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2018 TECHNICAL REPORT

Information Technology – Operational Technology Convergence Guidebook

First Edition

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3002012479
Final Report, June 2018

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Acknowledgments

The Electric Power Research Institute (EPRI) prepared this report.

Principal Investigator
R. Rhodes

This report describes research sponsored by EPRI.

This publication is a corporate document that should be cited in the literature in the following manner:

Information Technology – Operational Technology Convergence Guidebook: First Edition.
EPRI, Palo Alto, CA: 2018.
3002012479.

Abstract

Information technology (IT) and operational technology (OT) platforms have been converging as computing and communications technologies expand and mature. This convergence particularly affects asset-intensive industries where an extensive OT application portfolio is necessary to monitor and control their production systems and capital assets.

Electric utilities have a wide range of OT systems across generation, transmission, and distribution domains. As distributed energy resources (DER) adoption advances, those systems are being extended to monitor grid-edge resources. The grid itself is becoming fully digital as electromechanical systems are replaced with embedded computing devices and fully responsive automation.

In past work on IT-OT integration, EPRI surveyed utilities for their approach to this convergence and their strategies for adopting best practices across IT and OT applications. EPRI also addressed IT and OT application portfolio management as well as the economic impacts of various organizational integration strategies.

The objectives of this guidebook are to

- Clearly define concepts and terms to promote better understanding across both IT and OT domains.
- Provide additional context as to how business and technology changes are reshaping the IT-OT convergence challenge.
- Present EPRI research on IT-OT convergence in a format that can be updated and expanded annually.
- Identify areas for further research.

Keywords
IT-OT
Operational technology
Convergence
Alignment
Integration
Enterprise architecture

Deliverable Number: 3002012479

Product Type: Technical Report

Product Title: Information Technology – Operational Technology Convergence Guidebook: First Edition

PRIMARY AUDIENCE: Enterprise architects

SECONDARY AUDIENCE: Electric utility business and IT executives

KEY RESEARCH QUESTION

Electric utilities recognize that technologies used in operational technology (OT) applications are converging with those used in information technology (IT) applications. This research investigates best practices for addressing the organizational and technical impacts of this trend in a guidebook format.

RESEARCH OVERVIEW

Information technology (IT) and operational technology (OT) platforms have been converging as computing and communications technologies expand and mature. This research synthesizes publicly available information from research advisory firms, academic institutions, consultants, systems integrators, and software vendors. Additional contributions were sourced from discussions with enterprise architects and other utility representatives at EPRI conferences.

KEY FINDINGS

- IT-OT integration challenges for electric utilities exceed those of other industries due to the dynamic, real-time nature of electricity generation and delivery.
- Utilities report their most difficult challenges are less about technology and more about managing organizational change and bridging cultural differences between IT and OT groups.
- Electric utilities' past reliance on proprietary control systems architectures will eventually be superseded by a careful migration toward to a shared platform that can service both IT and OT domains.
- Today's distinctions between IT and OT will subside in importance as industrial Internet of Things (IoT) architectures find acceptance in electric utilities.

WHY THIS MATTERS

Global support for energy decarbonization and rising distributed energy resources (DER) adoption are driving electric utility organizations toward developing an integrated grid, but the legacy of separate IT and OT cultures is standing in the way. EPRI members can use this guidebook to jump-start their efforts, move past their IT-OT challenges, and develop a fully digital grid.

HOW TO APPLY RESULTS

The culture of OT practitioners focuses on reliability and safety. Key factors in OT architecture and design include fault tolerance, determinism, consistency, and longevity. The culture of IT practitioners focuses more on standardized, repeatable technology solutions with shorter lifetimes. Developers and designers in IT focus instead on consumer-class user experience and high flexibility for changing business processes. Both of these cultures are necessary for the future. Given the gradual convergence of underlying IT and OT technology platforms, the question answered in this guidebook is how to blend the best practices and skill sets of each culture within IT, OT, or blended IT-OT organizations.

