The premature deterioration of infrastructure resulting from lack of maintenance has adverse consequences…. The failure to maintain roads means that fewer people have access to health clinics and fewer children go to school. Poor maintenance of water reticulation systems results in higher prevalence of disease.

Matthew Dornan

Just as maintaining a healthy infrastructure of water delivery and roads is essential to the functioning of cities and towns, maintaining a healthy infrastructure of information technology is essential to the functioning of universities. Deterioration in IT infrastructure can lead to deterioration in research, teaching, and administration. While this is self-evident to IT professionals, it may not be as obvious to senior administrators who more commonly deal with other types of university infrastructure. Given the importance of information technology to all functions of the university, and that higher education spends about 40% of central IT budgets on IT infrastructure, IT professionals must be strong advocates for appropriate life-cycle processes for IT infrastructure. One of the responsibilities of IT leaders is to provide their managers with appropriate background, analysis, and recommendations about IT infrastructure, focusing on the impact that inappropriately maintained or out-of-date IT infrastructure may have on the academic, research, and administrative functions of the institution. Particularly with the move to the cloud, the very concepts of IT infrastructure are changing, and the way in which a college or university’s IT leaders present infrastructure alternatives to decision makers will affect IT performance for years to come.

This research bulletin develops a framework that can be used by IT management to assess the need for IT infrastructure projects; to analyze the issues and risks in implementing and maintaining IT infrastructure; and to engage other university officials in better understanding the impact of IT infrastructure projects. While this framework attempts to bring some rigor to the analytical process, especially where financial ROI may be difficult to calculate, it should not require a heavyweight effort to implement. The value of the ideas presented here will be in their ability to be used on a regular basis. Finally, like all frameworks and templates, this one is meant to serve as a guide for further adaptation to the specific projects and environments in which it is used.

Outline of the Approach

The primary purpose of this bulletin is to assist IT staff in evaluating and justifying infrastructure projects to university decision makers. The basic approach is to show how to value a project by looking at the capabilities to be implemented or updated, the benefits to different parts of the university community, the risks entailed in undertaking the project (or not undertaking it), and the costs (including ongoing maintenance and operational costs)—all based on a fundamental understanding of the different types of infrastructure projects and their purposes. Decisions should be based on how a proposed project compares to different alternatives, including maintaining the status quo.
The approach to infrastructure project analysis is shown in figure 1. For existing infrastructure, begin by making a determination of its status (a “health check,” as described later) before determining what type of project is necessary. The type of project—initial implementation (for new infrastructure), maintenance, reimplemention, or technology migration—dictates the factors to be considered in the analysis. After capabilities are studied, the bulk of the analytical effort is spent in assessing benefits, risks, and costs. Finally, a Value Scorecard brings together the analysis and compares the project under consideration with alternatives, including maintaining the status quo. Because the benefits that other departments (both academic and administrative) derive from infrastructure projects are not always obvious, it is up to IT to lead them through the justification. Although other departments should be brought into the process, IT has the lead responsibility for convincing the rest of the organization that an infrastructure project is important enough to be given the green light.3

**Figure 1. Approach to infrastructure project justification**

**Definition of IT Infrastructure**

The term *infrastructure* (or “below the structure”) is widely used in discussion of public works such as water and electric delivery systems, roads, and bridges and, even more generally, to refer to any systems that support our society or indeed an organization. Therefore, a brief discussion of *IT infrastructure* is useful in clarifying the topic.

In the broad context of IT systems and services, we can distinguish infrastructure from applications and end-user services, as the definitions below demonstrate. The IT Infrastructure Library (ITIL) defines IT infrastructure as follows:

> All of the hardware, software, networks, facilities, etc., that are required to Develop, Test, Deliver, Monitor, Control or support IT Services. The term IT Infrastructure includes all of the Information Technology but not the associated people, Processes and documentation. 4
Many similar definitions can be found, such as this from a government CIO:

IT infrastructure consists of [in current usage.] the equipment, systems, software, and services used in common across an organization, regardless of mission, program, or project. IT Infrastructure also serves as the foundation upon which mission, program, and project-specific systems and capabilities are built.\(^5\)

In short, IT *infrastructure* is the stuff on which we build and operate IT *applications*. IT application software represents the structure; everything else is the *infrastructure* (this is the ITIL definition). Note that while people are specifically excluded from this definition, the costs of people to implement and maintain infrastructure are included in analyzing IT infrastructure projects. The people are not defined as infrastructure per se, but they are necessary to implement and maintain infrastructure.

