Measuring Progress Toward Implementing a Sustainable Transportation Security Program in the Russian Federation

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ABSTRACT

The U.S. Department of Energy Material Protection, Control, and Accountability (MPC&A) Program has supported security upgrades to protect special nuclear materials during transport in the Russian Federation for the last decade. Implementing security upgrades and operations that are sustainable is an important goal of the program. This raises a natural question, how to measure sustainability? An approach for measuring MPC&A sustainability implementation progress was suggested in an earlier paper coauthored by one of the authors of this paper (Pillai et al., 2005). This paper expands on that previous work. Notions of sustainability that have been developed in a variety of fields are reviewed to establish a conceptual basis for sustainability measurement. Then the concept of separating sustainability program elements that enable and support good sustainable operations from the operating practices themselves is introduced. Measurements can be used for a variety of purposes, and what constitutes the most useful metric for a particular purpose may vary depending upon its use. Alternative methods for identifying metrics appropriate for different applications, such as management oversight, project tracking, decision support, planning, and operational support are suggested. Practical considerations are explored for a specific application to the national, cross-cutting Transportation Security Project.

INTRODUCTION

The U.S. Department of Energy (DOE) established the Office of International Material Protection and Cooperation to work cooperatively with our Russian Federation (RF) partners to reduce the proliferation risk of nuclear material at RF sites. Initially, the most common practice was to install accepted Material Protection, Control, and Accounting (MPC&A) technologies. As initial upgrades were completed and the MPC&A program progressed, more attention was given to programmatic and infrastructure needs required for sustaining the desired level of protection for the long term.

The Office of National Infrastructure and Sustainability (ONIS) established an Operations and Sustainability project as part of the MPC&A Program to help develop an integrated, continuously improving, and sustainable national MPC&A program for the RF. The Operations and Sustainability project, like other cross-cutting projects within ONIS, works with individual nuclear sites, regional organizations, and national organizations to improve and sustain safeguards and security upgrades. The objectives of this sustainability program are the following:

- Ensure that a designed level of protection is maintained for the indefinite future.
- Support the development of an integrated system of activities, programs, facilities, and policies for the protection of special nuclear material (SNM) in the RF during its storage, processing, and transfer.

- Plan for transition of responsibility to the RF by encouraging the development of Russian commitments to operate and maintain these security improvements.

The Transportation Security Project (TSP), also an ONIS national cross-cutting project, is helping to upgrade SNM transportation security equipment and systems at multiple RF facilities and sites as part of the MPC&A Program. The goal of the TSP is to reduce the risk of diversion of SNM in transit (within and between sites). The project has made significant progress in upgrading security on existing railcars and trucks, deploying secure railcars and trucks, and implementing communication centers. To maintain both the near-term and the long-term effectiveness of completed and future upgrades and to ensure the ultimate success of the project, a comprehensive and integrated transportation security sustainability plan was developed and is being implemented.

Sustainability is a worthwhile goal but one that will require significant effort and resources. This suggests that a means to characterize a project's progress and its sustainability would be useful. Some questions naturally arise: What is sustainability? And how can it be measured? This paper suggests approaches for answering these questions. After reviewing notions of sustainability, concepts, models and evaluation tools helpful for addressing both questions are discussed.

Sustainability Measurement Challenges

Sustainability indicators should allow organizations to understand the current state of the MPC&A program and gaps that must be filled to reach the end state. A good indicator will help determine what needs to be done, and help track resources, program health, system health and activities. This enables organization to make necessary adjustments to ensure that MPC&A systems continue to perform at the level at which they were designed.

Implementing a comprehensive and sustainable TSP in the RF is complex and requires intense effort at multiple organizational levels (top-down and bottom-up). A sustainable TSP requires integrating the vast national network of organizations and institutions involved in the efforts to secure the nuclear material as it moves through the country. Implementing it requires a combination of a physical, a programmatic, and a regulatory framework to inspire and govern organizations and individuals so that they understand the importance of safeguards and security requirements and principles and apply them systematically on an ongoing basis. Sustainability requires an integrated view of the program, using multidimensional indicators that show the links among site, regional, and national infrastructure and national programs.

Traditional indicators of progress, such as the amount of material protected by certain upgrades or the amount invested, are useful management measures. Depending upon the end use, more detailed measurements may be needed. Measures that characterize long-term operations capability (resource requirements vs. resource availability); integration of MPC&A components with the site, regional, and national infrastructure; and interdependencies may be useful for other applications. Indicators must be relevant to their purpose, understandable, and based on available data.

Measurements can be used for a variety of purposes, and what constitutes the most useful metric for a particular purpose may vary depending upon its use. Management oversight, project tracking, trade-off studies, decision support, planning, and operational support are potential applications.