LEARNING AND ENGAGEMENT OPPORTUNITIES

- EPRI report 3002009979, *A Strategic/Economic View of IT/OT Convergence* (January 2018), proposed a strategic framework for considering whether IT and OT organizational units should be combined into one organizational unit. The benefit of the strategic framework is to first examine and compare fully developed future states using rough economics to examine the end states, without delving into unnecessary details of the transition process.
- EPRI report 3002005249, *Information Technology (IT)/Operational Technology (OT) Convergence Strategies* (December 2015), noted that CIO responses could be segmented into three approaches: 1) Reorganize—merging IT and OT support groups into a combined organization, 2) Realign—selectively choosing and moving segments of IT or OT support groups with similar skill sets into a combined organization, and 3) Re-engage—choosing to not move anyone organizationally, but increasing efforts to raise awareness and improve communication among all stakeholders on IT and OT projects.
- EPRI report 3002007877, *Application Portfolio Management for Aligning Information Technology and Operational Technology: Challenge and Opportunity for Utilities* (November 2016), introduced Application Portfolio Management and explored the differences of viewpoints about this topic across IT organizations and OT support groups within business units. The research noted the level of effort necessary to build a transparent, objective system that equally engages IT and OT counterparts.

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Table of Contents

List of Figures

List of Tables

Section 1: Introduction

What is IT-OT Convergence?

Much has been written about the evolution of operational technology (OT) and its eventual convergence with IT. Content on this topic is available from advisory research firms (e.g. EPRI, Gartner, IDC, Forrester, ARC, McKinsey and others), from consultants and system integrators, from vendors, and even academia. No single source has an authoritative, comprehensive answer. This topic is by nature broad and interdisciplinary. There is however general agreement on definitions, issues, trends, and solutions.

Table 1-1 provides some working definitions we will use for purposes of this guidebook.

Table 1-1
Important Definitions for Discussing IT and OT

Term	Definition
Information Technology	This is the common term for the entire spectrum of technologies for information processing, relying on commercial off-the-shelf (COTS) life-cycle software, hardware, communications technologies and related services.
Operational Technology	Hardware and software systems that detect or cause a change through the direct monitoring and/or control of physical devices, processes, and events in the enterprise. OT systems often include embedded technologies that generate data for localized monitoring and control.
IT/OT Convergence	IT/OT convergence describes the trend for IT and OT technical platforms to converge, as well as the gradual changes within the organizations supporting these systems.
IT/OT Alignment	IT/OT alignment is an approach to deal with the internal changes within an organization in response to IT/OT technical convergence.
IT/OT Integration	IT/OT integration refers to an end state sought by asset-intensive organizations where instead of separate IT and OT areas with differing areas of authority and responsibility, there is integrated process and information flow across the organization.

Brief Examples for Electric Utility Context

Given the above definitions, it will be helpful to add some examples for each category. Those are listed below for clarity.

Information Technology

Electric utility IT examples are those enterprise software applications that manage information used to optimize corporate performance and meet regulatory requirements. Examples include:

- Customer Information System (CIS)
- Enterprise Asset Management (EAM)
- Human Resources Information System (HRIS)
- Geographic Information System (GIS)
- Outage Management System (OMS)
- Meter Data Management System (MDMS)
- Asset Performance Management (APM)
- Mobile Workforce Management (MWM)
- Security Information and Event Management (SIEM)

Operations Technology

Electric utility OT examples include:

- Energy Management System (EMS)
- Distributed Control System (DCS)
- Distributed Energy Resources Management System (DERMS)
- Supervisory Control and Data Acquisition (SCADA)
- Advanced Distribution Management System (ADMS)
- Substation Automation System
- Distribution Automation System
- Digital Relays
- Digital Fault Recorders (DFRs)
- Power Quality Meters (PQMs)
- Phasor Measurement Units (PMUs) and Phasor Data Concentrators (PDCs)
- Programmable logic controllers (PLCs)
- Telecommunications switches, gateways and controllers
- Operations WAN, LAN and FAN systems
- Building energy management systems (Building EMS)

IT-OT Convergence

OT systems have changed substantially in the last decade, adopting significantly more commercial technologies than in the past. Smart grid projects created a broader view of interoperability and set the stage for a broader vision of a digital grid.

