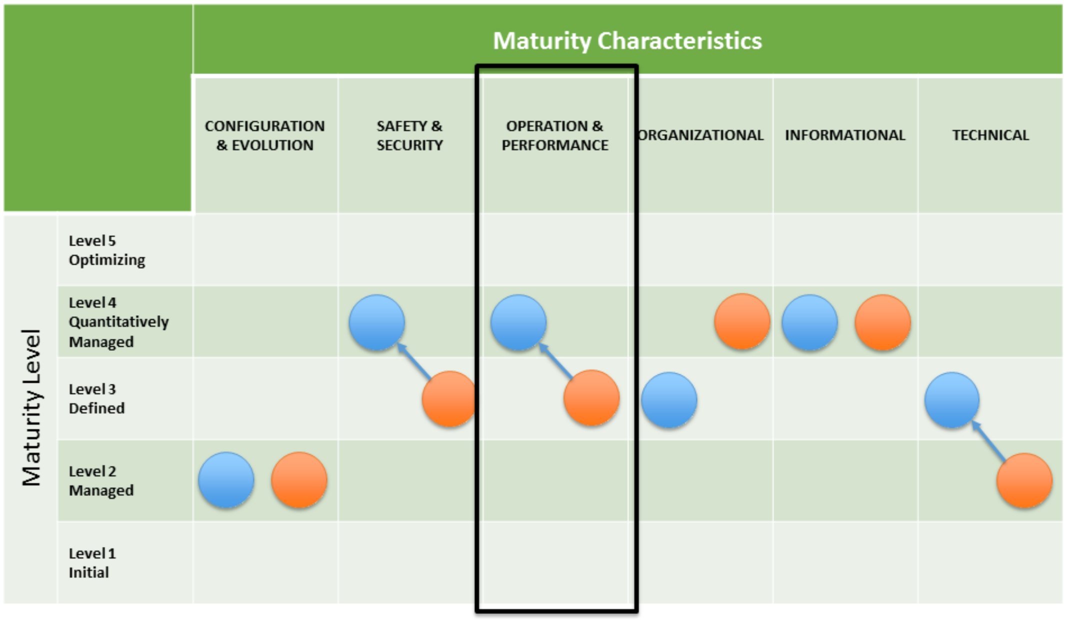

Figure 3.5. Example Selection of Criterion for Roadmap Development

Having identified Operation & Performance as the category to focus on, it is time to look at the scores for the individual criteria that generated this score. Figure 3.6 shows the scores for the criteria that were identified as Operation & Performance in Figure 3.2. Note that only Criteria 14 and 16 fall below the target level, but both are only currently at Level 2.

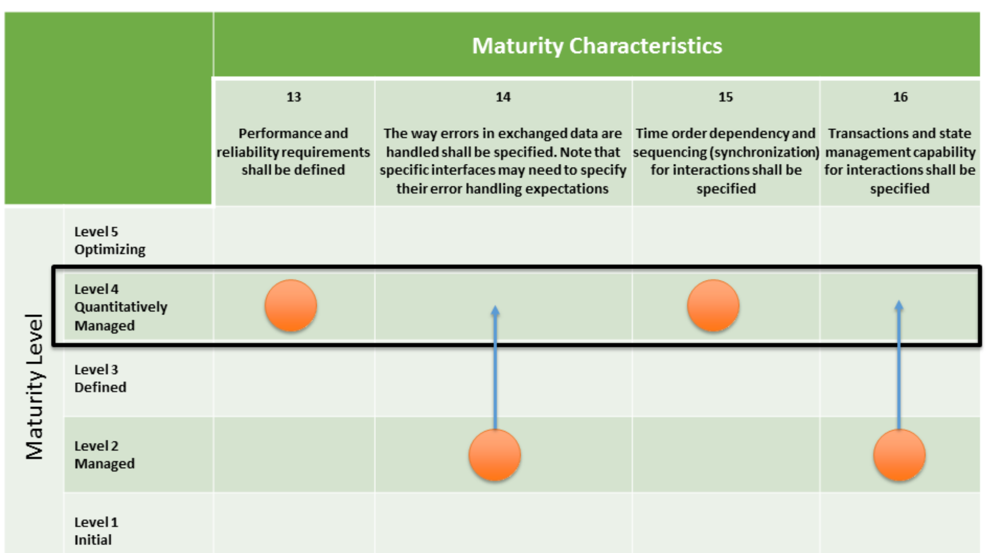

Figure 3.6. Example Gaps for Specific Operation & Performance Criteria

Figure 3.7 shows the scores for the criteria that were identified as Community in Table 2.1 but were mapped[2] to Operation & Performance. Note that four of the five criteria fall below the target level.

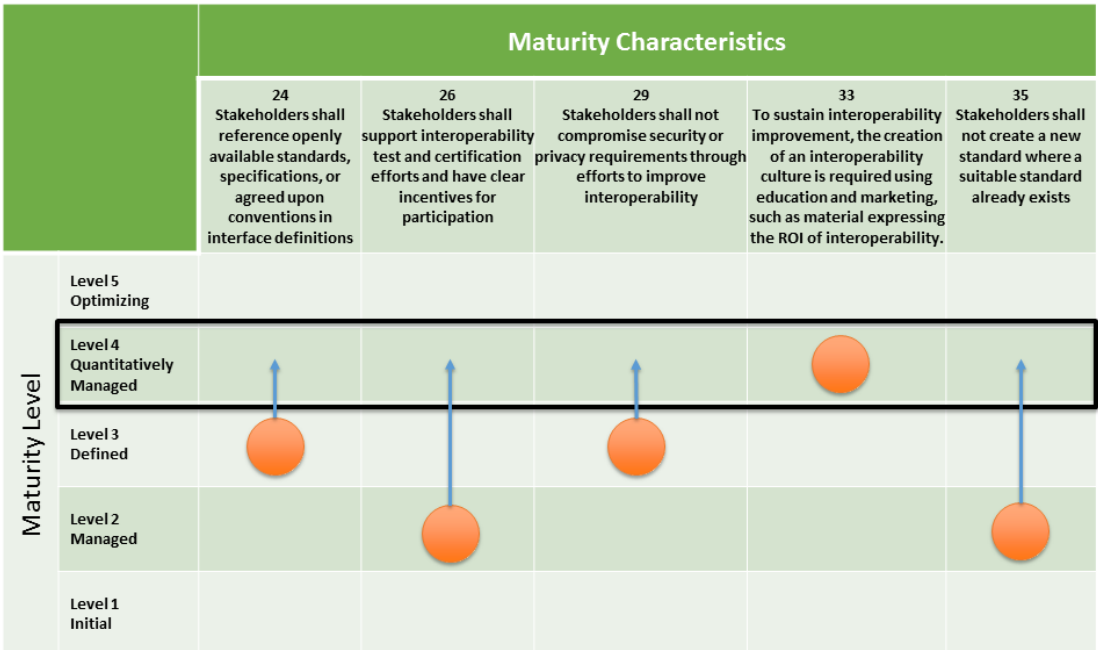

Figure 3.7. Example Gaps for Community Criteria Mapped Against Operation & Performance

For each of the criteria that scored below target the stakeholder next needs to look at the criteria themselves and the statements of Level 4 maturity (because the goal is Level 4):

- Criteria Currently at Level 2
  - – The way errors in exchanged data are handled shall be specified.
    - ○ Level 4 – The management of error handling in exchanged data is described for most projects and is tested against applicable standards with notable interoperability improvements.
  - – Transactions and state management capability for interactions shall be specified.
    - ○ Level 4 – Transaction and state management are managed for many systems and components with predictable efforts and results without customizations of standards or specifications.
  - – Stakeholders shall support interoperability test and certification efforts and have clear incentives for participation.
    - ○ Level 4 – Interoperability testing is performed for most systems and components and lessons learned are used to make improvements. Some systems and components have been certified against interoperability requirements.
  - – Stakeholders shall not create a new standard where a suitable standard already exists.
    - ○ Level 4 – Processes exist to map standards functionality. There is some participation in multiple standards due to legacy constraints.