Two related terms deserve mention: *critical infrastructure* and *cyberinfrastructure*. These terms have entered the popular vernacular and may be known to non-IT personnel on campus. *Critical infrastructure* is a term that has been around for almost a hundred years, referring to those infrastructure assets critical to the functioning of society. While this traditionally has referred to infrastructure dealing with necessities such as the water supply, electricity, transportation, and food supply, the federal government now includes information technology in critical infrastructure, both in terms of the organizations that supply IT and the organizations that use IT.\(^6\) IT infrastructure is certainly a critical infrastructure to our universities.

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**Bridges and IT**

One of the motivations for this bulletin was the May 23, 2013, collapse of the Skagit River Bridge in Washington State. The collapse illustrates the importance of appropriate maintenance for physical infrastructure, and the lessons gleaned from the incident seem equally applicable to the discussion of IT infrastructure maintenance and upgrades.

Luckily, injuries were light in the collapse of a 160-foot section of this 4-lane, 57-year-old bridge. Press reports from sources including the *Seattle Times*, *Los Angeles Times*, and *New York Times* followed with commentary by experts and government officials regarding maintenance, design, upgrades, and replacement—all topics relevant to other types of infrastructure. Key points included the fact that the bridge was built to handle future traffic projections made in the 1950s that were far exceeded, something also very common in IT.

Based on an analysis I conducted on various reports of the bridge failure, I offer the following ideas relevant for infrastructure of any form:

- When your infrastructure is judged “functionally obsolete,” you should inspect it regularly. And when you do inspect it, be prepared to do required maintenance or “reduce loadings.”
- When something is judged “fracture critical” (many single points of failure, in IT parlance), don’t be surprised when it fails.
- New design techniques can help us make our systems more fail-soft.
- While we don’t have an equivalent of the Federal Highway Administration’s Recording and Coding Guide for the Structure Inventory and Appraisal of the Nation’s Bridges, we can certainly come up with reasonable criteria to measure and rate the health of our systems.
- It isn’t always necessary to rebuild the entire system. You can often preserve the components that are still in working order.
- There is never enough money to upgrade all infrastructure to the best level. You must prioritize.
Cyberinfrastructure is a newer term with at least two popular definitions. The term was first used in the academic community in an NSF-sponsored report over a decade ago to highlight the importance of information technology to the future research environment. The report defined cyberinfrastructure as a “layer of enabling hardware, algorithms, software, communications, institutions, and personnel” between hardware and the applications. In the more recent National Infrastructure Protection Plan, cyberinfrastructure is defined to a more general audience: “Cyber infrastructure includes electronic information and communication systems, and the information contained in these systems.” The importance of these definitions is that the first includes institutions and people, while the second includes data and information. For the purposes of this bulletin, institutions and people are included in the costs of IT infrastructure projects as they relate to the implementation and maintenance of infrastructure components.

Analyzing Different Types of Infrastructure Projects

Inadequate maintenance is also costly in a financial sense. A widely quoted figure for concrete structures is that for “every dollar of routine maintenance not performed, this ends up costing $5 in repairs, and ultimately, $25 in rehabilitation.”

Matthew Dornan

Infrastructure projects are not just about new infrastructure. They are about maintaining current infrastructure, deciding when to replace infrastructure, and even about moving to the cloud (the latest form of infrastructure—“as a service”). For example, when wireless networks were starting to be installed almost a decade ago, this was seen as totally new infrastructure, and it was not clear whether they would replace or augment wired networks. Universities that installed wireless networks then had to maintain them, fixing anything that broke, periodically upgrading wireless access points (and at some point replacing them), and upgrading network wiring and routers that connected those access points. These maintenance projects were sometimes very large infrastructure projects in themselves. This life cycle of build-maintain-upgrade-reimplement (when components become obsolescent or are superseded by other technologies or ways of providing infrastructure) results in the different types of infrastructure projects. The factors to be analyzed for each type of project are similar, but different types of projects require different levels of justification, with each type addressing capabilities, benefits, risks, and costs in its own way (see table 1), as discussed below.

