Guiding Principles for Designing & Growing a Campus Network for the Future

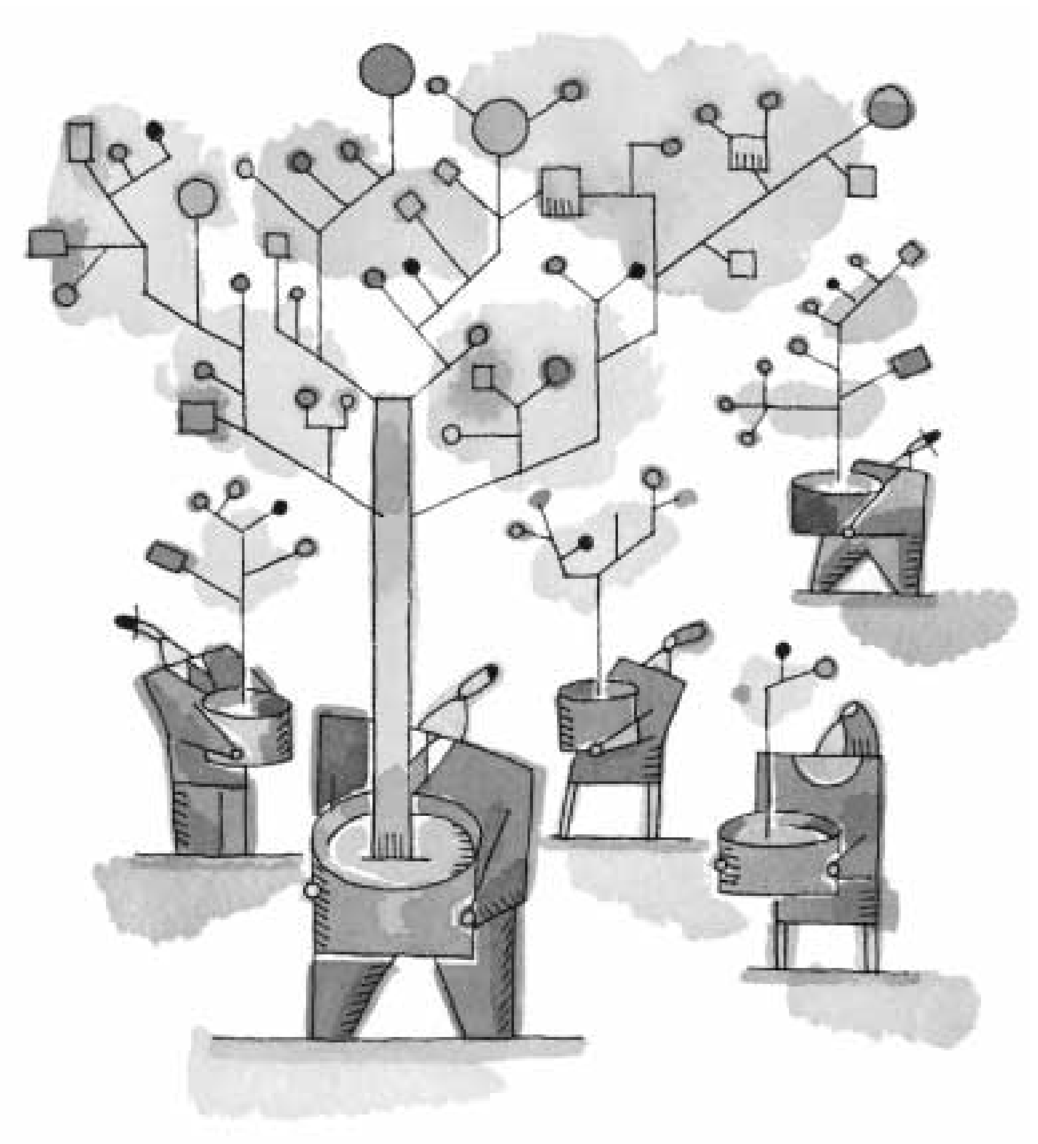
Communications networks are core infrastructure for higher education, providing an essential foundation for all electronic teaching, research, library, and administrative services. How can a school create, manage, and maintain these networks? With continuous advances in technology, how can a school prepare for an unknown future? This article shares some good news: by following some basic guidelines, a campus can ensure a course of network growth and renewal, providing continuous network upgrades and maintaining a position of flexibility to meet expected and unexpected future needs.[1]