[2] See Section 4.0B.7 for more information.

- Criteria Currently at Level 3
  - Stakeholders shall reference openly available standards, specifications, or agreed-upon conventions in interface definitions.
    - Level 4 – Interface definitions used for most systems and components reference openly available standards, specifications, or community conventions.
  - Stakeholders shall not compromise security or privacy requirements through efforts to improve interoperability.
    - Level 4 – Stakeholders shall not compromise security or privacy requirements through efforts to improve interoperability.

3.5 Creating the Roadmap

The roadmap development methodology makes use of the IMM to help define a target maturity level and outline steps to achieve it. The methodology for developing a roadmap is described separately and an overview of where the IMM fits within this methodology is provided in Appendix D of this document.

While many scenarios could be developed based on valid arguments for this example, Figure 3.8 represents one possible example of a high-level process for how to present the first few steps to be implemented to improve interoperability maturity.

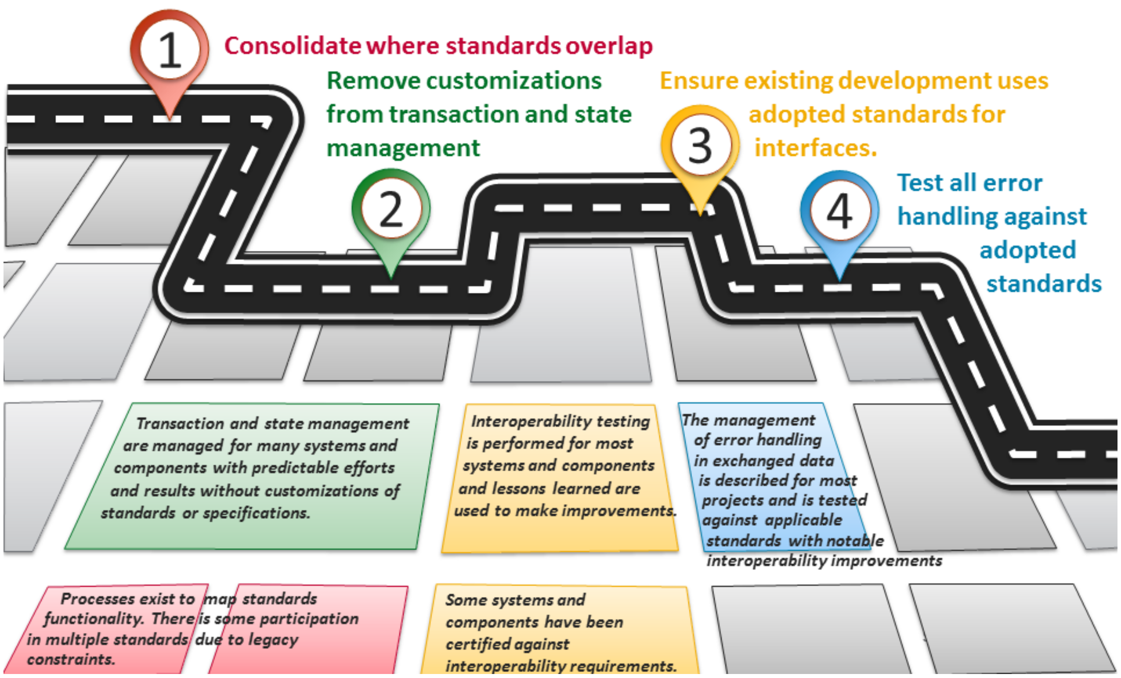

Figure 3.8. Example of High-Level Roadmap Actions

3.6 Concluding Thoughts

The IMM is one tool used in the interoperability roadmap methodology. It helps by measuring current interoperability maturity levels. The process by which current maturity is measured also creates discussion within the ecosystem, which can provide additional insights for the participating stakeholders when the measurement results are taken into consideration for building the roadmap.

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Appendix A

Interoperability Maturity Levels by Category

Appendix A

Interoperability Maturity Levels by Category

In the main body of this document the individual criteria to be used for assessing interoperability maturity were laid out in Table 2.1 and an example of how the GridWise® Architecture Council's (GWAC's) Beta IMM described maturity levels was presented in Table 2.2. Interoperability Maturity Levels from GWAC's IMM. It also provided an example of how the results of interoperability measurement and gap analysis can be applied to use gaps discovered by specific criteria to develop a roadmap and address areas where higher levels of interoperability maturity are desired or required. Figure 3.6 showed an example of gaps for specific Operation & Performance criteria.

This appendix describes the maturity levels for each category in general terms and in Table A.1 through Table A.6.

A factor that is very important when creating a maturity model is making sure that it will be applied consistently. If one reviewer has slightly different views from another reviewer who repeats the same assessment a year later to see what improvements have been achieved the result may be inconsistent assessments. Part of any continuous improvement program is assessing progress and evaluating it in a way that can be expressed quantitatively and consistently. The goal is to remove or reduce the element of subjectivity. For this to happen some boundaries need to be created that describe the level of maturity for each criterion more specifically than simply letting the reviewer make an estimate based on descriptions in Table 2.1 *Interoperability Maturity Criteria* and Table 2.2 *Interoperability Maturity Levels from GWAC's IMM*.

For this reason, the requirements to meet levels of interoperability maturity have been described for each individual criterion (see Appendix B). The descriptions are brief and areas of ambiguity still allow subjectivity to creep into the analysis, but it is a lot less subjective than not having the descriptions and it creates a level of commonality for each assessment. If the maturity level descriptions are found to be inadequate they can be updated rather than relying on subjective interpretations, thus consistency is created.

While the interoperability measurement category descriptions in Section 1.2 provide an overall description of the categories for organizing criteria there is not enough detail to enable a stakeholder to make an informed decision about which categories to focus on. Similarly, the descriptions of the levels of interoperability maturity for each individual criterion in Appendix B are too much information for a high-level overview, so the descriptions in this appendix were developed to provide a summary of interoperability maturity by level for each of the interoperability categories.

Note that there are no levels for Community because these criteria have been spread across the other categories and incorporated into assessments for those categories.

A.1 Configuration & Evolution

The criteria in this category address topics relating to vocabularies, concepts, and definitions across an integration ecosystem. This means that all resources need to be unambiguously defined to avoid clashes between identification systems. This is important over time as new automation components enter and leave the system, because resource identification is essential for discovery and configuration. This also provides the ability to upgrade (evolve) over time and to scale without affecting interoperability.

