University of California, Irvine
Construction Standards and Costs

The University of California, Irvine pursues performance goals in new construction and applies quality standards that affect the costs of capital projects. Periodic re-examination of these goals and standards is warranted.

Construction costs are not "high" or "low" in the *abstract*, but rather in relation to specific quality standards and the design solutions, means, and methods used to attain these standards. Thus, evaluating whether construction costs are appropriate involves determining whether:

- Quality standards are excessive, insufficient, or appropriate;
- Resultant project costs are reasonable compared to projects with essentially the same quality parameters.

"Quality" encompasses the durability of building systems and finishes; the robustness and life-cycle performance of building systems; the aesthetics of materials, their composition, and their detailing; and the resource-sustainability and efficiency of the building as an overall system.

Overall Goals and Quality Standards

UCI, in order to support distinguished research and academic programs, builds facilities of high quality. As such, UCI facilities are designed to convey the "look and feel," as well as embody the inherent construction quality, of the best facilities of other UC campuses, leading public universities, and other research institutions with whom we compete for faculty, students, sponsored research, and general reputation.

Since 1992, new buildings have been designed to achieve these five broad goals:

1. New buildings must "create a place," rather than constitute stand-alone objects – forming social, aesthetic, contextually sensitive relationships with neighboring buildings and the larger campus.
2. New buildings reinforce a consistent design framework of classical contextual architecture, applied in ways that convey a feeling of permanence and quality, and interpreted in ways that meet the contemporary and changing needs of a modern research university.
3. New buildings employ materials, systems, and design features that will forestall the expense of major maintenance (defined as >1 percent of value) for 20 years.
4. New buildings attain exemplary sustainability performance – at least LEED Gold and outperforming California's Title 24 energy efficiency standards by as much as 50 percent.
5. Capital construction projects are designed and delivered within the approved project budget, scope, and schedule.

UCI's goals for sustainable materials and energy performance were adopted partly for environmental reasons and partly to reverse substantial operating budget deficits. The latter problems include a multimillion-dollar utilities deficit that was growing rapidly in the early '90s, and millions of dollars of unfunded major maintenance that was emerging prematurely in buildings only 10-20 years old. Without the quality and performance standards adopted in 1992, utilities deficits and unfunded major maintenance costs would have exceeded $90 million during the past two decades, and these costs would still be rising out of control.

The campus's materials standards, building systems standards, sustainability and energy-efficiency criteria, and site improvements all add cost increments that can only be afforded through aggressive cost management. Institutions that cannot manage capital costs tend to build projects that consume excessive energy, that cost a lot to maintain, that suffer premature major maintenance costs, and that require high costs to modify. Such problems tend to compound and spiral into *increasingly costly* consequences. Every administrator with facilities experience understands this dynamic. Without effective construction cost management, quality would suffer and UCI would experience all of these problems.

The balance of this document expresses the building performance criteria and quality standards generally outlined above, organized according to building systems' component classes. Each section discusses key cost-drivers, cost-control strategies, and important cost trade-offs. Design practices cited are consistently applied, although some fall short of hard-and-fast "rules."

Building Organization and Massing

Construction cost management starts with the fundamentals of building organization and massing. UCI's new structures' floorplates tend to have length-to-width ratios <1.5 to avoid triggering disproportionate costs of external cladding, circulation, and horizontal mechanical distribution. Our new buildings tend to be at least four floors high – taller if floorplate areas do not dip below a cost-effective threshold, and generally taller in the case of non-laboratory buildings (but not so tall that a high-rise cost penalty is incurred). Other design ratios are observed, such as exterior cladding area/floor area <0.5 and roof + foundation area/floor area <0.4.

Architectural articulation is generally achieved through textured or enriched materials, integral material detailing (such as concrete reveal patterning), and applied detailing (e.g., window frames and sills), particularly at the building base. Large-scale articulation is concentrated at the roofline (e.g., shaped roof forms) and at the pedestrian level (e.g., arcades), where it will create the "biggest bang for the buck," rather than through modulating the building form itself. This is more than a subtle design philosophy, as the cost impact is substantial.

Lab buildings completed in the past two decades separate laboratory and non-laboratory functions into distinct, adjoined structures (although such a building may *look* like one structure). Consolidated non-laboratory functions include faculty, departmental, staff, post-doc, and graduate student offices; restrooms; circulation (elevators, lobbies, primary stairways); classrooms, seminar rooms, conference rooms, and social areas designed to foster interaction and to provide safe areas for eating and drinking; dry labs and dry lab-support functions; and general administrative support. Consolidating these functions into a separate structure yields considerable cost savings: lower-cost HVAC (heating/ventilation/air-conditioning) system, wider column-spacing, lower floor stiffness (less stringent vibration criterion), lower floor-loading, fewer fire-control features and other code requirements, steel-framed or steel/concrete hybrid structural system with concrete flat-slab flooring system, smaller footings, and possibly curtain-wall fenestration. This approach usually enables offices to have operable windows.