by **Philip E. Long**

The telecommunications industry has developed a standard set of high-level design building blocks and practices that the most basic network shares with the most complex. This substantial experience has enabled the development of a set of guiding principles for designing and managing networks to maximize investment value and promote flexibility to meet changing needs. The key to a campus network that will maintain currency and gracefully accommodate future advanced services is to use these principles to guide ongoing renewals of the standard building blocks to maximize network value, technology, and flexibility to meet campus needs.

Once critical mass is established with a standards-guided campus network, unit costs will level off, even with rapid expansion in connections and bandwidth. Because of rising user expectations and some external factors, however, overall costs for an evolving technology (for example, the data network) are likely to continue to rise at rates substantially above inflation for the foreseeable future. Specialty applications will require specialty equipment and knowledge (but will likely use standard network building blocks and cabling) and thus will come at a premium cost. But those costs need only be incurred when the need emerges locally and justifies the cost.

This article offers a set of principles to guide network planning and design; provides



examples of how these principles can be applied to standard building blocks and network design; and discusses the convergence of voice, video, and data networks in the long term, including potential strategies to consider in the immediate future.

Principles to Guide Network Planning and Design

Although the following principles are not inviolable, a network designer or administrator should question exceptions. The principles are illustrated with examples in a follow-on discussion of standard building blocks and data network design.

Planning should be ongoing. Campus needs and network technologies are changing continuously, so planning must be ongoing. Typically there should be a yearly update of the overall network plan and technical standards.

Network designs should be based on standard building blocks. Designing around the standard, replaceable network building blocks is critical but also appropriate and routine. Existing networks likely already conform in most if not all ways to the standard building blocks. Both design and building blocks are standard only at a high level and still need careful mapping to local buildings and campus needs. Commercial products will fit standard designs and building blocks. A corollary to this principle is the principle that *good design minimizes costs*. Networks are extraordinarily complex technical enterprises; bad design (for example, not observing the building blocks) quickly produces high operating and management costs.

Network costs are operating costs, not capital costs. All networks need ongoing renewal; except for pathway and cabling, networking costs are operating, not capital, costs. This is probably the most frequently violated principle. A close corollary to this principle is the *no free lunch* principle, which states that every addition of capacity or function to even a well-designed network does cost something, both to install and to maintain.

Networks should be continuously renewed. Because networks are still growing rapidly in terms of numbers of users, speed and capacity, services, and reliability, they are subject to constant changes in ways small and large. The key to establishing and maintaining a quality network is to use those ongoing changes to provide continuous upgrades within the periodically updated plan.

Networks should grow gracefully. Following these principles initially when constructing small networks allows those networks to evolve more or less seamlessly into more complex higher-speed networks that can fully support advanced services when those services are needed. A corollary to this principle is the *80-percent rule*, which requires upgrading any network component that is running about 80 percent of its capacity for any significant period of time. This rule applies to all the components across the layers, including pathway, cable counts, communications links, switches, routers, and more.

Network investments should be value based. Investment in network building blocks has a significant influence on future flexibility and costs. Investment should be proportional to the expected life span, allow for cost trends, and recognize that opportunity costs can easily dominate marginal cost. The shorter the life span for a particular network element, the closer capacity should be to actual need; the longer the life span, the more overcapacity is appropriate. If costs are dropping over time, investment should be close to actual need; if costs are rising, investment should usually include extra capacity. Opportunity costs may justify overcapacity; for example, marginal materials costs may be quite low to provide extra capacity. Note that the *no free lunch* principle reminds us that all capacity incurs some level of ongoing maintenance, so overcapacity plans should always be related directly to existing or anticipated campus needs and should recognize the carrying costs.

