CAD standards and the institutions of higher education

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Abstract

This paper focuses on the need, development and implementation of CAD standards for institutions of higher education. To efficiently communicate planning, design, construction, and management information among the internal and external parties involved, thousands of these highly complex organizations worldwide are in need of CAD standards. These standards are instrumental in consolidating information; originating from operational and academic units of a university, they constitute the backbone of the Facility Management Information System (FMIS) and eliminate necessary conversions and duplication of efforts. This paper highlights the theoretical underpinnings for standardization and illustrates the strength and weaknesses of various standards and implementations in CAD and their uses in the Design Information Management component of a university FMIS. Although the paper concentrates on design information management, the very same standards are useful both in construction and in management information activities.

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Introduction

CAD is best understood as a design information management system. It is a tool, with which full-size, two- and three-dimensional graphic simulations of a building-site can be created. In turn, these simulations are used, shared, published, reused, and republished in various formats, views, scales, and levels of detail by those involved in planning, programming, designing and managing facilities. CAD drawings are not static collections of information, but dynamic documents that share information with other drawings, projects and applications. As their usefulness extends beyond simple documentation, CAD documents also may contain supplemental annotation, such as marginalia (digital "post-it" notes) about the design intent that is useful to store internally. In practice, most designers tend not to include such information naturally in the finished model or plotted drawings, because a technical representation is usually viewed as a finished product, not an evolving document. In fact, the plotted CAD drawing is just a filtered snapshot of a planning-design-management process at a specific point in time. In this continuum, CAD drawings are only considered as dynamic graphic databases, where the organized, standardized technical facility information resides.

Design information management system for higher education

Universities incorporate complex building types and spaces that are more varied and complex than those of an average corporation. This complexity is even further compounded in the case of multi-campus universities where each location may have special programs for its own unique facility management requirements. Many institutions of higher education have been using CAD not only for instructional purposes but also to literally draw their campuses. The least efficient way to use CAD is as a digital pen, simply emulating traditional methods of drawing and annotation. In different types of organizations, but especially in organizations of higher education institutions, CAD is best

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used as a design/facilities information management system, where numerous departments use facilities information for different purposes. Examples from the field are architectural design, engineering, physical plant, maintenance, custodial services, telecommunications, physical safety, and classroom scheduling, among others. Needless to say a drawing that the department of telecommunication uses to indicate the data lines, linkages, and communication hubs is quite different from a basic construction document submitted by outside contractors to architectural/engineering services for review and approval. In the past, because of the different physical appearance and the information contents of these drawings, it was justified to redraw plans many times over and maintain multiple file systems and standards. Today, however, one general purpose graphic database, prepared according to the appropriate CAD standards, can easily combine all the facility information needed on the campus and can be made accessible by a central unit, most preferably the FM department. This is analogous to combining multiple spreadsheets of various departments into one centralized database, which can be accessed by all parties that function under entirely different objectives of their own. In this respect, a common CAD database has the potential to benefit the entire campus operations. The information contained in these databases is shared and reused, as depicted in Figures 1-3. A uniform set of CAD standards, to which all departments and contractors adhere to avoid duplication of efforts, is the key to success in an institution of higher education, as well as in any similar organization (Erdener and Gruenwald, 1997).

Standards

Since clear communication of the design intent is the objective of drawings, standards should be simple, appropriate and economical. If simple, standards will be quickly understood by all parties that use the system and its information. In being appropriate, the standards must be to the point, relaying a message but not more than the message itself. Economy of time in preparation, use, and the required storage capacity, must also be considered in the design of standards (Berg and Berg, 1992).

CAD standards benefit

While drawings themselves are a creative expression, standards help unify the set of drawings into a whole, while eliminating petty decision making, allowing the designer to apply his/her creative energy to the building design, facilitating cross-referencing and retrieval of information from the drawings, and scheduled updates.