This two-structure approach can be seen clearly at the Gillespie Neuroscience Research Facility, Sprague Hall, Hewitt Research Hall, Sue & Bill Gross Hall, Natural Sciences I and II, Biological Sciences III, Engineering Hall, and UCI Medical Center's Edward Shanbrom M.D. Hall where consolidating and separating non-laboratory functions saved 8-10 percent in overall construction costs and 15 percent/year in energy expense. (The non-laboratory building incurs a small fraction of the energy expense of the laboratory block.)

Details and Macro-Concepts that Work Synergistically

A set of design strategies, applied in combination, has proven effective in controlling the cost of laboratories:

- Utilizing a consistent lab module
- Utilizing a reasonable vibration criterion and locating ultra-sensitive conditions at-grade or employing benchtop vibration isolation
- Using 22 ft. x 22 ft. column spacing
- Concentrating fume hoods and utility risers into a central "wet zone," thus limiting horizontal mechanical distribution
- Concentrating laboratory support areas into the central core of a laboratory structure, where utilities are available but daylight is not needed, thus enabling lab structures to be 110-132 feet wide
- Utilizing dual-usage circulation/equipment cross-corridors through this central lab support zone, with sufficient width (11.5-12 feet) to load both sides of the corridors with shared equipment while providing cross-circulation through the lab support zone
- Utilizing open laboratory layout with one or more "ghost" corridors for intra-lab circulation
- And, most importantly, concentrating non-laboratory functions into an adjoining, lower-cost structure (as discussed in detail above).

To further control laboratory construction costs, non-standard fume hood sizes are minimized, "generic" lab casework is specified, laboratory-grade movable tables typically alternate with fixed casework in every other lab bay, building DI systems provide intermediate water quality (with localized water purity polishing in the lab, rather than building-wide), facility-wide piped services do not include gases that can be cost-effectively provided locally via canisters, and glass-wash facilities are consolidated – typically, one glass-wash facility for an entire laboratory building.

Finally, our design philosophy leans toward generic, modular laboratories with movable casework and overhead flex-connections for benchtop services, supported by a robust building infrastructure, rather than highly customized spaces with limited capacity to make later changes. This is an important tradeoff. Although some post-occupancy expenses may be necessary to "fine-tune" a laboratory to a principal investigator's requirements, building infrastructure elements – typically oversized 20 percent, including HVAC supply ducts, exhaust system capacity, emergency generator capacity, and electric risers and service capacity – seldom limit the ability to modify labs to meet future researcher needs. And the cost premium for a modular/movable casework system is recovered many-fold on a life-cycle basis.

Structural and Foundation Systems

For both cost-benefit reasons and past seismic performance, UCI favors concrete shear wall or steel braced-frame structural systems. The correlating foundation systems depend on site-specific soil conditions. Past problems with undiscovered substrates and uncharacterized soil conditions are minimized through extensive, pre-design soil-testing. This minimizes risk to both the University and the design/build contractor.

When feasible, design/build contractors are allowed flexibility to propose alternate structural or seismic-force systems. All structural system designs must pass an independent peer review, in accordance with UC's Seismic Safety Policy. This process results in conservative structural design, and an associated cost premium. However, the seismic performance of University of California buildings constructed since this policy went into effect in 1975 appears to substantiate the policy's value.

Structural vibration is carefully specified in research buildings where vibration-sensitive protocols and conditions must be maintained on above-grade floors. The most cost-effective tools to control vibration are generally employed: first, to program vibration-sensitive procedures at on-grade locations or to isolate them at the bench; second, to space columns at a distance that does not entail excessive structural costs. In laboratory buildings, we typically utilize 22 ft. x 22 ft. column spacing. Conversely, where vibration is not problematic, a beam/column system can be cost-optimized and lighter floor loading tolerated. Design/build contractors are, accordingly, allowed more flexibility under such conditions.

To control costs, UCI avoids use of moment-resisting structures; unconventional seismic systems; non-standard structural dimensions; inconsistent, unconventional, or non-stacking structural modules; and non-standards means and methods.

Building Mechanical Systems

For more than two decades, UCI's new buildings have been designed to outperform California's Title 24 energy efficiency standards by 20-50 percent (more recently, the latter). UC Irvine's "smart" laboratory buildings lead the nation in terms of energy efficiency. This comprehensive approach to laboratory energy efficiency is summarized in a related paper describing UC Irvine's Smart Labs Initiative.

