THE ENGINEERING TITLE ACT STUDY:
The Practice/Title Act Distinction and Protection of Public Health, Safety and Welfare

Conducted for the California
Department of Consumer Affairs

by the CSUS Institute for Social Research
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THE ENGINEERING TITLE ACT STUDY: THE PRACTICE/TITLE ACT DISTINCTION AND PROTECTION OF THE PUBLIC HEALTH, SAFETY AND WELFARE

EXECUTIVE SUMMARY OF SIGNIFICANT FINDINGS AND RECOMMENDATIONS

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In defining the Title Act Study in SB2030, the California Legislature specified a series of tasks that, together, would lead to recommendations for change in licensing the state's engineers. These tasks included:

- Meeting with representatives of the engineering branches and other professional groups.
- Examining the types of services provided by different branches of engineering.
- Reviewing and analyzing educational requirements for the separate engineering disciplines.
- Identifying the amount of overlap between engineering disciplines.
- Reviewing alternative methods of regulation in other states and assessing the impact these regulations would have if adopted in California.
- Describing the manner in which local and state agencies utilize regulations and statutes to regulate engineering work.
- Recommending changes to existing laws regulating engineers after considering how these changes may affect the health, safety and welfare of the public.

Underlying these tasks were several overarching concerns. The first was the amount of overlap between engineering disciplines regulated in California. The second was whether there were sufficient distinctions between California's practice and title act disciplines to justify maintenance of its existing and unique regulatory structure. The third concern was whether this regulatory structure adequately protects the public health, safety and welfare or, more specifically, whether the practice branches of engineering pose more of a threat than the title branches, thereby justifying the practice/title distinction.

Recommendations for change in California's licensing of engineers are grouped under the appropriate overarching concern. Significant findings from the analysis of educational requirements, examination outlines, pass rates, engineering employment and registration patterns, complaints and insurance claims are summarized under the recommendations they support. Comparisons with ten other states and analysis of the treatment of engineering disciplines in California state and county codes and the Federal Code of Regulations were used to create a context for understanding California's licensing system.

OVERLAP BETWEEN ENGINEERING DISCIPLINES

Recommendation #1a: Remove all prohibitions against overlapping practice between engineering disciplines from the Professional Engineers Act and Board Rules.

Recommendation #1b: Give all regulated disciplines the right to responsible charge of engineering projects when justified by their education and experience.

Supportive Findings:

- California is the only state to specifically allow one-directional overlap of civil into all other disciplines and of electrical and mechanical into the title act disciplines and to prohibit the reverse. Guam is the only jurisdiction besides California that restricts the direction of overlapping practice for some disciplines.

- Education, examination taken and job experience are used to define areas of competence in all states, whether they use generic or discipline-based licensing. With the exception of Massachusetts, all large states and, indeed, most states irrespective of size, use generic licensing. In states with generic licensing, those who have passed the fundamentals and one specialty exam and met the experience requirement may practice any type of engineering as long as they are competent through education or experience. Those challenged through the complaint or legal processes must demonstrate competency. The discipline-based licensing states also define the specialty in terms of the subject matter of the comparable NCEES exam. They differ among themselves in the degree to which they regulate overlapping practice. Rhode Island allows no overlapping practice, while Massachusetts allows engineers to work outside their specialty with Board approval. None of the comparison states, including the two with discipline-based licensing, provided definitions of engineering branches.

- All engineers share a core of support units in physics, chemistry and math. These courses make up between 40% and 55% of all non-general education units required for an engineering degree at Berkeley, Stanford and UCLA, and between 28% and 35% at the CSU campuses. Some engineering disciplines also share engineering course work as well. Manufacturing and metallurgical engineering have many courses in common with mechanical engineering while electrical has very little in common with any engineering discipline, including civil. Failure to share a common educational background undermines the logic of allowing one-directional overlap by civil into electrical engineering while similarities in coursework among manufacturing, metallurgical and mechanical engineers highlights the inconsistency of restricting allowable overlap to mechanical engineers.

- Overlap between disciplines also occurs in the knowledge tested on national licensing exams. Roughly a third of the chemical exam is covered on the breadth and depth modules of the mechanical exam. There is extensive overlap between the manufacturing, control systems and fire protection exams and portions of the mechanical exam and between depth modules on the mechanical and civil exams. Conversely, there is virtually no overlap between any combination of the electrical and civil exam modules. There is less than 1% overlap between four of the five civil depth modules and the nuclear exam, less than 5% overlap between three of the civil depth exams and the chemical exam, and less than 5% overlap between all three electrical depth exams and the chemical exam.

- In many cases of overlapping exam content, title act disciplines had greater depth in a content area than the practice act disciplines. If the depth measured on the test accurately reflects the skills required in practice, title act engineers may sometimes be the more appropriate choice to serve in responsible charge of a project.

- Three discipline pairs topped the list on both measures of overlap-- the number of shared non-general units in their undergraduate preparation and the exam outlines. These were:

    - Mechanical and nuclear, sharing 52% of education units and an average of 17.7% shared content on the thermal and fluids systems module and nuclear exams.
    - Mechanical and manufacturing, sharing 51% of education units and an average of 31.4% shared content on the machine design module and manufacturing exams.
    - Mechanical and civil, sharing 44% of education units and an average of 21.1% of the machine design and structural depth modules.

- Discipline combinations with the greatest amount of overlap in exam content also had significant numbers of dual licenses. These include: nuclear (15% had a mechanical license), control systems (7% had an electrical license and 5%, a mechanical license), fire protection (7% had a mechanical license and 4% a civil license), metallurgical (4% had a mechanical license), industrial (3% had a mechanical license) and chemical (3% had a mechanical license). Since one-directional overlap and restrictions on responsible charge favor the practice disciplines, dual licenses open up opportunities but increase costs for the title disciplines. The necessity to acquire a practice act license is strong testimony to the economic motivations behind maintaining the practice/title distinction.

- Consistent with the lack of overlap in exam content and the one-directional overlap permitted by the regulatory structure, less than 1% of civil engineers had dual licenses involving the other practice act disciplines and less than 1% of electrical engineers had a civil license as well. Between 1 and 2% of mechanical engineers had licenses in civil and electrical.

- The order in which dual licenses were obtained is also of interest. Of those with dual licenses, a slight majority of the practice act engineers obtained their civil license first (55% and 54% for electrical and mechanical engineers). For the title act disciplines with meaningful numbers of cases, most of those with dual licenses obtained the civil first, ranging from 69% for agricultural engineers to 97% for fire protection. Control systems engineers with electrical and mechanical licenses also obtained the practice license first; 75% obtained the electrical and 53% the mechanical before obtaining the control systems license. The same was true for fire protection and nuclear engineers with mechanical licenses; 77% and 57% respectively obtained the practice license first. Only chemical engineers obtained the mechanical license second (84%).

- State comparisons suggest that the regulatory structure may be a factor in the pattern of complaints. Massachusetts prohibits overlapping practice without prior Board approval between any of its 46 disciplines while California permits one-directional incidental overlap for civil engineers into any discipline. While the proportion of electrical and mechanical engineers charged with unlicensed activity was similar in the two states (10% and 8% for electrical and 28% and 22% for mechanical in California and Massachusetts respectively), the proportion of civil engineers charged with unlicensed activity was almost four times greater in Massachusetts (12.7% vs. 3.5%).

- Another effect of the regulatory structures in Massachusetts and California can be seen in who gets charged with unlicensed activity. While the proportion of *unlicensed engineers* charged with unlicensed activity was virtually identical in these two states (52.1% in California and 51.9% in Massachusetts), *licensed engineers* in Massachusetts were three times as likely to be charged with unlicensed activity as they were in California (14.2% vs. 4.9%).

- The title act disciplines differ in the proportion licensed since the mid-1970s when six additional disciplines (agricultural, control systems, fire protection, manufacturing, nuclear and traffic) were given title protection. Chemical and petroleum were licensed in 1947, industrial and metallurgical in the mid-1960s. The ten disciplines fall into three distinct groups in terms of licensing activity during the past twenty years. Roughly half to two-thirds of currently licensed chemical, fire protection, traffic and petroleum engineers have been licensed since 1980, proportions comparable to two of the practice act disciplines (civil and electrical with 67% and 65% respectively). Three-fourths of mechanical engineers have been licensed since 1980. Between a fourth and a third of currently registered agricultural, nuclear and metallurgical engineers were licensed during the same period. There has been relatively little licensing activity during this period in control systems, industrial and manufacturing (between 3% and 19%).

- The OES survey indicates that California employs fewer engineers in some of the title act disciplines than many of the comparison states. For example, California and Florida have fewer chemical and materials engineers than any of the comparison states. California has fewer environmental engineers -- a branch counted by OES even though it is not regulated in California -- than all but one of the comparison states, and fewer industrial engineers than seven of the states. It also has fewer mechanical engineers than nine of the comparison states. It is difficult to determine how much of this under-representation is due to the state's industrial profile and how much to its regulatory structure.

- Many of those responding to the questions posed at the Forum on Engineering Licensing 2002 observed that several different types of engineers could perform a large portion of engineering work. For example, permitting for hazardous waste facilities could be done by civil or chemical engineers and issues relating to the flow of liquids through pipes are common to civil, mechanical, nuclear, chemical and petroleum engineering. There is no reason to limit approval of documents involving the flow of fluids through pipes to civil and mechanical engineers.

- There was general agreement among Forum participants and respondents that solutions to real world problems are multi-disciplinary, a fact recognized by engineering degree programs that include core courses in areas such as material properties, statics, dynamics, thermodynamics, fluid flow, mathematical concepts and electrical theory. Artificially restricting solutions to a single discipline may result in unnecessary costs or in less than optimal solutions.

- In general, complaints against the practice act disciplines come from the public while those against the unlicensed are more likely to come from the Board.[1]

- Most complaints (>70%) against civil, structural and geotechnical engineers come from the public while the source of complaints against mechanical engineers is almost equally divided between the Board (48%) and the public (46%) and allege in equal proportions incompetence (28%) and unlicensed activity (30%). The Board files two-thirds of the complaints against the unlicensed.

Rationale: These findings fail to support the current licensing system's one-directional allowable overlap of civil engineering into electrical, nuclear and chemical, and of electrical and mechanical into the title act disciplines. Currently, civil engineers are permitted to overlap into areas with little or no educational or exam content in common. Electrical engineers, with relatively little exam overlap, may overlap into chemical engineering whereas chemical engineers cannot overlap into mechanical engineering, even though a third of each exam's content is shared with the other discipline. If overlap is permitted where disciplines are extremely divergent, what is the logic for denying mutual overlap when they are more similar (e.g., between mechanical and civil or chemical)? In fact, case law suggests that the treatment of overlap between architecture and engineering -- allowing either discipline to practice in the overlapping areas -- would apply as well to overlap between engineering disciplines (1953 Lehmann vs. Dalis 119Cal.App2d p152). Board practice appears to recognize this since most complaints for unlicensed activity filed by the Board for Professional Engineers and Land Surveyors are against the unlicensed.

There is a similar inconsistency if the Board, in offering comity to migrating engineers, recognizes overlap between unregulated and practice act disciplines through acceptance of education and experience approximating the practice discipline. Where is the logic in denying, for example, Control systems engineers the right to overlapping practice when they have degrees --and often graduate degrees -- in mechanical or electrical engineering?[2] While the Board is recognizing overlap between unregulated

[1] An unknown number of Board complaints reflect referrals from public agencies.
[2] The 1998 Sunset Review Report gives the example of aeronautical engineering (page 35). Since California does not register this branch, an engineer with an ABET-accredited degree, completion of the NCEES aeronautical engineering exam and two years of experience under the supervision of a mechanical engineer would be granted a mechanical engineering license.

and practice act disciplines in one situation, it fails to recognize overlap between the title and practice act disciplines.

There are a number of findings that raise questions about the unique advantage given to civil engineers by the current licensing system -- an advantage that may be distorting the market for engineering services in the state. Although it has been suggested that the high rate of complaints alleging incompetence against civil engineers is due to the fact that they deal more with the public than other disciplines, this is not supported by the data. The number of complaints against civil engineers in relationship to the number lodged against mechanical and electrical engineers far exceeds the ratio of civil to mechanical and electrical engineers who are also employed in consulting services. Moreover, the insurance data indicate that civil engineers are *less* apt to be sued by clients/owners (as opposed to contractors and third parties) and more apt to be sued by third parties than mechanical and electrical engineers. This data also shows that civil engineers do not sustain more claims relative to their exposure in residential construction (the assumed public). Instead, they sustain more claims in areas where they would be dealing with governmental entities. Thus, the excessive number of complaints against civil engineers cannot be accounted for by their concentration in consulting services, the nature of their clients or the type of projects engaged in.

That the current licensing system advantages the practice act disciplines -- and civil in particular -- is also suggested by the source and nature of the complaints. In general, complaints against the practice act disciplines come from the public while those against the unlicensed are more likely to come from the Board. Most of the 2,149 complaints are evenly split between the practice disciplines and the unlicensed, with relatively few (66) involving the title act disciplines -- due perhaps to the limited sanctions that can be levied on those who may practice without licensure and are only licensed for use of a title. California's enforcement focus on mechanical engineers and the unlicensed -- through the filing of complaints for unlicensed activity -- seems to serve the function of protecting the boundaries of civil engineering. Since parts of mechanical and civil engineering share both educational background and exam content, overlapping tasks are to be expected and should be allowed in both directions. Massachusetts, a state allowing no overlap between any engineering disciplines, appears to maintain boundaries between disciplines in all directions, as indicated by the higher proportion of complaints against licensed engineers charged with unlicensed activity (14.2% vs. 4.9% in California) and by the higher proportion of complaints of unlicensed activity against civil engineers in that state (12.7% vs. 3.5% in California). California primarily charges disciplines other than civil engineering with unlicensed activity.

Does allowable overlap encourage civil engineers to over-reach their areas of competence, increasing the number of complaints? Does the restriction of responsible charge place civil engineers, sometimes inappropriately, in charge of projects beyond their area of competence? The broad nature of civil engineering may encourage this tendency. The fact that the proportion of civil engineers charged with unlicensed activity is almost four times higher in Massachusetts than in California suggests that allowable overlap in California suppresses official reaction to involvement outside the civil engineer's area of expertise.

Although the use of licensing to gain competitive advantage is a frequent observation in the literature, it would not seem to be in the public interest for this to be maintained in the licensing of engineers in California. All engineers have made a considerable investment in establishing their educational credentials. Title act engineers in disciplines that overlap with some part of civil or mechanical engineering are currently limited in their ability to benefit from that investment -- a restriction of trade that would not seem to be justified by differences in educational preparation or exam content. Although the hierarchical nature of responsible charge is ambiguously stated in the Engineers Act and Board Rules, letters and actions representing the Board's position have reinforced the idea that only the practice disciplines may be in responsible charge of engineering activities. Forum participants provided numerous examples of the limitations on their professional opportunities caused by this unique feature of California's regulation of engineering. (See Appendix I for the experience of a chemical engineer licensed in California, Arizona and New Mexico that illustrates the impact of California's responsible charge restrictions on the individual, the potential client and the quality and cost of engineering performed in the state.) Limiting responsible charge to the three practice disciplines restricts the search for engineering solutions to those within the competency and knowledge base of those disciplines when the optimal solution may depend upon scientific knowledge from other engineering specialties.

A January 9, 2002 article in *The Sacramento Bee* illustrates the benefits of being able to explore alternative approaches to a problem. On the government's Superfund list of most polluted sites in the country, Aerojet is seeking other solutions to the pumping and treatment of ground water contaminated by perchlorate, an ingredient of solid rocket propellant. The company's environmental engineers are now experimenting with in-place bioremediation as a quicker and less expensive replacement for the pump-and-treat system that has been in place since the early 1980s at a cost to Aerojet of $184 million.

Several participants felt that rapidly changing technology, from biomedical to software engineering, makes it even more critical that the most qualified person, regardless of discipline, be in responsible charge. With backgrounds in the biological or computer sciences and projects totally unrelated to the built environment, engineers in newly developing specialties may eschew licensing or seek exemption for their industry to avoid inappropriate supervision of their work. Moreover, it is in society's interest to consider alternate approaches to problem solution and to let social values and economics determine the ultimate approach.

The restriction of responsible charge (Article 3, section 6730 and 6730.2) to the three existing practice act disciplines may undermine protection of public health, safety and welfare and may be weakening the title act disciplines in the state. Relatively few have taken exams in some of the title act disciplines since they were initiated in the 1970s -- perhaps because they are employed by corporations where licensing is not an issue, or perhaps because they have taken the closest practice discipline exam. Only 3% of those licensed in Manufacturing have been licensed since 1980, 12% of those in Control Systems and 19% of those in Industrial. In addition, the OES survey indicates that California employs fewer engineers in some of the title act disciplines than many of the comparison states. Thus, there is a suggestion that one-directional overlap favoring civil engineering and the restriction of responsible charge to the practice disciplines has combined with the growth of industrial exemptions to weaken the title act disciplines in the state.

Forum participants noted that the hierarchical nature of responsible charge also distorts the licensing process because engineers in the more specialized and less powerful branches seek licensing in the practice branch closest to their specialty. The combination of disciplines with dual licenses supports this argument to some degree. A third of traffic engineers and a fifth of agricultural engineers also have a civil license, while 15% of nuclear engineers and half that many fire protection engineers have mechanical licenses. Control systems engineers with two licenses are divided between electrical (7%) and mechanical (5%) licenses.

The determination of allowable overlap in a technologically complex, rapidly changing set of disciplines is not practicable by a professional, political or disciplinary group. In general, licensed professionals should operate within the area of their education, training and examination, as currently specified in Board Rule 415. They and those who employ them should be held accountable for the use of their skills in an applied setting. Professionals operating outside of their area of expertise would be held accountable if they overreach their area of expertise, resulting in a complaint, lawsuit or insurance claim. The alternative to permitting overlap based on education, exam and experience is for the Board to approve overlap on a case-by-case basis -- a task that seems cumbersome in a large state and not the best use of the Board's efforts. The resources focused on overlap and protecting the interests of a single discipline could be better employed to protect public health and safety.

DISTINGUISHING CALIFORNIA'S PRACTICE AND TITLE ACT DISCIPLINES

Recommendation #2: Eliminate title protection and offer practice protection to all regulated disciplines.

Supportive Findings:

- No other state allows the unlicensed practice of regulated engineering disciplines. The licensing of title use rather than practice in all branches of engineering except the three practice act disciplines (civil, electrical and mechanical) and their related title authorities (structural and geotechnical) is unique to California.

- The review of federal, state and county codes indicates that several title act disciplines are referenced (chemical, fire protection, petroleum, and traffic). Prescriptive statements in the state and local codes -- requiring, for example, that fire protection and traffic engineers stamp plans -- indicate that state and local agencies recognize that skills held by persons with this training are important to decisions affecting the public health, safety and welfare. In effect, these prescriptive statements establish "de facto" practice disciplines, although in an uncoordinated manner within various state and county codes.