Typical examples demonstrating IT-OT convergence for electric utilities include:

- Substation automation vendors' full use of native Microsoft or Linux technology stacks for their solutions.
- Value Added Resellers (VARs) offering PLCs running Linux or Microsoft kernels.
- Networking equipment vendors ruggedizing their commercial off-the-shelf (COTS) offerings for substation and field use.
- EMS, ADMS, DCS, Historian, and other mission-critical application vendors adopting COTS operating systems, networking technologies, data storage systems, and virtualization technologies.
- SIEM system vendors adapting corporate technology systems to address threat detection and security incident response for utility OT systems.

IT-OT Alignment

Examples of how electric utilities have responded to convergence include:

- Aligning standards and governance for cybersecurity across IT and OT systems (often in response to governmental requirements) to ensure consistent application of security protocols and uniform threat detection and response.
- Exchanging or consolidating staff between IT and the business organizations supporting OT to ensure uniform processes and protocols are enforced across the enterprise.
- Moving from "ownership" to "responsibility and accountability" in order to reduce barriers to communication.
- Addressing labor relations barriers where necessary to manage and maintain IT devices as they are ruggedized and deployed to OT environments in the field.

IT-OT Integration

Few electric utilities have accomplished full or mature IT/OT integration, but steps along the way include examples like these:

- Implementing enterprise service bus (ESB) technology with embedded governance, model-driven integration, and web services within OT domains to support secure integration across IT and OT.

- Bringing data from the operations domain into the corporate environment (often using historian-based data aggregation as a part of a DMZ environment).
- Exploiting low-cost, direct-to-cloud communications for grid-edge asset sensors where security requirements can be addressed.
- Integrating IT and OT systems within combined Network Operations Centers (NOCs) to provide a holistic view of the operating environment or to reduce operations costs.
- Reorganizing support organizations if and when IT and OT distinctions can be reduced to a minimum.

Why Does IT-OT Convergence Matter?

While the electric utility industry recognized the impacts of convergence as early as a decade ago and many utilities have a good head start, the mandate for change seems to be increasing. Current utility industry changes are driving a stronger need for IT/OT alignment and integration projects. Following are some change drivers that EPRI members can consider as they prioritize IT-OT integration projects compared with other corporate initiatives.

Risk Management Success Depends on IT-OT Integration Maturity

Cybersecurity and risk management has been front and center as the key driver for integrating IT and OT. In the commercial sector the rapid maturing of cloud and mobile computing has introduced massive data privacy breaches, highlighting the need for comprehensive cyber- and physical-security systems. In utilities, broad deployments of automated metering infrastructure, distribution automation, field sensors, and DERs are expanding the threat surface and challenging the systems we have for device authentication and threat identification. The combination of rapid change in the commercial sector with expansions in OT presents utilities with a significant challenge. They must fit commercial cybersecurity solutions back into their OT environments. Electric utilities have the toughest challenge since grid control, protection, and communication systems are among the most complex legacy OT environments. These environments require features not typically supported by most commercial SIEM offerings. Therefore, the sophistication of integration requirements is rising, which builds the case for more consistency with IT and OT integration.

Technology Advancements Are Changing the IT-OT Integration Equation

Technology advancements are changing the way we look at integration itself. In one sense, we can learn from the consumer products world, where many new products are sold with a customer app or embedded monitoring capability. These apps and monitoring capabilities allow the customer or vendor to monitor both product and consumer usage patterns. (For vendors, it allows them to predict

future product failures, manage recalls, and creates a new channel for follow-on business offers). So, cloud-connected products are now the norm rather than the exception.

