

Standardization and Modularity in Network-Critical Physical Infrastructure

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White Paper #116

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Executive Summary

Failure to adopt modular standardization as a design strategy for Network-Critical Physical Infrastructure (NCPI) is costly on all fronts: unnecessary expense, avoidable downtime, and lost business opportunity. Standardization and its close relative, modularity, create wide-ranging benefits in NCPI that streamline and simplify every process from initial planning to daily operation, with significant positive effects on all three major components of NCPI business value – availability, agility, and total cost of ownership.

Introduction

Standardization so pervades modern life that we hardly notice it. From driving a car to replacing a battery, its influence is at work behind the scenes to make things more convenient, predictable, affordable, understandable, and safe. When we buy a light bulb, we know it will fit in the lamp socket. Our train travel is not interrupted at the border, as it once was, while our railcar is raised up and refitted with different wheels to match the track in the next state. Standardization is a powerful concept that has established itself as a critical ally in managing progress.

Despite standardization's long track record of success in streamlining business, Network-Critical Physical Infrastructure (NCPI) has missed the turn. A steady trend toward chaos has been at work in this industry but, unlike other industries, there has been no catalyst strong enough to initiate a reversal – nothing as publicly absurd as the switching of train wheels, nor as shocking as the 1904 Baltimore fire in which the city burned down because mutual aid from other cities couldn't connect to Baltimore's hydrants.

Systems analysts from any other mature industry would be aghast at the level of complexity and inconsistency that exists today in the NCPI of thousands of data centers worldwide. Lacking impetus from public scrutiny or broad industry interest in change, it is left for the industry's *users* to self examine – to call up their own experience and business sense to help instigate the turn toward the more stable and productive climate of standardization. The mission of this paper is to show that there *is* a catalyst: the NCPI user's substantial entitlement to eliminate the significant business cost of unnecessary downtime, lost opportunity, and expense caused by human error, lack of agility, and data center oversizing. Mistakes and waste are early and welcome casualties of standardization.

In recent decades, the old idea of standardization has gained new stature in other industries as a creative and compelling strategic enterprise philosophy. Similar success can be achieved by applying standardization to the design, deployment, and operation of Network-Critical Physical Infrastructure (NCPI).¹

¹ **Standardization vs. "standards"** The focus of this paper is the use of standardization in the design and delivery of a product or process, toward the goal of delivering new or increased benefits to users. "Standards" – meaning industry-wide specifications and codes established by bodies such as ISO and IEEE – are another kind of standardization, profoundly significant to industry and commerce but not the subject of this paper.

NCPI

Network-Critical Physical Infrastructure

NCPI is the foundation upon which IT and telecommunication networks reside.

NCPI includes:

- Power
- Cooling
- Racks and physical structure
- Cabling
- Physical security and fire protection
- Management systems
- Services

For more about NCPI see APC White Paper #117, "Network-Critical Physical Infrastructure: Optimizing Business Value."

Beyond classic upgrades such as mass production and compatible connections, opportunities for standardization populate nearly every aspect of NCPI product and process. The starting point is the design of NCPI equipment itself; this alone provides widespread and significant benefits, as described in this paper. From that foundation, users can carry the idea forward to its broader potential by applying standardization to the *processes* of their data center, and – for IT operations involving more than one data center – by using the same NCPI configuration and processes throughout all data centers. The payoff for users is a broad array of immediate and long-term benefits that reach from daily operation to the bottom line.

Roadmap for this paper

Standardization’s historical record of economic success speaks for itself and needs no further analysis here. The use of standardization in NCPI, however, requires careful attention because its critical value to the IT landscape is not yet widely understood. Here is how the major sections of this paper will present standardization as a new business strategy for NCPI:

Standardization vs. Uniqueness

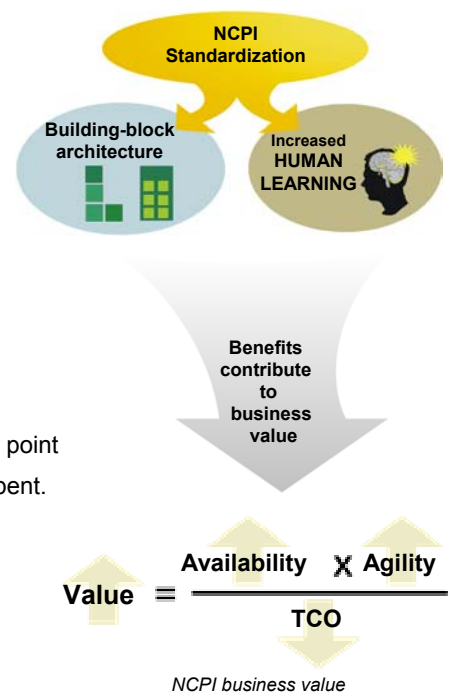
Both of these have their proper place in business and in life, but infrastructure of any kind is a clear candidate for standardization, *not* uniqueness. The contrary trend in NCPI has been toward one-time unique engineering, which has led to systems that are difficult to design, deploy, maintain, and manage.

Fundamental Characteristics of Standardized NCPI

Standardizing NCPI introduces two simple but powerful fundamental characteristics, **modular building-block architecture** and **increased human learning**. Their intrinsic value is intuitive – most adults can remember the limitless ways of configuring children’s blocks, and no one questions the benefits of learning. Their combined influence on NCPI is profound. From these two fundamental characteristics come an array of benefits that spread throughout the infrastructure and touch nearly every aspect of it.