- In contrast to the emphasis on practice disciplines, and especially civil, in the California Code of Regulations, the Federal Code of Regulations primarily references "registered or licensed professional engineers," independent of discipline.

- A 1990 decision by the Office of Administrative Law (Docket No. 89-009) found that the Board's policy of prohibiting fire protection engineers from performing design services and designing fire protection systems was a "regulation" that needed to be adopted in compliance with the Administrative Procedure Act if fire protection engineers were to be excluded from offering design services. The decision notes that definitions for five of the title acts (agricultural, chemical, industrial, nuclear and petroleum) include the performance of design services, yet communication of Board policies indicates that only the practice act disciplines may engage in design services.

- There are no systematic differences in registration rates between practice and title disciplines. One practice discipline, civil, had one of the highest rates, while another, electrical, had one of the lowest. Registration rates for title act disciplines were found throughout the range. Among the title disciplines, agricultural, chemical and nuclear have among the highest rates (88% and above), while materials/metallurgical and industrial have some of the lowest (18% and below).

- Consulting directly to the public is not a justification for distinguishing practice and title act disciplines since there were no systematic differences in employment location between them. Most electrical and title act engineers are employed by private corporations. More mechanical, chemical and "other engineering disciplines" are in engineering and architectural services than is the case for electrical engineers. Although there are more civil engineers in engineering and architectural services than any other discipline (38%), a majority (56%) of civil engineers work for the government.

- Considering the ratio of registered civil, mechanical and electrical engineers employed in engineering and architectural services, proportionately more complaints are filed against civil engineers (including traffic, geotechnical and structural) than mechanical or electrical engineers. While registered civil engineers in E&A services outnumber mechanical engineers 6.5 to 1 and electrical 35.5 to 1, the number of complaints against civil engineers outnumbers mechanical 25 to 1 and electrical, 55 to 1.

- Civil engineers are also over-represented, and electrical and mechanical engineers under-represented, among those who are the subject of insurance claims -- relative to their proportions in the engineering work force. None of the three are over-represented in proportion to client fees generated by the firms involved in claims, although structural engineers are.

- The nature of the client does not explain differences in claims experience. Fewer civil engineers are sued by client/owners (51% vs. 72% and 60% for mechanical and electrical) and more are sued by third parties (33% vs. 13% and 21% for mechanical and electrical).

- The type of projects involved in also does not explain discipline differences in claims. Different project types engaged in by a single discipline can generate positive and negative claims/fee ratios and the same project type engaged in by multiple disciplines can generate different claims/fee ratios for the separate disciplines. For example, civil engineering firms had positive ratios for their work on roads and highways, generating fewer claims and claim dollars than they earned in fees, but a negative ratio for work on wastewater, sewage and water treatment systems. Civil engineering firms engaged in residential projects came out even -- generating similar proportions of claims and fees -- while, for electrical engineers, residential projects were much more damaging -- generating six times the number of claims as fees.

Rationale: The finding of extensive overlap between the disciplines raises the question of whether distinctions between the practice and title disciplines outweigh their commonalities, and in doing so justify their separate regulatory status. One-directional overlap between practice and title disciplines, the responsible charge hierarchy, and the unlicensed practice of regulated disciplines are what makes California's licensing system unique. This system appears to have grown out of its geopolitical environment. Historically, water projects, highways and high-rise buildings have defined the state's growth and showcased the remarkable achievements of its civil engineers. Their position as the first licensed engineering discipline in California and their contributions to the infrastructure had a significant effect on the profession's development within the state. The introduction of other engineering disciplines with title rather than practice protection was an early indication of the competitive struggle over professional turf that continues half a century later. The intervening years have brought a growth in scientific knowledge and technology unimagined when the Professional Engineer's Act was first written. Although infrastructure is still important, other scientific disciplines and their engineering applications have contributions to make to the state's economy and its public works. The question underlying the Title Act study -- and most evaluations of licensing in the literature -- is whether regulation serves the economic interests of powerful members of a profession or the public health, safety and welfare of the state's citizens. In particular, the question is whether there is sufficient justification for making regulatory distinctions between the practice and title disciplines.

Many of the findings fail to support this distinction. In seeking a rationale for the practice/title distinction, ISR explored whether most consulting with the general public is done by practice disciplines. Although the proportion of civil engineers in "engineering and architectural services" is higher than other disciplines, electrical engineers are less likely to consult directly with the public than mechanical, chemical and "all other disciplines." Thus, if consulting directly with the public were the basis for practice protection, electrical engineering would be a title act and mechanical, chemical and "all other disciplines" -- along with civil -- would be practice acts.

However, the proportion in consulting is not the only important consideration. There is the assumption that the "public" the civil engineers are dealing with is somehow different from that of the other disciplines. Some would argue that civil engineers' consumers lack the knowledge necessary to decide who is competent or has the background necessary for a given project. Although the claims data describes only a portion of the client base, what's available does not support this perception. The claims/fee ratios show that civil engineers involved in residential construction have more positive ratios (e.g., fewer claims than exposure would lead one to expect) than those involved in wastewater, sewage and water treatment systems (e.g., more claims and claim dollars than fees collected). One would expect more "naïve consumers" in the former type of project than the latter, but they do not seem to be filing an inordinate number of claims. Instead, claims against civil engineers were filed by public agencies.

The client/consumer is only one small part of the public affected by engineering work. As the introduction to the Agricultural Job Analysis Questionnaires put it: "the public includes all individuals, groups and community interests, including employees, clients, plant and animal systems, and community environmental interests that could be harmed through incompetent practice." In the claims data, compared to structural and other practice act engineers, civil engineers were much more likely to be sued by third parties.

Another finding that fails to support a distinction between practice and title disciplines is the lack of systematic differences in registration rates between the two. It has been suggested that the small numbers of engineers registered in the title act disciplines might be an argument for deregulating all of them. What is important is the registration rate, the number of registered engineers relative to the number employed in a discipline. This measure shows no systematic differences in registration rates between practice and title disciplines. Some of the title acts have higher registration rates than mechanical engineering, while electrical has the lowest rate of any discipline. Using registration rates as the basis for deregulation would suggest deregulating electrical along with the title disciplines with low registration rates.

A third set of findings tests whether involvement in complaints and insurance claims vary by discipline. If complaints are indicators of threats to the public health, safety and welfare, then civil engineers constitute more of a threat than mechanical and electrical engineers, even when registration and involvement in engineering and architectural services is taken into account. Similarly, relative to their proportion of the labor force, civil engineers are also over-represented, and electrical, mechanical and all other engineers under-represented, among those who are the subject of insurance claims. If threat to public health, safety and welfare were the main justification for licensing, then -- using these indicators -- only civil engineers would be licensed.

The problem in using these indicators is that they may not accurately reflect the potential for harm posed by other disciplines. Since the Board has no significant authority over title act disciplines, there is little motivation to lodge a complaint with the Board. If most title act engineers are employed by private industry and their errors are theoretically redressed through legal actions unknown to the public, we really have no measure of the degree of threat posed by these disciplines.

In sum, if all of the other states, discipline-based or generic, acknowledge the equality of all regulated disciplines, what justification could there be for California's unique regulatory system? The extensive overlap and the lack of consistent differences between the practice and title act disciplines argues strongly for eliminating the regulatory distinction and licensing all disciplines with practice protection.

PROTECTING THE PUBLIC HEALTH, SAFETY AND WELFARE

Recommendation #3a: The Board of Professional Engineers and Land Surveyors should track engineering degrees, examinations taken (including the depth module where appropriate) and job experience at time of application for licensing as a means of identifying areas of expertise and assessing policies associated with exam administration. Limited information on licensees should be available to the public.

Recommendation #3b: If the justification for licensing is protection of public health, safety and welfare, and if the state recognizes engineering as a field with the potential for significant social harm, then the state should accept the responsibility of maintaining useful records on applicants for licensure and complaints against licensees so that evaluative questions can be asked of the data.

Supportive Findings:

- Among the comparison states, California has the lowest pass rates on the fundamentals exam, the civil breadth exam, the transportation and water resources depth exams, and, in four of the five years, the electrical exam.

Rationale: While California's tracking of data on the licensing and disciplining of engineers is better than what ISR was able to obtain from its comparison states, the limited resources assigned to these functions in all of the states studied undermines accountability to the public. Although tracking applicant background and exam performance for internal analysis would add to the Board's responsibilities, it would improve accountability to the public and the profession. At a minimum, degrees and their specializations, the university granting the degree, qualifying job experience, and primary language should be in a file with scores on the exams taken. If applicant background information were kept in a single database linked to exam performance, it would be possible to assess what backgrounds were associated with success or failure on the exams. Educational backgrounds associated with success on the exams could be summarized for the benefit of those seeking licensing. In addition, this information could be used to understand the reasons for California's performance on the fundamentals, civil and electrical engineering exams. It would also be possible to determine whether the "special civil" requirement places an unusual burden on those seeking licensing in portions of civil that are less involved with the built environment (e.g., environmental and water resources).

This licensee data should also be linked to data files summarizing complaints and their outcomes. This would allow an analysis of the backgrounds of engineers generating complaints and their outcomes. Currently, complaint outcomes are not adequately captured in the database. Ultimate disposition after referral to another agency and disciplinary actions taken (suspensions, probation, revocation of license, fine) are not included. The inability to link licensee background and complaint data and the quality of the complaint variables limits the ability to analyze patterns of relationships between factors associated with incompetent practice and outcomes. For example, this type of analysis could be used to inform policy by examining whether the outcomes are appropriate to the problem and whether recurring problems are associated with a particular discipline. A licensing system that is accountable to the public should maintain records that permit the identification of problems in a regulated discipline and the assessment of whether the complaint and legal processes are adequately protecting the public.

Tracking professional training could also benefit the public as well as potential clients and employers. Currently, California's constitution protects the privacy of a professional's educational preparation. Civil Code 1798 of the Information Practices Act restricts the information that can be disclosed to the registration and license number. This does not appear to be in the public's best interest. At a minimum, potential clients and employers should be able to confirm an engineer's degree and areas of specialization, the university granting the degree and the licensing examination completed as general indicators of the individual's competencies.

Recommendation #4: The legislature should mandate the reporting of legal actions, including out-of-court settlements, against engineers, licensed or unlicensed, and against corporations engaged in engineering activities, to the Board.

Rationale: Similar to medicine, but on a larger scale, engineering activities have the potential for significant harm to large numbers of people. According to Forum participants and respondents, incompetent practice of most engineering disciplines would be harmful. In medicine, there appears to be more accountability. Errors are reported by hospitals and legal actions are reported to licensing boards. Engineering lacks a parallel reporting system. Mandated reporting would provide information on the potential for harm in exempt industries, and among unregulated disciplines and licensed engineers. If health and safety impacts are the major rationale for licensing, this information could be used to decide which engineering disciplines needed to be regulated. The widespread use of exemptions from licensing in California and its comparison states may undermine the public health, safety and welfare. There is less accountability in a regulatory system that registers less than half of the states' engineers. The frequency of recalled products (e.g., automobiles) and industrial contamination of the environment suggests that dependence upon the courts for after-the-fact redress of harm fails to protect public health, safety and welfare. Relying on employing industries to ensure competent practice places the public health, safety and welfare in competition with the private sector's focus on profit.

A March 23,2002 article in the *Sacramento Bee* illustrates the kind of outcome that can occur when public health and safety concerns conflict with the economic interests of an industry. The article reported that two-thirds of a sample of 150 upgraded gasoline storage tanks in four California counties leaked both gasoline and toxic fumes. Extrapolated statewide, "the findings would suggest that as many as 32,000 of the state's 48,000 underground fuel storage systems are leaking vapors." William Rukeyser, Cal-EPA spokesman, noted that "When technicians designed the upgraded systems and legal requirements were put in place, the focus was on liquid leakage…We've investigated further, and it has become obvious they did not focus on the question of vapor loss." Firms required to incur costs to reduce public health threats caused by their industry's activities may construe the requirement in the narrowest terms. Errors of omission by design technicians, or a management decision to disregard engineering recommendations if the solution is too costly, result in significant social costs and a lack of accountability by the engineers involved. These threats to public health, safety and welfare are not captured by the complaints and claims data described in this report and there are no publicly available records of the frequency with which these types of engineering activities threaten the public.

Broader involvement in licensing may add more professional weight to advocates for sound engineering practices in industry. A parallel process has occurred in medicine where the licensing of physicians assists them in asserting standards of practice -- although changes in the organization of medicine may be weakening this power. Some Forum participants thought that broader involvement in licensing would strengthen their position within industrial and governmental bureaucracies when other organizational interests conflict with the engineers' best practices recommendations. Licensing, as a state function, should support regulated disciplines in the maintenance of high professional standards and protect the public through establishing minimum levels of competence independent of job setting. Engineers should be given both the protection and the responsibility of licensing. In medicine, we hold both physicians and their employers accountable. If engineering offers the potential for significant harm, why would we not do the same when engineering principles are violated and the public is harmed?

While many exempt engineering activities may be harmless, and the current licensing system's restrictions sufficiently onerous as to discourage industry's use of licensed engineers, part of the difficulty may lie in the intrusion of an inappropriate hierarchy of responsibility represented by the practice/title distinction and the rule of responsible charge. If, as Forum participants argued, all engineering disciplines affect the public health and safety, then there is something illogical about widespread exemptions -- unless there is substantial regulation of the exempt industries whose activities threaten public health and safety. There is also something illogical about applying exemptions to all disciplines except civil unless there is strong evidence that this discipline constitutes more of a threat than any other. The claims data does not support making a distinction between civil and the other practice and title disciplines. With the exception of structural, all of these disciplines make up a smaller proportion of claims and claim dollars than their percentage of client fees collected.

The reporting of legal actions against engineers would provide the data necessary to determine whether disciplines, regulated and unregulated, really differ in their potential for harm and whether exemptions actually have an effect on public health and safety.

Recommendation #5a: Develop better information on the public health, safety and welfare impacts of engineering branches before making regulatory distinctions between them. Only when legal actions are reported and more comprehensive complaint data and insurance premium and claims data are available can the state determine whether there is any justification for deregulating currently regulated disciplines. Current information relevant to the Sunrise criteria supports extending practice protection to all currently regulated disciplines. If stronger data becomes available, the need for continuing regulation can be evaluated at that time.

Recommendation #5b: Accept as new regulated disciplines those with an NCEES or California-developed examination if their assessment under the Sunrise Criteria is comparable to existing regulated disciplines.

- Degree programs and specializations exist for all practice and title act disciplines. (Sunrise criteria VIII)
- NCEES job analyses identify the knowledges, skills and abilities required for nationally regulated disciplines and California's Office of Examination Resources provides similar profiles for several disciplines where NCEES exams are lacking or insufficiently reflective of the discipline's practice in this state. Summaries based on the job analyses measure degree of consensus on what skills define a discipline. Both sets of exams, built on the job analyses, measure minimum competence in all of the practice and title disciplines regulated in California. Consensus on the skills encompassed by a discipline and the measurement of minimum competence respond to questions included within Sunrise criteria VI and VIII.
- Most of the comparison states use the existence of an NCEES exam to recognize specific engineering disciplines. (Sunrise criteria III)
- There is not enough publicly available data to objectively address some of the Sunrise criteria questions, particularly those in criteria I, II and III.

Rationale: California determined in the early part of this century that the engineering profession should be regulated to protect the public health, safety and welfare. In the 1990s, the Sunrise criteria were introduced to provide more systematic guidelines for determining what occupations should be licensed. The current regulatory structure for engineering appears to treat the various branches of engineering as separate occupations, expecting each branch to justify practice protection independently. However, existing data provides inadequate information to answer the questions posed under several Sunrise criteria for any engineering disciplines and fails to support the current regulatory distinction between the practice and title branches. If recommendations 2 through 4 were in place and if the state could obtain the information, then insurance claims and premiums data, reported legal actions, and future complaints against fully licensed engineering disciplines could be used to decide whether some branches no longer required regulation and whether emerging branches justified it.

In compiling this report, ISR could only obtain very limited information from the insurance companies. If the state were able to obtain data on the varying costs of insurance coverage and the number and cost of claims by engineering discipline, this could be one of the best indicators of the effect different branches have on public health, safety and welfare. The claims data made available to ISR only described claims against engineering firms, which employ a minority of engineers. The state would want to determine whether the costs of insurance held by industries and agencies engaged in engineering activities and employing the majority of engineers could be identified with the work of specific engineering disciplines. If insurance premiums and claims data tied to particular engineering branches were available for exempt industries and public agencies, this information could be used to decide whether some branches have so little impact on public health and safety that registration would not be required and that others perhaps should not be exempt.

In addition, mandated reporting of legal actions against exempt companies and agencies hiring engineers and producing engineered products and services would be a necessary complement to the insurance data. Legal actions would measure threats in the broadest arena of engineering activity. The challenge in using insurance and legal data would be the difficulty in assigning responsibility for actionable incompetence or negligence to practitioners of specific engineering disciplines. The extent of overlap between disciplines and the subsuming of emerging disciplines within older branches, such as environmental within civil engineering, could make assigning responsibility for errors difficult.

Finally, the state's complaint data would provide a more complete picture of incompetent practice by discipline if all regulated branches were practice acts and subject to the same sanctions. Under the current regulatory structure, there is little incentive to file complaints against title act engineers because of the limited sanctions available. Therefore, the number of such complaints probably understates their potential for harm.

Thus, in order to decide which disciplines should continue to be regulated as practice disciplines, or which new ones should be admitted to practice protection, the state would need access to insurance and legal data not currently available and it would need more detailed complaint data on all existing disciplines after practice protection had been extended to include the current title disciplines. Without this crucial information, there is no basis for recommending that any disciplines be deregulated.

In fact, information developed in this report provides significant reason to recommend that all of the disciplines be retained with practice protection. The report shows that job analyses identify defined tasks for the separate disciplines, and that while overlap in education and exam content exists between some discipline pairs, they are distinguishable from each other. The regulated disciplines are taught in engineering schools and their knowledges and skills are testable using NCEES and California exams. The comparison states do not distinguish California's practice and title act disciplines in their licensing structure. They require a similar education and experience background and recognize passage of an NCEES exam as the route to generic or discipline-based licensure. Thus, there are no systematic differences between practice and title disciplines on those Sunrise criteria for which information is available.

Recommendation #6a: California's legislature, Board and engineering organizations should work closely with NCEES to standardize the goals, methodologies and analytical techniques used in its job analyses across all engineering disciplines.

Recommendation #6b: Both California and NCEES should maintain non-proprietary data files describing the job analyses to assist educators and licensing boards in understanding and tracking changes in the field.

- The current job analyses vary in the goals, methodologies, and analytical techniques used by the separate disciplines in their survey design. Some disciplines provide a very brief and general description of important tasks and knowledges in their discipline, while others seek to provide a more extensive and detailed description of their field. Most focus on the more common tasks performed by practitioners in their discipline; one discipline (manufacturing) omits the more common tasks and focuses on less widely shared tasks in newly developing or unusual applications of the discipline. The surveys differ in the measurement of educational background and job experience and in whether unlicensed engineers are included in the sample. Published reports on the results vary in the descriptive statistics used and in how the sample is grouped for analysis. Some describe the sample as a whole while others describe only subgroups within the sample. Most disciplines do not profile the variations in tasks in different job settings or in exempt or non-exempt employment, or by engineers with different levels of experience.