Table 1. Analysis factors for different types of infrastructure projects

<table>
<thead>
<tr>
<th>Factor</th>
<th>Project Type</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial Implementation</td>
</tr>
<tr>
<td>Capabilities</td>
<td>Basic capabilities</td>
</tr>
<tr>
<td>Benefits</td>
<td>To different constituencies</td>
</tr>
<tr>
<td>Risks</td>
<td>New technology acceptance</td>
</tr>
<tr>
<td>Costs</td>
<td>Maintaining prior infrastructure</td>
</tr>
</tbody>
</table>
Initial Implementation Projects

When approaching the task of implementing a completely new infrastructure, most IT organizations focus on the capabilities that infrastructure will bring to the campus. In the wireless network example cited above, the core capability was to provide Internet access throughout the campus without having to connect to a wall outlet. This capability provides different benefits to different constituencies: students would be able to use their laptops anywhere (including in classrooms, which might not necessarily be seen as a benefit by some faculty members) and would not need computer cluster rooms all over campus; staff members could gain access to systems and the Internet as they held meetings in the many conference rooms across campus; groups of researchers would be able to work wherever they could gather; office layouts would not have to be driven by where network outlets were available; and so forth.

In addition to those immediate benefits, IT staff often raised the possibility of an additional benefit: that wireless networks would reduce or even eliminate the need for most wired networks, thus reducing the cost of that infrastructure. What sometimes escaped notice (or at least was not always highlighted) was the fact that you had to get wires to all those wireless access points, so the wired network would still need to go everywhere wireless went (although not necessary to each desktop), as well as that there would be dozens of new wireless devices that would keep demanding more and more bandwidth, which meant that the wired network would need to keep up. Another factor to be considered was that wireless technology was relatively new and that the entire infrastructure would likely need to be replaced in three or four years. All these considerations of the initial infrastructure project (short term and longer term) need to be accounted for in the justification.

Some points might be discussed in terms of the risks (the other side of the benefits coin) of installing the new infrastructure. Again in this example:

- What if students did not bring their laptops to campus and still needed computer clusters around the campus?
- What if wireless networks did not replace wired networks and the university had to bear the costs of both?
- What if the wireless components that were initially installed were soon outmoded and had to be replaced with different technology?

This is common in IT—install a new infrastructure and end up maintaining the old one for a very long time (how long did you still run those old COBOL systems, for example?), or install a new technology and discover that a new version (or even a completely different technology) supersedes that one in short order. So while you can expect various benefits from new infrastructure, there is always a risk that those benefits will not be realized. A thorough risk analysis will look at the impact of expected benefits not being realized, as well as at other potential risks, including obvious ones such as cost overruns and not-so-obvious ones such as impact on other systems or departments. Meeting with staff from multiple departments (including the users!) to brainstorm risks associated with big projects is one way to help avoid surprises and demonstrate to decision makers that risks have been broadly studied. Of course your justification for the project will also have to show how you intend to mitigate those risks.

With a completely new infrastructure, you will be describing benefits and risks without much data to draw upon, although there will certainly be stories from the experiences at other campuses (unless you are the very first campus to work with a technology, in which case your colleagues on other campuses will be
looking to you for the stories!). This means your analysis will be highly qualitative and anecdotal, although you may be able to quantify some factors. The decision-making process will rely more on subjective assessments of benefits and risks than strictly on quantitative assessment, and in such situations, your analysis will be (or at least should be) scrutinized even more carefully. Subjective assessments may come from anecdotes or interviews or surveys. For example, in the 2012 ECAR study on research computing, participants agreed that “having research computing resources makes an institution more competitive in recruiting and retaining faculty with research computing needs.” Recruiting and retaining faculty is a real benefit to the university, and an acknowledgement of infrastructure’s role in that process should be included in the analysis.

In addition to capabilities, benefits, and risks, the other important part of the analysis is the cost model. This will include the costs for the initial project, as well as expected operational costs for several years (typically 3–5) and any major expected upgrades or replacements if they occur within that time. Going beyond a 3–5 year time frame may have limited value in IT infrastructure because technology changes may significantly affect the options available after that time.