Networks should use commodity goods. Wherever possible, commodity goods should be used; commercial trends drive prices down and encourage innovation to extend the life and utility of common commercial products.

Networks should use open standards. Wherever functional needs can be met, open standards should be adopted and proprietary standards avoided. This is the *commodity goods* principle applied to software. The Internet community will use and develop open standards providing low cost and high innovation, compared to what an individual company or set of companies can do with proprietary protocols.

Networks require active management. A network is a highly complex technical enterprise and can meet predictable service standards only if it is engineered from the ground up to provide management data and error reports and to permit active probing and management by network administrators.

Networks need appropriate redundancy. Network plans should provide for a level of redundancy appropriate for the number of nodes or the amount of capacity that would be disabled by a particular network element failure. Note that as campus expectations for reliability rise, the level of redundancy needed will rise correspondingly. The *no free lunch* principle reminds us that although redundancy may be needed to meet reliability goals, it adds complexity to a network and thus raises costs, so it should be added wisely.

Outsourcing should be used judiciously. A campus should generally have full control over issues that directly affect its programs, but it often makes sense to leave nonprogrammatic issues to others. Data network functions are still critical to the ongoing and rapid development of program-related activities such as providing access to library materials, distance education, and administrative streamlining, so few campuses currently consider outsourcing the core design and management of their data network as they might, for example, their phone network (see further discussion later about voice and video). The use of off-the-shelf components within standard designs provides some benefits similar to outsourcing. And many campuses are outsourcing network services that have standard interfaces to the campus network and are undergoing rapid commercialization or innovation (for example, remote network access). Any outsourcing arrangement requires careful management to ensure that campus program needs drive the services.

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- ✓ Networks should grow gracefully.
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- ✓ Networks should use commodity goods.
- ✓ Networks should use open standards.
- ✓ Networks require active management.
- ✓ Networks need appropriate redundancy.
- ✓ Outsourcing should be used judiciously.

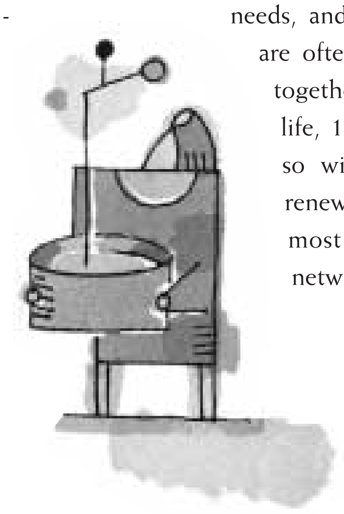
Applying the Principles to Standard Building Blocks and Network Design

At a high level, a campus network consists of precisely defined functional "layers" that build from the physical infrastructure to network applications. Each layer relies on the layer below it (layering is simplified):

- *The physical layer* includes the physical plant that carries electrical signals—the conduit through which the cabling runs (pathway) and the cable itself.
- *The network layer* includes protocols and electronics that turn electrical signals into messages—for a data network, the network hubs, switches, routers, gateways, firewalls, and computer network interface cards that assign names and addresses to devices on the network and that govern how messages are passed.
- *The application layer* includes network applications that turn messages into services. Core data network applications include electronic mail, directories, Web servers and browsers, and so on.

Both the simplest local area network, connecting three machines to a printer, and the most advanced campus networks use these layers and basic building blocks: pathway, cabling, network electronics, and protocols. Each of a network's standard building blocks has a useful life after which it must be renewed. Guided by an overall plan, individual building blocks can be renewed to upgrade and improve each of the areas over time, providing a gradual improvement in function and capacity across the entire network in the normal course of maintenance.