Figure 1 Information reuse – a basis for standards

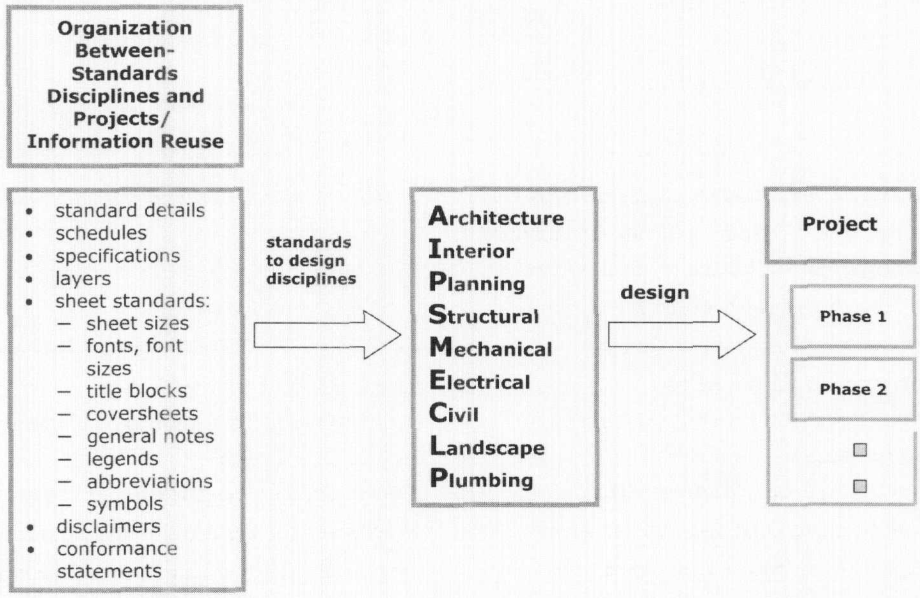

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Figure 2 Information reuse between project phases, drawings, and parts of a drawing – a detailed basis for standards

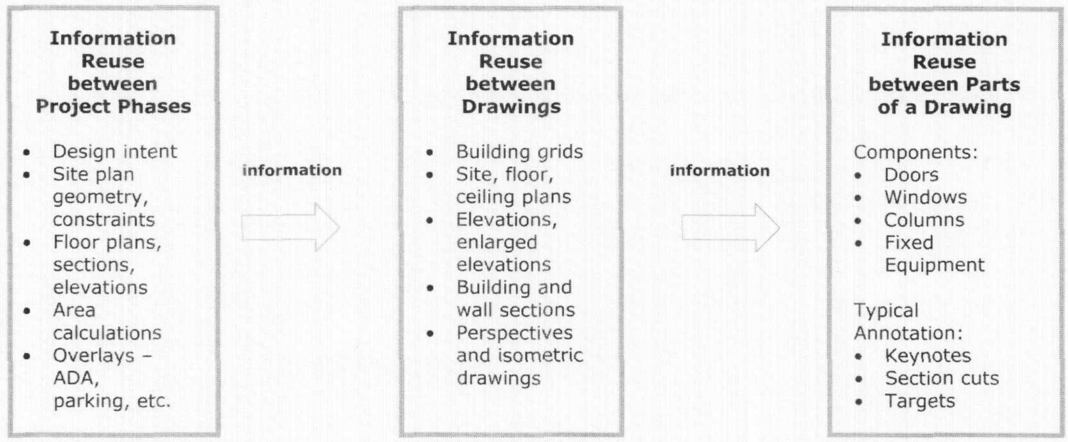
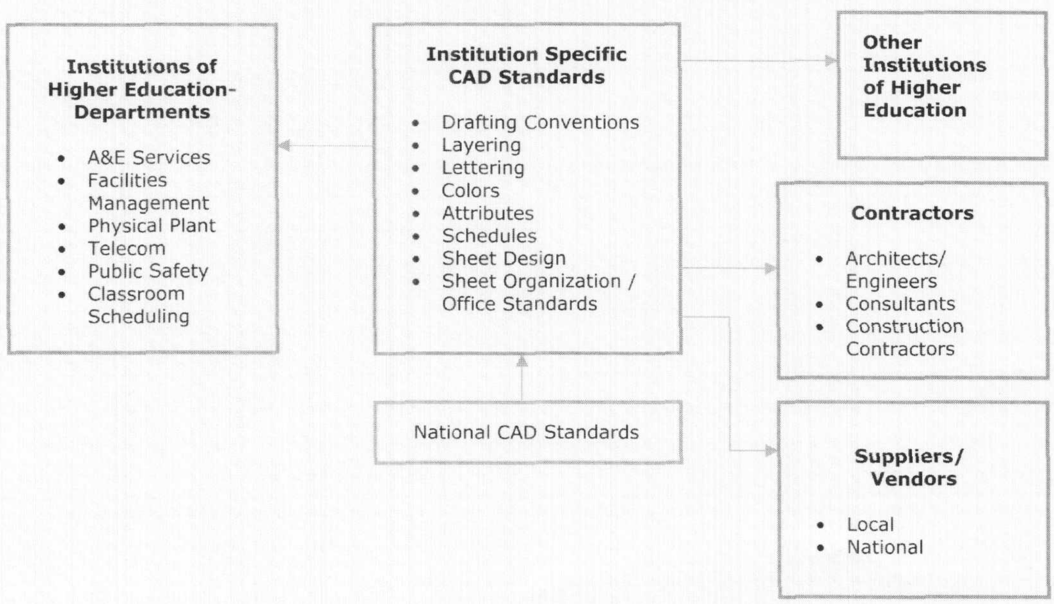