How Standardization Drives NCPI Business Value

The clincher for modular standardization is its multi-faceted, point by point contribution to NCPI “business value” – benefit received per dollar spent. The benefits that flow from modular architecture and increased human learning contribute in multiple ways to every one of the three major components of NCPI business value: availability, agility, and total cost of ownership (TCO). (For more about this NCPI business value equation and why it is an appropriate metric, see APC White Paper #117, “Network-Critical Physical Infrastructure: Optimizing Business Value.”)



Standardization vs. Uniqueness

Standardization and uniqueness are familiar opposites. It is not difficult to recognize the crucial, but very distinct, roles played by the two; everyday experience is filled with examples of how each has its proper place in the effective delivery of a product or process.

Uniqueness is not for infrastructure

Uniqueness can be a wonderful thing. A striking building, Mom's peach pie, a piano sonata, art of every kind – no one would argue that standardization has any place in experiences valued for their sensory qualities or other interesting characteristics. Certain things are intended to be unique, and they are the better for it.

Infrastructure is different. Infrastructure consists of system underpinnings that support and deliver the part of the system we are actually interested in. In each of the above examples there are elements that can be considered "infrastructure": the building's construction materials, Mom's measuring spoons, the piano keys, the canvas that holds the paint. The job of infrastructure is to be functional and reliable – it is just supposed to *work*.

The time-tested characteristic that makes infrastructure effective, reliable, predictable, and worry-free is the opposite of uniqueness; it is **standardization**. Because of standardization, the infrastructure of our day-to-day pursuits has become part of the woodwork of modern life – so commonplace and commonsense that we rarely think about it. One would expect data center infrastructure to follow the same paradigm, but until now there has been little movement in that direction. Nearly 40 years after its birth, IT physical infrastructure is still, in many ways, a craft industry: disparate components from different vendors are typically custom engineered into one large infrastructure system that is unique to the facility.

Unique NCPI means unique problems

One-time engineering of an entire NCPI results in a unique system, with unique problems that require unique diagnosis and repair – a process that is not only expensive and time-consuming, but also provides little learning that can be applied to further unique problems in the future, or to problems at other data centers in the organization. Standardization eliminates the need for one-time engineering and eliminates the overhead of dealing with unique problems in the infrastructure, freeing up resources for developing the data processing functionality of the IT layer *supported* by the infrastructure, which is the real mission of the data center.

The goal of NCPI standardization is to drive out the inefficiencies and error-prone complexity of one-time unique engineering – to transparently manage the routine business of IT physical infrastructure and create that same signature quality expected of any infrastructure: *it just works*.

Configurable solutions using standardized building blocks

Customization of connections and components simply to get things to work (the Rube Goldberg effect) adds no real value; it merely introduces complexity and increases opportunities for human error. However, the ability to configure – *and reconfigure* – NCPI size or functionality to fit rapidly changing business needs is critical to the effectiveness and value of NCPI.

How can standardization be used to advantage when a critical IT requirement is flexibility? As this paper will show, the key to harnessing the power of standardization in a changeable environment is *modularity* – pre-engineered, standardized building blocks that can be configured as the user wishes (**Figure 1**). The ability to quickly assemble standardized components into a logical and understandable configuration to respond to changing functional and financial requirements is one of the primary benefits of NCPI standardization – it is called *agility*.

Figure 1 – *Unique engineering vs. standardized modular building blocks*



Unique one-time engineering
Good for art, bad for infrastructure



Standardized modular components
*Changeable, scalable, repeatable,
understandable, integrated*

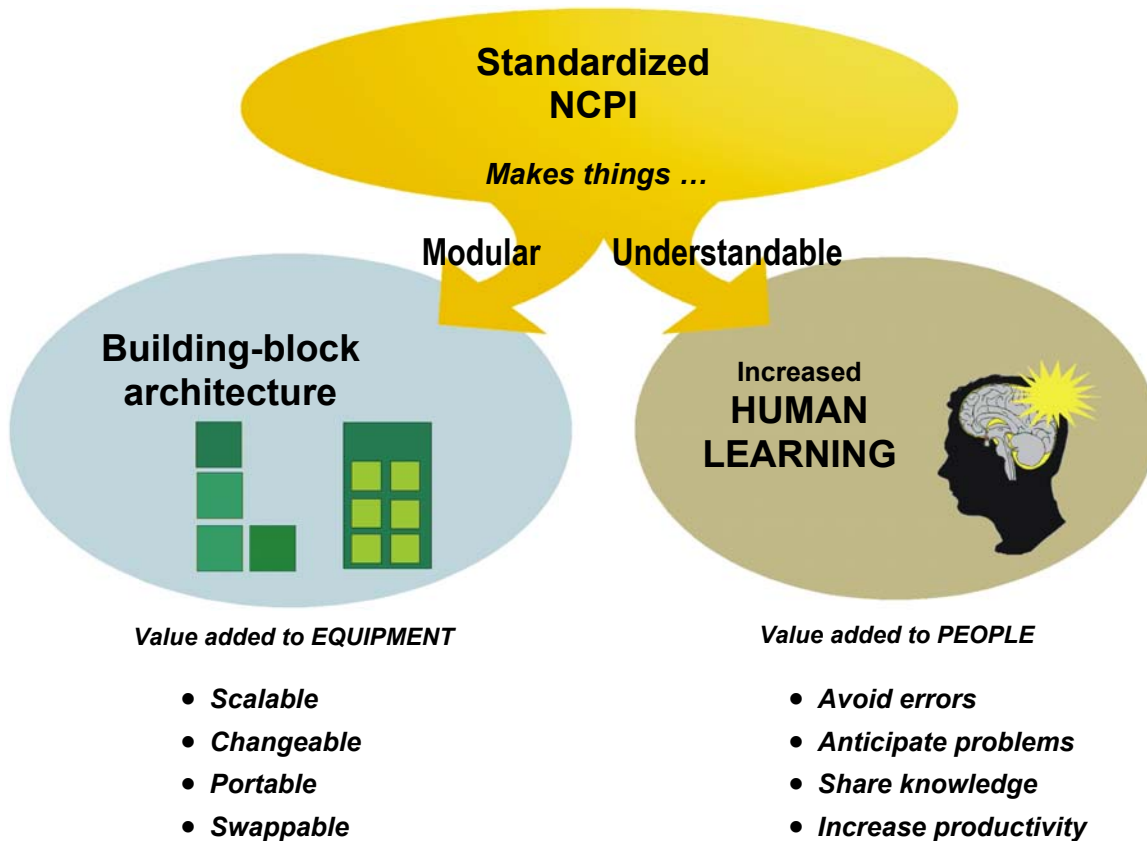
One step further: Standardized data centers