Pathway. Buried (in walls, underground) pathway is the most difficult network element to add or modify. Pathway has the longest useful life of any network element, on the order of the life of a building, certainly 20 or even 50 years. With respect to the principle of *value-based investment*, pathway entails generally high construction costs, which usually increase at inflation or higher rates, and high opportunity costs for construction (a project is expensive to initiate). However, once construction is under way, marginal costs to provide extra capacity (more pathway) are usually low. For these reasons, constructing adequate buried pathway when the opportunity arises is critical, and it makes sense to overbuild to provide maximum future flexibility. Spare pathway ensures the potential to adjust wired networks to future developments. A rough formula to overbuild pathway is to estimate the maximum concretely foreseeable use and double it. An unfortunate but common problem can occur if construction engineers design pathway as part of a building project and do not adequately anticipate rapidly growing network needs; pathway design needs the attention of network planners who are fully up to date with current and future campus network needs.



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Cabling. Both within-building and interbuilding cabling should consider telephone and cable TV as well as data needs, and different kinds of cables are often pulled or even bundled together. Cable has a long useful life, 10 years or more, but even so will eventually need to be renewed. A key point is that the most common problem with network planning is misunderstanding or not taking seriously the useful life of cabling (and other components) and failing to plan to renew at the end of that useful life. The application of the guiding principles to cabling is a balancing act between the characteristic of pathway of a very long useful life and the characteristic of network electronics of a short life and frequent technology changes.

Network electronics. Network electronics are the electrical devices that turn cables into a network, for example, Ethernet hubs and switches. Because these are essentially specialty computers, network electronics evolve quickly, improve in price/performance quickly, and have a correspondingly short useful life, typically three years. In terms of the *value-based investment* principle, network electronics can be quite easily replaced with new electronics to provide faster speed or other improvements, assuming the network protocols do not change. Individual units can be replaced to provide new functionality or service to one subset of the campus network without requiring changes to the rest of the network and usually without requiring changes to end user machines.

Protocols. With regard to protocols and the *open standards* principle, the Internet protocol (IP) wins! Essentially all network-based applications are converting to run over IP networks. There is no need to consider other protocols for the foreseeable future. This provides an excellent example of how quality open standards outperform proprietary standards for mainstream needs. Looking at this industry standard protocol through the lens of the *commodity goods* principle, network electronics are commodity goods, and prices for hubs, switches, bridges, routers, and so forth track along the lines of the fast improvement of hardware price/performance. In terms of the *continuous renewal* principle, a new version of the Internet protocol, IP V6, will gradually phase in to increase capacity and management options in IP networks, but this introduction will coexist with existing networks, allowing network managers to plan this upgrade in the natural course of network renewal.

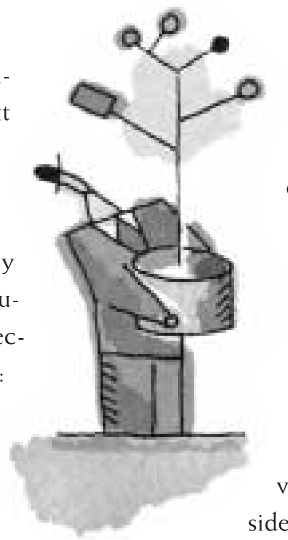
Possible "killer applications" that could impact network capacity in the future—as did the emergence of the World Wide Web six years ago—include full-motion digital video over the data network or a shift in the underlying network to support guaranteed response such as is needed for real-time process control. Each of these has the potential to drive new technology and possibly protocols, but each is already in use to a limited degree and networks are already preparing for their increased demands. By definition, it is difficult to foresee these kinds of applications, but one is likely to emerge again in the next 5 to 10 years. When it does, assuming the standard building block design does not change, pathway needs and cabling demands will not change radically although a new killer application could accelerate a migration from copper to fiber station cabling. What is most likely to change are network electronics, the number of cables used, and possibly network interface equipment in the instruments (computers or phones) themselves. All of these are subject to regular change anyway. A well-designed network should be able to accommodate these changes more or less gracefully, possibly with an extra investment to accelerate turnover of equipment or to add new cables.