Table A.1. Configuration & Evolution Maturity Level Descriptions

Configuration & Evolution		
Level 5	Community, open standards, continuous improvement	Vocabularies, concepts, and definitions are standardized and shared within the community Definition and identification of resources is unambiguous and automated where needed. A history of successful upgrades exists where interoperability was not negatively impacted.
Level 4	Managed by community without customization, with testing and metric definition/collection	Vocabularies, concepts, and definitions are consistent among most systems and components. Implementation approaches follow standard guidelines and only a few are dissimilar. Community specifications exist for ubiquitous definition and identification of resources and are implemented by most systems and components.
Level 3	Managed by community, repeatable process/effort	Vocabularies, concepts, and definitions are consistent for the interface(s). Implementation approaches follow standard guidelines but some are still dissimilar. Community specifications exist for ubiquitous definition and identification of resources and are implemented in many deployments.
Level 2	Managed by system or components, some coordination and guidance	Vocabularies, concepts, and definitions are consistent among some systems and components. Implementation approaches follow guidelines; no community agreed-upon specifications or standards are followed. Community specifications exist for ubiquitous definition and identification of resources but are only implemented by some systems and components.
Level 1	Ad hoc, no guidance	Vocabularies, concepts, and definitions do not exist or vary considerably among multiple communities and organizations. Some common threads exist but implementations vary and dissimilarity is the norm. No community specifications exist for ubiquitous definition and identification of resources.

A.2 Security & Safety

The criteria in this category are concerned with aligning security policies and maintaining a balance of the tension between minimizing exposure to threats while supporting performance and usability. This includes the capability to troubleshoot and debug problems that span disparate system boundaries, while placing the integrity and safe operation of the electric power system above the health of any single automation component.

Table A.2. Security & Safety Maturity Level Descriptions

Security & Safety		
Level 5	Community, open standards, continuous improvement	Security, performance, and usability are standardized within a community or ecosystem. Methods employed and specifications are standardized. The impacts of security, performance, and usability are balanced and considered. Capabilities exist to troubleshoot and debug problems that span disparate system boundaries. The integrity and safe operation of the electric power system is placed above the health of any single automation component except for documented exceptions.
Level 4	Managed by community without customization, with testing and metric definition/collection	The impacts of security, performance, and usability on each other are managed to agreed-upon community specifications. Policies and specifications are aligned for most systems and components.
Level 3	Managed by community, repeatable process/effort	The impacts of security, performance, and usability on each other are monitored and understood by the community. Policies and specifications are aligned for many deployments.
Level 2	Managed by system or components, some coordination and guidance	The impacts of security, performance, and usability on each other are understood in a project implementation, but no policies exist to coordinate them together. Policies and specifications for automation components are aligned for some systems and components.
Level 1	Ad hoc, no guidance	Security, performance, and usability are treated separately. Methods employed and specifications vary considerably.

A.3 Operation & Performance

The criteria in this category focus on synchronicity and quality of service, as well as operational concerns such as maintaining integrity and consistency during fault conditions that disrupt normal operations such that distributed processes can meet expected interaction performance and reliability requirements.

Table A.3. Operation & Performance Maturity Level Descriptions

Operation & Performance		
Level 5	Community, open standards, continuous improvement	Specifications are based on open and/or community standards. The specification of synchronicity and quality of service are managed consistently and coordinated within the community Agreements between systems and components allows interacting parties to perform consistently during fault conditions.
Level 4	Managed by community without customization, with testing and metric definition/collection	Methods employed and specifications are based on community practices and policies and use published standards. The specification of synchronicity and quality of service are consistent and repeatable. There is consistency for responding to fault conditions in deployments.
Level 3	Managed by community, repeatable process/effort	Methods and specifications employed are based on community practices and policies. The specification of synchronicity and quality of service are consistent and repeatable. There is consistency for responding to fault conditions.
Level 2	Managed by system or components, some coordination and guidance	Methods and specifications employed are project based practices and policies and may involve significant customization. The specification of synchronicity and quality of service vary between implementations. There is no consistency for responding to fault conditions except for a few instances.
Level 1	Ad hoc, no guidance	Methods and specifications employed vary considerably. The specification of synchronicity and quality of service are ad hoc. Inconsistency during fault conditions disrupts normal operations.

A.4 Organizational

The criteria in this category represent the pragmatic aspects of interoperability. They represent the policy and business drivers and the process for interactions. Interoperability is driven by the need for businesses (or business automation components) to exchange information and it requires agreement on the business process integration that is expected to take place across an interface.

Table A.4. Organizational Maturity Level Descriptions

Organizational		
Level 5	Community, open standards, continuous improvement	Policies and business processes are represented in standardized forms within a community. Business processes are integrated across all automated interface(s).
Level 4	Managed by community without customization, with testing and metric definition/collection	Policies and business process representation are based on community (open) specifications and policies with very few customizations.
Level 3	Managed by community, repeatable process/effort	Policies and business process representations are based on community specifications and policies with some customization.
Level 2	Managed by system or components, some coordination and guidance	Policies and business process representations are based on project agreed-upon specifications and policies. Interface customization is common.
Level 1	Ad hoc, no guidance	Policies and business process representations are not standardized.

A.5 Informational

The criteria in this category emphasize the semantic aspects of interoperability. They focus on what information is being exchanged and its meaning and focus on human recognizable information. At this level it is important to describe how modeled entities are related to each other, including their relationships to similar entities and any constraints that may exist.

Table A.5. Informational Maturity Level Descriptions

Informational		
Level 5	Community, open standards, continuous improvement	The community describes how entities and information exchanged are related to each other, including their relationships to similar entities across domains and any constraints that may exist. Terminology and semantic models used are consistent within the community and based on open standards.
Level 4	Managed by community without customization, with testing and metric definition/collection	Information exchanged is managed by against semantic models in most deployments. Semantics are captured in a well-defined information model and activity to define and link information elements is organized.
Level 3	Managed by community, repeatable process/effort	Information exchanged is managed in an information model for many deployments. Coordination of semantics is an organized community activity. Relationships between semantic models are well described.
Level 2	Managed by system or components, some coordination and guidance	Information exchanged is managed in an information model for on a project basis. Semantic models are treated separately and only a few items are linked between models.
Level 1	Ad hoc, no guidance	Information exchanged is managed by individual deployments. Any coordination of semantics is ad hoc.

A.6 Technical

The criteria in this category emphasize the syntax or format of the information. They focus on how information is represented within a message exchange and on the communications medium. They describe the digital format of data between systems, encoding, protocols, and ensuring that each interacting party is aligned with one another.