Once the purpose has been determined, i.e. why the measurement is needed, then we can determine

- What to measure
- Where to measure
- When to measure
- How to measure

Notions of Sustainability

Before answering these measurement questions, it will be helpful to first explore what sustainability is—its nature, its characteristics, its properties, and its behavior. What is this sustainability thing that we want to measure? To this end, the notions of sustainability that have been developed in several fields are mentioned to introduce the reader to some of the different ways the term is used.

Sustainable economic development has been the subject of studies of emerging economies for several decades. In this context, the essential idea is that an economy, operating with available resources, can meet human needs indefinitely while preserving or even improving the environment. Although the terms "resource," "needs," and "environment" appear, the emphasis is often on the operations of the economy. Contrast this with sustainable land use. In this case, a finite resource, land, is used in such a way that it can continue to be used indefinitely. The emphasis is on how a limited resource is used without adversely impacting the environment (and in this case, the resource and the environment are the same). Note that in addition to understanding how operations can change the environment, how organizations and operations can adapt to a changing environment is also of interest. Now consider an example from nuclear technology. In a study of the sustainability of various nuclear fuel cycles, Brogli and Krakowski (2002) base their analysis on three general criteria: economy, environment, and society, supported by multiple metrics identified for each of these general criteria. Based on these examples, sustainability seems to pertain to

- Limited or finite resources
- Operations on or using those resources
- Meeting human, technical, or societal needs
- Economy
- Environment
- Society
- Change
- A long period of time

Here our interest is meeting safeguards and security needs in the RF nuclear-complex environment.

Supporting Models

To get a better sense of the nature of sustainability, some familiar models and theories that include some of the "parts," "pieces," or attributes listed are discussed. These models and theories are mentioned here to provide some insight and help illustrate a particular aspect of sustainability. Some of these are also useful tools for analyzing what to measure and where to measure it. However, the limitations and incompleteness of each model should be recognized, as most do not capture all of the dimensions, intricacies and interactions involved in sustainability.

Input/Output Models

Input/output or balance models are familiar in science, technology, economics, and many other fields. In their simplest form, a set of inputs is operated on by a process to produce a set of outputs. For an MPC&A system, inputs include material flows, resources (funding, expertise, equipment, and parts), information, and technical assistance. The operations and associated MPC&A system make up the process to meet operational and MPC&A needs. Outputs include the performance of the system, various material and equipment flows, including wastes, and information flows. The input/process/output model may itself be placed in an environment (another input/process/output model). The inputs, outputs, and process may change over time, i.e., they may be dynamic. For our purposes, the inputs and outputs are measurable quantities.

This model construction has many of the pieces of sustainability mentioned above. But is it a complete model of sustainability? Not necessarily. Sustainability involves multiple interacting components. The simple input/output model may not describe this more complex structure and the interactions of the components parts.

System Models

To describe the complex structure and interactions between component parts, system models are used. System models are often constructed by combining, connecting or embedding a number of simpler models. System models describe some aspect of the overall behavior of the system as well as the behavior of its component parts. An important benefit of a system model is the understanding gained about how the component parts interact and their relative importance.

Meta-Processes and Models

To measure sustainability, it is useful to separate sustainability program elements that enable and support good sustainable operations from the actual operating practices themselves. Sustaining a process involves more than day-to-day operations, even if they are performed well (although there is some overlap)! In some respects, sustainability elements are like a meta-process that operates on the day-to-day operations and practices from outside and separate from them. One distinguishing attribute of these sustainability meta-processes is their longer characteristic time scale. An example may help to illustrate this point.

Consider a secure transport vehicle in which a particular security widget wears out and must be replaced periodically. The mean-time-between-failure for this item is well known, and a sophisticated failure and risk model is used to stock local inventory. Based on an explicit tradeoff between cost and risk, a decision has been made not to maintain a large excess inventory of spare parts locally. An efficient supply chain process has been put in place to restock the parts in time for most credible failure scenarios. Although highly unlikely, multiple units fail at nearly the same time, and the local inventory is not sufficient to repair all the failures. The additional replacement parts that are needed are ordered; but, as luck would have it, the supplier only has the minimum required inventory in stock, which is not enough to replace all of the failed units. Further, the next production run is not scheduled for several weeks.

In this extreme Murphy's Law example, the part failures caused immediate perturbations to the transportation operations (operations, rapid dynamics). The delivery of all the required replacement parts is delayed by the supplier's production schedule, which in turn delays how quickly all units can be brought back into service. However, the risks of multiple parts failures and the potential supply-chain delay are well understood and accepted in the decision process.