Figure 3 The departmental use of CAD standards within institutions of higher education and external parties



CAD standards can make facility information quite efficient, in terms of accessibility, usability and inner organization, as explained below:

- Drawings will be more consistent, meaning cleared communication and less time spent to correct misunderstandings.
- Drawings will be better organized and have less duplicated, conflicting or misplaced information, that can mean fewer errors and omissions.
- Drawings will be more convenient for almost all users.
- Drawings will be a convenient, comprehensive off-the-shelf resource available to in-house users and sub-contractors.
- Drawings created by vendors and consultants are already in the correct layer standard.
- Drawings will use a nationally recognized layer standard with a hierarchical format following the *AIA CAD Layer Guidelines*.
- You will be able to easily maintain your layer standard 100 per cent of the time without layer names.
- Layer name descriptions and properties are stored in an external file, avoiding the consequences of loading all layers into a prototype drawing.
- Will enable new and current users to instantly locate the layer they need by an on-screen description without having to stop production to look it up in a manual.

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- The ability to instantly update the layer standard (including descriptions) for all users without having to reprint and redistribute a layer standards manual.
- Will allow vendors and consultants from across the country and elsewhere in the world to easily receive or download from the Internet the up-to-date electronic layer standards, including descriptions. They then can quickly plug it into their system and maintain the layer standard.
- Creation of user-defined, special purpose layers that can be saved with a description, allowing other users to use it for the same purpose in the future.
- Easy to print a hard copy of the up-to-date layer standard with layer name, description, colors and line type (Pipes, 1985).

CAD standards and the design process

The design process involves several steps, ranging from program development, schematic design, design-development, to construction documents. Established primarily for working drawings, graphic standards provide a greater level of detail than is necessary in the schematic design phase. Inclusion of detailed information, such as door type and hardware that are based on decisions not made in the initial design phase, will slow down the CAD design process. Thus, it is important to have an open-ended standard that allows additional information to be added to the graphic database, as it becomes relevant and available as design progresses. As the scale of a drawing increases from one design phase to another and the detailed decisions are made, the amount of information to be included in the database increases. This ever increasing information complexity is at once a tool of buildability (design), reality (as built), and credibility (accuracy), which represent the effectiveness of the FM department in any college/ university. This attention to detail is most critical when drawing the thickness of those materials that are cut in plan. Careful attention should be paid to wall and door thickness, wall terminations, corner conditions, and stair details (Stitt, 1994; Jacobs, 1991).

Colors

While the use of color is most often thought of as an enhanced visualization tool, both for rendering and for two-dimensional line drawings, its use is visually essential in the identification of parts, assemblies and systems in complex drawings. Adding color to the display allows one to include considerably more information on a common drawing. For example, furniture, walls, ceilings, electrical and plumbing systems can be displayed clearly in color, while they overlap and are completely unreadable in black-and-white drawings (Harper, 1968).

Reference files

Reference files are simple pointers to other CAD drawings. Each time a drawing is opened, each of its reference files is opened as well, so each reference file reflects its most current state. The simplest use of reference files in architectural drawings is sheet borders, title blocks, and floor plan grids. Reference files are the key tools for producing architectural drawings that contain redundant information, such as ceiling plans and enlarged floor plans. The enlarged plan can exist as a separate drawing and reference shared information as required from the overall floor plan (Feldman and Feldman, 1996).