Table A.6. Technical Maturity Level Descriptions

Technical		
Level 5	Community, open standards, continuous improvement	The syntax or format of the information uses open standards and is consistent within the community. The representation of message exchange and the communications medium are specified and focus on the digital format of data between systems, encoding, protocols, and ensuring that each interacting party is aligned with one another.
Level 4	Managed by community without customization, with testing and metric definition/collection	The syntax of the information represented within message exchanges follows standards. Hardware and software component selection requires conformance to community.
Level 3	Managed by community, repeatable process/effort	The syntax or format of the information represented within message exchanges is follows standards for many deployments. Management of syntax and selection of hardware and software components is based on community agreements.
Level 2	Managed by system or components, some coordination and guidance	The syntax or format of the information represented within message exchanges is common for some deployments but not based on published standards. Selection of hardware and software components is based on project guidelines with limited standardization.
Level 1	Ad hoc, no guidance	The syntax or format of the information represented within message exchanges is not standards-driven. Management of syntax and selection of hardware and software components is ad hoc.

Appendix B

Interoperability Maturity Levels by Criteria

Appendix B

Interoperability Maturity Levels by Criteria

For each criterion, this appendix has a table that contains high-level descriptions. Table B.1shows an example of the type of information that has been tabulated for each criterion.

Table B.1. Example Describing the Contents of Maturity Levels for Each Criterion in this Appendix

#	C&E **S&S** **O&P** **O** **I** **T** ***Statement that describes a situational or capability criterion for interoperability maturity***
Level 5	Scenario/description that describes Level 5 maturity for this criterion.
Level 4	Scenario/description that describes Level 4 maturity for this criterion.
Level 3	Scenario/description that describes Level 3 maturity for this criterion.
Level 2	Scenario/description that describes Level 2 maturity for this criterion.
Level 1	Scenario/description that describes Level 1 maturity for this criterion.

Reference for the criterion — **Interoperability maturity level** — **Description of what is required for the level of maturity for this criterion** — **The description of the criterion** — **These represent the six categories. Blue tabs indicate for which categories this criterion is used.**

B.1 Configuration & Evolution

These criteria address topics related to vocabularies, concepts, and definitions across a community. This means that all resources need to be unambiguously identified in order to avoid clashes between identification systems. This is important over time as new automation components enter and leave the system because resource identification is essential for discovery and configuration. This category of concerns also facilitates (but does not guarantee) the ability to upgrade (evolve) over time and to scale.

1	C&E / S&S / O&P / O / I / T
	The accommodation and migration path[1] for integration between legacy and new components and systems shall be described.
Level 5	Migration paths are planned for each new deployment prior to installation.
Level 4	All legacy and new components and systems that require integration have been integrated and are interoperating successfully.
Level 3	Some legacy and new components and systems that require integration have been integrated and are interoperating successfully.
Level 2	Plan(s) are in place and documented; they detail migration paths for integration between legacy and new components and systems.
Level 1	The need to address integration between legacy and new components and systems has not been formally addressed.

2	C&E / S&S / O&P / O / I / T
	Capability to revise and extend interface capabilities over time (versioning) while accommodating connections to previous versions of the interface shall be supported.
Level 5	The ability to revise and extend capabilities exists for most interface(s) and is based on open standards.
Level 4	The ability to revise and extend capabilities is supported for many interface(s) and is based on community specifications and agreements.
Level 3	Versioning is not ubiquitous but is managed by the community.
Level 2	Some versioning exists but is managed on a project-by-project basis.
Level 1	The need to address capability extension has not been formally addressed and is addressed in an ad hoc manner.

3	C&E / S&S / O&P / O / I / T
	The way regional and organizational differences are supported shall be described.
Level 5	The ability to support regional and organizational differences exists for most interface(s) and is based on open standards.
Level 4	Support for managing organizational and regional differences is available for many interface(s) and is based on community specifications and agreements.
Level 3	Support for regional and organizational differences is managed by communities of projects working together.
Level 2	There is no central coordination of how differences are supported but some projects support them.
Level 1	Differences are not fully understood and are supported in an ad hoc manner.

[1] There are three basic approaches here: 1) update to make an old system current; 2) integrate to develop a bridging mechanism to extend the useful life of an existing system, while enabling interoperability with new/different systems; and 3) replace legacy systems that do not meet the criteria set for approaches1 or 2.

4	C&E	S&S	O&P	O	I	T
	Configuration methods to negotiate options or modes of operation including the support for user overrides shall be described.					
Level 5	Configuration methods are fully described and are based on agreed-upon community and/or open standards as appropriate for the interface(s).					
Level 4	The management of options within interface(s) and user overrides is described for most projects.					
Level 3	The management of options within interface(s) and user overrides is described for many projects.					
Level 2	The management of options within interface(s) and user overrides is described for some projects.					
Level 1	The management of options within interface(s) or user overrides is ad hoc.					

5	C&E	S&S	O&P	O	I	T
	The capability to scale the integration of many components or systems over time without disrupting overall system operation shall be supported.					
Level 5	The ability to scale without disrupting overall performance can be demonstrated and the capabilities are regularly reviewed and improved.					
Level 4	The management and scaling of the integration of components or systems over time without disrupting overall system operation is described for most projects.					
Level 3	The management and scaling of the integration of components or systems over time without disrupting overall system operation is described for many projects.					
Level 2	The management and scaling of the integration of components or systems over time without disrupting overall system operation is described for some projects.					
Level 1	No studies exist that show impacts of scaling on system operations. The capability to scale is undetermined.					

6	C&E	S&S	O&P	O	I	T
	The ability of overall system operation and quality of service to continue without disruption as parties enter or leave the system shall be supported.					
Level 5	The ability to continue operation and quality of service as all parties enter or leave the system can be demonstrated and the capabilities are regularly reviewed and improved.					
Level 4	System operation and quality of service level specifications for when parties enter or leave the system are adopted by all community members.					
Level 3	System operation and quality of service level specifications for when parties enter or leave the system are adopted by most community members.					
Level 2	System operation and quality of service levels are specified for when parties enter or leave the system.					
Level 1	The operation of the overall system is not consistent when different parties enter or leave the system.					

7	C&E S&S O&P O I T ***Unambiguous resource identification and its management shall be described.***
Level 5	The ability to unambiguously identify resources can be demonstrated and the capabilities are regularly reviewed and improved.
Level 4	Resources are identified unambiguously and resource management requirements for resource identification are adopted by the whole community.
Level 3	Resources are identified unambiguously and resource management requirements exist to describe how resource identification shall be performed for the community.
Level 2	Resources are identified unambiguously but no documentation exists to describe how unambiguous resource identification and management shall be performed.
Level 1	Resource identification and management is ad hoc and little documentation exists to describe it.

8	C&E S&S O&P O I T ***Resource discovery methods for supporting configuration shall be described.***
Level 5	The ability to discover resources can be demonstrated and the capabilities are regularly reviewed and improved.
Level 4	Documentation exists to describe how resource discovery methods based on community definitions are used to support configuration for most projects and metrics are kept to measure success.
Level 3	Documentation exists to describe how resource discovery methods based on community definitions are used to support configuration for many projects.
Level 2	Documentation exists to describe how resource discovery methods are used to support configuration for some projects.
Level 1	No documentation exists to describe how (ad hoc) resource discovery methods are used to support configuration.

B.2 Safety & Security

These criteria are concerned with aligning security policies and maintaining a balance of the tension between minimizing exposure to threats, while supporting performance and usability. This includes the capability to troubleshoot and debug problems that span disparate system boundaries, while placing the integrity and safe operation of the electric power system above the health of any single automation component.