- California's Office of Examination Resources does not maintain job analysis data files that support examinations currently in use. It also does not report important descriptive statistics, specifically the standard deviations, which would allow an assessment of the degree of agreement on task frequencies and criticality.

Rationale: California's Legislature, Board and engineers have a shared interest in improving NCEES' job analyses that are used to develop its exams. Since disciplines vary in the proportion registered and job analyses differ in the degree to which they take licensing status and job setting into account, the exams based on them do not present a complete picture of the various engineering disciplines. If licensing exams are taken early in an engineering career, following completion of the required experience, examinees may not know whether they will find employment in exempt or non-exempt settings. To the extent that advances in engineering occur in exempt industries, recent engineering graduates with training in some of the new technologies may be unable to pass an exam based on more traditional content that reflects what registered engineers employed in non-exempt industries do. A lack of fit between the exam and the discipline as it is practiced in a variety of settings would increase failure rates, especially in those states where technological advances are being made.

Without underestimating the difficulties involved, engineering would benefit from not only coordinating sampling methods, but also standardizing the design of job analysis instruments across all disciplines and from a more sophisticated analysis of variations in tasks by licensing status and job setting that would link the exams more closely to the population taking them. Greater standardization in the methodologies of job analyses would make the resulting exams more equivalent as tests of competence in multiple engineering disciplines and would increase the usefulness of the job analyses in the assessment of overlap, a feature of importance to licensing boards. The lack of standardization prohibited the use of job analyses for this purpose in the current study.

If the job analyses are important to the profession, state legislatures and licensing boards for their separate purposes, then NCEES and California's Office of Examination

Resource should retain all job analyses data files for historical purposes. Although the most recent data collection is used to update the exams, earlier job analyses could be used to track changes in the field.

CHAPTER 1

INTRODUCTION TO THE TITLE ACT STUDY

In defining the Title Act Study in Senate Bill 2030, the California Legislature specified a series of tasks that, together, would lead to recommendations for change in licensing the state's engineers. These tasks included:

- Meeting with representatives of the engineering branches and other professional groups.
- Examining the types of services provided by different branches of engineering.
- Reviewing and analyzing educational requirements for the separate engineering disciplines.
- Identifying the amount of overlap between engineering disciplines.
- Reviewing alternative methods of regulation in other states and assessing the impact these regulations would have if adopted in California.
- Describing the manner in which local and state agencies utilize regulations and statutes to regulate engineering work.
- Recommend changes to existing laws regulating engineers after considering how these changes may affect the health, safety and welfare of the public.

ISR assembled as much information pursuant to these tasks as possible within the time available. Some of the information necessary to fully satisfy the legislative requests outlined above was either proprietary (e.g., job analyses performed by private firms for NCEES, insurance rates and claims data for different types of engineers), not publicly available (e.g., national and state pass rates for NCEES exams), or inadequately defined and administered (e.g., state data on complaints against engineers). The unavailability of good information on a profession with significant impact on the public health, safety and welfare limits accountability in the exercise of that profession. Lack of accountability itself threatens the public's health, safety and welfare.

Underlying these tasks were several overarching concerns. The first was the amount of overlap between engineering disciplines regulated in California. Overlap occurs in the coursework required for degrees in different branches of engineering, in the work that employed engineers perform (formally measured through NCEES sponsored job analyses), in the NCEES exams used in licensing engineers that are based on job analyses, and in state regulatory structures that either permit or disallow the performance of work outside areas defined by educational preparation, the NCEES exams taken and/or subsequent work experience. The second overarching concern was whether there were sufficient distinctions between California's practice and title act disciplines to justify maintenance of its existing and unique regulatory structure. No other state allows unlicensed persons to practice any branch of engineering. Only California licenses use of a title, but permits unregulated practice of all but three engineering disciplines (Civil, Electrical and Mechanical). The third concern was whether this regulatory structure adequately protects the public health, safety and welfare and whether a differential impact on public health, safety and welfare, if any, might be one justification for the practice/title distinction.

Significant findings from the analysis of educational requirements, job task profiles, examination outlines, pass rates, engineering employment and registration patterns, exemptions, complaints and insurance claims are discussed in the data Chapters 3-10 and summarized in Chapter 11 in sections corresponding to the three overarching concerns.

Comparisons with ten other states and analysis of the treatment of engineering disciplines in California state and county codes (the California Code of Regulations (CCR) and those for Los Angeles, San Diego and San Francisco counties) and the Federal Code of Regulations (FCR) were used to create a context for understanding California's licensing system.

Methodology

Ten comparison states were selected based on population, density, percent urban, and amount of residential and commercial construction and regulatory model. These ten states were surveyed about their regulatory structure and asked to provide registration, exam and complaint data. States were classified as either discipline-based licensing or generic licensing states. States were also classified as either board-dominated or agency-dominated states. The ten comparison states were also asked to consent to NCEES providing ISR with exam data. Existing data from the OES survey, the US Census and the Economic Census was used to get an estimate of the number of employed engineers, employment location and to compute registration rates. Exam pass rates were converted to standard normal Z-scores to show California's relative placement in comparison to the ten other states. The Z-test of proportions was used to compare the pass rates of discipline-based licensing states vs. generic licensing states and board-dominated vs. agency-dominated states.

Two sources of data served as imperfect indicators of the relative impact on public and safety of different engineering disciplines. Data on the number and dollar value of insurance claims relative to client fees generated by engineering firms involved in claims was made available by DPIC, a major insurer of engineers. The power presentation also included limited information on types of damages, suing parties and project types involved in claims. Data on complaints filed against engineers were used as a second indicator of impact on public health, safety and welfare. California, Massachusetts, New York, North Carolina and Texas provided information in varying depths on complaints in their states. California provided the most detailed information, allowing summaries of the source, nature and disposition of the complaint by engineering discipline. Wherever possible, comparisons were made with the other states. Complaint rates were computed using number of registered engineers as the base for complaints against licensed engineers and the number of employed engineers as the base for complaints against the unlicensed.

The uses of licensing by federal, state and local agencies were explored through several online searches. The Federal and California state and county codes of regulation were searched for references to engineers and the State Personnel Board's online Classification Information Search System searched for registration requirements associated with engineering job classes. Finally, information from the State personnel Board's Report 5102 was used to describe the proportion of registered engineers among the permanent civil service employees in engineering job classes.

Overlap between engineering disciplines was examined by looking at educational requirements and NCEES exam outlines. The original intent was to explore discipline overlap through the comparison of NCEES and California job analyses. Due to the unavailability of job analysis data for many disciplines and lack of comparability in those that were available, use of job analyses data and reports was limited to preparation of task profiles for each of the engineering disciplines. Educational requirements were compared using degree requirements in online catalogues from the seven largest engineering schools in California. Undergraduate and graduate degrees and specializations for the currently regulated disciplines were used to compare the degree of overlap in engineering and non-general education supporting units between engineering disciplines. Subject matter experts were selected to review NCEES exam outlines and compare content on paired discipline exams. The results of the SME's reviews were used to calculate overlap between disciplines in exam content.

Data Sources Used

- State Occupation Employment Statistics Survey 1998
- National Occupation Employment Statistics Survey 1988-90, 1998, 1999 and 2000
- US Census 1990 and 2000
- Economic Census 1997
- ISR State Board Survey, 2000
- NSPE Engineering Licensure Laws Summary and Analysis 2001
- NCEES 2000 Survey
- California BPELS Survey
- Registration data, 1994/1995- 2000/2001 (California and eight comparison states)
- NCEES exam pass rate data 1997-2001
- DPIC Power Point presentation on insurance claims 1989-2001
- Complaint Data 1991-2001 (California, New York)
- Complaint Data 1988-2001 (Massachusetts)
- Complaint Data 1997/1998 and 1999/2000 (North Carolina, Texas)
- California Code of Regulations (CCR), county codes for Los Angeles, San Diego and San Francisco and the Federal Code of Regulations (FCR)
- California State Personnel Board's online Classification Information Search System
- California State Personnel Board Report 5102
- Degree requirements from the seven largest engineering schools in California for 2001
- Job Analysis reports and raw data for the Agricultural, Electrical, Mechanical, Metallurgical, Petroleum and Structural engineering exams
- Job Analysis reports only for the Chemical, Civil, Control Systems, Geotechnical, Industrial, Manufacturing, Special Civil, and Traffic engineering exams
- Subject Matter Experts' review of NCEES exam outlines

Outline of the Report

Chapter 2 reviews the relevant literature on the regulation of occupations and the justification for licensing.

The history of engineering licensing in California and a comparison of regulatory structure between California and ten economically and demographically comparable states is described in **Chapter 3.**

Differences in engineering disciplines are examined through employment estimates, employment location and registration rates nationally and for California and its ten comparison states in **Chapter 4.**

Standard normal Z-scores are used to compare California's pass rates for the Fundamentals and Principle & Practice specialty NCEES exams to the average pass rate for the comparison states in **Chapter 5.**

Differential impact of engineering disciplines on public health, safety and welfare is analyzed using insurance claims and complaint data in **Chapter 6.**

Treatment of engineering disciplines in the California Code of Regulation (CCR), county codes for Los Angeles, San Diego and San Francisco and the Federal Code of Regulations (FCR), and registration requirements for State Personnel Board engineering job classes are described in **Chapter 7.**

Overlap between disciplines in engineering and non-general education supporting units is analyzed for the seven largest engineering schools in California in **Chapter 8.**

Discipline task profiles based on NCEES and California job analyses are described in **Chapter 9.**

Overlap identified in NCEES exam content by subject matter experts is analyzed in **Chapter 10.**

Chapter 11 summarizes the findings of data Chapters 3-10 and the implications of the findings.

Recommendations for changes to the California's licensing structure and the impact of those changes are discussed in **Chapter 12.**

CHAPTER 2

THEORY OF PROFESSIONAL REGULATION: A REVIEW OF THE LITERATURE

The licensing literature depicts two models of state-regulated professional licensure. One model views licensure as a means of protecting the public from fraud, the offering of services by the unqualified and other threats to their health, safety and welfare. The other model sees regulation as a process promoted by a profession to limit competition, monopolize the market for, and thereby increase the costs of, their services. In the academic literature, these are presented as competing rationales for licensure, with the overwhelming majority of research and theory emphasizing the interest group aspects of licensure rather than its role in the protection of public health, safety and welfare.

Protection of Public Health, Safety and Welfare

American attitudes toward protection of the public's health, safety, and welfare have undergone historic changes that reflect the state of science and the economy (Burnham, 1996). Early conceptions of health and safety (15th to 19th centuries) were fatalistic, with people resigned to the considerable perils of everyday life. Some care was taken to avoid accidents and injury, but the risks were tremendous and accidents were very common. With the emergence of a modernist view of life in the late 18th and early 19th centuries, corresponding to developments in science and industry and promoting the ideology of human control over the environment, people in America became more proactive in promoting their health and safety on an individual level. Education about the risks that one was exposed to in daily life was believed to be an effective deterrent to accidental injury and death.

During the middle of the 20th century, responsibility for the management of risks shifted from the individual to the collective. This resulted from the growing involvement of public health professionals in accident prevention. Over the next few decades, voluntary approaches to educating individuals on health and safety issues were replaced by the growth of regulations that would protect public health and safety through the creation of safer products and a safer environment. Research indicating that voluntary and personal approaches were not effective contributed to the change in emphasis. Much of the regulated activity involved the work of engineers.

Engineering solutions to health and safety issues dominated during the later decades of the 20th century as Americans' faith in the sciences and technology peaked. However, by the end of the 20th century, a resurgence of emphasis on individual responsibility emerged, possibly due to intensification of the deregulation ethos and corporate concerns over the costs of liability.

Nevertheless, the major justification for professional licensure is that without regulation the public might be harmed. Occupations that become professionalized require careful preparation and claim a distinctive knowledge base. (Wilensky, 1964) Licensing boards verify the qualifications of applicants and test their knowledge to see if it meets minimum standards, a procedure that has been called "preventive enforcement" The goal of preventive enforcement is to keep unqualified individuals from entering practice, thereby reducing the likelihood of their causing injury to the public. The screening out process that occurs prior to licensure is distinct from the disciplinary process. (Shimberg, 1982)

The licensing board also protects the public from incompetent or unscrupulous practitioners by investigating complaints and disciplining licensees (Zhou, 1993). Disciplinary and enforcement actions by the board include citations, reprimands, fines, suspension and revocation of the license. (Shimberg, 1982)

Some scholars are skeptical about the effectiveness of licensing in protecting public health and safety. Although the commitment to safeguarding the health and safety of clients and the broader public is common to the professions, in corporate settings this commitment may conflict with issues of efficiency and profitability. Thus, unlicensed engineers, working under the industrial exemption and depending upon corporate employment, may find their commitment to professional ethics compromised. (Martin, 1992) Studies of disciplinary actions in law and medicine in the 1970s found licensing boards reluctant to discipline licensees for incompetence; many states did not even include incompetence as a basis for discipline. (Gross, 1984, pp 148-151) "In general, boards tend to be more zealous in prosecuting unlicensed practitioners than in disciplining those already licensed." (Gross, p. 148) Inadequate budgets, staff and record keeping were common in agencies charged with oversight responsibilities. Cohen and Miike (1974) attributed the ineffectiveness of licensing boards to four other factors: a reluctance to invoke disciplinary action against fellow practitioners; the threat of lawsuits; the role conflict in being both rule makers and adjudicators; and the usually ambiguous statutory grounds for board sanctions, leading to judicial reluctance to enforce them.

Economic Effects of Licensure

Economists generally view regulation and licensure as a method for professions to decrease competition and inflate wages. Three common objections to licensing among economists are: it is a form of paternalism (potential consumers are being told that they are incapable of making rational choices so the state must make decisions for them); it promotes irresponsibility among consumers because they rely on the judgment of the board rather then researching the qualifications of professionals on their own; and state boards often become captured by the profession being regulated and are then used to promote a monopoly. Economists tend to prefer “free market” approaches instead. (Cagle, 1999)

Howard (1998) suggests that a cause of licensing is the desire of professions to restrict their numbers, which increases wealth by reducing competition. Wealth and sufficient numbers increases a profession's political power, which assists in controlling the regulatory process. The ability of a profession to restrict entry for new practitioners and to control task boundaries increases earnings over the long run for the profession and raises the price of their services due to reduced competition (Kleiner and Kudrle, 1992; Mills and Young, 1999).

Some argue that certification (title) provides information to consumers about the quality of service they can expect (Chan and Leland, 1982, Kleiner and Kudrle, 2000), while licensing (practice) prevents the least costly producers from entering the market, increasing the costs for consumers who would have been willing to sacrifice quality for price. (Shapiro, 1986; Gahvari, 1989; Blevins, 1998) Shapiro (1983) finds that achieving optimal quality standards, such as with occupational licensure, excludes from the market services that some consumers would choose because they are less costly.

However, minimal quality standards also protect consumers from choosing solely on the basis of price, regardless of quality. In the case of engineering, the public that benefits from less costly services being available is primarily business or government. These arguments ignore employees of exempt employers and the public that purchases products and uses facilities developed by these employers, even though they are not direct purchasers of the engineering services. Placing pubic health and safety in the hands of corporations that are beholden first to their shareholders may be placing consumers at risk-- unless it can be determined that what some engineers do has no impact on public, health, safety and welfare, or that some branches of engineering pose less of a threat than others.

Control and Responsibility in the Professions:
The Costs and Benefits of Licensure

Every state in the U.S. has laws regulating engineering practice in some way, yet due to exemptions, a majority of practicing engineers are not licensed (Anderson, 1999). Support for registration is increasing among some branches of engineering that have been indifferent to the idea in the past, for example electrical engineering (Bellinger, 1995). The increased support for licensing correlates with the increase in engineers wanting to go into consulting, where industrial exemptions are not an option. Another motivation is that trained engineers want to distinguish themselves from other technical workers in companies who are being given job titles with the word “engineer” attached. The benefits of licensure are that the engineer can then be in responsible charge of a project, can testify as an expert witness, and can expect higher wages and an improved chance of promotion (Lange, 1993).

Two drawbacks to licensure for the licensee are the cost of obtaining and renewing the license and the lack of comity among many U.S. states. Pashigian (1980), in comparing 24 occupations, concluded that a major effect of licensing is reduced interstate mobility -- an important concern given the concentration of employment in national and international firms. For both the licensee and employer, restrictions on labor force mobility compete with public health and safety arguments for licensing. Feisel (1998) addressed this issue by noting that the benefits and problems of licensure vary with the constituency. This includes not only engineers in private practice and in industry, but engineering faculty, industrial employers, clients and the public at large.

General Theories of Regulation: The Public Interest

Policies regarding professional licensure affect three groups: the professionals being regulated, the clients or consumers of professional services, and those who are affected by the interactions of the professionals and their clients. Those who are affected include employers, employees of exempt employers and the public that purchases products and uses facilities developed by these employers, even though they are not direct purchasers of the engineering services. Balancing the interests and concerns of these diverse groups is the challenge of public policy making.

According to Wolfson, et al., a policy that is designed to protect the “public interest” should strike a fair balance among all relevant interests that need to be taken into account and incorporate principles of efficiency, accountability, fairness, and practicability. (in Rottenberg, 1980) Wolfson et al. argue that in addition to the interests of the parties involved, societal values or principles also influence policy. In the U.S., considerations of technical and economic efficiency should be factored into all policy goals. Policies should be developed to ensure that there is minimal waste in the production, distribution, and consumption of professional services, and that the real needs of the consumers and their ability to pay for services are acknowledged. Another principle of importance to policy making in the U.S. is fairness, particularly procedural fairness or due process. This is of particular importance for the professional group. In order to be fair, the licensing procedure must treat all people of similar circumstances according to the same standard, policy enforcement cannot be arbitrary, and changes to policies should include some form of compensation for those whose careers are disrupted because of the change in policy. Practicability is another consideration informing occupational licensure policies in the U.S. New policies should be evaluated for ease of implementation. Practicability applies both to how easy a policy is to put into effect and how easy it is to change if the results are not as intended. Finally, policy must consider the principle of accountability, which requires effective representation of interests and effective dissemination of information to the public. Those who make public policy should be held accountable to those who are affected by their decisions and those who disagree with the decisions must have avenues to seek redress.

CHAPTER 3

ENGINEERING LICENSURE IN CALIFORNIA AND ITS COMPARISON STATES

The History of Engineering Licensure in California

The variety of specialties within engineering reflects a divergent history. While many branches of engineering grew out of traditional crafts, at least two (electrical and chemical engineering) grew out of the physical sciences and the industries that depended upon the application of physics and chemistry to extractive and manufacturing pursuits. With the exception of electrical and chemical engineering, evolution within most engineering branches was from the technical to the scientific, from "rule of thumb" or "cut and try" methods to more scientific and research-based approaches to problem solving.