Components

Components are named reusable sets of data that are copied multiple times within a drawing. They behave like digital rubber stamps but are more flexible and powerful compared with their counterparts in manually prepared drawings. Various CAD systems have different names for components, such as blocks in AutoCAD, cells in Microstation, or symbols in most other CAD systems. Components are an efficient way to manage repetitive parts of drawings, such as doors, windows, fixtures, targets, labels, or grid bubbles. When a component instance is placed on a drawing, only the location, scale and rotation of the instance are added to the drawing file, but its definition (the elements that comprise it) is stored only once. Most CAD systems even allow components to be

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nested, which means that their definitions can contain other component definitions. The definition of a local component resided inside the drawing, whereas the definition of global components resides outside the drawing and is dynamically updated each time the drawing is opened. Components also can have attributes, such as part numbers, product description and price. This can be a helpful tool for both cost estimating and inventory control.

Layering guidelines

Layers are the basic organizational structure of most CAD systems and allow selective filtering, viewing, sharing and plotting of graphic information. The classic analogy is a sheet of mylar in an overlay drafting system. Comparatively, layers are more powerful but also more complex. A typical overlay drawing may include three or four sheets of mylar, while a typical CAD drawing includes dozens of layers. Different drawings can be produced from the same building model by turning layers off and on and by sharing the information contained in some layers with other drawings.

Toward a national standard-layering

The National Institute of Building Science (NIBS) has spearheaded the US National CAD Standards Project Committee with members from private industry, government agencies and higher education. The goal was to develop a US National CAD Standard, which is based on the *AIA CAD Layer Guidelines*, 2nd edition, to be compatible with ISO standards.

The latest revised American Institute of Architects (AIA) CAD layering standard is the most frequently used model-layering standard in the design-construction industry. This revised second edition of the *CAD Layer Guidelines* (Schley, 1998) was coordinated between the AIA and the CAD Council – a cooperative group.

The AIA layering format is a system by which different groups of building systems and components are put into major categories or major groups. Each major group is further subdivided into minor groups. Each group represents a layer in CAD. Eight (8) major groups are defined in the *AIA Layering Guidelines*. They are:

(1) A = architectural, interiors and facilities management.
(2) S = structural.
(3) M = mechanical.
(4) P = plumbing.
(5) F = fire protection.
(6) E = electrical.
(7) C = civil engineering and site work.
(8) L = landscape architecture.

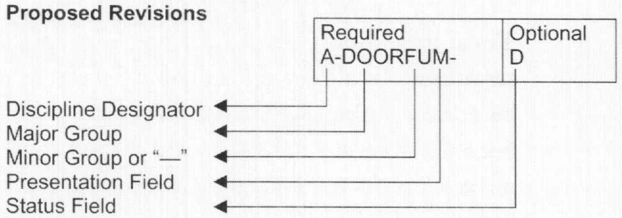
Each major group is subdivided into minor groups. The architectural major group, for example, includes the following minor groups:

- A-WALL = walls.
- A-DOOR = doors.
- A-GLAZ = windows, window walls, curtain walls, glazed partitions.
- A-FLOR = floor information.
- A-EQPM = equipment.
- A-FURN = furniture.
- A-CLNG = ceiling information.
- A-ROOF = roof.
- A-AREA = area calculation boundary line.
- A-ELEV = interior and exterior elevations.
- A-SECT = sections.
- A-DETL = details.

Proposed revisions are shown in Figure 4.

Figure 4 Proposed revisions

Proposed Revisions



Information	Proposed US National CAD Standard
• Title Block	A-ANNO- -PQ
• Text & Drafting Symbols	A-ANNO- -MS
• North Arrow	A-ANNO- -MS
• Doors	A-DOOR - -M -
• Floor Information	A-FLOR - - M -
• Overhead Items	A-FLOROVM-
• Plumbing Fixtures	A-PFIX - - M –
• Dimensions	A-ANNO- -MD
• Door & Window Headers	A-DOORHEM-
• Interior Notes	I-ANNO - - MS
• Interior Dimensions	I-ANNO- - MD
• Doors	I-DOOR- -M -
• Floor Information	I-FLOR - - M -
• Casework	I-FLORCAM-
• Room Numbers, names	I-FLOR- -MI
• Recommended designations for architecture, engineering and facilities management	

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Each group is placed on a single CAD layer and each layer is labeled using consistent, easy-to-remember AIA abbreviations. Flexibility and power AIA layering format allows the user maximum flexibility in viewing, altering and printing plans. Using this system, the user can view and modify only those items relevant to the issue at hand.