Initial implementation projects may be treated as capital expenditures and be funded from a budget different from that of operational expenditures. Costs should be determined for planning, design, and implementation, both in total and on a monthly or quarterly timeline, depending on the expected duration of the project. If it is possible to put a time frame on when the technology will become obsolete (or at least obsolescent), then costs can also be estimated for replacement or major upgrade and can be included in the overall cost model as well.

Regardless of which budget a project may come from, all costs should be considered, including ongoing maintenance costs. This means hardware, software, other equipment, construction, and, of course, personnel. Personnel costs (both contractors and employees) are often a significant figure and should include full- and part-time people involved in the project, both from IT and any other departments involved, such as the construction department.

The decision on whether to implement new infrastructure should consider all the capabilities, benefits, risks, and costs of that infrastructure, whether direct (as in wireless directly benefiting students or as in new servers costing more in electricity and cooling) or indirect (as in a new mobile app infrastructure providing capabilities for future application developers). IT’s job is to develop and organize all the information on all these dimensions so that decision makers can make the best decision possible.

**Maintenance and Upgrade Projects**

Analysis of maintenance projects includes the same basic factors as for new infrastructure projects: capabilities, benefits, risks, and costs. Maintenance projects run the gamut of simple software upgrades when a manufacturer puts out a bug-fix release to more complex efforts that might involve retesting entire networks, systems, or databases, including all the systems that rely on them. One of the unfortunate facts of life in higher education—and, indeed, in other public and private institutions—is that there is never enough money to maintain or upgrade all infrastructure to the highest and most productive level. Look around your campus and you will see this fact playing out in classrooms, offices, and laboratories, as well as in equipment and IT. The result is that you have to establish priorities, which requires a strong understanding of the benefits of maintaining and the risks of not maintaining IT infrastructure. For
example, the failure to maintain networks means that fewer people will have high-speed access to online computation and other research facilities and that, as a result, fewer multi-institutional research projects will take place. Poor maintenance of administrative systems results in more outages and errors. Discussions with people who use the various types of infrastructure (networks, systems, software, facilities, etc.) will yield an anecdotal record of the impact of deferring maintenance, and that can be counted in the risk column. In one instance, a physics professor asked the CIO at his institution for a written commitment that the university would increase bandwidth to the Internet to keep pace with other institutions in the physics research community because he wanted to submit that document with a grant application! Without this commitment, he was unlikely to win the grant. This type of anecdote is an important part of the analysis in justifying IT infrastructure maintenance projects.

Before going forward with a particular maintenance project, an institution must consider several key questions:

- How often should the maintenance be performed? For example, because there is a cost to testing software upgrades, should every upgrade coming from the software vendor be tested and installed?
- When should replacement be considered instead of maintenance? Just like with your car, you can decide to replace infrastructure on various fixed or variable schedules—every $n$ years, when the cost of the next repair seems too expensive, or when it falls apart. If the equivalent of getting stuck on a back road in the middle of the night without any cell phone signal scares you, then you probably want a replacement schedule based on manufacturers’ expected end of life rather than when you have a failure you can’t fix.\(^13\)
- Is there a new or emerging technology on the horizon that may change the approach to maintenance? For example, how would you change your timing or approach to maintaining hardware infrastructure if you determined that large parts of your workload would be moving to the cloud in the next several years? And, how would that affect the overall cost analysis for infrastructure services?

With the answers to these questions in hand, you can decide what and how much maintenance is appropriate. From there, you can develop a cost model for infrastructure maintenance, in terms of either a single upgrade or ongoing activities.