Energy-efficient mechanical systems entail a significant cost premium that the campus pays for using savings derived *elsewhere* throughout the project. These higher costs include premium-efficiency materials and components; increased duct, plenum, fan housing, and filter sizes to slow HVAC airspeeds (a primary factor in reducing HVAC energy consumption and operating costs); increased building volumes in terms of riser sizes, mechanical room sizes, and above-ceiling volume as needed for oversize HVAC distribution components; sophisticated, computer-based (digital) controls; and multiple, smaller, occupancy-controlled HVAC zones for control and efficiency. This is just a sampling of the energy-efficiency design practices we employ. In addition, many macro-scale efficiencies are realized at the Central Plant. The latter "count" toward our buildings' LEED ratings.

Other design objectives apply to laboratory mechanical systems, in particular. Safety is of paramount concern. Reliability and robustness are important to a first-rate research infrastructure. Avoidance of major maintenance for at least 20 years is necessary given the University's backlog of deferred maintenance, its underfunded routine maintenance, and its complete absence of funding for major and deferred maintenance. In addition to specifying premium-quality mechanical equipment, we typically install a weather-protection canopy over roof-mounted equipment, which adds years to the useful life of such equipment (even if it is rated for outdoor use).

Another important dimension of mechanical system robustness is the extra 20 percent capacity that is typically designed into primary, core distribution systems and risers, fans, conduits, and mechanical rooms. In other words, the elements that are practically impossible to expand later are intentionally oversized, while easy-to-add items, such as branch ducts and circuits, are *not* oversized.

The UCI concept for a "smart" laboratory building mechanical system is addressed at https://www.ehs.uci.edu/programs/energy/UCISmartLabsInitiative_Feb222016.pdf.

Roofs and Flashings

UC Irvine specifies 20-year roofing systems and stainless steel or copper flashings whenever possible. At a minimum, we specify hot-dip galvanized flashings.

Why this emphasis on flashings? Our roof replacement projects typically double in cost when the old roofing is torn off only to reveal that the flashings have deteriorated. Moreover, many roof leaks of recent years have been due to faulty flashings, rather than roofing membranes or coatings, per se. Saving money on flashings is false economy.

Site Development

In accord with the design goal of "creating a place," most UCI projects include exterior landscape and hardscape elements such as plazas, walkways, seat walls and retaining walls, site lighting, and landscape materials that extend all the way to neighboring buildings. Since there is no capital budget for site development, per se, a new building project provides the "now or never" opportunity to fund site improvements.

We prefer to use interlocking, heavy-duty concrete pavers rather than a poured monolithic material for walkways and plazas, for two reasons: aesthetics and cost. The latter reason centers around long-term costs, as pavers initially cost more than asphalt or concrete. However, pavers cost less on a life-cycle basis, because in a growing research campus practically every walking surface will need to be excavated in order to install new utilities or to fix underground utilities problems. When pavers are involved, the patch is invisible once the job is completed.

The campus uses reclaimed water for landscape irrigation, and landscape materials are specified in UCI's "Green and Gold Plan." These practices have been in effect for two decades and are consistent with the University of California's Policy on Sustainable Practices. Site lighting is provided by concealed-source fixtures, consistent with green building standards. Projects' site development costs include extension of utilities to the project as well as infrastructure capacity upgrades necessary to support a new building.

Exterior Cladding and Interior Finishes

Buildings completed during the past two decades use notably different exterior materials than those completed during the 1980s. Due to stringent capital budgets, many of the 1980s projects used exterior stucco cladding (including Social Ecology, the Paul Merage Graduate School of Management, the Ayala Science Library, and the Physical Sciences Annex). Buildings completed since 1993 are clad with masonry, poured-in-place concrete, and other permanent materials that do not require initial or periodic painting and patching. Exterior plaster (stucco) is now used only as a surface coating over a masonry substrate (as distinct from a lightweight stucco system) or in weather-sheltered areas, such as areas recessed behind an arcade. We do use stucco exteriors in student housing in combination with generous eave overhangs and ample expansion joints.

Buildings completed over the past 20 years have used high-performance glass on sun-exposed elevations, typically specified for a high ratio (~1.5) of visible light transmittance to shading coefficient. (This maximizes useful daylight relative to unwanted solar gain.) High-performance glass and solar shading are our first line of defense in keeping solar heat gain out of buildings at the point of entry. Our buildings use generous amounts of north-facing glass for daylighting. Well-detailed curtain-wall window systems are readily used where cost-effective (e.g., office windows in the Gillespie Neurosciences Research Facility and Sprague Hall).