9	C&E	S&S	O&P	O	I	T
	The requirements and mechanisms for auditing and for logging exchanges of information shall be described.					
Level 5	Auditing and logging requirements are aligned among community members and are regularly reviewed and updated as necessary.					
Level 4	Information logging and auditing of information exchanges are described for most deployments (based on community agreements with reference examples) and examples of audits are available.					
Level 3	Information logging and auditing of information exchanges are described for many deployments (based on community agreements) with documented examples available.					
Level 2	Information logging and auditing of information exchanges are described for some deployments (mostly project-centric).					
Level 1	No documentation exists to describe auditing and logging of information used in interface(s).					

10	C&E	S&S	O&P	O	I	T
	Privacy policies[1] shall be defined, maintained, and aligned among the parties of interoperating systems.					
Level 5	Privacy policies are aligned among all parties.					
Level 4	Privacy policies for information exchanges are described and applied for most deployments (based on community specifications) and examples of alignment between parties are available.					
Level 3	Privacy policies for information exchanges are described and applied for many deployments (based on community specifications) with documented examples available.					
Level 2	Privacy policies for information exchanges are described for some deployments (mostly project-centric).					
Level 1	No documentation exists for privacy policies used in interface(s).					

11	C&E	S&S	O&P	O	I	T
	Security policies[2] shall be defined, maintained, and aligned among the parties of interoperating systems.					
Level 5	Security policies are aligned among all parties.					
Level 4	Security policies for information exchanges are described and applied for most deployments (based on community specifications) and examples of alignment between parties are available.					
Level 3	Security policies for information exchanges are described and applied for many deployments (based on community specifications) with documented examples available.					
Level 2	Security policies for information exchanges are described for some deployments (mostly project-centric).					
Level 1	No documentation exists for security policies used in interface(s).					

[1] A statement or a legal document that discloses some or all the ways a party gathers, uses, discloses, and manages a customer or client's data. (http://www.businessdictionary.com/definition/security-policy.html)
[2] A set of rules defining who is authorized to access what and under which conditions, and the criteria under which such authorization is given or cancelled. (http://www.businessdictionary.com/definition/security-policy.html)

12	C&E	S&S	O&P	O	I	T
	Failure mode policies shall be defined, maintained, and aligned[1] among the parties of the interoperating systems to support the safety and health of individuals and the overall system.					
Level 5	Failure mode policies conform to community standards (are aligned among interoperating parties) and are regularly reviewed.					
Level 4	Community-based failure mode policies that address safety and health are described and implemented (without customization) for most deployments.					
Level 3	Community-based failure mode policies that address safety and health are described and implemented (with some customization) for many deployments.					
Level 2	Failure mode policies that address safety and health are described for some deployments (mostly project-centric).					
Level 1	Failure mode policies are ad hoc and not aligned among interoperating parties.					

13	C&E	S&S	O&P	O	I	T
	Performance and reliability requirements shall be defined.					
Level 5	Metrics are based on open or widely used standards and are used to identify areas for improvement.					
Level 4	Performance and reliability requirements exist and are documented. Metrics are collected.					
Level 3	Performance and reliability requirements exist but documentation cannot be provided for both or they are managed to informal agreements.					
Level 2	Performance and reliability requirements exist but vary considerably.					
Level 1	Performance and reliability requirements are ad hoc or do not exist.					

B.3 Operation & Performance

These criteria focus on synchronicity, and quality of service, as well as operational concerns such as maintaining integrity and consistency during fault conditions that disrupt normal operations such that distributed processes can meet expected interaction performance and reliability requirements.

14	C&E	S&S	O&P	O	I	T
	The way errors in exchanged data are handled shall be specified. Note that specific interface(s) may need to specify their error-handling expectations.					
Level 5	The ability to handle errors in exchanged data can be demonstrated and the capabilities are regularly reviewed and improved.					
Level 4	The management of error handling in exchanged data is described for most deployments, based on community specifications, with notable interoperability improvements documented over time.					
Level 3	The management of error handling in exchanged data is described for many deployments and is based on documented community specifications.					
Level 2	The management of error handling in exchanged data is described on a project basis.					
Level 1	Error handling is ad hoc and few interface(s) specify how to handle data errors.					

[1] Defined, maintained, and aligned creates three sub-criteria. Complying with all pieces is required to meet this criterion.

15	C&E S&S **O&P** O I T
	Time order dependency and sequencing (synchronization) for interactions shall be specified.
Level 5	Time order dependency and sequencing requirements are specified for all interface(s) and are regularly reviewed.
Level 4	Time order sequencing and dependency are specified and tested for many deployments with predictable efforts and results without modifications to standards or specifications.
Level 3	Time order sequencing and dependency are specified for most components with predictable efforts and results.
Level 2	Time order sequencing and dependency are managed on a project basis.
Level 1	Time order dependency and sequencing is ad hoc. In practical terms this means that individual transactions may be coordinated but that whole subsystems are not.

16	C&E S&S **O&P** O I T
	Transactions and state management capability for interactions shall be specified.
Level 5	The management of transaction and state management is ubiquitous and requirements are specified for all interface(s) and are regularly reviewed.
Level 4	Transaction and state management is managed for many deployments with predictable efforts and results without customizations of standards or specifications.
Level 3	Transaction and state management is managed for many projects and are based on (community) specifications with some customization.
Level 2	Transaction and state management is managed for some projects and are based on project specifications.
Level 1	Transaction and state management is ad hoc; i.e., on an interface-to-interface basis.

B.4 Organizational

These criteria represent the pragmatic aspects of interoperability. They represent the policy and business drivers and process for interactions. Interoperability is driven by the need for businesses (or business automation components) to exchange information and it requires agreement on the business process integration that is expected to take place across an interface.

17	C&E S&S O&P **O** I T
	Compatible business processes and procedures shall exist across interface boundaries.
Level 5	Interface messages that support the business processes are specified for the community and are consistent with the business context information model and processes are reviewed and improved as required.
Level 4	Interface messages that support the business processes are specified for the community and are consistent with the business context information model.
Level 3	Interface messages that support the business processes are specified by project and are consistent with the project’s business context information model.
Level 2	Interface messages that support the business processes are specified by some projects and are consistent with the project’s business context information model where they exist.
Level 1	Interface messages that support the business processes are not always consistent with the project’s business context information model where they exist.

18	C&E	S&S	O&P	**O**	I	T
	Where an interface is used to conduct business within a jurisdiction or across different jurisdictions, it shall comply with all required technical, economic, and regulatory policies.					
Level 5	Business conducted within and across jurisdictions complies with all required policies and policies are regularly reviewed for compliance.					
Level 4	The business community has interface(s) that are aligned with required policies across jurisdictions and compliance is required.					
Level 3	Business is conducted across multiple jurisdictions and work is under way to eliminate the seams.					
Level 2	Business is conducted across multiple jurisdictions but seams[1] exist between jurisdictions.					
Level 1	Business is conducted across multiple jurisdictions in an ad hoc manner and no formal community exists.					

B.5 Informational

These criteria emphasize the semantic aspects of interoperability. They focus on what information is being exchanged and its meaning. At this level it is important to describe how information classes are related to each other, including the relationships to similar entities across domains and any constraints that may exist.