NCPI designed this way – configured from standardized modular elements – provides significant benefits in the deployment and operation of a data center, as described throughout this paper. For broader IT operations that span multiple data centers, the benefits of standardization can be extended even further by deploying the same, or similar, NCPI at all installations – incorporating standardization not only *within* a data center but also *across* data centers. Data centers that are the same in as many respects as possible – from the same floor plan to the same labels on circuit breakers – take full advantage of standardization's enormous potential for efficiencies in design, installation, operation, maintenance, error avoidance, and cost. Most of the benefits described in this paper are magnified significantly when standardized NCPI is deployed in multiple data centers.

Fundamental Characteristics of Standardized NCPI

The benefits of standardization in NCPI affect every dimension: the way it occupies physical space, its functionality, and its evolution over time – from initial design and installation to reconfiguration at each refresh cycle. These benefits take a variety of forms and occur in many places throughout NCPI structure and process, but nearly all can be traced, in one way or another, to two powerful fundamental attributes of standardized NCPI: **modular building-block architecture** and **increased human learning** (Figure 2). These characteristics create benefits that propagate throughout the infrastructure, combining in a cumulative positive effect on nearly every aspect of NCPI.

Figure 2 – Modular architecture and increased human learning are two fundamental characteristics of standardized NCPI



Modularity: Divide and standardize

The cornerstone of standardization in NCPI is **modularity**. Modularity is achieved by dividing up a complete product or process into smaller chunks – modules – of similar size or functionality that can be assembled as needed to create variations of the original product/process. Flashlight batteries are a familiar example: batteries (modules) are combined in different numbers to obtain varying amounts of power. Blade servers and RAID arrays are examples of modularity in IT equipment – multiple units combined to create varying amounts of server or storage capacity. Modules needn't be identical: Lego™ bricks are modular, but they are in some ways the same and in some ways different – color, size, and shape are different, but sizes and connections are standardized so that the bricks (modules) can work together as an integrated system. Different modular systems incorporate different amounts of sameness and difference – that is, varying levels of standardization – into their modules, depending upon the desired goal in dividing up functionality.

Flashlight batteries, blade servers, and RAID arrays are examples of very basic modularity, with little or no variation in the units that make up a complete system. A more complex system with multiple functions to be integrated – such as NCPI – requires careful engineering by the manufacturer in order to modularize in ways that optimize the balance between level of standardization and amount of flexibility to users. NCPI provides opportunities for effective modular design at a variety of levels. Some examples:

- *Interchangeable UPS power and battery modules.* Enables scalability of power, redundancy, and runtime and can be hot-swapped for repair without system shutdown.
- *Standardized modular wiring distribution.* Breaks down room wiring into row-level or rack-level modules. Eliminates confusing and mistake-prone wiring tangles, and simplifies and speeds the process of unplug-rearrange-reconnect. Modular power distribution can range from rack-sized units that serve an entire row to power strips that serve a single rack.

Modularity and “Component Count”

Modularity is a powerful new concept in this industry. Unless classic reliability analysis is updated to include it, modularity's substantial advantage to users risks misunderstanding and potentially expensive delays in acceptance.

Modularizing a system can, in some cases, increase the number of internal components – for example, large UPS capacity modularized into a bank of smaller power modules will increase the number of certain electrical components and connectors. To be valid, reliability analysis of modular systems must consider component design, function, and dependencies, and not just rely on simple multiplication of parts. Further, reliability analysis based on component count alone is incomplete – even potentially misleading – because it leaves out the new and overriding reliability advantages of modular structure, most importantly:

- Swappable modules can be removed for **factory service**, enabling continuous quality improvement in which defects are diagnosed at the factory and engineered out as they are discovered (this process is called “reliability growth” in systems analysis).
- Modules are manufactured in much greater quantity than a larger non-modular system, increasing even further the quality improvements already inherent in **mass production**.
- The generally smaller size of modules (compared to non-modular design) tends to mean less manual work during manufacture.
- Modular design allows for the considerable reliability advantage of **fault tolerance** – redundant modules operating in parallel, allowing for individual module failure without affecting overall system performance.

- *Rack-level air distribution.* Breaks down room airflow into local control at the racks for precise cooling of hot spots.
- *High-density clusters.* Integration of racks, power distribution, and cooling into a self-contained, enclosed “room” to isolate and cool heat-intensive IT equipment. (In this case, a “module” is the whole integrated cluster.)

Modular components with standardized structure and connections make everything easier, faster, and cheaper – from manufacture and inventory at the vendor, through design and engineering at the planning table, to installation and operation at the customer site. Modular design is the source of one critically important component of NCPI business value (**agility**, the ability to respond to changing or unexpected business opportunities) and a major contributor to the other two (**availability** and **total cost of ownership**).