Design-build teams are urged to evaluate the comparative costs and benefits, on a life-cycle basis, of controlling insolation using exterior shading devices and interior window coverings vs. electrochromic glazing with a down-sized HVAC capacity.

Exterior materials and their application in recent buildings are consistent with a campus design philosophy that has been affirmed by the Regents, UC and campus leaders, and by many members of the UCI campus community. “Classical contextual architecture” derives partly from building forms and detailing, and partly from the consistent use of materials that reinforce a feeling of permanence and quality – architecture that is “institutional” in the best sense of that term.

Interior finishes are typically conventional and employ standard materials, detailing, and means and methods of construction in order to control building costs. Durability is an important goal that leads to such features as quality hardware (e.g., locksets); corner-guards, plasticized coatings, chair-rails, and wall coverings in heavily trafficked corridors; full-height ceramic tile in restrooms; welded door jambs; and institutional quality doors and hinges. We provide more acoustical isolation between adjacent offices than is conventional, and more bedroom and bath sound isolation in residential facilities (although we specify generic acoustical finishes and materials rather than specialized products). New classroom designs apply an extensive set of design standards and criteria in order to attain excellent seeing and hearing conditions as well as modern instructional resources. See “Design Criteria for Effective Classrooms” in the Society for College and University Planning publication, “Special Planning for Special Places.”

Priorities and Trade-Offs

UCI’s building designs intentionally trade off particular design choices and the associated costs in order to achieve priority performance goals and quality standards. These goals and standards would not be attainable within established capital budgets without rigorous cost-control in the areas targeted for intentional trade-offs.

This entire decision-making system and its precepts warrant review, fine-tuning, and affirmation to ensure that capital investment decisions are cost-effective, both initially and on a life-cycle basis. Incidentally, this is not only sound campus policy, but also an inherent part of the UC Policy on Sustainable Practices.

Benefits and Cost-Control Strategies

To review, current practices and standards applied to new buildings' designs at UC Irvine aim to affect the shifts in costs and quality summarized in the following table. There is no way to realize the benefits in the right-hand column without the cost-control strategies summarized in the left-hand column.

Cost-Control and Savings Strategies	Areas Into Which Savings are Redirected
Building ratios for floorplates, exterior "skin," etc. (p. 2) Cost-effective architectural detailing and articulation strategies (pp. 2 and 7) Consolidation/separation of non-laboratory functions into adjoined structure (pp. 2-3) Portfolio of cost-effective laboratory design practices (pp. 3-4) Generic, modular approach to laboratory design (p. 4) Conventional structural, seismic, and foundation systems (p. 4) Close column spacing in laboratory structures and cost-effective approaches to vibration control (pp. 3-4) Exterior stairways Avoidance of custom-fabricated, exotic, specialized materials (p. 7) Conventional interior finishes (pp. 6-7) Generic acoustical materials (p. 7) Curtain-wall window systems (p. 6)	Regents' Sustainable Practices Policy requirements and UCI energy-efficiency objectives, in particular: ▪ "Smart Labs" design standards (p. 5) ▪ Reduced energy consumption and utilities expense (p. 2) ▪ Low life-cycle costs (pp. 6-7) ▪ Durable hardware and interior finishes (pp. 6-7) ▪ Glazing that provides generous daylighting with high solar-gain performance (p. 6) ▪ Small, occupancy-controlled HVAC zones for comfort as well as efficiency (p. 5) ▪ LEED Gold (or better) sustainability ratings (pp. 1 and 5) Robust laboratory core infrastructure systems to support inexpensive future modification and flexibility (p. 5) Durable materials and system quality to avoid major maintenance expenses (pp. 1, 2 and 5) Quality exterior cladding systems (pp. 2 and 6) High-quality teaching spaces (p. 7) Flashings (p. 5) Operable office windows (p. 3) Quality hardscape and landscape features (p. 6) Sound isolation (e.g., between offices), p. 7 Weather-protection canopy to extend life of roof-mounted equipment (p. 5)
Evaluate on life-cycle basis: Eliminate exterior sun-shading and interior window coverings and downsize HVAC (p. 7)	Electrochromic glazing system with "smart" controls (p. 7)

The priorities, trade-offs, and underlying assumptions inherent in the table above should be discussed, understood, and adjusted or reaffirmed periodically to ensure that the University's construction standards are appropriate and that the capital program remains cost-efficient and response to academic needs and priorities. And these standards and quality criteria need to be understood in order to arrive at valid cost comparisons.

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