Mechanical engineering constituted a hybrid with its practitioners following separate career paths. Some of the more powerful mechanical engineers in the nineteenth century had been skilled mechanics who had become shop managers or owners while others were scientifically trained engineers who took advantage of the growing opportunities in corporate employment. The early American Society of Mechanical Engineers (ASME) was dominated by a "shop-culture" elite who had become leaders of industry. In contrast, university trained mechanical engineers emphasizing academic credentials and scientific training sought their success through promotion into management within large industrial corporations.

The history of engineering licensure in California that began in the early 20^{th} century had its roots in these 19^{th} century developments. Civil engineering as a profession grew out of the early canal and railroad building efforts, forming the first professional organization of engineers, the American Society for Civil Engineering in 1852. The American Institute of Mining and Metallurgical Engineering followed in 1871, the American Society of Mechanical Engineers in 1880, the American Institute of Electrical Engineers in 1884 and, in 1908, the American Institute of Chemical Engineers.[1] With the exception of metallurgical engineering, the licensing of engineers in California followed a similar order beginning with civil engineers in 1929 and adding chemical, electrical, mechanical and petroleum engineering almost 20 years later (1947). The recognition of additional disciplines in the 1960s and 70s reflected either growth in scientific knowledge (nuclear engineering), the application of engineering principles to new areas (agricultural, fire protection, corrosion and traffic engineering), or the new 20^{th} century focus on the social organization of production (control systems, manufacturing, industrial, quality and safety engineering).[2] The pace of licensing mirrored the post World War II growth of the state and its industries. California's refineries, the expansion of its cities and agribusiness and the water projects needed to support both spurred the addition of new engineering licenses. (Table 3.1)

Title and Practice Act Disciplines

Following the licensing of civil and structural engineers, California introduced a distinction between two types of engineering licenses that remains unique to the state. The licensing of civil engineers prohibits all others from *practicing* civil engineering. The subsequent licensing of chemical, electrical, mechanical, petroleum, metallurgical and industrial engineers in the 1940s

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[1] David F. Noble, *America by Design: Science, Technology, and the Rise of Corporate Capitalism*. New York; Alfred Knopf, 1977. See especially Chapters 1, 3 and 10.
[2] Ibid., pp. 258 - 261.

and 1960s prohibits others from *using the title* of their discipline, but permits anyone to practice it. In the late 1960s, electrical and mechanical engineering were converted to practice protection while the disciplines of the 1970s were given title protection only. Structural and geotechnical engineering were defined as title authorities, an amalgam of practice and title protection. Licensed civil engineers may take additional exams to use the titles of structural or geotechnical engineer; but they may practice either type of engineering with their civil license.

With the exception of civil engineering, the practice act disciplines are minimally defined in the Professional Engineers Act, Sections 6702 of the Business and Professions Code. Mechanical and electrical engineering and the title act disciplines are defined in Rules of the Board for Professional Engineers and Land Surveyors, California Code of Regulations Title 16, Chapter 5, paragraph 404. These definitions describe the purview of each discipline and specifically restrict the title act disciplines from practicing civil, electrical or mechanical engineering. Practice act disciplines, however, may engage in any engineering activities as long as they are "incidental" or "supplementary" to work in their branch of engineering.

Thus, a hierarchy is established between the practice and title disciplines that is reflected in placement in the Business and Professional code vs. Board Rules, in allowable one-directional overlap by the practice disciplines into title areas and prohibition of the reverse, and in a complaint process that can only reinforce practice protection. Since it is against the law to practice civil, mechanical and electrical engineering, no action can be taken against those who practice in the title disciplines. On the other hand, action *can* be taken against title branch engineers who do incidental work in a practice discipline.

It is a reasonable question whether there are clear and sufficient differences between the branches of engineering to justify differential treatment of the various disciplines. No other state allows unlicensed persons to practice any branch of engineering and most states of any size do not even distinguish the branches, offering licensing as a "professional engineer" to those completing a prescribed set of exams. When this question was posed at the Forum on Engineering Licensing 2002 and on DCA's website announcing the forum, participants and others offering public comment could not identify any criteria that distinguish practice and title disciplines other than the legal distinctions that have arisen with the historical development of engineering in this state.

According to the participants, the distinction between practice and title disciplines is based on variations in degree of specialization, the number practicing in the discipline, and the historical period in which the discipline developed. Practice act disciplines are generally older and more populous, are largely associated with the built environment, and have a more generalized knowledge base. The title act disciplines are more specialized and have developed more recently with rapid growth in the development of new technologies and the application of the physical sciences (physics, chemistry, biology) to problems in the physical and medical environment (air and water pollution, health-related technologies). The unregulated disciplines are also highly specialized and either attract so few engineers that they do not justify an NCEES exam or they work in environments where the oversight that regulation provides is not desired and the impact of their work on public health and safety is unclear.

Licensing history in California is not completely consistent with these perceptions. Although civil is unquestionably the oldest discipline, mining and metallurgical engineering predated electrical, mechanical and chemical but it wasn't licensed until twenty years later. And despite their age, electrical and mechanical were initially given only title protection. The number practicing in these areas when they were originally licensed hasn't survived; but it if is assumed that the relative numbers were similar, electrical would have outnumbered civil and mechanical and thus justified practice protection from the beginning. Finally, it might be difficult to defend an argument that chemical engineering represents a less generalized knowledge base than the practice disciplines.

Chapters 4,5, and 6 of this report explore what distinctions, if any, can be documented between California's practice and title disciplines in terms of their employment location, examination pass rates, registration rates, number and types of complaints and insurance claims. An evaluation can then be made whether the specific differences support maintaining a distinction in law between these groups of disciplines.

Generic vs. Discipline Based Licensing

Two licensing systems are in use in the United States. Most states have generic licensing, registering those who passed the Fundamentals of Engineering and at least one specialty exam as "Professional Engineers." Engineers in these states stamp plans with a seal that identifies them as a "Professional Engineer." In states with discipline-based licensing, those passing the Fundamentals and a specialty exam are licensed under the specialty that is usually noted on the seal. California's use of practice and title protection locks it into a discipline-based licensing system.

While not unique, discipline-based licensing is relatively uncommon, used primarily in 16 smaller and more rural states and territories. Massachusetts and California are the only large states to license in this way. The 16 states vary widely in the number of specialties offered for licensing, ranging from six in Rhode Island (chemical, civil, electrical, environmental, mechanical and structural) to 46 in Massachusetts (see Appendix A).[3] California licenses 15 different specialties. Table 3.2 summarizes the licensing system in all of the states identified by at least one source as discipline-based as well as the states with generic licensing that were selected as comparison states.

Most of the discipline-based licensing states define the disciplines in terms of the subject matter of the comparable NCEES exams. Rhode Island provides no discipline definitions, but indicates that it allows no overlapping practice between disciplines. Massachusetts also has no published definitions, but it allows engineers to work outside their licensed area with board approval. Guam is the only jurisdiction besides California that restricts the *direction* of overlapping practice for some disciplines. Industrial engineers may not engage in the incidental practice of other disciplines licensed in Guam (civil, electrical, chemical, mechanical and structural) and chemical engineers may not overlap into civil, electrical or mechanical. This use of the term "overlap" to mean work performed that is "incidental" or "supplemental" to the "normal" work of a specific engineer is common in the discipline-based licensing states.

A second meaning of the term "overlap" is used by states with "generic" licensing. Licensees, recognized as "professional engineers," may practice any type of engineering, as long as they are competent through education or experience. This is a modified form of self-certification.[4]

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[3] Although their published codes identify a limited number of disciplines, a telephone interview determined that Massachusetts licenses 46 branches of engineering. In many cases, there is no appropriate NCEES exam.
[4] A third meaning of "overlap," explored in some depth in Chapters 8, 9, and 10 of this report, refers to commonalities in education, expected knowledge as defined by the content of NCEES exams, and job tasks between various engineering disciplines.

While registered engineers must pass an exam, presumably based on their education, they may practice in any branch of engineering for which their experience equips them. They and their clients are the sole judges of that competence unless errors occur that require them to demonstrate, after the fact, an appropriate level of competency.

Selection of Ten Comparison States

SB 2030 directed a review of alternative methods of regulation in comparable states. ISR defined comparability in terms of population size, density, percent urban, amount of building activity as measured by number of residential building permits and the dollar value of heavy construction. It seemed important to include demographically comparable states that varied in their licensing structure so states were ranked on the demographic variables using 1990 and 2000 data from the U.S. Census of Population and Housing and the 1997 Economic Census. Each state was identified as having generic or discipline-based licensing by reading their state codes and comparing this with the states' self-classification in California's Board survey.

Ten comparison states were selected by ranking states on the demographic and construction measures and taking, in addition to California, the top five in each licensing category. Since there are relatively few states with discipline-based licensing, several large states with generic-based licensing were passed over in order to include what were initially assumed to be the largest discipline-based states. Thus, the generic licensing states included the four highest ranking states in terms of population size, density, percent urban, number of building permits and dollar value of heavy construction (Florida, New York, New Jersey and Illinois). Choice of the fifth generic state (North Carolina) gave more weight to the construction variables, while retaining as much strength as possible in the demographic ones. North Carolina was selected over Michigan because the former provided more variety in regulatory models (see below). States initially selected as discipline-based licensing states included Massachusetts, Ohio, Pennsylvania, Texas and Rhode Island. (Table 3.4)

After conducting interviews with state boards, ISR determined that eight of the ten selected states really have generic licensing. Only two of the 16 states with discipline-based licensing are sufficiently large and urban to be considered comparable to California: Massachusetts and Rhode Island. Rhode Island is included because it ranks 2nd and 3rd in density and percent urban respectively, even though it ranks low in population (43rd), the number of building permits (43rd) and the dollar value of heavy construction (42nd). It is, therefore, not a strong comparison state for California. Massachusetts is a better comparison in terms of population size (ranked 13th), percent urban (5th) density (3rd), and the dollar value of heavy construction (10th), even though it is close to the median in the amount of building activity (26th in building permits). The states most comparable to California have chosen generic licensing. (Table 3.4)

After selection of the comparison states, four independent sources, in addition to ISR's reading of state codes, were used to confirm a state's licensing system. These included: NSPE's 2001 report, and surveys by NCEES, California's Board, and CSPE. Of 16 states and territories identified by at least one source as having discipline-based licensing, agreement on the type of licensing occurred on only seven. All five sources rated and agreed that Nebraska, Nevada, and the Northern Mariana Islands had discipline-based licensing. Four sources rated and agreed that Hawaii and Alaska were discipline-based states. And three rated and agreed that California and the District of Columbia offered discipline-based licensing. Although three sources agreed on Rhode Island and Massachusetts as discipline-based licensing states, the NCEES 2000 report listed Rhode Island as a generic state and the NSPE 2001 summary identified Massachusetts as generic as well. (Table 3.2)

Regulatory Model

A third, but less important criteria in the selection of comparison states was its regulatory model. Since the model's importance could not be determined in advance -- and demographic comparability and licensing structure seemed on *a priori* grounds to be more important -- this feature was used to select among several reasonably large states with generic licensing. In *Questions a Legislator Should Ask*, Benjamin Shimberg and Doug Roederer define five models that describe the organization of professional and occupational regulation in the states.[5] These vary from a board-dominated model (A) to an agency-dominated model (E), with shared power and responsibilities characterizing models in between. Developing a questionnaire that, among other things, measured the division of responsibility between board and agency on the major regulatory tasks, ISR interviewed board or agency staff in California and each of the comparison states. This section of the interview sought staff assessments of the division of responsibility between the board and agency in their state on each of the following tasks:

- Hiring board and agency staff
- Making decisions regarding office location, purchasing and procedures
- Maintaining financial records for licensing
- Setting qualifications for those taking the exams
- Collecting fees for the exams
- Collecting fees for the renewal of registration
- Answering inquiries from licensees and the public
- Mailing applications for licensing and renewals
- Issuing licenses
- Handling complaints
- Disciplining licensees

Table 3.5 summarizes staff responses to the questions used to determine the distribution of responsibilities between board and agency. (See Appendix B for the questionnaire.)

California and its ten comparison states fall into two fairly clear categories. California, along with Texas, North Carolina, Ohio, and Rhode Island are board-dominated states. New York, Illinois, Pennsylvania, Massachusetts, and New Jersey are agency-dominated in varying degrees with New Jersey the most balanced. Florida is somewhat unique because a private corporation serves as the agency in that state, providing most of the agency's functions. Where appropriate, this report will explore whether regulatory structure is related to other licensing features.

Exempt Employment

California and its comparison states exempt from registration engineers employed in a variety of settings.[6] Seven of the eleven states, including California, exempt between 10 and 14 categories of employment settings, although the particular categories vary with the state. New Jersey has the fewest exemptions (3). (Table 3.6)

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[5] Benjamin Shimberg and Doug Roederer, with Kara Schmitt, Editor, *Questions a Legislator Should Ask*, Second Edition, Council on Licensure, Enforcement and Regulation, Lexington, Kentucky: 1994. See especially pages 18 - 23.

[6] This discussion is based on the National Society of Professional Engineers *Engineering Licensure Laws: Summary and Analysis*, 2001.

California and all of the comparison states exempt employees and subordinates of licensed engineers. All but one of the eleven states (New Jersey) exempts engineers employed by public utilities or manufacturing firms. Conversely, only Florida and Texas exempt engineers employed in academia and only North Carolina exempts other unspecified licensed professions.[7] Five states, however, exempt specific licensed professions, most typically architecture, but also land surveying, landscape architecture, fire sprinkler contractors, and -- in California -- licensed contractors, architects and realtors. All but two of the eleven states exempt federal government employees (Florida and New York), engineers engaged in manufacturing or scientific research (New Jersey and Ohio), work on one's own property (New Jersey and New York), and persons engaged in temporary practice (Illinois and Texas). In contrast, only Florida and Pennsylvania exempt the incidental practice of engineering by other professions and only California and Texas exempt persons testifying as expert witnesses.

State and local government employees are generally not exempt in California and the comparison states. Only Florida, Illinois and Ohio exempt engineers employed by state and local government, while New York exempts local government employees only. Similarly, public transportation officers are more often not exempt, although five states (Illinois, Massachusetts, New York, North Carolina and Rhode Island) do exempt them from registration. On the other hand, engineers employed by industrial firms or corporations are usually exempt from registration, with Florida, New Jersey, Ohio and Rhode Island the only exceptions. (Table 3.6)

Along with its use of title acts and one-directional allowable overlap, California appears to be unique in excluding civil engineers from most exemptions. That is, Chapter 7 of the Business and Professions Code, Paragraph 6747 exempts manufacturing, mining, public utility, research and development and other industrial corporations from having to employ a licensed engineer for the performance of engineering work *unless* it involves civil engineering. This interpretation is reinforced by the *Plain Language Pamphlet of the Professional Engineers Act and the Board Rules* that prohibits an unlicensed civil engineer in an exempt industry from serving as a reference for someone applying for licensing.[8] In contrast, unlicensed mechanical and electrical engineers may be used if they work in an exempt setting.

The widespread use of exemptions from licensing means that, in California and throughout the nation, many practicing engineers are not licensed. This state of affairs may undercut the main justification for licensing -- protection of public health, safety and welfare. A common argument is that only unsophisticated consumers of engineering services require the protection of licensing. However, consumers include employees of exempt employers and the public that purchases products and uses facilities developed by these employers, even through they are not direct purchasers of the engineering services. Placing public health and safety in the hands of corporations that are beholden first to their shareholders may be placing consumers at risk -- unless we can determine that what engineers do has no impact on public health, safety and welfare, or that some branches of engineering pose less of a threat than others. Later chapters of this report will attempt to deal with this issue.

[7] The Texas exemption does not appear in the NSPE summary, but was communicated personally to ISR.
[8] Section 2, Question 26.

Table 3.1. Historical Development of Engineering Licensing in California

Year	Defined as Title Act	Defined as Practice Act	Defined as Title Authority	Removed as Title Act
1929		Civil		
1931			Structural	
1947	Chemical Electrical Mechanical Petroleum			
1965(TS) 1967 (SR)	Metallurgical Industrial			
1967		Electrical Mechanical		
1970s	Agricultural Control systems Corrosion Fire Protection Manufacturing Nuclear Quality Safety Traffic			
1982			Geotechnical	
1999				Corrosion Quality Safety

Authority to recognize new branches moved from the legislature to the Board of Registration in 1968, returning to the legislature in 1985.

Table 3.2. Source of Identification as Discipline-Based or Generic Licensing State

State	NSPE 2001[1]	NCEES 2000[2]	CSPE Survey[2]	Board Survey[3]	ISR[4]
Alaska	Discipline	Discipline	Discipline	N/A	Discipline
Arizona	Generic	Generic	N/A	N/A	Discipline
California	Discipline	Discipline	N/A	N/A	Discipline
Delaware	Discipline	Generic	N/A	N/A	Generic
District of Columbia	Discipline	Discipline	N/A	N/A	Discipline
Florida	Generic	Generic	Generic	N/A	Generic
Guam	Discipline	Generic	Discipline	Discipline	Discipline
Hawaii	Discipline	Discipline	N/A	Discipline	Discipline
Illinois	Discipline[5]	Generic[5]	N/A	Generic	Generic[5]
Louisiana	Discipline	N/A	N/A	Discipline	Both
Massachusetts	Generic	Discipline	N/A	Discipline	Discipline
Nebraska	Discipline	Discipline	Discipline	Discipline	Discipline
Nevada	Discipline	Discipline	Discipline	Discipline	Discipline
New Jersey	Generic	Generic	N/A	N/A	Generic
New York	Generic	Generic	Generic	Generic	Generic
North Carolina	Generic	Generic	Generic	Generic	Generic
Northern Mariana Islands	Discipline	Discipline	Discipline	Discipline	Discipline
Ohio	Generic	Generic	Generic	Generic	Generic
Pennsylvania	Generic	Generic	N/A	N/A	Generic
Rhode Island	Discipline	Generic	N/A	Discipline	Discipline
Texas	Generic	Generic	N/A	Not Clear	Generic
Vermont	Generic	Discipline	N/A	Discipline	Discipline
Virgin Islands	Generic	N/A	N/A	Discipline	Discipline
Wyoming	Generic	Discipline	Generic	Discipline	Discipline

[1]NSPE does not define their use of the terms "Generic" and "Discipline"

[2]Both NCEES and the CSPE survey use the same definitions for the terms "Generic" and "Discipline". Both sources define "Discipline" as "A discipline-specific engineer, restricted to practice in a specific field." Both sources define "Generic" as "A professional engineer limited to practice to his/her field(s) of expertise."

[3]Board Survey asked states "How does your state register engineers? Generic, quasi-generic, or by discipline?"

[4]ISR defines discipline states as those states that specify a discipline on the license and on the seal. ISR defines generic states as those states whose license and seal says "professional engineer" only.

[5]Structural engineers licensed separately.