The Internet2 effort provides a useful illustration of these principles applied to future developments: national network traffic has been doubling roughly every six months since the founding of NSFNET. The Internet2 project will attempt to develop applications and technologies for next-generation national backbone networks that will be able to accommodate traffic needs for the next decade but that will do so using standard campus connections and technologies. Any new Internet2-style services may require new protocols, but routine upgrades in campus connection bandwidth will be just that: routine.

Voice, Video, and the Specter of Convergence

The guiding principles apply as much to development and management of voice and video networks as they do to data networks. Existing voice and video networks, however, are using mature technology which is changing far less rapidly than data network technology, so the time scales for useful life and continuous renewal are generally far longer than for data. *Outsourcing* is appropriate for a mature technology when program activities would not be compromised, and both traditional voice networks and video networks based on cable-TV technology may qualify for consideration. Even so, many campuses have historically insourced these networks for either of two reasons: (1) a campus-based service could provide better function and/or lower cost through a local switch or more responsive service than a commercial phone or cable company could or (2) margins on these services, e.g., telephone long distance, were high enough to sustain needed investment in voice, video, and data networking infrastructure.

Technically, voice, video, and data networks will converge: technology exists at this writing to deliver all these services on a data backbone network.



With maturity in these technologies and commercial competition, full function and responsive service are increasingly available from commercial providers in some geographic areas. Competition has also driven down margins on long distance and cable TV service, eroding a source of network investment whether insourced or outsourced. For these reasons, many campuses that currently insource voice and video are considering the economics and service options of outsourcing.

The *outsourcing* principle requires that any outsourced service will still require campus-based planning and management. Most outsourcing failures result from a mismatch between campus needs and the outsource service agreements and management plan. While outsourcing voice and video has seemed increasingly attractive over the last few years, a new development is giving pause: the potential for convergence of these networks onto a single network infrastructure.

Technically, voice, video, and data networks will converge: technology exists at this writing to deliver all these services on a data backbone network. But standards for service and reliability suggest it will be some time, certainly five years, probably longer, before fully functional and reliable voice and video comparable to current analog-based services can be delivered.

Potential advantages of a converged network are compelling. For example:

- A common cabling infrastructure would eliminate costly individual voice circuits in the network core.
- A single qualified installer could efficiently install all three services in a single visit.
- Costly traditional specialized telephone and cable electronics would be replaced by highly competitive data network electronics where costs continue to drop rapidly.
- A single network operations center staff and tool set could diagnose problems across all services.

Realities, however, are likely to temper some of these potential advantages, and experiences with other new technology architectures suggest that some critical issues very likely remain hidden. For example, an equally compelling set of advantages motivated the industry shift from terminal-to-host computer systems to client-server computing. Most industry analysts believe this shift is appropriate and in the end will yield the promised benefits, but the shift has been far more costly and drawn out than industry promoters suggested. Migrating to a converged voice, video, and data network is comparable to the migration to client-server and is likely to incur comparable false starts, hidden costs, and delays.

The biggest impediment to convergence is easily understood: in its 100-year history, the voice industry has achieved the so-called "five-nines" standard of service and reliability, that is, the service works 99.999 percent of the time. Although many individuals will tolerate relatively poor voice service to make a single Internet-based voice call, that does not suggest that institutions could run their business with even a 99-percent voice service standard. The core of any converged network will be data network technology, which today is very far from providing even a 99-percent reliability record. The data network will need massive investments in improved and fully redundant switches before it can approach the reliability of today's voice or even video networks.

Even when data technology can provide high reliability, a converged network will have to consider issues such as how end users can report a problem if the network is down; inventing and acquiring new diagnostic tools; training staff; and much more. No doubt these issues will be solved over time, but experience with massive shifts in core technology in other areas suggest that convergence will take some time to evolve, so campuses will likely need a hybrid plan during this transition. Informed by the guiding principles, such a hybrid plan is likely to include strategies such as:

- Piloting converged technology where it makes most sense—in remote locations where the cost of running separate networks is highest and the choice may be service via a converged network or very expensive commercial service (for example, service to a remote building on or off campus).
- Using converged technology to address isolated needs within a system where commercial products and successful reference sites exist (for example, trunk lines between separate campuses).
- Maintaining a full complement of analog voice and video services but minimizing long-term commitments to major equipment expenses (for example, telephone switches).
- Developing a flexible plan calling for increased use of emerging converged technologies based on service (not technology) milestones.