19	C&E	S&S	O&P	O	**I**	T
	Information models relevant for the interface shall be formally defined using standard information modeling languages.					
Level 5	Documentation can be provided for all information models for selected interface(s). All models were defined using information modeling languages.					
Level 4	Documentation can be provided for all information models for selected interface(s). Some models were defined using information modeling languages.					
Level 3	Documentation can be provided for all information models for selected interface(s). None of the models were defined using information modeling languages.					
Level 2	Documentation is project-based and can only be provided for some information models for selected interface(s).					
Level 1	Documentation cannot be provided for information models for selected interface(s).					

[1] Inconsistencies and/or incompatibilities between processes.

20	C&E	S&S	O&P	O	I	T
	Information exchange relevant to the business context that is derived from information models (i.e., ontologies) shall be specified.					
Level 5	Information exchanged has specifications that links it to the relevant ontologies for all interface(s) and specifications are regularly reviewed against the ontologies.					
Level 4	Documentation can be provided for the specification of information origin and context for most selected interface(s).					
Level 3	Documentation can be provided for the specification of information origin and context for many selected interface(s).					
Level 2	Documentation can be provided for the specification of information origin and context for some selected interface(s).					
Level 1	The specification of information origin and context is inconsistently documented for most interface(s).					

21	C&E	S&S	O&P	O	I	T
	Where the information exchanged derives from multiple information models, the capability to link data from different ontologies shall be supported.					
Level 5	Specifications for linking ontologies together exist in the form of a canonical model that is maintained and regularly reviewed.					
Level 4	The specification of information origin and context is well documented for most interface(s) being reviewed. Documentation that links the ontologies together is maintained and made available for use.					
Level 3	The specification of information origin and context is well documented for many interface(s) being reviewed.					
Level 2	The specification of information origin and context is well documented for some interface(s) being reviewed, mostly dependent on project/system.					
Level 1	The specification of information origin and context is inconsistently documented for most interface(s) and no canonical model exists to link the ontologies.					

B.6 Technical

These criteria emphasize the syntax or format of the information. They focus on how information is represented within a message exchange and on the communications medium. They focus on the digital exchange of data between systems, encoding, protocols, and ensuring that each interacting party is aligned with one another.

22	C&E	S&S	O&P	O	I	**T** (highlighted)
	The structure, format, and management of the communication transport for all information exchanged shall be specified.					
Level 5	Specifications for the structure, format, and management of the communication transport for all information exchanged is maintained and regularly reviewed.					
Level 4	The structure, format, and management of the communication transport is (consistently) described for most deployments and metrics are collected from testing against community specifications.					
Level 3	The structure, format, and management of the communication transport is (consistently) described for many components and systems and is tested against community specifications.					
Level 2	The structure, format, and management of the communication transport is (consistently) described for some components and systems.					
Level 1	The structure, format, and management of the communication transport is ad hoc. It is not managed equally for all interface(s).					

23	C&E	S&S	O&P	O	I	**T** (highlighted)
	The informational and organizational categories in an interface definition specification shall be independent from the technical categories.					
Level 5	Informational and organizational categories in interface definitions are specified separately and are independent of technical implementation.					
Level 4	Informational and organizational categories in interface definitions are specified separately from the technical categories but are still not implemented separately.					
Level 3	The general information models from which the business context is derived are independent of the technical communication requirements.					
Level 2	Informational and organizational categories in interface definitions are specified separately but are still dependent on the technical categories					
Level 1	Informational and organizational categories in interface definitions are dependent on and integrated with the technical categories.					

B.7 Community (Multi-category Criteria)

24	C&E	S&S	**O&P** (highlighted)	O	**I** (highlighted)	T
	Stakeholders shall reference openly available standards, specifications, or agreed-upon conventions in interface definitions.					
Level 5	All interface definitions use open standard specifications.					
Level 4	Interface definitions used for most systems and components reference openly available standards, specifications, or community convention					
Level 3	Interface definitions used for many systems and components reference openly available standards, specifications, or community conventions.					
Level 2	Interface definitions used for some systems and components reference only openly available standards, specifications, or community conventions.					
Level 1	Interface definitions are ad hoc and based on project specifications.					

25	C&E	S&S	O&P	O	I	T
	Stakeholders shall participate in development of interoperability standards efforts consistent with their business.					
Level 5	Participation is active and ongoing for most standards consistent with the ecosystem's business.					
Level 4	A list of relevant standards exists in which participation is planned and participation is ongoing for the majority.					
Level 3	A list of relevant standards exists in which participation is planned and participation has started for some.					
Level 2	A list of relevant standards exists in which participation is planned.					
Level 1	No evidence can be produced of participation in interoperability standards efforts.					

26	C&E	S&S	O&P	O	I	T
	Stakeholders shall support interoperability test and certification efforts and have clear incentives for participation.					
Level 5	Interoperability testing is managed by the community and interoperability capability has been certified for all interface(s).					
Level 4	Interoperability testing is performed for most systems and components and lessons learned are used to make improvements. Some systems and components have been certified against interoperability requirements.					
Level 3	Interoperability testing is performed for many systems and components and lessons learned are documented. Plans exist to obtain certification.					
Level 2	Interoperability testing is coordinated for some systems and components, but testing for certification has not been performed.					
Level 1	Interoperability testing is ad hoc. No certification exists.					

27	C&E	S&S	O&P	O	I	T
	Stakeholders shall actively identify and share lessons learned and best practices resulting from interoperability improvements.					
Level 5	Interoperability lessons learned have been included in future planning for continued improvement.					
Level 4	Interoperability improvements exist and lessons learned have been shared.					
Level 3	Interoperability improvements exist and lessons learned have been documented.					
Level 2	Interoperability improvements have been measured, but lessons learned have not been documented.					
Level 1	No documented evidence of interoperability improvements can be provided.					

28	C&E	S&S	O&P	O	I	T
	Stakeholders shall periodically review refinements and extensions to interface definitions.					
Level 5	Processes are in place and are regularly reviewed to review refinements and extensions to interface definitions.					
Level 4	Most components and systems have processes in place to review the use of extensions to interface definitions with reference examples.					
Level 3	Many components and systems have processes in place to review the use of extensions to interface definitions.					
Level 2	Some projects/systems have a process in place to review the use of extensions to interface definitions.					
Level 1	There is no process in place to review interface extensions periodically and no documentation to describe such reviews.					

29	C&E	S&S	O&P	O	I	T
	Stakeholders shall not compromise security or privacy requirements through efforts to improve interoperability					
Level 5	Interoperability, security, and privacy requirements are aligned and do not affect each other.					
Level 4	Interoperability, security, and privacy requirements cause some conflict.					
Level 3	Plans exist to integrate security and privacy into interoperability requirements.					
Level 2	Security and privacy policies exist, but are treated independently from interoperability.					
Level 1	Security and privacy policies do not exist.					