**Reimplementation Projects**

There comes a time in the life cycle of any software, hardware, or network system when it is appropriate to start over.\(^14\) Technology refresh cycles in the IT infrastructure realm can be as short as 2–3 years or as long as 5–7 years.\(^15\) Moreover, whereas some network routers, for example, have a useful life in the upper end of that range, newer equipment may have 10 to 100 times the capability for the same or lower price. When maintenance costs start to equal replacement cost, it is time to reimplement, taking into account the ongoing maintenance costs of new infrastructure, of course, which may be higher or lower than current maintenance costs. However, replacement is rarely as simple as a “fork lift upgrade” (the direct replacement of one piece of equipment with another or one software system with another). The related impact on facilities, networks, and other systems has to be taken into account. If current computer hardware requires power of 5kW per rack but new hardware requires 10 or 20kW, the cost of upgrading electrical and cooling equipment can equal or exceed the cost of replacing the computer hardware. Replacing software infrastructure such as the database system could impact hundreds of applications, perhaps requiring replacing these systems as well. Clearly the implications of reimplementing infrastructure can be far reaching, and that must be part of the analysis.
The benefits of replacing infrastructure (rather than maintaining or upgrading) can also include increases in capacity and improved reliability. In an example from civil engineering, bridges built at the beginning of the construction of the interstate highway system were built using design standards of that time—the 1950s—and were based on estimates of usage that have been long surpassed. As stated by Deborah Hersman, chair of the National Transportation Safety Board, about the collapse of the 58-year-old Skagit River Bridge in 2013, "I think you can see with this bridge that if it had been built today, it would have been built to different design standards to make sure that there were accommodations for the kind of traffic that we’re seeing today." There are benefits of replacement infrastructure that simply derive from the introduction of newer technology, and these can be key to the analysis.

**Technology Migration Projects**

Sometimes a reimplementation project is based on technology so dramatically different that the infrastructure project is essentially a new implementation except that the old infrastructure has to be migrated to the new. When universities started to shift from "plain old telephone service" (POTS) to IP-based telephony (voice over IP, VoIP) or from on-premise servers to cloud-based servers, the migration of services from one infrastructure to another was a major factor in the reimplementation. In this type of situation, the cost analysis has to show the overlap of both services as well as costs attributable to the migration effort. Figure 2 illustrates this. The existing POTS infrastructure is maintained at full cost during the period when the VoIP infrastructure is planned and implemented. Costs are reduced during the migration and end when the POTS system is decommissioned. Maintenance costs accrue or may be incurred for the VoIP system as soon as the first users are live. The migration project costs are shown as a separate item.

![Figure 2. Example of technology migration project cost model](image-url)
Assessing Existing Infrastructure via a “Health Check”

One of the questions in justifying infrastructure maintenance or replacements is, Why do this now? While a leaking roof is a sure sign of the need for building maintenance, the need for other types of maintenance may not be so obvious. Even a leaking roof might require expert analysis to determine whether repair, upgrade, or replacement is the appropriate course of action. The building trades and other engineering professions have established many types of metrics and even standards to guide this decision making. Academics have studied the optimal replacement cycles for physical assets for decades and teach courses about how to do it.\textsuperscript{17} The first step is to assess the state of the infrastructure in question. Engineers call this the “state of repair,” where a state of good repair would mean that the infrastructure is “safe, reliable, and keeps the customer satisfied.”\textsuperscript{18} More explicit criteria exist for some engineering artifacts, such as bridges, for which the Federal Highway Administration provides very specific criteria.\textsuperscript{19} In IT, we haven’t achieved that level of standardization, but we can certainly do the analysis and create measures that will be useful in comparing the state of repair of our various IT infrastructure components.

Applying ideas from engineering disciplines, we can develop a straightforward approach to assessing the state of repair of infrastructure systems by measuring their state of usefulness, reliability, and technological obsolescence. Ratings on the different criteria can be established in various ways, ranging from subjective opinions of people knowledgeable about the specific system to detailed technical analysis performed by outside consultants. Once individual measures have been assessed, the infrastructure system or component can be given an overall rating or “health check score” depending on the decisions to be made:

- **Maintenance level of effort**: an indication of the level of effort (low, medium, high) needed to bring the infrastructure up to some established level of performance
- **Maintenance time frame**: when significant maintenance will likely be necessary
- **Useful life time frame**: when the infrastructure is likely to fall below the acceptable threshold for usefulness, reliability, or technological obsolescence

Regardless of which measures are used, having an indication of the overall health of your IT infrastructure, updated annually, will provide valuable input to setting priorities for infrastructure projects.\textsuperscript{20}