Table 3.3. Status of Engineering Disciplines[1] in California and the Nation

	Regulated in California	Not Regulated in California
NCEES Exam	Agricultural	Building/ Architecture
	Chemical	Environmental
	Civil	Mining/ Mineral
	Control Systems	Naval Architecture/ Marine
	Electrical & Computer[2]	
	Fire Protection	
	Industrial	
	Manufacturing	
	Mechanical	
	Metallurgical	
	Nuclear	
	Petroleum	
	Structural	
No NCEES Exam	Geotechnical[3,4]	Aerospace[4]
	Traffic[3]	Bioengineering
		Biomedical
		Construction[4]
		Corrosion[4]
		Quality[4]
		Safety[4]
		Software[5]

[1]This list of engineering disciplines includes: degrees from more than one of the seven largest California universities; disciplines regulated in one of the ten comparison states (Florida, Illinois, Massachusetts, New Jersey, New York, North Carolina, Ohio, Pennsylvania, Rhode Island, and Texas); or specialty exam offered by NCEES.

[2]The NCEES exam is Electrical & Computer, but the California license is for Electrical.

[3]Geotechnical and Traffic are depth modules on the NCEES Civil exam, however there is no separate Geotechnical or Traffic NCEES exam.

[4]The Massachusetts board regulates these disciplines although there is no NCEES exam.

[5]The Texas board regulates this discipline, although there is no NCEES exam.

Table 3.4. Ranking on Selected Demographic and Construction Variables of Potential Comparison States

State	Ranking Based on 1990 Census					Ranking Based on 2000 Census Data					Types of Licenses
	Population	Percent Urban	Density	Building Permits	Average	Population	Building Permits	Dollar Value[1] in Heavy Construction	Average[2]	Selected	
California	1	2	12	1	4.00	1	2	1	3.60	✓	Discipline
Florida	4	4	10	2	5.00	4	1	3	4.40	✓	Generic
New York	2	6	6	12	6.50	3	12	5	6.40	✓	Generic
New Jersey	9	1	1	22	8.25	9	16	16	8.60	✓	Generic
Illinois	6	11	11	10	9.50	5	9	4	8.00	✓	Generic[3]
Massachusetts	13	5	3	24	11.25	13	26	10	11.40	✓	Discipline
Ohio	7	20	9	9	11.25	7	10	7	10.60	✓	Discipline[5]
Pennsylvania	5	21	8	11	11.25	6	13	6	10.80	✓	Discipline[5]
Maryland	19	9	5	13	11.50	19	22	22	15.40		Generic
Michigan	8	18	14	8	12.00	8	8	11	11.80		Generic
Virginia	12	19	15	5	12.75	12	11	12	13.80		Generic
Texas	3	16	29	4	13.00	2	3	2	10.40	✓	Discipline[5]
Georgia	11	26	21	6	16.00	10	4	14	15.00		Generic
Washington	18	17	28	3	16.50	15	14	9	16.60		Generic
North Carolina	10	37	17	7	17.75	11	5	8	15.60	✓	Generic
Connecticut	27	10	4	31	18.00	29	35	27	21.00		Generic
Rhode Island	43	3	2	43	22.75	43	45	42	27.00	✓	Discipline[4]

[1]Dollar value of heavy construction from Economic Census 1997

[2]Mixed average using 2000 data for population and building permits, 1997 dollar value of heavy construction and 1990 data for percent urban and density. Percent urban and density were not available for 2000.

[3]Plus structural

[4]Limited number (chemical, civil, electrical, environmental, mechanical, and structural)

[5]Texas, Pennsylvania and Ohio were originally identified as discipline-based licensing states through a reading of their state codes and California's 1998 Board Survey. After selection as comparison states, this categorization was revised in light of interviews with the selected states and comparisons with the other sources. (See Table 4.2)

Table 3.5. Board vs. Agency-Dominated Classification of California and Ten Comparison States

	Board- Dominated States					Agency-Dominated States					
	TX	NC	OH	CA	RI	NJ	MA	IL	PA	NY	FL
Who is responsible for hiring Board Staff?	B	B	B	B	B	A	E	O	A	E	A/C
Who is responsible for hiring Agency staff?	N/A	N/A	N/A	A	N/A	A	A	A	A	A	A
Who makes decisions about office location, purchasing, and procedures?	B	B	B	B	O	A	A	A	A	A	A/C
Who maintains the financial records for licensing?	B	B	B	B	B	A	A	A	A	A	A/C
Who sets qualifications for people taking the exams?	B	B	B	B	B	B	C	O	O	A	A/C
Who collects the fees for exams?	B	B	B	B	B	O	O	O	O	A	A/C
Who collects the fees for renewal of registration?	B	B	B	B	B	A	A	A	A	O	A/C
Who answers inquiries from licensees and the public?	B	B	B	B	B	B	A	A	A	A	A/C
Who prepares and mails applications for licensing and renewal?	B	B	B	B	B	A	A	A	A	A	A/C
Who issues licenses?	B	B	B	B	B	A	A	A	A	A	A/C
Who handles complaints?	B	B	B	B	B	B	A	O	D	A	A/C
Who disciplines licensees?	B	B	B	B	B	B	D	A	D	A	A/C
How are complaints against unlicensed individuals handled?	B	R	R	O	R	R	R	A	A	R	A
Percentage Distribution of Responsibilities											
Board	100	91.7	91.7	84.6	83.3	30.8	0.0	0.0	0.0	0.0	0.0 (0.0)
Agency	0.0	0.0	0.0	7.7	0.0	53.8	61.5	69.2	69.2	76.9	15.4 (100.0)
All Others	0.0	8.3	8.3	7.7	16.7	15.4	38.5	30.8	30.8	23.1	84.6 (0.0)

[1]Florida is unique in having a Corporation that works on behalf of the Agency with the Board.

KEY	A=Agency	A/C=Corporation working on behalf of Agency
	B=Board	C=Board Initiated, Agency Approval Required
	O=Other	D=Agency Initiated, Board Approval Required
	R= Referral to various outside agencies	

Table 3.6. Exemptions to Licensing in California and Ten Comparison States

Exemptions	CA	FL	IL	MA	NJ	NY	NC	OH	PA	RI	TX
1. Other Licensed Professions (general)							✓				
2. Specific Licensed Professions	✓	✓	✓			✓	✓				
3. Temporary Practice	✓	✓		✓	✓	✓	✓	✓	✓	✓	
4. Employees and Subordinates	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
5. Federal Government Officer or Employee	✓		✓	✓	✓		✓	✓	✓	✓	✓
6. State Government Officer or employee		✓	✓				✓				
7. Local Government Officer or Employee		✓	✓			✓	✓				
8. Public Utility Officer or Employee	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
9. Public Transportation Officer or Employee			✓	✓		✓	✓			✓	
10. Manufacturing or Scientific Research	✓	✓	✓	✓		✓	✓		✓	✓	✓
11. Industrial Firm or Corporation	✓		✓	✓		✓	✓		✓		✓
12. Manufacturing Firm or Corporation	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓
13. Academia		✓									
14. Incidental Practice of Engineering by Other Professions		✓							✓		
15. Expert Witness	✓										✓
16. Work on Own Property	✓	✓	✓	✓			✓	✓	✓	✓	✓
17. Other Exemption	✓	✓	✓	✓		✓	✓	✓	✓		✓
Public Works Provision											
18. Statute Prohibits Exemption of Public Works		✓	✓		✓			✓			✓
19. Public Works Exempt Below Project Cost						✓		✓			✓
20. Public Works Exempt Below Project Size											✓
Private Works Provision											
22. Private Works Exempt Below Project Cost						✓	✓				
23. Private Works Exempt Below Project Size						✓	✓				✓
Building Design											
25. Statute Lists Buildings Only PE May Design				✓	✓						
26. Legislation to List Buildings Only PE May Design											
27. Statute Limits Buildings PE May Design			✓		✓						
28. Legislation to Limit Buildings PE May Design											
29. Statute Exempts Building Types	✓			✓		✓	✓	✓			✓
30. Legislation to Exempt Building Types								✓			

Excerpt from 2001 NSPE Summary of Licensure Laws, selected states

CHAPTER 4

ENGINEERING DISCIPLINE, EMPLOYING INDUSTRY AND THE REGISTRATION OF ENGINEERS

This chapter explores the relationship between employment location and the licensing of engineers and whether employment locations contribute to varying registration rates among the branches of engineering. Since many exemptions from licensing are based on employment location, it is reasonable to expect that the distribution of a state's engineering work force would affect the state's registration rate. If different engineering disciplines are concentrated in particular employment sectors, this would help to explain variations in their registration rates.

Information on employment location comes from the Occupation Employment Statistics (OES) survey, jointly sponsored by the U.S. Bureau of Labor Statistics (BLS) and State Employment Security Agencies (SESAs). Prior to 1996, the program produced only national industry-specific estimates of occupational employment, with data collected from selected industries in each year of a three-year cycle. Beginning in 1996, the OES program collected occupational employment data for selected industries in every state, reporting employment data by both occupation and industry. The last three-year cycle covered 1996 through 1998. These three years have been combined to produce the 1998 results. Data has been collected annually for all covered industries beginning in 1999.

Another change in the OES survey affecting the data used in this report also occurred in 1999. In that year, BLS changed the occupational classification system to that used by the Office of Management and Budget (OMB). The Standard Occupational Classification (SOC) system is now used by all federal statistical agencies for reporting occupational data. Although most engineering occupations are the same, the previous OES category of "all other engineers" is no longer published and biomedical and environmental engineers have been added. Two categories in the old system, computer engineering and electrical and electronic engineering, overlapped by each counting computer hardware engineers within their area. In the new system, two categories have become five with computer software, applications and computer software, systems distinguished within the former category of computer engineering and electrical and electronic distinguished within their area. Computer hardware became the fifth category, separated from both. For all tables using 2000 data, electrical, electronic, and computer hardware have been combined into one category. For all tables using 1988-1998 data, the category of computer engineer has been excluded.

While BLS publishes the national data, individual states are responsible for making their state's data available to users. Data was available for all three discipline-based licensing states and four of the generic licensing states (Florida, North Carolina, Pennsylvania and Texas) post their OES data on the web. As a result, these are the only states described in the tables on employment industry.

Engineering Discipline

Proportional distribution of disciplines. In 2000, the OES survey found that, nationally, persons employed as electrical engineers outnumbered mechanical and civil by 1.7 to 1.[1] This ratio varies widely in California and its comparison states and is noticeably greater in discipline-based than in generic licensing states. Discipline-based states average 2.5 electrical engineers for every mechanical engineer and 2.4 for every civil engineer; comparable ratios in generic

[1] Electrical engineering includes electrical, electronic (except computer) and computer hardware.

states are 1.6 for both mechanical and civil. Collectively, these three disciplines account for 63.8% of all employed engineers in the nation, with industrial engineering the only other branch with double-digit percentages.

There are more environmental engineers (4.8% vs. 3.5%) and twice the proportion of chemical engineers (3.4% vs. 1.5%) in the generic licensing states than in the discipline-based states. Finally, there is three times the proportion of aerospace engineers in discipline-based than in the generic states, largely due to their concentration in California and, to a lesser extent, in Texas and Florida. (Table 4.1 and 4.2)

There has been a noticeable shift in the proportion of engineers employed in different disciplines between 1988-90 and 2000. The proportion of chemical engineers has declined by almost 50%, mechanical and electrical engineers by 17%, and aeronautical/ aerospace engineers by 15%. Disciplines that have increased include civil (by 19%), industrial (by 23%), mining (by 100%) and safety (by 112%). (Table 4.3)

Rates per 100,000 population. A state's licensing type and registration rate may be related to the relative numbers of engineers in the state. The number of employed engineers per 100,000 population was computed for California and the ten comparison states and summarized for the discipline-based and generic licensing states. Discipline-based states have 42% more engineers than generic licensing states (519 vs. 365 per 100,000). Discipline-based states have almost twice as many electrical engineers (197 vs. 106 per 100,000 in generic states) and 25% to 30% more mechanical and industrial engineers (87 vs. 69 and 72 vs. 55 respectively), but similar rates for civil (68 vs. 65). However, the number of civil engineers per 100,000 is higher in California (84) than in any of the comparison states (a range of 42 to 78). The newer and more specialized branches of engineering are more common in the discipline-based states. There are roughly twice as many aerospace and biomedical engineers (21 vs. 9.8 and 4.7 vs. 1.75 per 100,000 respectively), and roughly 50% more environmental and health and safety engineers (26.3 vs. 18.1 and 14 vs. 9.5) as in the generic states. Marine and mining engineering are specialties found more often in the generic states, but in small numbers. (Table 4.4 and 4.5)

Employing Industry

Engineers in the three disciplined-based licensing states have very different industry profiles. The proportion employed in engineering and architectural services in Massachusetts is double that in California (25.1 vs. 12.1%) and three times the proportion in Rhode Island (8.6%). On the other hand, Rhode Island's engineers are mostly in government employment (60%) while almost three-fourths of employed engineers in Massachusetts and California work for corporations (72% each). The generic states are diverse as well. Pennsylvania is similar to Massachusetts in the proportion in engineering and architectural services (29%), but more like California and Florida in having a moderate amount of government employment (13.7 vs. 15.7% and 14.4%). It therefore has fewer engineers in corporate employment than the other generic states for which employment data are available (57% vs. 71 to 84%). (Table 4.6)

In 2000, engineers as a whole were primarily employed by industrial corporations (69%), with 20% in engineering and architectural services and 11% in government employment. In contrast to the other disciplines, civil engineers were much more apt to be employed in engineering and architectural services than in government or private industry (50.6% vs. 29.4% and 20% respectively). Agricultural engineers had the second highest proportion in consulting services (22.1%) and the second fewest in corporate employment (56.9%). Most engineers in the other disciplines are employed by corporations (between 72% and 95%). In addition, only civil, agricultural and nuclear engineers are employed by government in any significant numbers (29.4%, 21% and 15.8% respectively). (Table 4.7)

This represents a shift over the preceding decade of agricultural engineers *into* government employment and of civil engineers *out* of it. There was little change for either discipline in the proportion in corporate employment. In contrast, several disciplines diversified out of corporate employment into engineering and architectural services and government. More mechanical and petroleum engineers moved into consulting services while electrical and nuclear engineers increased their representation in government employment. (Table 4.7)

Registration

The number of registered engineers for 2000/2001 was obtained from California and all but two of the comparison states (Pennsylvania and Florida). Using OES survey estimates of the number of employed engineers in these states, a registration rate was computed for nine of the eleven states. (See Table 4.8.) With the exception of Rhode Island, where 60% of engineers work for a government agency and the registration rate is 9.5%, registration rates vary between 43.5% (Texas) and 68.4% (New Jersey). Three states (New Jersey, North Carolina, and Ohio) are grouped at the high end of this range, with registration rates between 64.4% and 68.4%. The remaining states are also grouped, but at the lower end of the range, between 43.5% (Texas) and 48.9% (Illinois). (Table 4.8)

Registration rates can also be computed by comparing the number of registered engineers to a state's population and to the dollar value of heavy construction in a state. Each of these rates provides a different way of looking at the supply of licensed engineers. Using population as the base is a useful standard for comparing states and disciplines, but population alone is not necessarily related to engineering activities. The amount of heavy construction is an appropriate base for engineering disciplines closely allied with construction, but it is less useful in considering the number in disciplines unrelated to construction. (Table 4.9)

The number of registered engineers per 100,000 population varies from a low of 37 in Rhode Island to a high of 292 in Massachusetts. The average for discipline-based licensing states is 193 compared with 210 in generic states. If Rhode Island is removed from this average because of its unusually small number of registered engineers and the unusually high proportion of engineers employed by government in this state, the average registration rate for the two remaining discipline-based licensing states jumps to 272 -- almost 30% higher than the number of registered engineers per 100,000 population in the generic licensing states. Apparently, discipline-based licensing encourages the licensing of engineers. (Table 4.9)

Registration rates are more closely related to the dollar amount of heavy construction. The average for discipline-based licensing states is 4.43 compared with 5.03 in generic licensing states. Once Rhode Island is removed because of its unusually small number of registered engineers, then the registration rate of 5.98 per million in heavy construction for the discipline-based licensing states is 19% higher than the rate of 5.03 in the generic licensing states. With the exception of Rhode Island, the states vary between a low of 4.1 registered engineers per million dollars of heavy construction and a high of 7.0. California, Ohio and New Jersey have approximately 6 registered engineers while Massachusetts, New York, North Carolina, Texas and Illinois have approximately 4 per million spent on heavy construction. (Table 4.9)

Registration by discipline. Registration by discipline was available for two of the three discipline-based licensing states -- California and Rhode Island. Due to the dominance of government employment among Rhode Island's engineers, registration rates in that state are not good comparisons for California. For purposes of this report, however, discipline variations *within* California are instructive. (Table 4.10)

When the number of 2000/2001 registered engineers in California is compared with OES survey estimates for 2000, the percent registered varies widely by discipline. (Table 4.10) Some of the smaller disciplines (agricultural and chemical engineering) have more registered than OES counted in its survey. This could be due to engineers continuing their registration even though they are no longer employed as engineers or it could be a result of sampling error and the selection of firms and industries. Finally, licensees with multiple licenses would contribute to the disparity between employment and registration. Civil, one of the larger disciplines, also has more registrants than OES counted in the employed population -- 50% more. The disparity may be due to employers identifying engineers by their position or occupational classification rather than the discipline in which they are registered. Thus, registered civil engineers may be employed in positions identified as environmental or aeronautical/aerospace. In addition, OES may not sample a sufficient number of engineering and architectural services firms in California. Since nationally, roughly half of all civil engineers are employed in consulting firms and California has the second smallest percentage so employed in the seven states with available OES survey data, this may account for their under-representation. (Tables 4.7 and 4.6)

Agricultural, chemical and civil engineering are the three disciplines where the number registered is greater than the number estimated to be employed in the state (2.33, 1.54 and 1.04 respectively registered for every one employed). Nuclear and mechanical engineers have the next highest registration rates, with 88% and 60% respectively. Roughly half of all petroleum engineers in California are registered. Rates are lowest for materials (18%), electrical (13%) and industrial (4%). (Table 4.10)

When registration rates per 100,000 population are computed for California and Rhode Island, registered civil engineers outnumber all other disciplines combined (129 vs. 112 per 100,000 population). Registered civil engineers per 100,000 population outnumber electrical engineers 5:1 and mechanical engineers 3:1. The next largest groups are structural, control systems and chemical with 9, 7 and 6 registered per 100,000. (Table 4.11)