As always, such strategies need to be informed by how aggressive an institution wishes to be relative to leading-edge technologies. For example, an aggressive campus may prefer to limit voice and video service commitments to 5 years rather than investing significant capital which might take 10 years to pay back.

Future Technology: Wireless Issues

Cellular technology is certainly not a future issue; it is already on campus today among faculty, students, and staff, but the full implications have yet to unfold. Some trends are already apparent: cellular technology works very well and scales successfully. Some individuals will move away from wired phones completely, but that will not relieve a campus from providing wired phone capability for the indefinite future. Cellular phone plans often provide free long distance and this is likely accelerating the decline in campus long distance revenues, particularly among students. There is also some significant adoption of cellular data services, but data entry, small screen, and bandwidth issues suggest this will not soon become a substitute for a full-function data connection.

Wireless LAN (local area network) data technology is less mature and the prospects are correspondingly less certain. To date most individuals want even their "wireline" data connections to be faster, and current evidence suggests that wireline data connections will provide significantly faster speeds than wireless for the indefinite future. This technology, however, provides significant convenience when wireless speeds are good enough to meet particular needs. Depending on network engineering, current wireless LAN technologies (802.11) can provide good e-mail and Web browsing service but most clients will prefer wireline connections to support streaming media and bulk file transfer.

Applications for wireless LAN technology that have already demonstrated success or show great promise include:

- data access for particularly difficult-to-wire locations including, for example, classroom and lab settings and library stacks;
- data access for wide open spaces, indoors or out (for example, courtyards); and
- convenient data access everywhere, for example, across an entire campus.

Current wireless LAN data radio spectrum tends to be absorbed by steel, concrete, paper, and books. The future adoption of wireless LAN beyond open spaces will very much depend on future technology developments.

In the next few years all schools are likely to adopt wireless LAN in some locations to meet particular needs but it will not be a substitute for a wired infrastructure for the foreseeable future. Between these two extremes, it is not possible to forecast client preference for convenience versus state-of-the-art performance in the face of rapidly developing wireless LAN technology. Commercial practices are also likely to affect speed of adoption; for example, interest would grow rapidly if Internet service providers began to offer wireless LAN services in airports or public spaces.

These various wireless services also raise business opportunities and issues regarding partnering with wireless vendors to

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Avoiding Problems in Implementing Administrative Systems

When software implementations go bad, the temptation is to blame the software. Some faults do indeed lie there, but many others lie in our administrative decisions. This article examines four aspects of administrative systems implementations that administrators need to understand to avoid implementation pitfalls.

by **Joel M. Smith**

The September 24, 1999, article in *The Chronicle of Higher Education*, entitled "Delays, Bugs, and Cost Overruns Plague PeopleSoft's Services," reported on the frustrations that administrators at a number of institutions have experienced in implementing a new generation of administrative software from PeopleSoft. In fact, similar frustrations have plagued institutions implementing commercial student administration, financial, and human resource systems from the time they became a viable alternative for colleges and universities to locally developed software.

As the article noted, a number of structural features of that class of software, often known these days as enterprise resource planning or ERP software, can lead to cost overruns and dissatisfaction with the results of its implementation. Those features include the software's complexity, the difficulty of deciding about initial configuration options, the dangers of choosing to customize the software, and the realities of coping with bug fixes and updates to the software. However, the article did not give details about how to avoid or at least mitigate the problems it described.

Even worse, without more detailed information about the challenges of implementing ERP systems, the article might lead an administrator new to dealing with this class of software to the incorrect conclusion that he or she must simply choose the right software, that is, something other than PeopleSoft, to avoid the problems described. That conclusion would be unfair to PeopleSoft, a company that has worked closely with higher education to produce high-quality, innovative products for our purposes.