A parallel development is taking place in the industrial sector, with the declining costs of sensors and IoT systems. Commercial Asset Performance Management offerings are available to leverage better asset data as these systems blur the lines between digital and physical systems.

For these reasons, enterprise computing for utilities is making a shift toward platform solutions –systems with API-rich development environments and integration options. The integration tools market itself is also moving to the cloud as vendors have developed Integration Platforms as a Service. Other vendors are offering machine learning-based features within their data integration tools, making it easier and faster to integrate enterprise systems.

Major industrial software and equipment vendors are pursuing this with new offerings that utilities can use as distributed computing platforms, as they pursue a stronger customer connection and a more systematic approach to managing DER growth. Examples are the commercial platforms offered by GE (Predix), Schneider Electric (EcoStruxure) and Siemens (MindSphere), and Itron (Riva). This argues for fresh thinking on how new architectures will affect IT and OT concerns and what type of vendor partnerships will help address those issues.

Electrification Expansion Will Require Even Stronger IT-OT Integration

Electrification expansion is requiring integration with more application domains. Examples include expanding EV adoption and the eventual impact of autonomous transportation on driving and charging patterns. There is also a parallel trend emerging in the energy efficiency services industry - "electrify everything." This, and the movement toward smarter cities, will open the door for utilities to collaborate more closely with state and local governments to shape energy end-use patterns. Many newer players in the transportation, solar and energy storage markets do not have an “OT history.” They are coming to market with industrial IoT-based solutions that more strongly leverage mainline commercial technologies. This will put more pressure on electric utilities to move beyond their traditionally favored protocols and integration patterns.

Utilities Must Master IT-OT Convergence to Develop a Software-Driven Grid

Rising DER adoption at the grid edge accentuates IT/OT integration challenges. Industry consensus and direction is to move toward supporting high-penetration variable energy resources (VER). Over 50% of new VER is distribution-connected, and this is driving significant research at EPRI and elsewhere regarding the concept of a software-driven grid. We know that utilities will be managing and optimizing with dynamic models that depend on stochastic analysis and financial market incentives rather than traditional control schemes.

Therefore, utility communication systems will have to support faster, low-latency designs as DERs will need to communicate with one another and the grid. Network model management will emerge as a key discipline and as a discrete distribution application category. And utilities will have to rethink their traditional integration approaches to achieve the goal of increased network observability and more rapid deployment of applications in OT environments.

Section 2: Overcoming Challenges to IT-OT Integration

Following are some suggestions for overcoming the challenges presented by IT and OT convergence and tackling the organizational issues that stand in the way.

Recognize the Cultural Differences Separating IT and OT Professionals

The culture of OT practitioners focuses on reliability and safety. Fault tolerance, determinism, consistency, and longevity are the key factors in architecture and design. The culture of IT practitioners has focused on standardization and repeatability. Frequent change, shorter lifetimes for products and systems, user or customer convenience and "the experience" are primary drivers for IT.

Both of these cultures were necessary in the past, and both are necessary for the future. Given the gradual convergence of underlying IT and OT technology platforms, the question is then how to blend the best practices and skill sets of each cultures within IT, OT, or blended IT/OT organizations. Electric utilities have identified these underlying cultural differences as their most significant change management challenge.

EPRI has observed several typical points where organizational convergence efforts can take place among IT, OT, and telecom environments. This is illustrated in Figure 2-1 as a starting point for discussion.