There are other layering standards that are less frequently used or apply to other industries or countries. Fourteen countries, including the USA, were involved in the development of the ISO format. The format was developed over a period of several years and in strict accordance with the ISO consensus rules. The standard has been adopted by most of the participating countries with the notable exceptions of the USA and Germany. The format was intended to support multiple needs not only for today but also for the future.

Another such set of standards was introduced by the Construction Specification Institute (CSI) under the title of the uniform drawing system (UDS), organized around the following sections.

The uniform drawing system (UDS)
- Drawing set organization.
- Sheet organization.
- Schedules.
- Layering.
- Drafting conventions.
- Attributes.
- CAD standards.
- Color (CSI, 1997).

Drawing set organization

The drawing set organizational module establishes standard discipline designators for each discipline, such as A for architectural, as well as for unique types of construction elements in addition to the order of presentation of these disciplines within a drawing set. UDS also establishes modifiers for each designator, allowing for more detail if required by the project. The standardized drawing set has the following sections in the given order:
- A = architectural.
- E = electrical.
- M = mechanical.
- L = landscape.
- P = plumbing.
- S = structural.

Sheet organization

UDS establishes consistency through the use of standard sheet types that are common to all disciplines. Sheet types are classified as plans, elevations, sections, large-scale views, details, schedules/diagrams, and three-dimensional (3D) representations. These classifications create consistency in the organization and use of the drawing set. A numerical sheet type designator is assigned to each sheet type classification.

Drafting conventions

The drafting convention module is a joint effort of the CSI and the Tri-Service CAD/GIS Technology Center. It addresses standard conventions used in drawings including symbols, material indications, line types, dimensions, drawing scale, diagrams, notation, and abbreviations and terminology.

Attributes

The Tri-Service CAD/GIS Technology Center is responsible for the Attributes Module, with input from the CSI. This module provides a standard for attributes to organize and format textual information as linked to graphic representations used in construction documents within a CAD environment.

Uniform drawing system (UDS)
Construction Specification Institute task force includes:
- American Institute of Architects (AIA).
- Construction Specifications Institute (CSI).
- Certified Construction Specifiers (CCS).
- Certified Construction Contract Administrators (CCCA).
- National Institute of Building Sciences (NIBS).
- Sheet Metal and Air-Conditioning Contractors National Association (SMACNA).
- US Coast Guard.

Sheet design guidelines

The standard sheet layout should include standards for line types, text, notations,

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dimensioning and abbreviation terminology. The most obvious standard is the title block on each sheet. Title blocks identify the work with a particular firm. Parties having an interest in the project will refer to the name, address and phone number of the firm or department. There should be room for job titles, sheet numbers and professional seals. The drawn-by and revision dates are also essential parts of the title block. Job titles fit into the title block and serve to identify each sheet as a portion of the contract documents. For this reason, each job title should follow exactly the same format and should include name, number, street address and locale. Office personnel use this information for filing.

Standardized lettering

The appearance of drawings can be further enhanced by the use of standardized lettering. This becomes important when more than one department works on the drawings. It is especially important for lettering to be standardized when reduction processes and photographic techniques are utilized. When drawings are reduced, lettering, the characters, the space between characters, and the space between lines of lettering are also reduced. Because of increased use of faxing, copying and reduction techniques, the trend is towards larger, precisely spaced, well-executed lettering to retain legibility of such documents (Kennedy, 1986).

Prototype drawing

This should include:

(1) Standard coordinate system:
- paperspace;
- user defined coordinates;
- world coordinates.

(2) Prototype drawing file:
- standard prototype drawings;
- for various applications.

(3) Standard sheet sizes and formats:
- sheet sizes 8½" × 11" – 24" × 36";
- title block.

(4) Graphics:
- company logo;
- text;
- font;
- style;
- size.

(5) Dimensioning:
- dimensioning scheme for various drawing types/applications.

(6) Fill and hatch:
- hatch patterns for materials.