- Modular systems are **scalable**. Modular NCPI can be deployed at a level that meets current IT needs, with the ability to add more later. This ability to “rightsize” can provide a significant reduction in total cost of ownership.
- Modular systems are **changeable**. Modular design provides great flexibility in reconfiguring NCPI to meet changing IT requirements.
- Modular systems are **portable**. Self-contained components, standard interfaces, and understandable structure save time and money when modular systems are installed, upgraded, reconfigured, or moved.
- Modular components are **swappable**. Modules that fail can be easily swapped out for upgrades or repair – often without system shutdown.

The portable and swappable nature of modular components allows work to be done at the factory, both before delivery (such as pre-wiring of power distribution units) or after (such as the repair of power modules). In-factory work has, statistically, a far lower rate of defects than work done on site – for example, factory-repaired UPS power modules are 500-2000 times less likely to cause outages, introduce new defects, or inhibit return to fully operational status compared to field-repaired modules. The ability to perform factory repair is a significant reliability advantage.²

For larger IT operations that occupy multiple facilities, modular architecture facilitates keeping as much as possible the same between installations (see earlier paragraph, **One step further: Standardized data centers.**) Selected elements of a master NCPI design can be modified, added, or eliminated to accommodate differences in size or function between data centers without affecting other parts of the design, thereby maximizing the extent of infrastructure the data centers have in common.

² Based on reliability studies by MTechnology, Inc.

Human learning: The power of understanding

Modularity enhances the effectiveness of *equipment*. **Understandability** enhances the effectiveness of *people*. Standardization is, by its nature, a simplifying process; a standardized system facilitates learning at every level. Increased knowledge and understanding enables people to work more efficiently and with fewer mistakes, helps them to teach others, and empowers them to participate in problem-solving. In a standardized environment, things are not only more understandable but also more *predictable* and *repeatable*, making problems less likely to occur and easier to recognize when they do.

When things are easier to understand and more predictable, they are easier to explain, to document, to operate, to troubleshoot, and to fix. As these effects build upon each other, they enable staff to:

- **Avoid errors.** The most significant human-learning effect of standardization is reduced human error in the data center. Studies have shown that human error is the cause of 50-60% of data center downtime,³ and the potential to reduce it represents the single largest user entitlement to increased availability. Reducing human error is a classic benefit of standardization – from fewer errors in a standardized assembly process to fewer errors in diagnosing trouble in a standardized system. Standardized systems make documentation and training easier and more effective, resulting in more skilled staff who are less likely to make mistakes. Standardized controls, interfaces, and connections provide additional protection by making correct operation more self-evident. If documentation itself is standardized, error-avoidance is further enhanced by having information easily accessible in expected places and formats.
- **Anticipate problems.** Understanding how things work, combined with standardized procedures for such things as equipment monitoring and predictive maintenance, is a powerful defense against what might otherwise be considered “unexpected.”
- **Share knowledge.** Having structure and function “make sense” fosters ongoing learning by encouraging sharing of information – when people understand things, they are more likely to engage in conversation, collaborate on analysis and problem-solving, and learn from each other. This enhanced climate of knowledge and insight permeates everything that needs to be done with, or understood about, NCPI.
- **Increase productivity.** As these learning effects interact and proliferate, there is an overall increase in productivity. A more knowledgeable staff means that time spent on NCPI-related matters is used more efficiently. With equipment and procedures easier to understand, less time is spent training and being trained. With reduced human error, less time is spent recovering from human-caused problems and less help desk time is spent responding to calls related to such problems. All these economies of time free up human resources for the functional business of the data center – the work of the IT equipment that is powered, cooled, and protected by NCPI – rather than for management of the NCPI layer itself.

³ Based on studies by The Uptime Institute, 7x24 Exchange, and confidential analysis by major financial firms using large-scale data centers.

Mass Production and Interchangeable Parts: Looking Back

The standardization of components enables dramatic economies in the production, delivery, and servicing of goods. The most well-known of these is the ability to mass produce a product. Although the idea has been around since the 1100's, when the Venice Arsenal in Italy produced nearly a ship a day using assembly lines and mass produced parts, it was reintroduced in the Industrial Age by Henry Ford's famous moving assembly lines and task-oriented workers.

While Henry Ford's assembly lines demonstrated the dazzling improvements in production capacity, cost reduction, quality, and delivery speed that can be obtained by mass producing a complex product, the previous century had already seen the use of mass production for another important purpose: not just benefits in the assembly of a *product*, but also in the production of *interchangeable parts* – in particular, firearms parts. Eli Whitney amazed Washington officials in 1801 by demonstrating that he could make ten gunlocks by selecting randomly from ten piles of gunlock parts he had brought from his new musket factory. Standardized, interchangeable parts enabled battlefield repair of rifles and introduced a critical new capacity: *field service*.^{*} Craftsman in workshops making custom-fit parts for the creation and repair of one item at a time were rapidly overtaken by mass production in factories and on-site parts replacement. Quality went up, cost went down, delivery time was slashed, and service was streamlined.

Benefits of Mass Production

- Lower cost
- Higher quality
- Easier servicing
- More product capabilities
- Faster delivery

Standardization of parts and processes is what enables mass production

^{*}The NCPI equivalent of field service using interchangeable parts is *swappable modules*.

One type of human error that is reduced before the user even sees the product is human-caused manufacturing defects. Standardized modular design maximizes the opportunity to mass produce, which drives out human error in the manufacturing process by the repeatable nature of standardized assembly and by the increased ability to recognize and eliminate defects in such a process.