Registration among California's title act disciplines. In addition to civil, the oldest engineering disciplines in California are the two other practice acts (mechanical and electrical) and chemical and petroleum, the first title acts, licensed in 1947. In the mid-1960s, industrial and metallurgical were added to the list of title act disciplines and mechanical and electrical, initially defined with title protection only, were given practice protection. In the mid-1970s, six additional disciplines (agricultural, control systems, fire protection, manufacturing, nuclear and traffic) were given title protection. Those active in these areas at the time were not required to take exams, but were grandfathered into licensing. One indicator of the continuing viability of these disciplines is the proportion of those currently licensed that became registered since 1980. The ten disciplines fall into three distinct groups in terms of licensing activity during the past twenty years. Roughly half to two-thirds of currently licensed chemical, fire protection, traffic and petroleum engineers have been licensed since 1980, proportions comparable to two of the practice disciplines (civil and electrical with 67% and 65% respectively). Three-fourths of mechanical engineers have been licensed since 1980. Between a fourth and a third of currently registered agricultural, nuclear and metallurgical engineers were licensed during the same period. There has been relatively little licensing activity during this period in control systems, industrial and manufacturing (between 3% and 19%). (Table 4.12 and 4.13)

Table 4.1. Distribution of Employed Engineers by Discipline for California and Ten Comparison States, 2000

Discipline[1,2]	Discipline-Based Licensing			Generic Licensing								National
	CA	MA	RI	FL	IL	NC	NJ	NY	OH	PA	TX	
	%	%	%	%	%	%	%	%	%	%	%	
Aerospace	12.1	0.0	0.0	6.3	0.0	0.6	0.9	1.6	3.0	0.0	7.0	6.0
Agricultural	0.1	0.0	0.0	0.4	0.1	0.0	0.1	0.1	0.0	0.1	0.2	0.2
Biomedical	0.5	1.8	0.0	0.9	0.9	0.4	0.0	0.0	0.3	0.8	0.4	0.6
Chemical	1.1	2.8	1.7	1.1	4.8	4.2	6.2	2.3	2.8	5.8	3.0	2.6
Civil	16.1	12.2	10.7	27.1	20.1	15.1	22.9	21.9	11.2	16.6	13.9	17.3
Electrical	36.3	37.2	41.2	31.4	24.0	32.8	34.4	33.6	21.9	24.9	32.0	29.2
Environmental	2.8	6.3	6.1	4.9	2.8	5.1	7.7	8.5	4.7	4.7	2.9	4.0
Health and Safety	2.7	3.0	2.4	4.1	2.1	3.0	2.2	0.0	2.4	4.3	2.7	3.6
Industrial	11.5	15.6	14.4	9.1	15.9	18.6	7.9	14.2	26.6	15.7	11.5	14.3
Marine	0.1	0.1	0.0	1.1	0.0	0.0	0.1	0.4	0.0	0.0	0.0	0.4
Materials	1.3	3.3	3.2	1.6	2.3	2.6	1.4	1.8	3.4	3.3	1.5	2.0
Mechanical	13.8	17.3	20.2	11.6	25.7	16.6	16.0	15.3	23.1	19.7	19.0	17.3
Mining	0.5	0.0	0.0	0.4	0.4	0.2	0.0	0.1	0.4	0.7	1.4	0.6
Nuclear	0.6	0.3	0.0	0.0	0.5	0.8	0.1	0.0	0.0	3.5	0.1	1.1
Petroleum	0.5	0.0	0.0	0.0	0.3	0.0	0.0	0.2	0.1	0.0	4.3	0.9
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Total # of Engineers	176,860	40,900	4,100	46,290	44,160	25,290	27,820	58,730	48,720	44,250	111,320	1,197,540

[1]Employment data from 2000 Occupation Employment Statistics. The OES survey is a Federal-State cooperative program between the Bureau of Labor Statistics (BLS) and State Employment Security Agencies (SESAs). In 1999 the OES survey switched from the OES occupational classification system to the new Office of Management and Budget (OMB) Standard Occupational Classification (SOC) system, which will be used by all Federal statistical agencies for reporting occupational data. 2000 OES uses SOC system. Most engineering occupations are the same in the old OES classification system and the new SOC system. The old category of "All other engineers" is no longer published and Biomedical and Environmental Engineers have been added. Two categories in the old system, Computer engineering and Electrical and Electronic engineering, overlapped by each counting Computer Hardware engineers within their area. In the new system, two categories have become five with Computer Software, Applications and Computer Software, Systems distinguished within the former category of Computer engineering and Electrical and Electronic distinguished within their area. Computer Hardware became the fifth category, separated from both. For all tables using 2000 data, Electrical, Electronic, and Computer Hardware have been combined into one category. For all tables using 1988-1998 data, the category of Computer Engineer has been excluded.

[2]Disciplines registered in California but not included in OES are Fire Protection, Control Systems, Manufacturing, Geotechnical and Structural.

Table 4.2. Distribution of Employed Engineers by Discipline for Discipline-Based and Generic Licensing States, 2000

Discipline [1,2]	Discipline[3] %	Generic[3] %	National %
Aerospace	9.7	3.3	6.0
Agricultural	0.1	0.1	0.2
Biomedical	0.7	0.5	0.6
Chemical	1.5	3.4	2.6
Civil	15.3	17.9	17.3
Electrical	36.6	29.5	29.2
Environmental	3.5	4.8	4.0
Health and Safety	2.8	2.5	3.6
Industrial	12.3	14.6	14.3
Marine	0.1	0.2	0.4
Materials	1.7	2.1	2.0
Mechanical	14.5	18.6	17.3
Mining	0.4	0.6	0.6
Nuclear	0.6	0.5	1.1
Petroleum	0.4	1.3	0.9
	100.0	100.0	100.0
Total # of Engineers	221,860	406,580	1,197,540

[1]Employment data from 2000 Occupation Employment Statistics. The OES survey is a Federal-State cooperative program between the Bureau of Labor Statistics (BLS) and State Employment Security Agencies (SESAs). In 1999 the OES survey switched from the OES occupational classification system to the new Office of Management and Budget (OMB) Standard Occupational Classification (SOC) system, which will be used by all Federal statistical agencies for reporting occupational data. 2000 OES uses SOC system. Most engineering occupations are the same in the old OES classification system and the new SOC system. The old category of "All other engineers" is no longer published and Biomedical and Environmental Engineers have been added. Two categories in the old system, Computer engineering and Electrical and Electronic engineering, overlapped by each counting Computer Hardware engineers within their area. In the new system, two categories have become five with Computer Software, Applications and Computer Software, Systems distinguished within the former category of Computer engineering and Electrical and Electronic distinguished within their area. Computer Hardware became the fifth category, separated from both. For all tables using 2000 data, Electrical, Electronic, and Computer Hardware have been combined into one category. For all tables using 1988-1998 data, the category of Computer Engineer has been excluded.

[2]Disciplines registered in California but not included in OES are Fire Protection, Control Systems, Manufacturing, Geotechnical and Structural.

[3]Proportions are weighted by the total number of engineers in each group of states.

Table 4.3. Distribution of Employed Engineers by Discipline[1,2], 1988-90 and 2000

1988-1990	%	2000	%
Aeronautical	6.9	Aerospace	6.0
Agricultural	0.3	Agricultural	0.2
Chemical	4.7	Chemical	2.6
Civil, incl. traffic	14.5	Civil	17.3
Electrical	35.0	Electrical	29.2
Industrial	11.6	Industrial	14.3
Marine	0.4	Marine	0.4
Mechanical	20.8	Mechanical	17.3
Metallurgical	1.8	Materials	2.0
Mining	0.3	Mining	0.6
Nuclear	1.0	Nuclear	1.1
Petroleum	1.1	Petroleum	0.9
Safety	1.7	Health and Safety	3.6
All Other	22.2		
		Biomedical	0.6
		Environmental	4.0
	100.0		100.0
Total # Engineers	1,125,020		1,197,540

[1]1988-1990 employment data from 1988-1990 National Occupation Employment Statistics.2000 data from 2000 Occupation Employment Statistics. The OES survey is a Federal-State cooperative program between the Bureau of Labor Statistics (BLS) and State Employment Security Agencies (SESAs). In 1999 the OES survey switched from the OES occupational classification system to the new Office of Management and Budget (OMB) Standard Occupational Classification (SOC) system, which will be used by all Federal statistical agencies for reporting occupational data. 2000 OES uses SOC system. Most engineering occupations are the same in the old OES classification system and the new SOC system. The old category of "All other engineers" is no longer published and Biomedical and Environmental Engineers have been added. Two categories in the old system, Computer engineering and Electrical and Electronic engineering, overlapped by each counting Computer Hardware engineers within their area. In the new system, two categories have become five with Computer Software, Applications and Computer Software, Systems distinguished within the former category of Computer engineering and Electrical and Electronic distinguished within their area. Computer Hardware became the fifth category, separated from both. For all tables using 2000 data, Electrical, Electronic, and Computer Hardware have been combined into one category. For all tables using 1988-1998 data, the category of Computer Engineer has been excluded.

[2]Disciplines registered in California but not included in OES are Fire Protection, Control Systems, Manufacturing, Geotechnical and Structural.

Table 4.4. Number of Employed Engineers per 100,000 Population[3] by Discipline for California and Ten Comparison States, 2000

	Discipline-Based Licensing			Generic Licensing								National
Discipline[1,2]	CA	MA	RI	FL	IL	NC	NJ	NY	OH	PA	TX	
Aerospace	63	0	0	18	0	2	3	5	13	0	37	25
Agricultural	0	0	0	1	0	0	0	0	0	0	1	1
Biomedical	3	12	0	3	3	1	0	0	1	3	2	2
Chemical	6	18	7	3	17	13	21	7	12	21	16	11
Civil	84	78	42	78	72	47	76	68	48	60	74	74
Electrical	190	240	161	91	85	103	114	104	94	90	171	124
Environmental	14	41	24	14	10	16	26	26	20	17	16	17
Health and Safety	14	19	10	12	8	9	7	0	10	15	14	26
Industrial	60	101	56	26	56	59	26	44	114	56	61	61
Marine	0	1	0	3	0	0	0	1	0	0	0	0
Materials	7	21	12	5	8	8	5	6	15	12	8	9
Mechanical	72	111	79	34	92	52	53	47	99	71	102	74
Mining	2	0	0	1	1	0	0	0	2	3	8	2
Nuclear	3	2	0	0	2	2	0	0	0	13	1	4
Petroleum	3	0	0	0	1	0	0	1	0	0	23	4
Overall	522	644	391	290	356	314	331	309	429	360	534	435

[1]Employment data from 2000 Occupation Employment Statistics. The OES survey is a Federal-State cooperative program between the Bureau of Labor Statistics (BLS) and State Employment Security Agencies (SESAs). In 1999 the OES survey switched from the OES occupational classification system to the new Office of Management and Budget (OMB) Standard Occupational Classification (SOC) system, which will be used by all Federal statistical agencies for reporting occupational data. 2000 OES uses SOC system. Most engineering occupations are the same in the old OES classification system and the new SOC system. The old category of "All other engineers" is no longer published and Biomedical and Environmental Engineers have been added. Two categories in the old system, Computer engineering and Electrical and Electronic engineering, overlapped by each counting Computer Hardware engineers within their area. In the new system, two categories have become five with Computer Software, Applications and Computer Software, Systems distinguished within the former category of Computer engineering and Electrical and Electronic distinguished within their area. Computer Hardware became the fifth category, separated from both. For all tables using 2000 data, Electrical, Electronic, and Computer Hardware have been combined into one category. For all tables using 1988-1998 data, the category of Computer Engineer has been excluded.

[2]Disciplines registered in California but not included in OES are Fire Protection, Control Systems, Manufacturing, Geotechnical and Structural.

[3]Population data from 2000 Census.

Table 4.5. Average Rate of Employed Engineers per 100,000 Population by Discipline for Discipline-Based and Generic Licensing States, 2000

Discipline[1,2]	Discipline-Based Licensing	Generic Licensing	National
Aerospace	21	10	25
Agricultural	0	0	1
Biomedical	5	2	2
Chemical	10	14	11
Civil	68	65	74
Electrical	197	106	124
Environmental	26	18	17
Health and Safety	14	10	26
Industrial	72	55	61
Marine	0	1	0
Materials	13	8	9
Mechanical	87	69	74
Mining	1	2	2
Nuclear	2	2	4
Petroleum	1	3	4
Total	519	365	435

[1]Employment data from 2000 Occupation Employment Statistics. The OES survey is a Federal-State cooperative program between the Bureau of Labor Statistics (BLS) and State Employment Security Agencies (SESAs). In 1999 the OES survey switched from the OES occupational classification system to the new Office of Management and Budget (OMB) Standard Occupational Classification (SOC) system, which will be used by all Federal statistical agencies for reporting occupational data. 2000 OES uses SOC system. Most engineering occupations are the same in the old OES classification system and the new SOC system. The old category of "All other engineers" is no longer published and Biomedical and Environmental Engineers have been added. Two categories in the old system, Computer engineering and Electrical and Electronic engineering, overlapped by each counting Computer Hardware engineers within their area. In the new system, two categories have become five with Computer Software, Applications and Computer Software, Systems distinguished within the former category of Computer engineering and Electrical and Electronic distinguished within their area. Computer Hardware became the fifth category, separated from both. For all tables using 2000 data, Electrical, Electronic, and Computer Hardware have been combined into one category. For all tables using 1988-1998 data, the category of Computer Engineer has been excluded.

[2]Disciplines registered in California but not included in OES are Fire Protection, Control Systems, Manufacturing, Geotechnical and Structural.

Table 4.6. Distribution of Employed Engineers[1,3,4] by Industry for California and Six Comparison States, 1998

		Engineering & Architecture Services[2]	Government	Industrial Corporation
		%	%	%
Discipline-Based Licensing	California	12.1	15.7	72.1
	Massachusetts	25.1	3.0	71.9
	Rhode Island	8.6	59.5	31.9
Generic Licensing	Florida	15.2	14.4	70.5
	North Carolina	13.0	3.3	83.7
	Pennsylvania	29.0	13.7	57.3
	Texas	17.7	2.9	79.4

[1]Employment data from 1998 State Occupation Employment Statistics except Texas. The three years of 1996, 1997, and 1998 have been combined to produce the 1998 results. Texas employment data from 2001 State OES. The OES survey is a Federal-State cooperative program between the Bureau of Labor Statistics (BLS) and State Employment Security Agencies (SESAs). In 1999 the OES survey switched from the OES occupational classification system to the new Office of Management and Budget (OMB) Standard Occupational Classification (SOC) system, which will be used by all Federal statistical agencies for reporting occupational data. 2000 OES uses SOC system. Most engineering occupations are the same in the old OES classification system and the new SOC system. The old category of "All other engineers" is no longer published and Biomedical and Environmental Engineers have been added. Two categories in the old system, Computer engineering and Electrical and Electronic engineering, overlapped by each counting Computer Hardware engineers within their area. In the new system, two categories have become five with Computer Software, Applications and Computer Software, Systems distinguished within the former category of Computer engineering and Electrical and Electronic distinguished within their area. Computer Hardware became the fifth category, separated from both. For all tables using 2000 data, Electrical, Electronic, and Computer Hardware have been combined into one category. For all tables using 1988-1998 data, the category of Computer Engineer has been excluded.

[2]SIC 871 Engineering & Architecture Services not available for Texas and Massachusetts. Estimates from SIC 87 Engineering & Management Services used instead

[3]Disciplines registered in California but not included in OES are Fire Protection, Control Systems, Manufacturing, Geotechnical and Structural.

[4]This table excludes the following OES engineering occupations: Aeronautical, Mining, Marine, and Safety.

Table 4.7. National Distribution of Employed Engineers by Industry, Discipline and Year, 1988-90 and 2000

Discipline[1,2,3]	1988-1990 E&A Services %	1988-1990 Government %	1988-1990 Industrial Corporation %	2000 E&A Services %	2000 Government %	2000 Industrial Corporation %
Agricultural	45.23	--	54.77	22.10	20.99	56.91
Chemical	10.90	--	89.10	9.73	5.26	85.00
Civil	37.97	39.56	22.47	50.57	29.43	20.00
Electrical and Electronic	7.50	1.45	91.05	13.16	9.24	77.60
Industrial	4.10	--	95.90	3.38	0.98	95.64
Metallurgical	13.79	--	86.21	3.56	6.34	90.11
Mechanical	4.07	--	95.93	15.51	4.99	79.50
Nuclear	23.16	--	76.84	12.22	15.76	72.03
Petroleum	--	--	100.00	13.41	4.67	81.92
All Other	5.23	5.56	89.21	--	--	--
Overall	12.03	6.64	81.33	19.73	11.17	69.10

[1]1988-1990 employment data from 1988-1990 National Occupation Employment Statistics. 2000 employment data from 2000 National OES. The OES survey is a Federal-State cooperative program between the Bureau of Labor Statistics (BLS) and State Employment Security Agencies (SESAs). In 1999 the OES survey switched from the OES occupational classification system to the new Office of Management and Budget (OMB) Standard Occupational Classification (SOC) system, which will be used by all Federal statistical agencies for reporting occupational data. 2000 OES uses SOC system. Most engineering occupations are the same in the old OES classification system and the new SOC system. The old category of "All other engineers" is no longer published and Biomedical and Environmental Engineers have been added. Two categories in the old system, Computer engineering and Electrical and Electronic engineering, overlapped by each counting Computer Hardware engineers within their area. In the new system, two categories have become five with Computer Software, Applications and Computer Software, Systems distinguished within the former category of Computer engineering and Electrical and Electronic distinguished within their area. Computer Hardware became the fifth category, separated from both. For all tables using 2000 data, Electrical, Electronic, and Computer Hardware have been combined into one category. For all tables using 1988-1998 data, the category of Computer Engineer has been excluded.

[2]Disciplines registered in California but not included in OES are Fire Protection, Control Systems, Manufacturing, Geotechnical and Structural.

[3]This table excludes the following OES engineering occupations: Aeronautical, Marine, Mining, and Safety. This table excludes the following SOC engineering occupations: Aerospace, Biomedical, Environmental, Health and Safety, Mining, and Marine.

Table 4.8. Registration Rate Among Employed Engineers for California and Eight Comparison States, 2000

		OES Estimate 2000[1,2]	Registered 00/01[3]	Proportion of Employed Engineers Registered
Discipline-Based Licensing	California	176,860	85,083	0.481
	Massachusetts	40,900	18,521	0.453
	Rhode Island	4,100	390	0.095
Generic Licensing	Illinois	44,160	21,611	0.489
	New Jersey	27,820	19,017	0.684
	New York	58,730	26,376	0.449
	North Carolina	25,290	16,876	0.667
	Ohio	48,720	31,376	0.644
	Texas	111,320	48,434	0.435

[1]Employment data from 2000 Occupation Employment Statistics. The OES survey is a Federal-State cooperative program between the Bureau of Labor Statistics (BLS) and State Employment Security Agencies (SESAs). In 1999 the OES survey switched from the OES occupational classification system to the new Office of Management and Budget (OMB) Standard Occupational Classification (SOC) system, which will be used by all Federal statistical agencies for reporting occupational data. 2000 OES uses SOC system. Most engineering occupations are the same in the old OES classification system and the new SOC system. The old category of "All other engineers" is no longer published and Biomedical and Environmental Engineers have been added. Two categories in the old system, Computer engineering and Electrical and Electronic engineering, overlapped by each counting Computer Hardware engineers within their area. In the new system, two categories have become five with Computer Software, Applications and Computer Software, Systems distinguished within the former category of Computer engineering and Electrical and Electronic distinguished within their area. Computer Hardware became the fifth category, separated from both. For all tables using 2000 data, Electrical, Electronic, and Computer Hardware have been combined into one category. For all tables using 1988-1998 data, the category of Computer Engineer has been excluded.