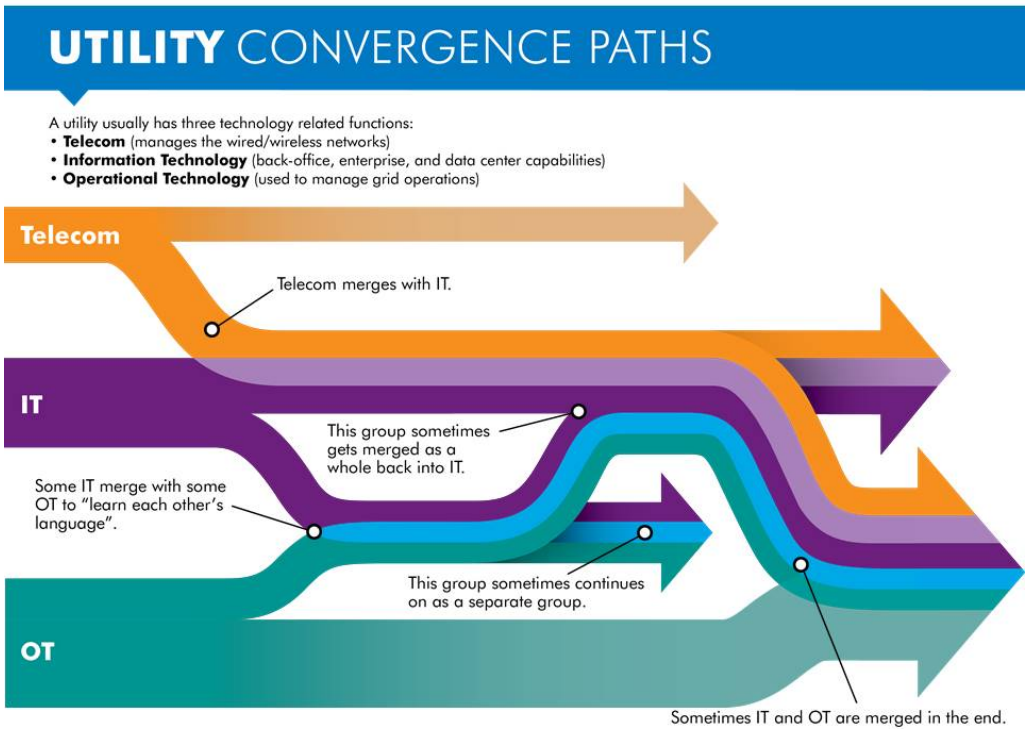

Figure 2-1
Paths for IT-OT Convergence

Minimize IT-OT Silos by Adopting Best Practices in Governance

Vendors of operational technology are increasingly moving away from customized operating systems, data management systems and user experience libraries toward widely available operating systems, development languages, and servers. Traditionally IT's services have focused on an organization's administrative capabilities while OT focused on operational capabilities. As a result, these environments have different security, latency, and reliability requirements. OT systems are typically event-driven and frequently include real-time software applications and devices with embedded software. Governance of OT is quite different from most IT systems, and therefore offers a starting point for building understanding of IT-OT convergence across the silos of differing practice.

EPRI members have advised these best practices:

- Ensure governance changes focus more on information and processes, not chiefly on technology decisions.
- Accept architecture variations between technologies, but create integrated planning.
- Alternate chairmanship of key steering groups among IT, OT, and other stakeholders to build trust and shared outcomes.

- Develop a shared strategy, value and risk management dashboard with agreed-upon KPIs that bridge IT and OT.
- Adapt project lifecycle standards to address both IT and OT
- Frame organizational discussions in terms of accountability and responsibility, rather than in terms of ownership.
- Adopt employee-sharing across IT and OT where needed to implement governance changes.

Build IT-OT Maturity by Improving Software Asset Management

Few organizations have mature infrastructure and processes for managing their complete portfolio of software assets. Software asset management (SAM) is a collection of organizational business practices and processes that manage and optimize the life cycle of software investments while deployed, maintained, and disposed within an organization. Typical SAM processes include:

- Tracking and controlling software usage
- Procuring new software licenses and associated maintenance, including patches and upgrades
- Authorization of requests and software deployment
- Software license re-distribution and compliance enforcement

These processes vary considerably across IT and OT domains. Software licensing terms for OT vendors (for example, applications such as SCADA, EMS and historian software) is still significantly different from those of commercial IT vendors. Utilities operating transmission networks still typically require EMS vendors to move through a factory acceptance test and site acceptance test cycle. Development and test systems are deployed in parallel, supporting a more rigorous patch management process. Early ADMS deployments have so far resembled EMS projects far more than deployments of commercial enterprise software.