30	C&E	S&S	O&P	O	I	T
	Stakeholders shall manage the balance between information exchange transparency and privacy agreements across the interface.					
Level 5	Transparency and privacy agreements are regularly reviewed and conform to organizational and community policies.					
Level 4	Transparency and privacy agreements are based on policies (without customization) that reference each other in most cases.					
Level 3	Transparency and privacy agreements are based on policies (with limited customization) that reference each other in many cases.					
Level 2	Transparency and privacy agreements are based on policies, but do not reference each other in most cases.					
Level 1	Privacy agreements are not explicitly referenced in information exchange requirements.					

31	C&E	S&S	O&P	O	I	T
	Stakeholders shall manage the balance between usability and security in interface definitions.					
Level 5	Usability and security balance is regularly reviewed and managed by a (community) quality improvement process.					
Level 4	Usability and security requirements are based on policies (without customization) that reference each other for many systems and components.					
Level 3	Usability and security requirements are based on policies (with limited customization) that reference each other for many systems and components.					
Level 2	Usability and security requirements are based on policies, but do not reference each other for many systems and components.					
Level 1	Usability and security are treated separately and any balancing of priorities is ad hoc.					

32	C&E S&S O&P **O I T**
	Purchasers of connected technology shall specify interoperability performance language in relevant procurement contracts.
Level 5	Connected technology purchase requirements explicitly reference interoperability performance language that refers to open standards.
Level 4	Connected technology purchase requirements reference community standards without customization.
Level 3	Many connected technology purchase requirements reference community standards with customization in some cases.
Level 2	Some connected technology purchase requirements reference community specifications or standards with customization in many cases.
Level 1	No interoperability requirements were explicitly included in recent (12 months) procurement contracts.

33	**C&E** S&S **O&P O** I T
	To sustain interoperability improvement, the creation of an interoperability culture is required using education and marketing, such as material expressing the return on investment (ROI) of interoperability.
Level 5	For most interface(s) the ROI has been calculated for interoperability improvements (both historical and future looking) and the organization actively promotes interoperability.
Level 4	Most new projects, components, and systems reference community standards for interoperability without customization.
Level 3	Many new projects, components, and systems reference community standards for interoperability with customization in some cases.
Level 2	Some new projects, components, and systems reference community standards for interoperability with customization in some cases.
Level 1	Interoperability is managed ad hoc (project to project) and ROI is not calculated for most projects.

34	**C&E** S&S O&P O **I T**
	Stakeholders shall work to specify existing, mainstream, modern information exchange technologies that fit their business objectives and maximize the longevity of interface definitions.
Level 5	Technology ROI and interface longevity are managed continuously to meet community standards and business objectives.
Level 4	Information exchange technologies are (centrally) aligned with business objectives for most projects/implementations with longevity as a specific consideration.
Level 3	Mainstream, modern information exchange technologies are aligned with business objectives for many projects/implementations in a somewhat coordinated manner.
Level 2	Mainstream, modern information exchange technologies are aligned with business objectives, but only for individual implementations.
Level 1	Technology ROI and interface longevity are managed ad hoc, project by project.

35	C&E S&S O&P O I T
	Stakeholders shall not create a new standard where a suitable standard already exists.
Level 5	Processes exist to map standards functionality. There is no participation in multiple conflicting/overlapping standards. Participation in new (overlapping) standards exists only where old standards are planned to be replaced.
Level 4	Processes exist to map standards functionality. There is some participation in multiple conflicting/overlapping standards due to legacy constraints.
Level 3	Processes exist to map standards functionality. The stakeholder has participated in the past in overlapping standards development.
Level 2	Currently participating in standard development that includes overlaps. (Not as a replacement standard).
Level 1	Plans exist to participate in future standard development efforts that overlap existing standard(s). (Not as a replacement standard).

Appendix C

Scoring Using the Interoperability Maturity Model

Appendix C

Scoring Using the Interoperability Maturity Model

Table C.1 shows where scores are required for each category of interoperability criteria. When using the Interoperability Maturity Model (IMM), please refer to Appendix G before starting the exercise of measuring interoperability maturity using specific criteria.

Table C.1. Criteria Selection for Applying the IMM

	Configuration & Evolution	Safety & Security	Operation & Performance	Organizational	Informational	Technical
1	✓					
2	✓					
3	✓					
4	✓					
5	✓					
6	✓					
7	✓					
8	✓					
9		✓				
10		✓				
11		✓				
12		✓				
13		✓				
14			✓			
15			✓			
16			✓			
17				✓		
18				✓		
19					✓	
20					✓	
21					✓	
22						✓
23						✓
24			✓		✓	
25	✓			✓		
26			✓	✓		✓
27	✓	✓	✓	✓		
28	✓				✓	
29		✓	✓			✓

	Configuration & Evolution	Safety & Security	Operation & Performance	Organizational	Informational	Technical
30		✓			✓	
31		✓			✓	
32				✓	✓	✓
33	✓		✓	✓		
34	✓				✓	✓
35	✓	✓	✓	✓	✓	✓

To use the IMM it is first necessary to determine which categories are going to be evaluated. Table C.1 shows which criteria need to be selected. If a criterion is included in multiple categories that are selected for evaluation, then its score is included for each category.

It is not necessary to have received a successful evaluation at any level n of the IMM before being evaluated for level n+1; however, an incremental improvement program is probably a wise approach.

Determining whether a criterion has been met is a function of determining whether the basic intent of the level is observable and verifiable. The basic intent for each criterion by level is described in Appendix B.

C.1 Guidelines

In determining whether the basic intent of the level is observable and verifiable asking and answering the following questions may provide helpful guidance:

- Is there evidence that the practice described in the criterion is being performed?
- Is there evidence that the capability described in the criterion is being practiced?
- Is there evidence that implementations meet the described criterion?
- Are the expected outputs observable and available for inspection?
- Is the practice described in the criterion documented and shared with all who need to know?
- Have the standards and guidelines that support the practice/criterion been identified and implemented?
- Is the practice/criterion supported by policy, and is there appropriate oversight over the performance of the practice?
- Are practice/criterion improvements documented and shared across internal constituencies so that the organization reaps benefits of these improvements?
- Is there a community-sponsored definition of the practice/criterion from which organizations can derive practices that fit their unique operating circumstances, while still achieving the shared goals of the community?

C.2 Performing the Scoring

The scoring rubric is as follows:

- **Step 1.** Score the criteria in each category. Each criterion in a category is scored by answering whether there is documented evidence to support whether the criterion is being met as defined by the required level description, and scored as follows:
  - ***performed*** when the question is answered with a “Yes”
  - ***not performed*** when a question is answered with
    - Incomplete evidence
    - No
    - Not Answered
  - If the result for a criterion is “Not Answered” the criterion shall be scored the same as a “No.”
- **Step 2.** Create the score for each Category. The score (rating) for the category is then determined as follows:
  - ***achieved*** when all practices are performed
  - ***partially achieved*** when some practices are performed
  - ***not achieved*** when no practices are performed

Appendix D

Identifying Interoperability Gaps and Developing Roadmaps

Appendix D

Identifying Interoperability Gaps and Developing Roadmaps

A tool to identify interoperability gaps and a methodology for developing roadmaps are are mutually dependent and linked to each other. Interoperability gaps (both capability and implementation related) will be identified by application of an interoperability maturity assessment tool to specific technology domains. Once these gaps have been identified, strategic plans can be developed to address the gaps.