[2]Disciplines registered in California but not included in OES are Fire Protection, Control Systems, Manufacturing, Geotechnical and Structural.

[3]Registration data from State licensing boards.

Table 4.9. Number of Registered Engineers per 100,000 Population and per $1,000,000 in Heavy Construction for California and Six Comparison States, 2000/2001[*]

		Registration Rate per 100,000 population	Registration Rate per $1,000,000 in Heavy Construction
Discipline-Based Licensing	California	251	6.98
	Massachusetts	292	4.98
	Rhode Island	37	1.33
	Average of 3 states	193	4.43
	Average w/out RI	272	5.98
Generic Licensing	Illinois	174	4.07
	New Jersey	226	6.05
	New York	139	4.99
	North Carolina	210	4.45
	Ohio	276	6.52
	Texas	232	4.10
	Average	210	5.03

[*]Registration data provided by State boards. Population from US Census 2000. Heavy Construction from Economic Census 1997.

Table 4.10. Registration Rate Among Employed Engineers by Discipline for California and Rhode Island, 2000/2001

Discipline [1,2,3]	California			Rhode Island		
	OES Estimate 2000	Registered 00/01[4]	Proportion of Employed Engineers Registered	OES Estimate 2000	Registered 00/01[4]	Proportion of Employed Engineers Registered
Agricultural	120	280	2.33	0	-	-
Chemical	2,030	2,121	1.04	70	7	0.10
Civil	28,450	43,710	1.54	440	197	0.45
Electrical	64,280	8,312	0.13	1,690	64	0.04
Environmental	4,890	-	-	250	4	0.02
Industrial	20,360	845	0.04	590	-	-
Materials	2,270	418	0.18	130	-	-
Mechanical	24,330	14,646	0.60	830	77	0.09
Nuclear	1,110	980	0.88	0	-	-
Petroleum	940	476	0.51	0	-	-
Total	148,780	71,788	0.48	4,000	349	0.00

[1]Employment data from 2000 Occupation Employment Statistics. The OES survey is a Federal-State cooperative program between the Bureau of Labor Statistics (BLS) and State Employment Security Agencies (SESAs). In 1999 the OES survey switched from the OES occupational classification system to the new Office of Management and Budget (OMB) Standard Occupational Classification (SOC) system, which will be used by all Federal statistical agencies for reporting occupational data. 2000 OES uses SOC system. Most engineering occupations are the same in the old OES classification system and the new SOC system. The old category of "All other engineers" is no longer published and Biomedical and Environmental Engineers have been added. Two categories in the old system, Computer engineering and Electrical and Electronic engineering, overlapped by each counting Computer Hardware engineers within their area. In the new system, two categories have become five with Computer Software, Applications and Computer Software, Systems distinguished within the former category of Computer engineering and Electrical and Electronic distinguished within their area. Computer Hardware became the fifth category, separated from both. For all tables using 2000 data, Electrical, Electronic, and Computer Hardware have been combined into one category. For all tables using 1988-1998 data, the category of Computer Engineer has been excluded.

[2]Disciplines registered in California but not included in OES are Fire Protection, Control Systems, Manufacturing, Geotechnical and Structural.

[3]This table excludes the following SOC engineering occupations: Aerospace, Biomedical, Health and Safety, Mining, and Marine.

[4]Registration data from State licensing boards.

Table 4.11. Number of Registered Engineers per 100,000 Population by Discipline for California and Rhode Island, 2000/2001*

Discipline	California	Rhode Island
Civil	129	19
Geotechnical	3	-
Structural	9	5
Electrical	25	6
Mechanical	43	7
Agricultural	1	-
Chemical	6	1
Control Systems	7	-
Fire Protection	3	-
Industrial	2	-
Manufacturing	4	-
Metallurgical	1	-
Nuclear	3	-
Petroleum	1	-
Traffic	4	-
Environmental	-	0

*Registration data provided by State boards. Population from US Census 2000.

Table 4.12. Year License Issued by Discipline, for Engineers with Current California Licenses as of 2002

Year license issued	Practice Act Disciplines			Title Act Disciplines										
	Civil	Elec-trical	Mechan-ical	Agri-cultural	Chem-ical	Control Systems	Fire Pro-tection	Industrial	Manu-facturing	Metal-lurgical	Nuclear	Petroleum	Traffic	Total
1937	1													1
1938	1													1
1939	3													3
1940	6													6
1941	5													5
1942	6													6
1943	9													9
1944	8													8
1945	10													10
1946	21													21
1947	28	1												29
1948	48	163	71		24							21		327
1949	59	73	218		41							10		401
1950	37	10	17		4									68
1951	60	8	8		2							3		81
1952	67	8	17		3							1		96
1953	120	14	25		4									163
1954	156	17	12		1							1		187
1955	274	34	47		5							4		364
1956	166	32	39		8							3		248
1957	214	38	76		2							4		334
1958	157	22	35		9							2		225
1959	353	50	53		10							11		477
1960	157	22	41		7							6		233
1961	256	52	107		8							7		430
1962	210	40	49		2							1		302
1963	442	52	49		11							6		560
1964	335	62	59		7							4		467
1965	608	94	26		15							4		747
1966	467	47	80		8					142		1		745
1967	519	80	65		14			2		53		2		735
1968	384	62	68		14			152		27		6		713
1969	717	103	11		13			289		9		2		1,144
1970	392	67	83		8			113		3		3		669
1971	860	136	83		15			40		7		3		1,144
1972	586	102	137		17			21		1		2		866
1973	968	175	108		21			5		15		7		1,299
1974	575	116	198		13			3		1		4		910
1975	1,128	254	163	16	56	79	29	13	25	10	29	13	46	1,861
1976	1,125	171	38	96	32	266	110	6	132	9	24	3	185	2,197
1977	999	289	461	68	63	471	237	14	167	8	477	5	313	3,572
1978	1,047	328	494	6	111	1,119	37	11	832	12	46	8	58	4,109
1979	985	221	540	5	69	103	24	12	149	3	11	8	49	2,179
1980	1,080	213	425	5	60	18	16	5	4	3	10	13	19	1,871
1981	1,205	262	471	4	38	14	6	10	1	8	8	10	22	2,059
1982	1,565	269	499	5	109	19	12	10	4	11	4	15	14	2,536
1983	1,464	260	606	10	112	16	10	12		9	11	16	16	2,542
1984	1,292	271	589	2	103	22	9	12	3	7	12	29	25	2,376
1985	819	200	479	2	29	15	6	10	3	8	11	43	13	1,638
1986	1,114	173	1,139	6	22	12	24	3	1	10	6	24	27	2,561
1987	1,972	244	1,137	4	15	7	9	8	1	7	193	27	36	3,660
1988	190	206	444	1	36	11	19	7	1	5	4	19	30	973
1989	1,254	305	622	2	53	3	21	12	1	6		15	24	2,318
1990	1,312	256	494	3	79	4	11	11	1	8		6	26	2,211
1991	2,075	188	541	7	61	16	16	7	1	6	3	14	40	2,975
1992	1,234	233	368	1	137	13	17	12	2	1	6	16	40	2,080
1993	1,236	264	509	3	70	6	22	8	1	1	5	17	111	2,253
1994	1,679	288	422		53	14	16	6		5	3	13	3	2,502
1995	1,784	381	411	2	88	13	31	4	5	1	4	3	44	2,771
1996	1,494	225	443	2	63	16	22	7	1	5		1	26	2,305
1997	1,361	334	333	2	68	9	20	5	1	4	3	4	55	2,199
1998	913	223	399	2	30	16	17	3	1	3	1	13	35	1,656
1999	1,155	206	331		52	13	25	3		5	2	8	53	1,853
2000	1,221	207	339	1	40	15	25	3	1	5	1	3	37	1,898
2001	1,402	222	309	1	38	9	10	2	1	5	3	7	53	2,062
2002	745	71	90	1	39	5	6	4	1			2	1	965
Total	44,135	8,444	14,878	257	2,012	2,324	807	845	1,340	423	877	473	1,401	78,216

Table 4.13. Percent of Currently Licensed California Engineers with Licenses Issued Before and After 1980

	Year license issued	Practice Act Disciplines			Title Act Disciplines										Total
		Civil	Electrical	Mechan-ical	Agri-cultural	Chemical	Control Systems	Fire Protection	Industrial	Manu-facturing	Metal-lurgical	Nuclear	Petroleum	Traffic	
Percent	Before 1980	33%	35%	23%	74%	31%	88%	54%	81%	97%	71%	67%	33%	46%	36%
	1980 or later	67%	65%	77%	26%	69%	12%	46%	19%	3%	29%	33%	67%	54%	64%
	Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Number	Before 1980	14,569	2,943	3,478	191	617	2,038	437	681	1,305	300	587	155	651	27,952
	1980 or later	29,566	5,501	11,400	66	1,395	286	370	164	35	123	290	318	750	50,264
	Total	44,135	8,444	14,878	257	2,012	2,324	807	845	1,340	423	877	473	1,401	78,216

CHAPTER 5

NCEES EXAMINATION PASS RATES

Pass rates on NCEES examinations in California and the comparison states were obtained and described over a five-year period (1997 to 2001). In addition to the Fundamentals of Engineering (FE) exam, results were obtained for the following engineering disciplines: agriculture, chemical, civil and its five depth exams, control systems, electrical, fire protection, industrial, manufacturing, mechanical and its three depth exams, metallurgical, nuclear and petroleum. Since the focus of the analysis is on relative differences in pass rates between individual states, standard normal scores (z-scores) have been computed to describe each state's distance from the weighted pass rate for the ten states combined.[1] The higher the z-score the further a state's pass rate is from the rate for the combined states. A negative value indicates a lower pass rate than average while a positive value indicates a higher one. Actual pass rates are not shown in the report. Each comparison state has been assigned a code letter so that their identity is masked.

Fundamentals of Engineering Examination

Some states are consistently above average in their pass rates on the FE exam, while others are consistently below. Four states have above average pass rates (states I, J, K, and G), while three states have below average pass rates (California, and states F and E). With the exception of 1997, state D has a modestly above average pass rate, while, with the exception of 2001, state H has a below average rate. California's pass rate was at least nine standard deviations below the mean for the ten states in each of the five years, far and away the lowest among the comparison states. States G, K, and J were generally nine standard deviations or more above the mean. States H, E, and D were usually closest to the mean. (Table 5.1)

Reasons for this pattern are unclear. The quality of education in the respective states would be the most obvious hypothesis. States could also vary in screening those applying to take the fundamentals exam. They may also vary in the proportion of candidates educated abroad so that language facility and the focus of education play a role in states like California with a larger immigrant population.

In a search for other explanations, a relationship between pass rates and regulatory structure was explored. Although two different methodologies were used to test this difference, each gave the same answer: pass rates are higher in "board-dominated" states and lower in "agency-dominated" ones. The first methodology computed the average distance from the overall mean pass rate on the FE exam for board and agency states. The total taking the exam in the four board states was divided into the number passing to obtain a "weighted" pass rate, giving greater weight to the states with more examinees. Using weighted figures, pass rates are close to the average in the four "board-dominated" states -- despite California's well below average scores -- and significantly below average in the six "agency-dominated" states in two of the five years (1997 and 2000). Using an unweighted average of the normalized pass rates for each group of states, pass rates are well above average in the board-dominated states (with z-scores of 2 to 4.18 standard deviations above the mean) and well below or close to the mean in the agency-dominated states (-5.47 to .81). (Table 5.2a)

[1] Examination scores for state B were not available. Results for state A were only available for 2000 and 2001.

Pass rates were also compared for discipline-based and generic licensing states. Even stronger differences were found between these two groups of states, again independent of the methodology used. In three of the five years, this is a comparison of California with the eight generic licensing states. Exam data was only available for state A for 2000 and 2001. Using weighted or unweighted average standardized pass rates, California and state A are many standard deviations (-8.71 to -17.61) below the average pass rate for the comparison states while the generic licensing states are significantly above average (ranging from 1997 lows and 2001 highs of 6.30 to 14.84 standard deviations for weighted data and from 2.6 to 5.08 standard deviations for unweighted data). (Table 5.2b)

Civil Engineering Examination

California. In California, the fundamentals and civil exams appear to work as screening devices for those seeking licensing. Although California pass rates on the general civil exam are not as low as they are on the fundamentals exam, they are still significantly below average, varying between three and nine standard deviations below the mean for the ten states. A similar pattern is observed on the transportation depth exam that began in 2000 and to a lesser extent on the water resources depth exam that began in the same year. On all other civil depth exams -- and indeed, almost all other specialty exams -- California pass rates are very close to the average. California requires that civil engineers pass an additional exam in order to become licensed that tests knowledge of seismic principles and surveying. Because the examinees in California are preparing for this additional exam in conjunction with their preparation for the NCEES civil exam, their scores may be negatively affected. (Table 5.1, 3, 4, 4a and 4b)

Comparison states. On the civil exam, states E and F continue the pattern of lower than average pass rates established on the fundamentals exam while states I, J, and K continue to have significantly higher ones. State H is the only state to reverse directions. While pass rates were below average on the fundamentals exam, they were consistently above average on the civil exam. (Table 5.4)

On the transportation, water resources and structural depth exams, states E and F are right at the average for the six comparison states giving those exams in 2000 and 2001. State I in both years, and states J and H in 2001, had significantly higher pass rates on the transportation and water resources exams. Only states I and J exceeded the average on the structural depth exam in 2001 and only state H and J exceeded it on the geotechnical depth exam in the same year. State E's lower than average pass rate resurfaced on the geotechnical depth exam. None of the states varied much from the average on the environmental depth exam. (Table 5.4a, b, c, d and e)

Mechanical Engineering Examination

California. The HVAC and refrigeration depth exam was one of the exceptions to the general observation that California pass rates on the specialty exams were in the normal range. On this exam, the pass rate was two standard deviations below the average for seven states. However, California was close to the average for the comparison states on the overall exam in mechanical engineering. (Table 5.5 and 6)

Comparison states. States E and F are also significantly below average on pass rates for the mechanical engineering examination. States I, J and K in three of the five years, continued to have above average pass rates. States D and H, along with California, were close to the average in all five years. State H was also above average in its pass rate on the HVAC and refrigeration depth exam, while state I was somewhat above on machine design and state E somewhat below on thermal and fluids systems. With these few exceptions, the states' performance on the mechanical depth exams was very consistent. (Table 5.5)

Electrical Engineering Examination

California and its comparison states The other major exception to California's generally average pass rates on the specialty exams was its performance on the electrical engineering exam. Pass rates on this exam were significantly below average in four of the five years surveyed. State E was below average in three of the five years while states J and K were above average in four and five years respectively. States F and H were consistently close to the mean. (Table 5.7)

Chemical Engineering Examination

California and its comparison states. California was significantly below average in only one of the four years (2000). Most states varied closely around the mean, with occasional pass rates veering off in a positive (state J) or negative (states E and F) direction. Only state K was consistently above average in its pass rates on the chemical engineering examination in all five years. (Table 5.8)

Control Systems Examination

California and its comparison states. Pass rates for all states varied within a narrow range on the control systems examination, with only states H and J significantly below average in 1998. The number taking the exam in both states, however, was extremely small (3 and 6 respectively). (Table 5.9)

Fire Protection Examination

California and its comparison states. Pass rates were very consistent over all states and years. State E had modestly lower pass rates in 1998 and 2000, while state A had a modestly higher one in 2000. (Table 5.10)

Industrial Examination

California and its comparison states. Neither California nor its comparison states varied much from the average in any of the five years. (Table 5.11)

Petroleum Examination

California and its comparison states. In 1999, California had a modestly lower than average pass rate on the petroleum exam, while in the same year state K had a somewhat higher than average rate. Many states, however, did not administer this exam and those that did had few examinees. (Table 5.12)

Metallurgical, Nuclear, Agricultural and Manufacturing Examinations

California and its comparison states. Since very few take these exams, pass rates are unreliable. (Tables 5.13-16)

Table 5.1. Standard Normal (Z-Scores) for State Pass Rates on the Engineering Fundamentals Examination, 1997-2001

	1997		1998		1999		2000		2001	
State	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z
California	4100	-13.85 **	4257	-15.36 **	4703	-16.74 **	4568	-15.48 **	5272	-18.26 **
H	1669	-4.38 **	1525	-4.79 **	1499	-2.80 **	1337	-1.89	1395	0.09
F	508	-5.70 **	512	-4.11 **	413	-6.67 **	483	-4.36 **	416	-2.92 **
E	1953	-4.64 **	1877	-2.51 **	1864	-2.39 *	1934	-2.32 *	1866	-3.98 **
I	998	3.73 **	901	4.12 **	876	5.03 **	924	7.26 **	910	6.23 **
J	1691	10.14 **	1517	9.35 **	1437	9.23 **	1271	13.75 **	1181	12.51 **
D	2235	-0.65	2044	2.14 *	1939	0.46	1883	2.24 *	1772	3.58 **
K	2730	8.01 **	2433	11.37 **	2408	12.46 **	2097	11.17 **	2486	16.01 **
G	926	9.90 **	855	10.07 **	777	10.88 **	525	1.70	359	9.12 **
A							731	-1.94	614	-1.02

*p<0.05 **p<0.01

Table 5.2a. Average Weighted and Unweighted Z-Scores for State Pass Rates on the Engineering Fundamentals Examination by Regulatory Model, 1997-2001

	Board[1]			Agency[2]			Z	Significance of Difference in pass rates[3]
	Pass Rate	Unweighted Z	Weighted Z	Pass Rate	Unweighted Z	Weighted Z		
1997	0.67	2.01 *	0.68	0.65	-5.47 **	-2.84 **	2.86	0.0021 **
1998	0.61	2.37 *	0.49	0.61	.80	0.03	0.00	0.5000
1999	0.59	2.50 *	-0.39	0.59	-.52	-0.29	0.00	0.5000
2000	0.56	4.18 **	1.88	0.54	-1.10	-2.20 *	2.50	0.0062 **
2001	0.54	4.12 **	0.91	0.55	.81	0.88	-1.25	0.1056

*p < .05 **p < .01 ***p < .001

[1]Board states include California, North Carolina, Ohio, and Texas.

[2]Agency States include Florida, Illinois, Massachusetts, New Jersey, New York and Pennsylvania.

[3]The z-test of proportions for the difference between sample proportions was used to evaluate whether the difference in pass rates in discipline-based licensing and generic states could have occurred purely by chance. The probabilities in the table describe the likelihood of obtaining the differences observed purely by chance and lead to the conclusion that the differences are not random.