Require Integrator Competency Across IT and OT Domains

Over the last five years, utility service providers have recognized the importance of blending traditional IT system integrator delivery approaches with those of control system integrators and OT vendors. Notable events in the industry include Accenture's acquisition of Structure Group and the subsequent formation of the OMNETRIC Group in 2014 as a joint venture of Accenture and Siemens. Also, a number of systems integrators (in particular, India-based organizations with engineering and OT systems understanding as well as systems integration and outsourcing practices) have re-oriented their value propositions to emphasize their ability to deliver across IT and OT domains.

Another driver for cross-domain expertise is the current focus on analytics for distribution networks, in order to drive further return on investment for AMI systems and to manage DER integration at the grid edge (both of these are essentially IoT examples in the electric utility context). Systems integrators have to successfully cleanse, aggregate and transform data (such as time-series and event streams) from OT systems in order to successfully deploy commercial analytics systems. Not all utility-focused system integrators have a deep enough understanding of SCADA systems, historian applications, PMUs and other OT data sources to successfully achieve this integration. Cybersecurity requirements are also driving up the need for cross-domain expertise. Not all integrators are familiar with governmental cybersecurity requirements (e.g. NERC CIP in North America) and how those requirements impact OT software development and systems staging at vendors' locations. Few vendors are able to support a level of automation necessary for a DevOps style of testing, where software patches can be deployed with minimum delay.

Section 3: Insights from IT-OT Research

EPRI has been engaged with IT-OT topics since 2012. Three EPRI publications are summarized below to illustrate how organizations are adapting.

Information Technology (IT)/Operational Technology (OT) Convergence Strategies (December 2015, Publication 3002005249)

This research built on prior survey work from 2012 that confirmed utility CIO attention to IT/OT convergence. The findings from that research original survey indicated CIOS regarded IT/OT convergence was a significant issue. The research noted that CIO responses could be segmented into three approaches:

Reorganize – merging IT and OT support groups into a combined organization, reporting to a CIO or CTO.

Realign – selectively choosing and moving segments of IT or OT support groups with similar skill sets into a combined organization

Re-engage – choosing to not move anyone organizationally, but increasing efforts to raise awareness and improve communication among all stakeholders on IT and OT projects

The 2015 research delved further into these high-level strategies to determine what changes to convergence occurred since the original study; the factors that determined success; whether a correlation between the size of the utility and the level of convergence exists; and whether more clarity could be brought to the definition of OT. Data was gathered via one-on-one structured interviews with utility executives and via a web survey of utility enterprise architects.

Feedback from participants highlighted a low level of trust among IT and OT professionals (see Table 3-1).

Table 3-1
Perspectives Illustrating Mistrust Across the IT/OT Divide

OT Views Toward IT	IT Views Toward OT
IT lacks responsiveness; OT feels IT just doesn't respond quickly enough to support OT development requests.	By not following best practices and established procedures, OT produces fluid requirements, duplicates solutions, and lacks controls, endangering project success and exposing solutions to cyber security risks.
IT lacks understanding of OT priorities and perspectives. IT lacks language to communicate clearly with OT about their business needs.	OT lacks a strategic vision and is driven by near-term tactical forces that result in uncoordinated, rushed solutions that are not in sync with enterprise goals and standards and that can be difficult to support and maintain.
IT is too rigid or bureaucratic to be able to accommodate OT's needs	OT fails to understand the value of IT's processes and procedures, perceiving them only as obstacles and needless hurdles.
IT lacks understanding of structural limits such as bargaining unit control over job definitions, limiting IT's reach.	OT cost estimates and schedules are sometimes incomplete, not reflecting required processes and full lifecycle costs.
IT may not fully understand requirements related to safety and reliability in the operations domain.	OT sometimes does not possess the skills required to produce enterprise-quality solutions. Development tools are made widely available to untrained staff, inviting the development of "satellite" applications by a "shadow" IT staff.