Now consider some of the systems and processes that have been put in place to sustain the transportation operations. This includes the analysis methods for determining the acceptable spare parts inventory (failure analysis, decision analysis, risk analysis) and the parts supply chain design. These processes and systems are designed to handle many credible events. Although the operations were disrupted in this example, the systems in place to sustain operations performed as designed, i.e. with no detectible degradation in its performance, per se (sustainability enabling process, slow dynamics). However, these events might prompt a reexamination of the design basis.

Feedback Control

Another useful model from control engineering is the feedback control loop. In the control loop, one or more of the outputs is measured, the information is processed, and the inputs or the process is adjusted to keep the measured variables at their setpoints. Selection of a measurement point and measured variable is a rich area in the theory and practice of process control. For multiple input/output systems with complex processes, techniques such as principal-component analysis (PCA) have been useful for selecting optimum measurement points and measurement variables.

Stability

Sustainability and stability are related concepts. Stability theory is applied to process control system tuning, and analysis of linear and nonlinear systems. For our purposes, the idea of stability, that the process and its outputs do not change greatly or rapidly, is also useful in analyzing and characterizing sustainability. This tool can be applied to evaluate the behavior of sustainability systems over time and to help differentiate sustainability variables from process variables.

Multi-criteria Decision Analysis

Several examples of decision analysis applied to sustainability are mentioned in this paper, the fuel cycle sustainability study and a sustainability index concept (Pillai et al, 2005). These methods are useful for reducing a complex set of criteria into a more manageable set.

Other Properties of Sustainability

There are other properties that we have not explored that could have important implications for measurement. Are the sustainability processes linear or nonlinear? Are the elements of sustainability independent or inter-dependent?

The elements of sustainability are often discussed as independent pieces that fit together. But these pieces are connected through information flows and communications, and they exist in a cultural environment. These interactions and the connections between elements impact the functioning of the sustainability system. Just as the coordination of organizations with different responsibilities impacts overall performance, these connections influence sustainability over time.

Sustainability Framework and Sustainability Index

The Operations and Sustainability project developed a sustainability framework that envisions a site-level sustainability program, regional and national infrastructure, and national standards. The site-level framework includes the following site-level elements:

1. MPC&A Organization
2. Site Operating Procedures
3. Human Resource Management and Site Training
4. Operational Cost Analysis
5. Preventative Maintenance, Repair and Calibration
6. Performance Testing and Operational Monitoring
7. Configuration Management

One potential approach for developing sustainability metrics is based on multi-criteria decision analysis. Pillai et al (2005) illustrate how this approach could be used to develop a sustainability index that considers two main factors, an operational readiness factor and a resource readiness factor. The operational readiness component is derived by estimating sustainability indicators for each of the elements listed, which are aggregated by a suitable weighting of elements into an overall operational readiness rating. In this formulation, site resource readiness is defined as the ratio of the resources provided by the RF to the total resources required to sustain the upgrades.

Additional Measurement Applications

The appropriate measurement depends upon its use. The following table lists metrics, or the tools that may be useful for determining the appropriate metrics for different applications. The applications are listed roughly in order of increasing complexity.

Program oversight	Use traditional measures such as the amount of material protected and the amount invested
Project tracking	Sustainability index
Decision support	Sustainability index. Additional multi-criteria decision analyses
Trade-off studies	Sustainability index. System model
Planning	Sustainability index. System model
Sustainability operational support	System model. Meta-model. Stability theory. PCA

In general, as more resolution is needed, the more complex the models must be and the more sophisticated the analysis must be to define the appropriate set of metrics. For operational support, PCA might be used with a system model to select optimum measurement points and measurement variables.

An example of sustainable operational support is the supply chain for spare and replacement parts. A supply chain is a logistics network that facilitates the physical movement of materials, services, information, and financial resources between its members. The members of the supply chain include manufacturers, service providers, transportation providers, distributors, and customers. An integrated supply chain includes information sharing and the development of intergrated long-term planning. Advances in information technology and data transfer technologies have enhanced the ability of efficient supply chains to operate. To achieve an efficient supply chain operation, a number of measures can be implemented throughout the system. These measures must be monitored on an ongoing basis to ensure an efficient system in a changing economic and technical enviromnent. Some of the key measurement indicators are demand forecast accuracy, on-time delivery, inventory levels, manufacturing cost, and time to market.

Conclusions and Recommendations

To measure sustainability, it is useful to separate sustainability program elements that enable and support good sustainable operations from the operating practices themselves. Information flow, coordination, communication and culture, and the processes that connect sustainability components are significant to the overall sustainability of system performance. Measurements can be used for a variety of purposes, and what constitutes the most useful metric for a particular purpose may vary depending upon its use. Alternative methods for identifying metrics appropriate for different applications—such as management oversight, project tracking, trade-off studies, decision support, planning, and operational support—were suggested.

References

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