How Standardization Drives NCPI Business Value

As shown in the previous section, modular structure and increased human learning – two fundamental and empowering characteristics of standardized NCPI – provide a wide range of direct and commonsense benefits. This section will look at standardization more closely, and from a different viewpoint – a bottom-line viewpoint – to demonstrate, point by point, the value of standardization to the enterprise. Modularity and increased human learning spawn benefits in three critical areas of performance which, taken together, constitute the *business value* of NCPI.

The NCPI business value “equation”

What gives Network-Critical Physical Infrastructure high business value? Since its primary function is to keep the IT operation up and running, **availability** is the first component of NCPI business value. The ability to respond quickly to changing IT needs is also critical to success, making **agility** another important component. The total cost of buying *and operating* NCPI over its lifetime – total cost of ownership, or **TCO** – is the third major component of business value (**Figure 3**). (For more about NCPI business value, see APC White Paper #117, “Network-Critical Physical Infrastructure: Optimizing Business Value.”)

Figure 3 – The NCPI business value equation

$$\text{Value} = \frac{\text{Availability} \times \text{Agility}}{\text{TCO}}$$

Things that *increase* availability or agility and things that *decrease* total cost of ownership are drivers of NCPI business value. In a remarkable network of causes and effects, standardization creates benefits that simultaneously drive all three of these “performance vectors.”

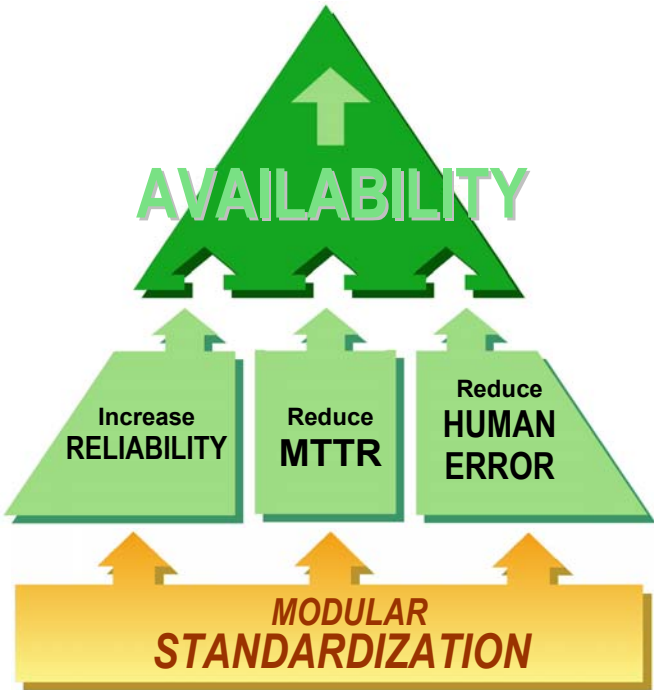
How standardization increases AVAILABILITY

The major factors affecting availability (Figure 4) are

- **Reliability of equipment** – Increased equipment reliability means reduced risk of downtime.
- **Mean time to recover (MTTR)** – Faster recovery after failure means less downtime.
- **Human error** – Less human error means less downtime.

$$\text{Value} = \frac{\text{Availability} \times \text{Agility}}{\text{TCO}}$$

Figure 4 – Standardization improves all major AVAILABILITY factors





Reliability of equipment. Standardized modular components can be mass produced in greater volume than non-modularized systems, which reduces production defects. Modular components can be returned to the manufacturer for factory service, which greatly improves the quality of repairs. (For more about these two advantages, see earlier section, **Fundamental Characteristics of Standardized NCPI.**) In addition, modular systems with standardized hookups can be configured at the factory the same way they will be configured on site, allowing for factory pre-testing to discover defects. Standardized modular components facilitate internal redundancy (no downtime at the time of component failure) and hot-swap replacement (no downtime during swap-out of a failed component). Standardized equipment monitoring systems enable easy-to-understand management tools that encourage *predictive* maintenance to identify problems before they escalate from trouble to major expense, and to reduce reliance on scheduled *preventative* maintenance, which creates additional exposure to human error.



Mean time to recover (MTTR). A failed modular component can be quickly swapped-out for replacement, so recovery isn't delayed while waiting for repair. Standardization makes things easier to understand and operate, making diagnosis of problems faster and increasing the potential for diagnosis and correction by the user.



Human error. Of all the ways to increase availability, reducing human error offers by far the greatest opportunity. With standardized equipment and procedures, functionality is more transparent, routines are simplified and easier to learn, and things operate as expected – all reducing the likelihood of everything from typing the wrong command to pulling the wrong plug.

A New/Old Idea

In recent years the centuries-old idea of standardization has become the focus of innovative business strategies to streamline the design, manufacture, and delivery of products and services. Southwest Airlines has become, quite literally, a textbook example of corporate-wide standardization. By standardizing their product (open seating, equal prices), operations (one IT platform for everything) and equipment (only one kind of plane) they have become one of the best on-time performing, lowest cost, highest quality – not to mention friendliest – airlines in the industry. Toyota Motor Company, also the frequent subject of business analysis, stays consistently in the top ranks of automobile quality by an aggressive commitment to “lean manufacturing,” which reduces defects as well as costs by simplifying, then standardizing, every step of the manufacturing process.

Techniques may differ by industry, but the underlying principle is the same: standardization, strategically applied, creates efficiencies in a multitude of ways that contribute to business value.