The IMM consists of a set of broad questions plus descriptions to identify the level of maturity for each criterion of the model. The output of the IMM tool shows the baseline interoperability maturity level. This baseline is compared with the target levels for each criteria and a set of prioritized actions are developed to adjust the baseline to meet target levels where appropriate.

The process of applying the IMM and then developing prioritized actions or roadmaps for improving interoperability capability requires the engagement of the appropriate stakeholders in technology integration domain of interest. The framework for this methodology has been heavily informed by work from the International Energy Agency (IEA 2014).

The IEA roadmap development process (Phases 1–4) is shown below in Figure D.1. Note that the GMLC interoperability team has added "Phase 0" and "Phase 5" for reasons that are explained below.

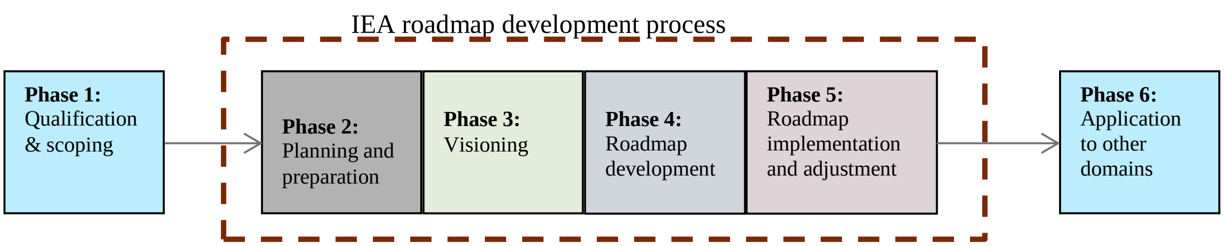

Figure D.1. Interoperability Roadmap Methodology

The IEA process has been designed to maximize stakeholder engagement in creating a roadmap with the guiding principle being that once consensus is built among the participants toward shared goals and results, these relationships can help support the roadmap implementation and will also increase the likelihood that the participants will implement the roadmap successfully.

The roadmap will help to develop a clear vision of the target interoperability maturity as well as the specific steps for reaching it. Key elements of the roadmap are:

- **Interoperability maturity goals**
  These targets should be clear, concise, and designed so that their achievement will result in the desired maturity. Interoperability criteria are inherently designed to be quantifiable, because this enables progress to be measured and provides clear, specific guidance (for a full list of characteristics of interoperability criteria; see the IMM documentation).
- **Milestones**
  These interim targets for achieving the goals should be keyed to specific dates.
- **Gaps and barriers**
  As identified above, one of the steps in the analysis of the IMM baseline results is to compare the

results with the target maturity. This step builds on that step to create an understanding of gaps between current interoperability as well as barriers or obstacles to achieving the milestones and target maturity.

- **Priorities and timelines**
  These identify the priority actions required to achieve the target interoperability maturity within the project timeframes and account for any dependencies between actions.
- **The roadmap**
  This is the plan for executing the specific prioritized actions that will be taken to achieve the target maturity.

The overall roadmap process is described in Figure D.2. The IMM toolkit is required throughout the roadmap development process to inform the roadmap development stakeholders. In Phase 0, the interoperability champion requires an executive overview of the IMM and the roadmap process itself to successfully gain buy-in from the rest of executive leadership, and to kick off the roadmap process by selecting key steering committee members. The steering committee itself will require details to determine the composition of the experts needed and to determine workflow during the workshops conducted during Phase 3.

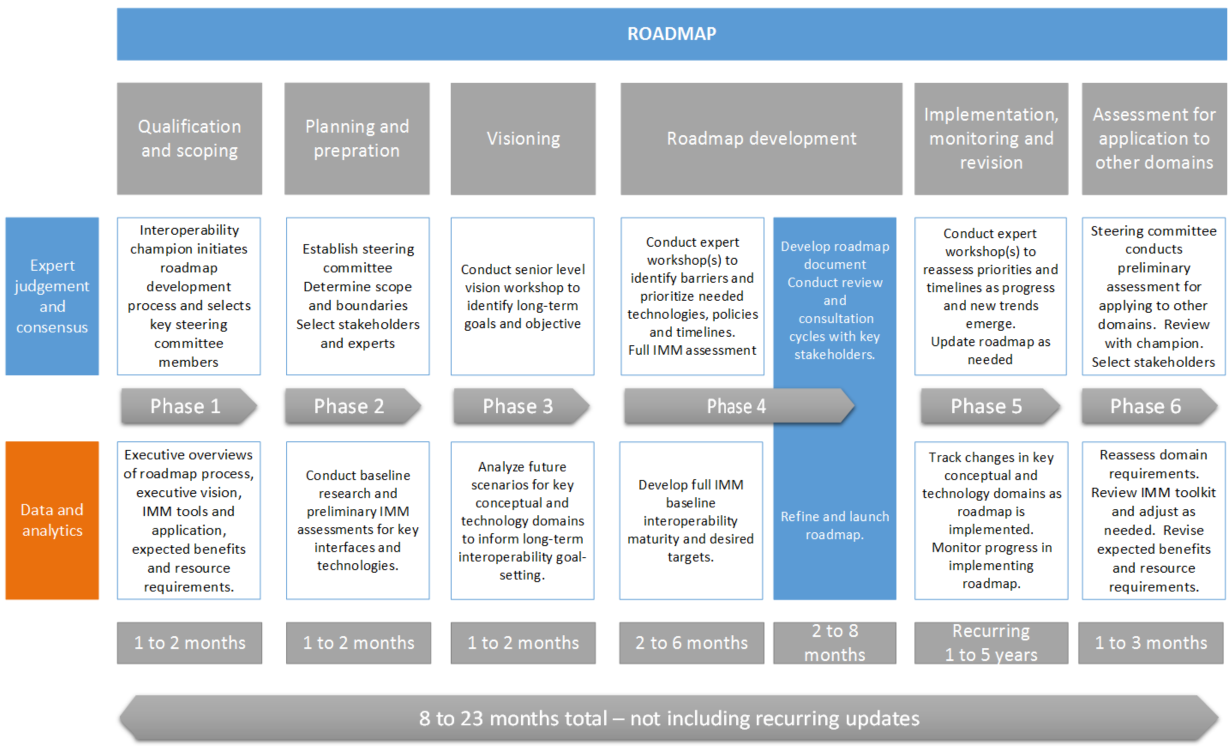

Figure D.2. Interoperability Roadmap Methodology in Detail

During the roadmap development phase, the IMM will be leveraged to provide a baseline maturity level for interoperability. During the workshops and analysis a target level will be established and specific action plans will be created to address any gaps that would hinder meeting the target interoperability level.

The IMM Toolkit links to the roadmap methodology in the following ways:

- Phase 1: executive overview of the IMM

- Phase 2: the IMM is used to measure current interoperability levels
- Phase 3: the IMM level descriptions can assist in determining long-term goals
- Phase 4: IMM output from Phase 1 is used to determine gaps and build the roadmap
- Phase 5: IMM can be reapplied during future iterations to continue improvement
- Phase 6: lessons learned can be included in the IMM.

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