In preparing for an annual budget review, one university IT department performed a health check on its infrastructure systems, using subjective ratings from multiple staff members. After collecting data on four criteria (meeting known needs, outage frequency, how up-to-date the technology was, and cost to maintain), the departments applied its knowledge of the technology environment and expectations of user needs to rate each infrastructure component on whether it would require significant maintenance or upgrade over specified time frames: 1–2 years, 3–5 years, or greater than 5 years (see table 2). According to the university’s CIO, “This made a powerful presentation going into the governance committees, particularly when we could show some systems past end of life or using completely outdated technology.” The health check was updated for subsequent annual budget reviews.
Table 2. Example health check rating of infrastructure systems

<table>
<thead>
<tr>
<th>Infrastructure System</th>
<th>Meets Need (Usability)</th>
<th>Outage Frequency (Reliability)</th>
<th>Up-to-Date Architecture (Tech Obsolescence)</th>
<th>Cost to Maintain</th>
<th>Health Check Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service management system</td>
<td>1</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>2.0</td>
</tr>
<tr>
<td>Enterprise storage</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>2.5</td>
</tr>
<tr>
<td>Web server</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2.5</td>
</tr>
<tr>
<td>Wireless network</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>3.0</td>
</tr>
<tr>
<td>Database</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>5</td>
<td>3.5</td>
</tr>
<tr>
<td>Identity and access management</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4.0</td>
</tr>
<tr>
<td>Wired network</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4.3</td>
</tr>
<tr>
<td>Printing management system</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4.5</td>
</tr>
<tr>
<td>Emergency response system</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4</td>
<td>4.8</td>
</tr>
</tbody>
</table>

Scale

- **1.0–3.5** Needs attention in the next 1–3 years
- **3.5–4.49** Needs attention in the next 3.5–5 years
- **4.5–5.0+** Needs attention after 5 years

Going through a health check exercise can also alert the IT organization to which infrastructure components deserve closer observation. To head off major problems, those in fair or poor health can be monitored more often or in greater detail than those in good condition. Further deterioration might be indicated by an increasing number of outages or user complaints. Further analysis might also be indicated if significantly better technology is now available. In the case of the Skagit River bridge, “the 58-year-old bridge is listed as ‘functionally obsolete’ in the National Bridge Inventory, with ‘somewhat better than minimum adequacy to tolerate being left in place as is.’ It received a sufficiency rating of 57.4 out of 100.”

The closer an infrastructure component is to being obsolete, the more attention needs to be paid to it, lest it collapse completely.

**Justifying Infrastructure Projects**

Justifying an infrastructure project is all about presenting the value proposition (in the corporate world, this is called “making the business case”). What is the value of developing, updating, or replacing infrastructure? Infrastructure investments “are the foundation of the IT portfolio,” and “the justification for these investments is sometimes cost reduction.” But often the justification involves other goals, such as improved capability or risk reduction. Infrastructure projects create value in many ways by providing new or improved capabilities, such as investments in IP-based communication or mobile technologies. But the case for these infrastructure projects will be up against the case for all the other demands on the IT budget and the value those activities create. Infrastructure often suffers in these comparisons because benefits (and risks) are thought to be difficult to explain or quantify. This isn’t necessarily the case, however, and a value analysis can be performed with a reasonable expenditure of time and effort. The issue should be whether the infrastructure project under consideration provides more value than other projects or than the status quo, not whether the value of the infrastructure project is adequately explained.
Return on Investment, as a Scorecard

Consider the value proposition for adding a redundant switch somewhere in your campus network. You are not reducing the cost of the network—it will clearly cost more to add a redundant switch. Having this redundancy will reduce the likelihood of an outage, but by how much, and how likely is it without the redundant switch? What is the cost of an outage? In other words, how do you calculate the value of this infrastructure project? Reducing risk has value, so there is a definite return on investment, but developing an ROI number for risk reduction is very difficult and fraught with uncertainty. Similarly, the benefits will be difficult to quantify, and any quantification will be subject to significant error bars. In practice, many risks and benefits can only be translated into financial terms by making gross assumptions on financial value that would be nearly impossible to verify. For example, saying that redundant hardware “reduces outage probability by x%” requires making a reasonable case for how x was calculated and how accurate that calculation is thought to be. While vendors may have failure statistics for any particular piece of their equipment, that does not tell you all you need to know to estimate failures in your own environment, which is affected by power variation, cooling, and other environmental factors. Vendor statistics are only one variable in the outage probability calculation. An approach that incorporates all that you know about the infrastructure project without attempting to boil it down to a single financial ROI number will be more justifiable.