How standardization increases AGILITY

Agility is the ability to respond quickly and effectively to business opportunity, necessity, or change (referred to as “on demand” in IT marketing). An agile NCPI targets three critical goals:

- **Speed of deployment.** Speed in the design and installation of a new facility, the move to a new location, or the implementation of a reconfiguration.

$$\text{Value} = \frac{\text{Availability} \times \text{Agility}}{\text{TCO}}$$

- **Ability to scale.** The ability to deploy at a level that supports present IT requirements, and increase capacity later by adding on as IT needs grow.
- **Ability to reconfigure.** The ability to reconfigure and reuse existing equipment without upheaval or waste.

Standardization in the form of standardized modular building blocks – modularity – has a major impact on agility, with significant benefits to all three major contributing factors (**Figure 5**).

Figure 5 – Standardization improves all major **AGILITY** factors



Speed of deployment. With modular components, planning and design is faster because the system’s structure can be configured in a logical way that aligns with design objectives, both in the physical arrangement of units and by using only the number and type of units needed to meet the current IT requirements. Deployment does not have to wait while management tries to justify the expense of an oversized data center design that attempts to predict the future ten years out. Special NCPI requirements don’t adversely affect planning time because flexibility of design is built into modular architecture. Delivery is faster because standardized, mass-produced units can be inventoried and ordered “off the shelf.” On-site configuration and hookup is faster not only because connections are standardized and simplified, but also because there is less equipment to install when using only the number of building blocks needed. Commissioning is faster because standardized modules can be connected up at the factory just as they will be on site, allowing for factory pre-test. Compared to traditional “legacy” all-in-one-piece infrastructure with

static custom design and one-time engineering, these efficiencies combine to cut concept-to-commissioning time from months to weeks, and reconfiguration time from weeks to days.

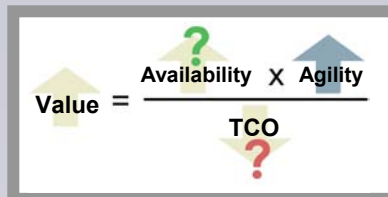
In addition, the time taken at all stages of deployment is further shortened by the next attribute – the ability to scale the design to meet only current IT requirements, thereby deploying a smaller infrastructure with less equipment than in typical legacy systems.

Ability to scale. With modular building-block architecture, functionality is available in bite-sized pieces that can be optimally configured for IT spaces of any size, from wiring closets to large data centers. Of even greater significance is the ability to design the infrastructure to support only the IT requirements needed at startup. Then, as IT requirements increase, more building blocks can be added without re-engineering the whole system and without the need for shutdown of critical equipment. This strategy of “rightsizing” can result in significant cost savings over the life of the data center. (See APC White Paper #37, “Avoiding Costs From Oversizing Data Center and Network Room Infrastructure.”)

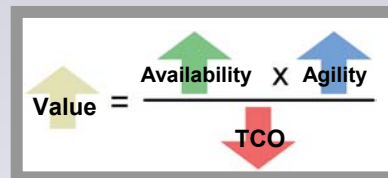
Ability to reconfigure. With typical IT refresh cycles of two years, the ability to reconfigure, upgrade, or move is a significant component of NCPI agility. Modular elements can be unplugged, rearranged, and reconnected. Beyond reconfiguration driven by business need, there is also the steady increase in power density of IT equipment resulting from shrinking physical size – blade servers – which will periodically require reconfiguration of racks, power, and cooling. Modular hot-swappable components also provide the ability to reconfigure for different levels of redundancy, different voltages, or different plug types. Not only does modular structure simplify the physical process of disconnecting, moving, and reconnecting, but the manufacturer’s careful design of the equipment’s modularity can minimize the need for redesign and maximize the ability to reuse equipment in a new configuration.

Is There a Tradeoff?

Q: Modular architecture improves **agility**, but does it compromise **availability** or **TCO** ?



A: No, **availability** and **TCO** are not compromised by modular architecture – in fact, they are *improved* by it. The remarkable thing about modular standardization is that it simultaneously benefits all three components of NCPI business value.



Availability is improved – Swappable modules reduce MTTR, understandable structure increases manageability and reduces human error. Hot-swappable modules can be replaced without downtime. Modules can be configured to run in parallel to take advantage of **fault tolerant** reliability strategies. Modules can be returned to the manufacturer for **factory service**, which (1) is much more reliable than on-site service, and (2) enables factory engineers to identify defects and design them out (“reliability growth”). Modules can be mass produced in greater quantities, which reduces defects.

TCO is improved – Actual equipment cost of standardized modular equipment is comparable to traditional equipment, and other costs are significantly lower: Non-equipment capital costs (planning, design, installation) are reduced by modular structure, total equipment cost is reduced because initial overbuilding is avoided, and operating cost over data center lifetime is reduced by rightsizing that matches IT needs.

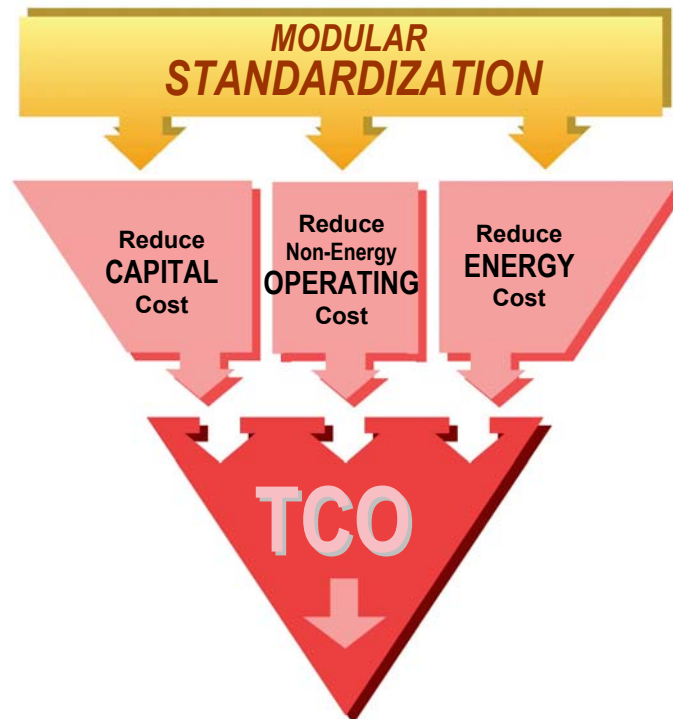
How standardization reduces total cost of ownership (TCO)