Research highlighted the following recommendations:

- Communicate a Clear Vision - identify the key challenge that is being solved, e.g. cyber-security, and provide incentives for collaboration toward that goal.
- Define Roles and Responsibilities - find leaders that can speak the language of both IT and OT.
- Leverage Cross-training Opportunities - train IT people (particularly, business relationship managers) on operations; train OT people on IT disciplines.
- Emphasize Governance – create well-defined gating processes for both IT and OT projects and align resources, skills, and investments.

- Start Small and Go Slow – create cross-skilled teams to solve a specific problem and then take incremental steps to build on that success and develop trust.
- Create Organizational Alignment – require executive leadership from the board of directors on down through the organization.

Application Portfolio Management for Aligning Information Technology and Operational Technology (November 2016, Publication 3002007877)

This research introduced Application Portfolio Management and explored the differences of viewpoints about this topic across IT organizations and the OT support groups within business units. The research noted the level of effort necessary to build a transparent, objective system that equally engages IT and OT counterparts.

APM is the process of "evaluating new and existing applications collectively on an ongoing basis to determine which applications provide value to the business in order to support decisions to replace, retire, or further invest in applications across the enterprise." APM is one element of enterprise IT governance, most directly connected with its neighboring elements, Investment Portfolio Management and Project Portfolio Management.

The APM process includes the following steps.

1. Data Collection – creating an initial inventory of applications that make up the portfolio.
2. Analysis – developing insights needed to inform subsequent decisions regarding possible changes in the application inventory.
3. Decision-making – creating an action plan for portfolio members: buy, hold, or dispose/replace.
4. Optimization – creating and executing projects to implement the action plan.

The research recommended including inputs from across IT and OT (illustrated in Figure 3-1).

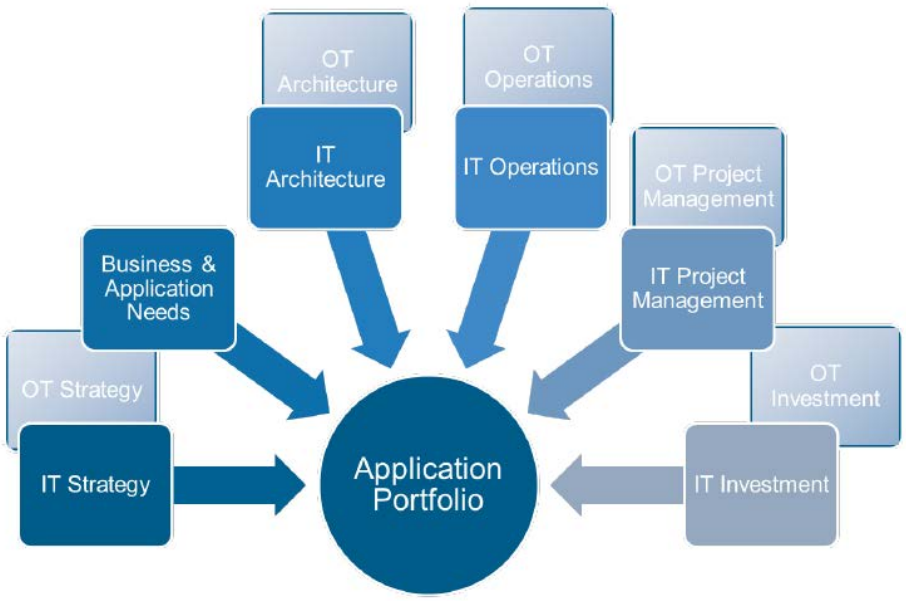

Figure 3-1
Enterprise Activities Related to Application Portfolio Management

The research further recommended developing a Portfolio Analysis Chart that objectively balances application portfolio needs across IT and OT, and then analyzing sourcing options according to their strategic importance and operational cost (see Figure 3-2).