(7) Line types:
- style;
- weights;
- colors.

CAD standards

The CAD standards module addresses various CAD-specific practices including reference files, presentation and model views, pen assignments, plotting guidelines and data exchange standards. This module is a joint effort of CSI, AIA, Tri-Services, and the US Coast Guard Civil Engineering Technology Center.

University CAD standards – examples

A large Midwest university has organized its ongoing facility information management efforts around creating a Web-based graphic database through its Local Area Network. Combined with intelligent links to existing departmental databases, and a construction project/scheduling application, that altogether constitute a centralized data-retrieval system, the system is used by a large number of departments for a variety of reasons, ranging from facility management, facility audits, to emergency response.

The established CAD standards, policies, procedures, and the current university facility data of this institution are accessible on the Web to consultants, professionals, university departments, and to other institutions of higher education.

The facility data are used for the following activities by the following departments on campus:

- design and construction management;
- facilities operations;
- networking and telecommunications services; and
- office of institutional research and planning.

Other university departments currently using the system:

- school of architecture;

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- athletics department;
- campus police; and
- administration department.

Some of the external parties using the system include:

- architects;
- engineers;
- other universities; and
- construction companies.

Having been quite active in the development of CAD standards and facility data, another US university has recreated the drawings of its campus buildings in CAD that makes changing, modifying, and updating facility information efficient in the virtual environment. The space/facility information database is available to the campus systems used by different departments for different purposes. Some of the services extended to users of this database are:

- campus maps documentation and maintenance;
- facilities inventory documentation and maintenance;
- "as built" drawing format standards;
- space utilization;
- CAD/database systems management;
- systems installation and maintenance;
- budget development and tracking;
- status reporting;
- consultant contracts (as required);
- coordination with campus development and project management processes;
- capital projects budgeting support;
- strategic planning support.

Conclusion

Because it is in graphical form, facility information no longer has to be hosted by the architectural/engineering (A/E) services in colleges and universities. Some institutions jumped to the other conclusion, that it should belong to telecommunications and computing services, as the information is now in digital form. No matter who maintains the database, a uniform standard should allow the sharing of information among the units of any organization (Goumain, 1989).

With the advent of the World Wide Web, communication methods and speeds have been changed forever. To share both public and privileged facilities information with a wider institutional constituent/client-base, CAD drawings are the graphical database format of choice. Today, the institutions of higher education are held, to an even higher level of accountability than ever before. These organizations are expected to be efficient in all types of services they offer, including designing, constructing and managing their facilities. Using Web-based technologies to create, store, and communicate CAD standard based facility information with any project participant, which consists of designer, consultants contractors and subs, the university is expected to streamline its facility related operations. To do that, it is necessary to establish a common base for professional communication and make its facility information base available on the Web to take advantage of the global competition.

A two-step approach is necessary to make the institutional CAD standards available to internal and external clients. First, these standards and other facility data are to be a part of an information base on the institutional intranet. Second, in case of a project, the university creates extranets (project Web pages) that share the project information among those that compete for the commission in the design bid phase, accessible through a password to the qualified and eligible professionals. The designer firm may take over the project Web page management after the design bid is rewarded. Using the affordable and available universal file formats of the Web, the project team can easily eliminate many communication problems caused by software incompatibilities. These project Web sites function throughout the design and construction phases as information and message centers that speed up the information exchange and eliminate costly paper work management and slow turnaround.

In the new global economy, the benefits of standardization in data creation and exchange are multidimensional, such as attracting a wider user-vendor base at national and international levels, shortened time frames in design, bid and construction phases, and decreasing response time during all the above phases, resulting in effective and timely decision making by all parties concerned (Laiserin, 1999a; 1999b). Increased communication speed and accuracy in the accessibility of facility information-standards not only accelerate the project related phases,

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but also lead to increased decision-making efficiency in other areas of academia, such as space and asset-inventories, classroom scheduling and emergency management. Institutions of higher education benefit not only from improved communication with their constituency, ranging from student, faculty, administrators, to other similar institutions, but also from the enriched communication among the professionals serving the needs of the institutions of higher learning (Mays, 1998). In summary, in the e-commerce-enriched economy, CAD and national-international CAD standards are vital in planning, programming, designing, constructing and managing complex facilities of higher education and eventually become a component of strategic facility planning.

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