That said, in some situations a financial ROI is useful, and those instances shouldn’t be ignored. For example maintenance or reimplementation projects are often cost-savings projects, in which case ROI may be all the justification that is needed. Note that very few universities have established a “threshold ROI” that a project must meet to be approved, so even this approach has a subjective component to it. ROI might only rarely be a key decision metric, but when it is, it is certainly a useful part of the analyst’s toolkit.

So how do you create the value proposition for infrastructure where a single financial ROI is not readily calculable? Create a return-on-investment scorecard using all that you know about the project. Some benefits and costs can be presented in quantifiable terms and some not, but all should enter into the decision-making process. Describe who benefits—specific groups of faculty, students, or staff. ROI is all the different types of returns—positive and negative, financial and nonfinancial—that accrue from implementing a project. The discussions in the sections above highlight a number of different types of returns, and all of these together constitute the value of an infrastructure project. If ROI is presented as a scorecard rather than a single number, then all types of benefits and costs can be presented, akin to presenting balanced scorecard in doing strategic planning.

Finally, it is important to know your audience. Who are the decision makers who will evaluate your analysis? What measures will resonate with them? If it is faculty, then the most important aspects might be how the infrastructure will aid their ability to do research, obtain research grants, or better teach students. If your audience is the CFO, then an argument with at least some discussion of financial return will be useful. This is not to say that either group is not open to the other type of information but that people have biases based on their backgrounds.

Justification via Comparison

An infrastructure project under review must be compared to other projects (whether infrastructure or not) and to doing nothing. Alternatives for the infrastructure project likely also exist, such as procuring equipment from different vendors or developing a different approach entirely, such as moving to the
cloud. The option of doing nothing also has benefits, risks, and costs and should be evaluated with other alternatives. If an infrastructure project is going to require a $1M investment and $250K/year in ongoing costs, you will need to evaluate that in comparison to taking a different approach that might cost more or less but have different capabilities, benefits, and risks. Staying with the current situation also has costs and benefits, and they need to be analyzed as well.

This evaluation should compare all the factors discussed, from general capabilities to benefits to risks and, of course, costs (capital and operational, external and internal, and investment and ongoing). Table 3, while not exhaustive, lists many of the criteria that can be used in final comparison, bringing together the factors discussed for justifying infrastructure projects.

Table 3. Analysis and comparison matrix template

<table>
<thead>
<tr>
<th>Framework</th>
<th>Criteria</th>
<th>Alternative 1</th>
<th>Alternative 2</th>
<th>Status Quo</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>Primary purpose of the infrastructure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Type of infrastructure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Specific capabilities</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Value/Benefits</td>
<td>Primary beneficiaries; how they benefit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ancillary beneficiaries; how they benefit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reduction of complexity or dependencies</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Impact on research</td>
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<td>Risk Analysis</td>
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<td>Compliance (legal) risk</td>
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<td>Schedule slippage (time risk)</td>
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<td>Cost overruns</td>
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<td>Unintended consequences</td>
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<td>Increased complexity or dependencies</td>
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<td>Cost Analysis</td>
<td>One-time costs of planning and implementation: external, including external personnel (range of cost)</td>
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<td>One-time costs of planning and implementation: internal, including internal personnel, amortization, nonbudgeted costs (range of cost)</td>
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<td>Cost of conversion/overlap: internal (range of cost)</td>
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<td>Annual (ongoing) costs: external, including external personnel (range of cost)</td>
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<td>Annual (ongoing) costs: internal, including internal personnel, amortization, nonbudgeted costs (range of cost)</td>
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Conclusion

IT leaders often hear that it is difficult to make a case for spending money on infrastructure systems, certainly much more difficult than making a case for spending money on application systems. The value proposition for infrastructure spending is undoubtedly complex, involving both financial and nonfinancial factors. This bulletin develops a framework for analyzing and presenting that value proposition and thus helping IT practitioners in justifying the need for individual infrastructure projects. It provides background to enhance understanding of the various types of infrastructure projects, present capabilities, analyze benefits and risks, develop a cost model, and, by comparing alternatives, develop the value proposition for presentation to decision makers. With this presentation, decision makers will be in a better position to appreciate the value of IT infrastructure and approve necessary projects. IT practitioners must then address the challenge of ensuring that approved projects are implemented successfully and provide the maximum value to their institutions.