More importantly, the notion that there is a product from any vendor that will work right out of the box with few dangers of cost overruns or of dissatisfaction with the results is simply mistaken. Administrators who reach that conclusion will make bad decisions for their institutions. Many of the dangers described in the article are inherent in the nature of this genre of software. Installing a complex administrative software system that is sufficient to meet the needs of a modern college or university requires more sophisticated knowledge and tactical decisions from us than have been required of college administrators in the past.

While it would be nice if we could depend on software vendors to educate us about the prerequisites and ramifications of implementing, maintaining, and using their products, we cannot. Salespeople say what we want to hear. For example, they often emphasize the very features of the systems—for example, ease of customizing the products to the potential buyer's current business practices—that will lead to serious problems down the road. They know we want to hear that we really don't have to change our ways to use their software.

Nor can we depend on the consulting firms that make their living implementing administrative software to give us the complete story about deploying the systems. After all, by far the biggest cost in any such implementation is often the exorbitant fees we pay consulting firms to help us set up and customize the software. Although they can be valuable partners, their interests do not always coincide with ours. Even the use of consulting firms at the beginning of the process cannot guarantee good cost estimates or risk assessments. The actual costs of implementation will not emerge until a detailed analysis is performed of how well the "vanilla" system fits your needs. This is usually a part of the implementation process that can take weeks or even months. Vendor or even third-party estimates of costs made without this information are often gravely mistaken. Ultimately, we have to depend on ourselves to know about the strengths and weaknesses of the software we are considering and about the inevitable risks and high costs of the process.

There are a number of good software systems, including PeopleSoft, that institutions can purchase. The problem is that it is all too easy to implement any of them using strategies that will lead to both short- and long-term problems. To prevent the problems, administrators need to understand the complexity of the systems; the dangers of customization; the critical nature of documentation; and the real costs of institutional staff time that must be devoted for the project, training, and the loss of key personnel.

System Complexity

First, the software packages are complex systems. Changes made to computer code or database structure in one part of the system can affect other parts. That is both good and bad news. It makes fixing some problems easy. One community college in California solved performance problems throughout its PeopleSoft system by making fairly simple changes in the programming commands that put data in and retrieved data from the underlying Oracle database. But changing code to fix one part of the system can produce problems in another part.

Knowledge of that aspect of large-scale software should result in some concrete administrative strategies. Changes to the software must be made serially, be heavily documented, and be tested carefully for unexpected consequences. If the staff of a consulting firm or the institution's own information technology (IT) staff is allowed to operate in any other way—for example, to make many changes at the same time or to fail to document changes carefully—unexpected problems and cost overruns are likely to occur.

Dangers of Customization

Second, implementation decisions must be made with future maintenance in mind. Failure to understand that fact is the most serious mistake administrators can make in implementing such software. For example, PeopleSoft allows the customer to customize its software or to create new applications to use alongside those that the company has developed. All commercial administrative systems either permit or require customization. Meeting your own business and student service needs is very likely to lead you to choose to customize the software.

Customizing a commercial application creates significant difficulties when the vendor releases a new version.

However, customizing a commercial application creates significant difficulties when the vendor releases a new version. That version might contain new features that conflict with the changes you have made or that remove structures you have depended on in your customization of the product. If you have customized the software, your IT staff will have to spend a great deal of time evaluating the relationships between your customizations and the vendor's changes before you can proceed with any upgrade. The more changes you make, the more time it takes to go through the process every time you upgrade your software.

Even though PeopleSoft provides sophisticated tools to help with the process of comparing your software with the new version, upgrades of extensively customized systems can take months. That is true for all of PeopleSoft's competitors too. If you don't have enough IT staff members to perform the upgrades, you will have to pay for high-priced consulting help.