The third component of NCPI business value is total cost of ownership (TCO) over the lifetime of the data center. The major components of TCO (Figure 6) are

$$\text{Value} = \frac{\text{Availability} \times \text{Agility}}{\text{TCO}}$$

- **Capital cost.** The cost of everything from planning and design up until the moment the system is turned on and begins doing its job. (Surprisingly, capital cost has historically often been the only cost considered when considering NCPI business value.)
- **Non-energy operating cost.** Operating cost, other than the cost of energy – operating staff, training, maintenance, and repair.
- **Energy cost.** The electric utility bill.

Figure 6 – Standardization improves all major TCO factors



↓ **Capital cost.** Standardized modular architecture reduces capital cost in two major ways: (1) It enables the infrastructure size to be scaled to align more closely with present IT requirements, rather than building out initial capacity to support the maximum projected requirements – you only buy what you need – and (2) its straightforward and understandable structure simplifies every step of the deployment process, from planning to installation. That simplification means less time spent in each stage, and often means a reduced need to bring in outside help. For example, standardized modular power distribution at the rack level provides cost savings from both scalability and simplicity: power and cabling can be deployed for only the racks installed, reducing the need for electrical contract work to wire the room. Similarly, standardized modular rack units

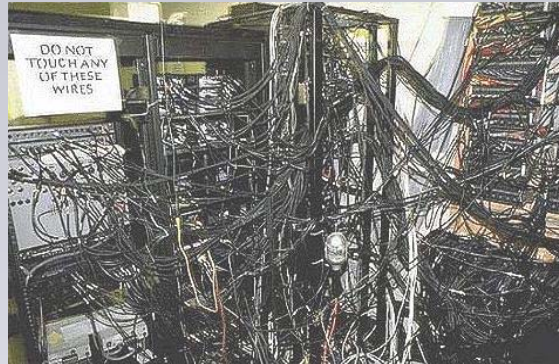
with integrated cabling and airflow provide infrastructure scalability and simplified design and installation that minimizes the need for design consulting and custom installation services. (For more about the substantial cost savings that can be obtained from properly scaling infrastructure size – “rightsizing” – see APC White Paper #37, “Avoiding Costs From Oversizing Data Center and Network Room Infrastructure.”)

Non-energy Operating cost. Simplified, easy-to-learn design means training is faster and more effective, and operation/maintenance procedures are more efficient and less prone to mistakes. Standardized, understandable equipment and procedures mean more maintenance can be done by IT staff, reducing the need for vendor-supplied maintenance. Standardized equipment monitoring systems enable easy-to-understand management tools that encourage predictive maintenance to identify problems before they escalate from trouble to major expense. Standardized modular components enable swapping out of modules for factory service, which is more reliable and less expensive than on-site repair. Fewer help-desk resources are needed to support downtime-related issues, because of the overall improvement in availability (see earlier section [How Standardization Increases AVAILABILITY](#)).

Energy cost. Electricity cost over the lifetime of the data center is the single largest component of TCO. Scaling the infrastructure to meet present IT needs, with the ability to add on incrementally as IT needs grow, means you only power and cool what you need. The resulting savings in electricity are substantial over the life of the data center. Modular internal UPS design enables UPS sizing more closely matched to load requirement, resulting in better UPS operating efficiency and reducing the size of the UPS modules needed to achieve redundancy. Modular cooling design, such as rack-level air distribution units, enables more accurate airflow for increased cooling efficiency, so less energy is consumed by cooling equipment.

For more about TCO, see APC White Paper #6, “Determining Total Cost of Ownership for Data Center and Network Room Infrastructure.”

How Did Things Get This Way?



The NCPI industry is behind in its evolution toward standardization in large part because its component elements (UPS, power distribution, controls, cooling) are technologically dissimilar and traditionally manufactured by different vendors.