Where to Learn More


Acknowledgments

The author is indebted to the many colleagues who, knowingly or unknowingly, contributed to this work by showing an interest in infrastructure systems and who engaged in discussions on this topic at MIT, at EDUCAUSE meetings, and in other forums. In particular, a session at the Common Solutions Group led by Jim Phelps (now at University of Washington after many years at the University of Wisconsin–Madison) and Sharif Nijim (University of Notre Dame) sparked the interest of Susan Grajek at EDUCAUSE and encouraged the writing of this report. Sally Jackson (University of Illinois) provided further background. The author acknowledges the thoughtful review and comments provided by Sharif Nijim and Susan Grajek, although responsibility for any errors and omissions lies fully with the author.

About the Author

Jerrold M. Grochow consults with universities on IT strategy and organization through Jerrold M. Grochow LLC. He retired as Vice President for Information Services and Technology at the Massachusetts Institute of Technology in 2009 and was interim Vice President of the University Corporation for Advanced Internet Development (Internet2).
Citation for This Work


Notes

2. Based on 2013 data from the EDUCAUSE Core Data Service.
3. Of course, IT can and should seek out key leaders among those who benefit to aid in this effort.
4. ITIL *English 2011 Glossary*.
9. At MIT, we found that wireless traffic soon equaled about half the wired traffic in any building where the wireless network was implemented, and it kept rising from there, to a point. So far, wireless hasn't completely replaced wired network access, and both infrastructures must be maintained.
10. I have seen many examples of project teams believing they must provide a quantifiable measure for just about everything, even when that analysis is of dubious quality or does not have any actionable value. Sometimes, qualitative analysis provides more than enough information to allow actions to be taken. For example, rather than trying to calculate "lost productivity" of a network outage to help justify some number of duplicate routers, it might be equally useful to note that having your university on the front page of a local or national newspaper for having a prolonged network outage is a reputational risk the president and trustees might not want to take very often. Different options for mitigating this risk can then be compared by analyzing costs and other factors.
12. One business case for an IT project that I saw explicitly excluded the cost of employees because they were considered part of ongoing costs. This is a fundamentally flawed approach because those employees could be redeployed or, if appropriate, laid off.
13. For a detailed discussed of these issues, see Andrew Jardine and Albert Tsang, *Maintenance, Replacement, and Reliability: Theory and Applications*, 2nd edition (Boca Raton, FL: CRC Press, 2013). Although this book is about physical asset management, many of the concepts can be applied to IT infrastructure.
14. Analysis of when to replace infrastructure is thoroughly studied in many other fields, although not so much in IT. Many of the principles found in a reference text apply to IT as well. See, for example, Jardine and Tsang, *Maintenance, Replacement, and Reliability*.
15. Replacement cycles for application systems are often longer, sometimes much longer. It is not unusual to hear of accounting systems still in use after 20 years or more.
17. See, for example, Jardine and Tsang, *Maintenance, Replacement, and Reliability*.

20. The same approach—with different criteria and ratings—can be used for IT application systems and for other IT functions such as customer service.

21. Murphy, “Seattle-area bridge collapse.”


23. See note 4.

24. Some might say that even presenting a single ROI number is attempting to simplify inherently complex processes beyond the point of usefulness. Try describing the weather in a single number—what would you use? Temperature, wind speed, precipitation, cloud cover? It takes all of these (and arguably more) to really describe the weather, let alone what it might be like in an hour, a day, or a week.

25. In my experience, ROI is generally a more significant decision criterion in the corporate world than in universities.

26. “Cost” in this case is the opposite of a benefit—when a new technology is introduced, there is a cost to building expertise in that technology.