Here again, knowledge of the details should lead to concrete strategies. You should change your business practices to match your software instead of customizing the product. That is going to be uncomfortable for many staff members, but not as uncomfortable as not being able to upgrade or patch the software because you don't have the resources to update a customized product.

Any good software will include ways to tailor it to your needs that don't involve customization. For example, with PeopleSoft you can write your own self-contained subsystems that don't cause the difficulties described above at upgrade time. In any system, you can use the report-writing tools to create custom reports that extract just the information you need from the system without customizing the software.

Documentation

Third, documentation of set-up decisions and changes is critical to a successful implementation. That may sound obvious, but the reality is that neither consultants nor information technology staff members like documenting, so it seldom gets done well, if at all. Poorly documenting the implementation of a complex administrative software system leaves the institution at the mercy of IT staff members, who are notoriously difficult to retain these days. Even worse, failing to create clear, usable, comprehensive documentation means that the software cannot be upgraded without figuring out how it was set up in the first place, which takes time and money.

Real Costs

Fourth, it is easy to misestimate the amount of time that the institution's own staff will have to devote to changing from a legacy to a commercial system. When you are paying consulting partners millions of dollars for the implementation, you might think that will be almost the entirety of the personnel costs for the project. The reality is that internal staff both from the IT groups and from virtually every office in the college or university will have to work side by side with the consultants in the implementation. Many will need to devote between 25 and 90 percent of their time to the project for varying periods of time. Temporary staff must be hired to backfill the internal staff who are working on the implementation. The result can be a significant cost overrun. The strategy should be to develop painfully realistic projections of the amount of time institutional staff will spend and the real costs (including recruiting and training costs) of backfilling their positions.

Training for both IT staff and users of the system will exceed your initial estimates. The strategy of training only a few staff with the expectation that they will return to train their fellow workers succeeds only if the returning staff are good trainers. Since it is seldom the case that they were hired for this talent, it is unlikely that many will be either good at or comfortable training their peers. This means that far more people will have to be sent away to the vendor's training than originally expected. A training plan for everyone on campus who will either support or use the new system should be part of the original cost projections.

Finally, any such project is vulnerable to the risk of losing key personnel. This means that plans for redundancy for everyone in the project—from the project manager to the database manager to the person in charge of posting progress reports on the Web—should be built into the plan and the costs of the plan from the beginning. It's cheaper in the short run not to create redundancy; in the long run, depending on your luck, it can be far more expensive.

When software implementations go bad, the temptation is to blame the software. Some faults do indeed lie there, but many others lie in our administrative decisions. We expect complex software systems to work right out of the box. We fail to arm ourselves with an understanding of the details of the systems we have chosen. We train our staffs insufficiently or incorrectly. We choose the comfort of customizing software to the way we've always done things over the difficulties of using the basic, easily upgradable product. We let staff members get away with poor documentation. We turn too many tasks over to consultants so that our staff members are lost when the consultants leave.

The technological sophistication required to implement administrative software is greater than that to which academic administrators are accustomed. But no piece of shrink-wrapped software alone can provide the functionality we need to serve students who live in the information age. We have to develop the more complex strategies required to implement and manage the tools of that age.

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provide/ensure campus coverage and potentially to share in risks and rewards. The key is to remember how quickly technology changes and that vendors come and go quickly as do substantial revenue streams.

The good news is that there is nothing mysterious about preparing a college or university for a networked future: a campus network can develop and grow according to well-understood principles in an orderly, well-coordinated process of planning and implementation. Today's campus leader, while having little need to be an expert in network technology, must nevertheless take personal interest and provide attention to ensure that this happens.

Endnote:

1. This article was adapted by the author from a chapter he authored in Mark A. Luker, ed., *Preparing Your Campus for a Networked Future* (San Francisco: Jossey-Bass Publishers, Inc., 2000). The book is available from EDUCAUSE (for ordering information, see http://www.educause.edu/pub/pubs.html#books) as well as from the publisher (see http://www.josseybass.com/). The material will also be included in a chapter of *College and University Business Administration*, to be published by the National Association of College and University Business Officers.

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