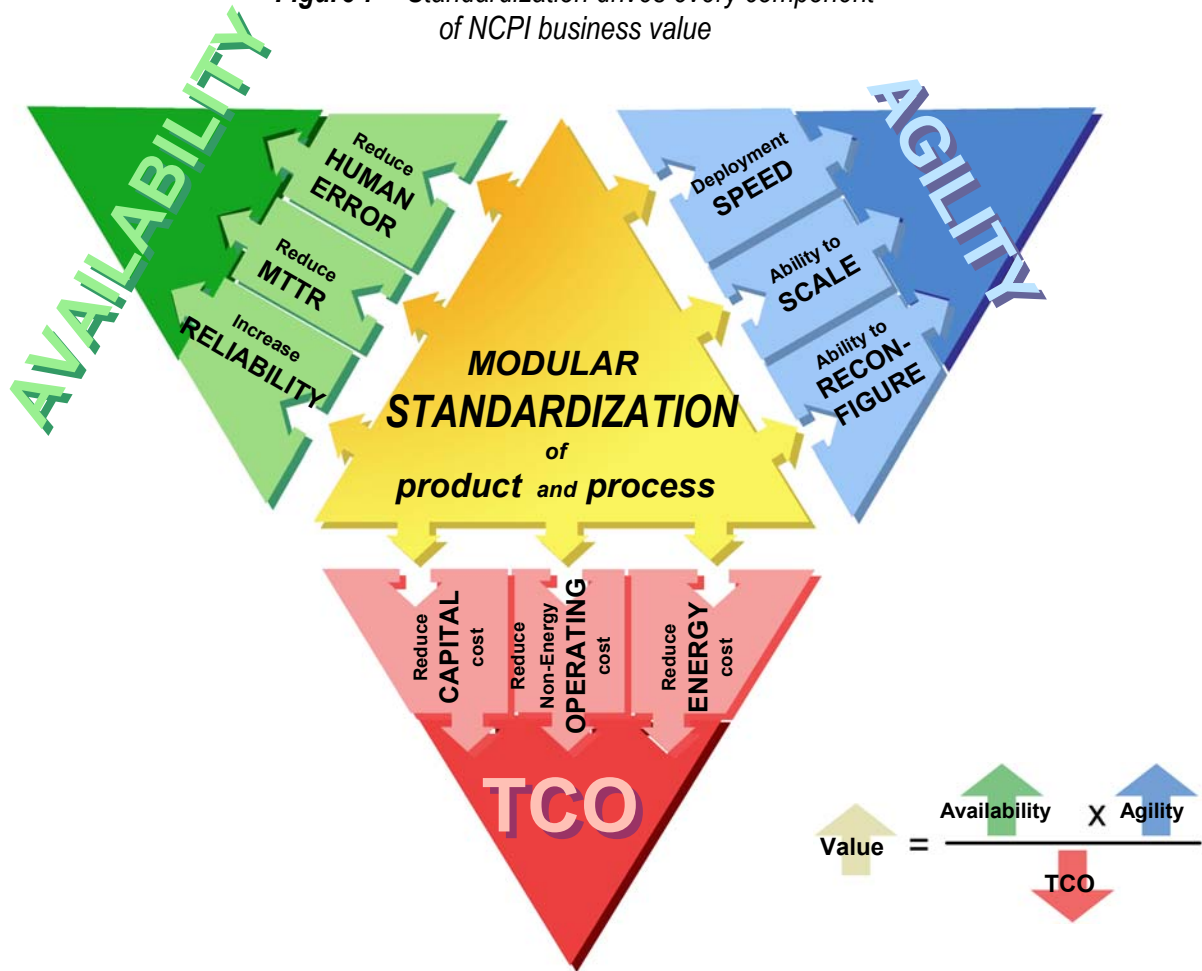
In such an environment:

- Procurement bidding focuses on the low bid for each component, not on suitability for integrated use.
- The focus is on specifications and reliability of individual components, diverting attention from integrated system performance.
- Infrastructure components are one-time engineered into a unique monolithic platform by consulting engineers designing the IT space. *Unique* is the opposite of *standardized*.
- The fragmented nature of the equipment supply is reflected in inconsistent design philosophies among manufacturers, consulting engineers, owners, and IT managers.

The bottom line: Standardization drives NCPI business value

Standardization, as shown in the preceding sections, acts directly and indirectly to enhance every major factor influencing availability, agility, and total cost of ownership. This wellspring of interrelated effects makes modular standardization a central driving force in increasing NCPI business value (Figure 7).

Figure 7 – Standardization drives every component of NCPI business value



Conclusion

Network-Critical Physical Infrastructure (NCPI) has become unmanageable to its users. Although characteristics of the industry have tended to support a culture of one-time engineering and custom installations, the time has come for the next step in its evolution toward becoming a streamlined support layer running in the background of IT operations, rather than a parallel operation competing for resources.

Standardization is a business strategy that has been used successfully for over 200 years to optimize products and processes in nearly every industry. The same principles can be put to work in data centers to provide the benefits of understandable, predictable, and efficient NCPI structure and function. Standardization can be analytically shown to improve, in some cases dramatically, every area of performance that drives NCPI business value – availability, agility, and total cost of ownership. Because of

these wide-ranging effects and nearly universal influence on deployment and operation over data center life span, standardization – in particular, *modular* standardization – is emerging as a key player in the optimization of the NCPI investment.

Next steps

Standardized modularity of NCPI equipment and interfaces provides widespread and substantial benefits to the users who deploy it, as described in this paper, and marks the beginning of a move toward data center standardization in this industry. NCPI users themselves can take the power of standardization even further:

- First, by applying the principles of standardization to their own methods and procedures in the data center. Maintenance, management, documentation, training, record-keeping, labeling – every process is a candidate for the techniques of standardization and its inherent benefits in efficiency and error-avoidance.
- Second – and even more powerful – by deploying of the same NPCI configuration and procedures in more than one data center. Leveraging experience with one data center into the identical operation of others is a new idea. Every advantage described in this paper becomes greater with the added dimension of multiple sites: predictability and understandability thrive on replication. This broad level of standardization has, in 2005, only been accomplished by a handful of enterprises worldwide.⁴

Once the extraordinary effects of standardization are understood and experienced first hand, opportunities for its effective use will continue to present themselves to the forward-thinking IT manager.

About the Author:

Suzanne Niles is a white paper author at APC's Engineering Design Center in Billerica, Massachusetts. She studied mathematics at Wellesley College and received a Bachelor's degree in computer science from MIT, with a thesis on handwritten character recognition. She has been educating diverse audiences for over 25 years using a variety of media from software manuals to photography and children's songs.

⁴ Deloitte's Amsterdam Cybercentre consists of identical twin data centers, a consolidation of the firm's 109 distributed IT facilities that embodies an enterprise-wide philosophy of standardization. Using standardized modular NCPI architecture, construction was completed in four months.