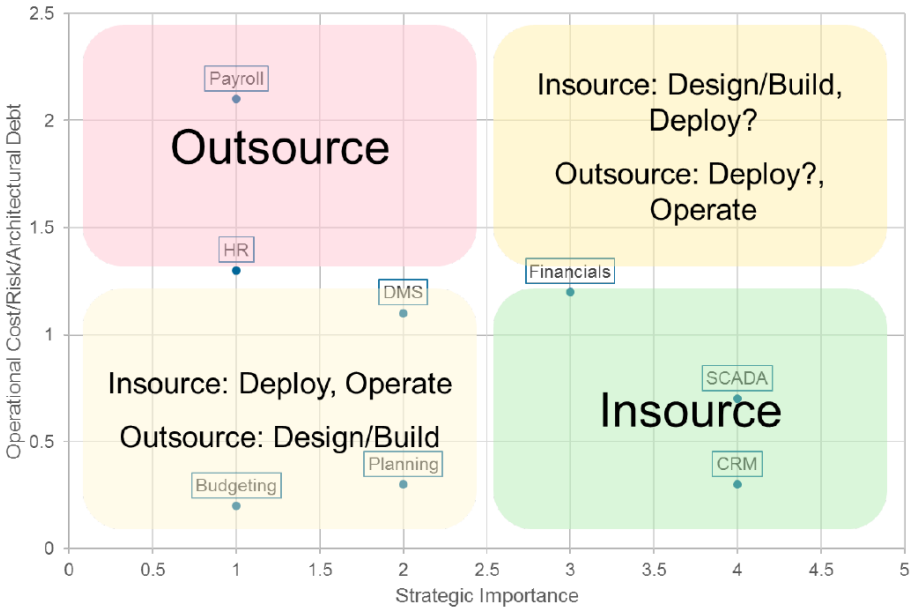

Figure 3-2
Possible Lifecycle Sourcing Actions Suggested by the Portfolio Analysis Chart

A Strategic/Economic View of IT/OT Convergence 3002009979)

This research proposed a strategic framework for considering whether IT and OT organizational units should be combined into one organizational unit (based on the premise that the IT and OT disciplines themselves have merged). The benefit of the strategic framework is to first examine and compare fully developed future states using rough economics to compare the end states, without getting into unnecessary details of the transition process.

The two alternative future states considered are those where a) IT and OT are still organizationally separated, and b) IT and OT converge into a single organization that serves all of the purposes that the separate organizations would perform.

The strategic planning process considered the characteristics of these converged and the unconverged scenarios; how the organization(s) would behave in the performance of their various duties; and how they would address problems such as cyber security in the future. Converged and unconverged scenarios were considered in terms of their shared characteristics (staff, network operating centers, licenses, software, infrastructure, security) and net differences (Monitoring and controlling IT environments and communications networks, patch and release management, break/fix, etc.). The research then laid out some example transitional issues that would need to be considered when upper management have settled a shared strategic vision of their future state.

Section 4: Recommended Future Research

Possible avenues for future research related to IT/OT include:

- How to build a maturity model that reflects the stages of typical IT/OT integration journeys for electric utilities.
- How to evaluate the impacts of enterprise architecture decisions and enterprise standards adoption on IT/OT integration maturity.
- Further investigation into best practices for tackling and resolving IT/OT issues at a project level (for example, implementation of asset performance monitoring, substation automation, phasor measurement units, ADMS, DERMS, etc.).
- How to manage changing application development patterns across IT/OT as a result of maturing tools in DevOps, IoT, and open source.
- How IT/OT integration challenges are impacted by emerging technologies such as blockchain, drones, augmented reality, virtual reality, etc.

Strategies for moving beyond an IT/OT way of thinking toward a fully digital approach to delivering customer value, with an integrated grid.

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