Table 5.2b. Average Weighted and Unweighted Z-Scores for State Pass Rates on the Engineering Fundamentals Examination by Licensing Model, 1997-2001

	Discipline-Based Licensing[1]			Generic Licensing[2]			Z	Significance of Difference in pass rates[3]
	Pass Rate	Unweighted Z	Weighted Z	Pass Rate	Unweighted Z	Weighted Z		
1997	0.57	-13.85 ***	-13.85 ***	0.70	2.60 **	6.30 ***	-16.25	0.0000 ***
1998	0.50	-15.36 ***	-15.36 ***	0.65	3.21 **	9.73 ***	-16.67	0.0000 ***
1999	0.47	-16.74 ***	-16.74 ***	0.64	3.28 ***	10.26 ***	-18.89	0.0000 ***
2000	0.45	-8.71 ***	-15.09 ***	0.60	3.44 ***	10.68 ***	-18.75	0.0000 ***
2001	0.43	-9.64 ***	-17.61 ***	0.61	5.08 ***	14.84 ***	-22.50	0.0000 ***

*p < .05 **p < .01 ***p < .001

[1]Discipline states include California and Massachusetts.

[2] Generic States include Florida, Illinois, Massachusetts, New Jersey, New York, North Carolina, Ohio, Pennsylvania, and Texas.

[3]The z-test of proportions for the difference between sample proportions was used to evaluate whether the difference in pass rates in discipline-based licensing and generic states could have occurred purely by chance. The probabilities in the table describe the likelihood of obtaining the differences observed purely by chance and lead to the conclusion that the differences are not random.

Table 5.3. Summary of Standard Normal (Z-Scores) for California Pass Rates on All Discipline Examinations

California		1997	1998	1999	2000	2001
Civil		-**	-**	-**	-**	-**
	Transportation[1]				-**	-**
	Water Resources[1]				-*	-**
	Structural[1]				ns	ns
	Geotechnical[1]				ns	ns
	Environmental[1]				ns	ns
Mechanical		ns	ns	ns	ns	ns
	HVAC and Refrigeration[2]					-*
	Machine Design[2]					ns
	Thermal and Fluids Systems[2]					ns
Electrical		-**	-**	-**	-**	ns
Chemical		ns	ns	ns	-*	ns
Control Systems		ns	ns	ns	ns	ns
Fire Protection		ns	ns	ns	ns	ns
Industrial		ns	ns	ns	ns	ns
Petroleum		ns	ns	-*	ns	ns
Metallurgical		ns	ns	ns	ns	none
Nuclear		ns	ns	ns	ns	none
Agricultural		ns	ns	ns	ns	ns
Manufacturing		ns	ns	ns	ns	ns

- indicates negative value

*p <.05 ** p<.01 ns= not significant

[1]Civil depth modules were added in 2000.

[2]Mechanical depth modules were added in 2001.

Table 5.4. Standard Normal (Z-Scores) for State pass Rates on the Civil Engineering Examination, 1997-2001

State	1997		1998		1999		2000		2001	
	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z
California	2600	-7.22 **	2853	-3.44 **	3104	-9.15 **	3753	-3.80 **	4133	-7.54 **
H	657	2.46 *	823	1.82	850	3.66 **	824	3.19 **	764	3.15 **
F	320	-1.01	349	-1.92	346	-2.50 *	379	-3.35 **	350	-2.88 **
E	776	-1.44	836	-2.29 *	773	-1.02	742	-3.64 **	704	-3.11 **
I	346	5.05 **	412	3.80 **	402	6.20 **	415	4.24 **	364	4.88 **
J	511	4.38 **	456	2.89 **	518	5.24 **	486	2.27 *	540	4.86 **
D	590	2.47 *	588	0.28	641	2.34 *	598	-1.53	606	0.13
K	395	6.49 **	520	4.51 **	551	6.84 **	655	7.41 **	595	10.75 **
A							232	4.24 **	128	4.23 **

*p<0.05 **p<0.01

Table 5.4a. Standard Normal (Z-Scores) for State Pass Rates on the Civil/ Transportation Depth Examination, 2000-2001

	2000		2001	
State	Number Taking Exam	Z	Number Taking Exam	Z
California	716	-4.06 **	1380	-6.40 **
H	149	3.81 **	259	4.38 **
F	68	-1.69	127	-1.18
E	148	0.47	253	0.29
I	101	4.49 **	166	5.79 **
J	88	1.77	173	4.00 **
D	111	2.01 *	242	1.60

*p<0.05 **p<0.01

Table 5.4b. Standard Normal (Z-Scores) for State Pass Rates on the Civil/ Water Resources Depth Examination, 2000-2001

	2000		2001	
State	Number Taking Exam	Z	Number Taking Exam	Z
California	499	-2.47 *	1299	-2.98 **
H	156	1.78	325	2.50 *
F	60	0.05	105	-1.43
E	64	0.07	148	-0.67
I	58	2.14 *	120	3.08 **
J	58	1.62	152	2.78 **
D	72	-0.37	185	1.90

*p<0.05 **p<0.01

Table 5.4c. Standard Normal (Z-Scores) for State Pass Rates on the Civil/ Structural Depth Examination, 2000-2001

	2000		2001	
State	Number Taking Exam	Z	Number Taking Exam	Z
California	358	0.15	765	-0.59
H	32	0.95	55	-0.65
F	29	-1.78	43	-0.20
E	55	-0.28	106	0.22
I	26	0.68	27	2.33 *
J	53	1.09	120	2.45 *
D	35	-0.96	94	-0.85

*p<0.05 **p<0.01

Table 5.4d. Standard Normal (Z-Scores) for State Pass Rates on the Civil/ Geotechnical Depth Examination, 2000-2001

State	2000		2001	
	Number Taking Exam	Z	Number Taking Exam	Z
California	286	-0.69	497	-0.27
H	68	3.29 **	88	2.29 *
F	22	-1.48	47	-0.28
E	87	-2.88 **	168	-2.65 **
I	33	0.52	38	0.11
J	35	1.29	75	2.17 *
D	42	0.33	57	0.41

*p<0.05 **p<0.01

Table 5.4e. Standard Normal (Z-Scores) for State Pass Rates on the Civil/ Environmental Depth Examination, 2000-2001

State	2000		2001	
	Number Taking Exam	Z	Number Taking Exam	Z
California	79	-0.26	192	1.33
H	24	0.47	37	-1.47
F	10	-0.20	28	-0.50
E	17	-0.31	29	0.17
I	6	0.89	13	1.01
J	11	0.88	20	0.19
D	9	-0.69	28	-1.70

*p<0.05 **p<0.01

Table 5.5. Standard Normal (Z-Scores) for State Pass Rates on the Mechanical Engineering Examination, 1997-2001

	1997		1998		1999		2000		2001	
State	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z
California	724	1.19	594	-0.39	517	-1.75	505	-0.29	460	-1.91
H	251	-1.76	192	-1.89	204	-0.10	169	-0.73	146	0.94
F	161	-2.62 **	139	-3.91 **	131	-4.29 **	126	-3.03 **	101	0.14
E	480	-4.07 **	386	-4.20 **	358	-3.20 **	318	-4.42 **	266	-3.55 **
I	134	0.68	144	2.11 *	138	3.38 **	113	3.21 **	97	1.93
J	266	3.22 **	219	3.64 **	227	3.40 **	177	1.14	105	-1.79
D	305	-0.21	233	0.51	234	1.50	163	1.89	199	0.50
K	235	5.62 **	208	4.92 **	166	3.23 **	201	2.77 **	182	5.17 **
A							48	1.71	33	-0.08

*p<0.05 **p<0.01

Table 5.6. Standard Normal (Z-Scores) for State Pass Rates on the Mechanical Engineering Depth Examinations, 2001

	HVAC and Refrigeration		Machine Design		Thermal and Fluids Systems	
State	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z
California	118	-2.05 *	59	-1.45	79	0.01
H	35	3.14 **	17	0.27	18	-1.30
F	24	0.08	12	-0.93	14	1.61
E	73	-1.14	28	-1.42	37	-2.29 *
I	19	1.13	8	2.16 *	12	1.66
J	24	0.49	36	1.83	17	0.83
D	34	1.28	20	0.64	22	0.66

*p<0.05 **p<0.01

Table 5.7. Standard Normal (Z-Scores) for State Pass Rates on the Electrical Engineering Examinations, 1997-2001

	1997		1998		1999		2000		2001	
State	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z
California	596	-3.40 **	469	-3.45 **	417	-3.60 **	430	-2.91 **	78	-0.20
H	172	0.97	154	-0.41	147	1.57	117	-1.01	140	-1.54
F	89	-0.79	90	-1.19	70	-0.60	57	-0.02	54	-1.40
E	292	-1.44	269	-2.77 **	250	-2.06 *	225	-1.42	180	-3.49 **
I	118	0.05	116	1.79	86	1.83	78	2.38 *	81	0.70
J	167	2.25 *	175	3.94 **	142	2.43 *	130	2.71 **	112	1.28
D	187	2.22 *	150	0.85	125	2.46 *	131	0.46	99	1.33
K	120	4.61 **	136	4.30 **	93	3.22 **	110	2.23 *	75	3.89 **
A							40	1.05	19	0.94

*p<0.05 **p<0.01

Table 5.8. Standard Normal (Z-Scores) for State Pass Rates on the Chemical Engineering Examination, 1997-2001

	1997		1998		1999		2000		2001	
State	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z
California	131	-1.42	91	-1.12	88	1.09	76	-2.24 *	66	-0.41
H	30	-2.07 *	22	-0.57	21	-1.25	11	0.16	16	-0.58
F	45	-0.27	36	-2.08 *	35	-1.27	34	-3.33 **	33	-1.33
E	53	-1.19	53	-1.02	45	-2.39 *	27	-0.24	20	-3.22 **
I	30	1.26	23	1.07	22	0.33	15	0.81	19	0.60
J	35	0.79	53	0.15	38	0.67	30	2.62 **	20	0.81
D	40	1.03	31	-0.09	32	-0.16	28	0.75	21	-0.75
K	58	2.84 **	56	3.55 **	26	2.81 **	36	2.87 **	41	2.84 **
A							3	1.99 *	5	2.19 *

*p<0.05 **p<0.01

Table 5.9. Standard Normal (Z-Scores) for State Pass Rates on the Control Systems Engineering Examination, 1997-2001

	1997		1998		1999		2000		2001	
State	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z
California	23	-1.62	15	-0.42	17	-0.72	9	-1.53	20	-1.40
H	7	-0.38	3	-2.39 *	3	-1.14	7	-0.35	15	-0.20
F										
E	3	-1.11	3	0.76	2	0.52	7	0.55	11	-0.02
I	8	0.65	8	1.23	4	0.74	6	1.34	17	1.93
J	8	1.38	6	-3.39 **	11	0.30	12	-0.85	20	-0.23
D	12	0.19	13	0.82	8	1.04	7	1.45	13	0.97
K	22	0.85	13	1.57	12	-0.50	11	-1.26	5	-1.28
A							2	0.77	1	0.47

*p<0.05 **p<0.01

Table 5.10. Standard Normal (Z-Scores) for State Pass Rates on the Fire Protection Examination, 1997-2001

	1997		1998		1999		2000		2001	
State	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z
California	28	-0.23	37	1.56	34	1.72	28	0.07	28	-1.11
H	5	-0.22	6	-0.53	6	-0.67	7	-0.81	11	-1.17
F										
E	6	-1.40	6	-2.17 *	6	-1.49	10	-1.97 *	12	-1.33
I	2	0.14	4	-0.77	6	0.15	2	-0.88	8	1.63
J	3	-0.41	4	0.24	2	-1.33	5	0.60	7	1.23
D	6	1.07	5	-1.08	10	-1.71	8	1.39	2	0.44
K	5	1.57	4	0.24	6	0.97	6	-0.60	6	0.77
A							8	2.20 *	9	1.29

*p<0.05 **p<0.01

Table 5.11. Standard Normal (Z-Scores) for State Pass Rates on the Industrial Engineering Examination, 1997-2001

State	1997		1998		1999		2000		2001	
	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z
California	11	-1.31	10	-1.46	7	-1.29	6	-1.83	9	-1.18
H	6	0.15	8	0.54	3	0.47	7	1.68	5	0.35
F										
E	1	1.06	2	-0.09	2	1.33	2	1.31	1	0.61
I	4	-0.88	6	0.67	5	-0.58	7	-0.59	2	-0.73
J	12	1.37	10	0.44	10	1.08	4	0.84	8	0.13
D	6	0.15	9	0.82	4	-0.12	2	-0.11	1	0.61
K	5	-0.31	8	-0.88	5	-0.58	6	-0.20	4	1.22
A							1	-1.08		

*p<0.05 **p<0.01

Table 5.12. Standard Normal (Z-Scores) for State Pass Rates on the Petroleum Engineering Examination, 1997-2001

State	1997		1998		1999		2000		2001	
	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z
California	19	0.04	17	-0.66	16	-2.58 *	13	-1.34	8	-1.41
H	1	-1.46			1	-1.02				
F										
E										
I					1	-1.02	1	0.75		
J	1	-1.46			1	0.98	1	-1.33	3	-1.73
D	5	1.53	1	-1.11			3	0.10		
K	31	-0.04	22	0.81	24	2.35 *	15	1.29	17	1.70
A										

*p<0.05 **p<0.01

Table 5.13. Standard Normal (Z-Scores) for State Pass Rates on the Metallurgical Engineering Examination, 1997-2001

State	1997 Number Taking Exam	1997 Z	1998 Number Taking Exam	1998 Z	1999 Number Taking Exam	1999 Z	2000 Number Taking Exam	2000 Z	2001 Number Taking Exam	2001 Z
California	6	-0.30	5	-0.47	4	0.59	3	0.64		
H	4	1.77	2	0.55			1	0.37		
F										
E							1	0.37	1	0.00
I	3	-0.79	3	-1.05	1	-3.39 **			1	0.00
J	5	-0.72	5	-0.47	2	0.42	2	-1.65	1	0.00
D	1	0.89	4	0.77	4	0.59	1	0.37		
K	6	-0.30	4	0.77	2	0.42				
A										

*p<0.05 **p<0.01

Table 5.14. Standard Normal (Z-Scores) For State Pass Rates on the Nuclear Engineering Examination, 1997-2001

State	1997 Number Taking Exam	1997 Z	1998 Number Taking Exam	1998 Z	1999 Number Taking Exam	1999 Z	2000 Number Taking Exam	2000 Z	2001 Number Taking Exam	2001 Z
California	2	-1.15	2	0.86	1	0.37	1	0.37		
H	1	-0.82	2	-0.73	1	0.37	1	0.37		
F										
E										
I	4	0.41	6	-0.35	2	-1.65	2	-1.65	6	0.90
J	1	-0.82			1	0.37	1	0.37	1	-2.71
D	6	1.33	4	1.22	1	0.37	1	0.37	1	0.37
K	1	-0.82	1	-1.64	2	0.52	2	0.52		
A										

*p<0.05 **p<0.01

Table 5.15. Standard Normal (Z-Scores) for State Pass Rates on the Agricultural Engineering Examination, 1997-2001

	1997		1998		1999		2000		2001	
State	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z
California	3	0.10	1	-1.00	1	-1.36	2	-1.11	3	-0.34
H	2	1.06	3	-0.58	7	-1.23	4	0.49	1	-0.87
F										
E							1	-0.78		
I	1	-1.33	6	0.82	9	2.20 *	3	-0.17	3	0.83
J	2	1.06	3	1.73	2	1.04	1	-0.78	3	0.83
D	1	-1.33	2	-1.41	2	-0.44	2	0.35	1	1.15
K	5	-0.19	5	-0.45	5	-1.17	3	1.03	3	-1.50
A										

*p<0.05 **p<0.01

Table 5.16. Standard Normal (Z-Scores) for State Pass Rates on the Manufacturing Engineering Examination, 1997-2001

	1997		1998		1999		2000		2001	
State	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z	Number Taking Exam	Z
California	2	0.00	3	-0.58	3	0.69	2	-0.17	3	-0.25
H					1	-0.47	1	0.89		
F										
E			2	-0.47	3	-0.81	2	-1.60	1	-1.64
I	1	-1.00	2	-0.47					3	-0.25
J	4	1.00	1	-0.33	3	0.69			3	1.05
D	1	-1.00			1	-0.47	2	1.25		
K			2	1.89			2	-0.17	1	0.61
A										

*p<0.05 **p<0.01

CHAPTER 6

DISCIPLINE IMPACTS ON PUBLIC HEALTH, SAFETY AND WELFARE

One of the legislatively defined study goals was to consider how changes to existing laws regulating engineers would affect the public health, safety and welfare. To assess this requires some measure of the degree to which the public health, safety and welfare are affected by the current licensing system. In seeking measures of relative impact on public health, safety and welfare, ISR looked for court records of cases involving engineers. According to Forum participants and others, most lawsuits are settled out-of-court, leaving no public record. Moreover, unlike medicine, there is no requirement that court decisions involving licensed engineers be reported to the PELS Board. Thus, there is no connection between civil redress for harm and professional accountability.

At the Forum on Engineering Licensing 2002, ISR posed two questions: "Do engineering disciplines differ in the degree to which their negligent practice could adversely affect the public health and safety?" and "Are there any data that can be used to make this determination?"

Participants seemed to agree that all engineering disciplines affected public health, safety and welfare and that it was not possible to quantify discipline variations in the level of impact. Several participants believed that an error made by practitioners of some engineering disciplines would injure more people while an error made by others would affect fewer. For example, structural engineers who design bridges and buildings used by millions of people may have a greater impact on public health, safety and welfare than control systems engineers who, in designing manufacturing procedures that affect the efficiency and effectiveness of a process, may have less impact on the safety of the product. Several participants also noted the omission of welfare in the question, encouraging its inclusion because -- on the positive side -- engineering also influences quality of life, economic prosperity and other aspects of public welfare.

Data that might differentiate engineering disciplines are lacking because the resolution of incidents is often private (e.g., out-of-court settlements and insurance claims) and no single agency is responsible for tracking engineering-related incidents of public harm, determining culpability and disciplining those involved. Moreover, participants argued, assigning responsibility for accidents that harm the public would be a challenging undertaking because they could occur for a variety of reasons besides incompetent engineering, including operator error, material or equipment failures, and management or supervisory decisions. In projects involving many engineering disciplines, it would be necessary and difficult to apportion responsibility for the incident across the several disciplines. Nevertheless, regulatory agencies and the courts routinely accomplish these difficult tasks when airplane accidents, common automotive failures or medical errors occur.

ISR identified two sources of data that offered the possibility of distinguishing the health and safety impacts of different engineering disciplines. The first was insurance data on fees collected by their insured and the number and cost of claims against them. The argument would be that disciplines posing a greater threat would generate more claims and more expensive claims than those with less impact. This is overly simplistic because the type of client also influences the filing of claims and client type may vary by discipline. Engineering disciplines also vary in their exposure to suit because of the location of their employment. Employment by governmental agencies or industrial corporations may limit exposure, thereby reducing the number of claims for some disciplines. Therefore, without the ability to compute a rate of claims relative to the number insured, it isn't possible to fully measure the impact of those disciplines offering services directly to the public. With a full data set, it would be possible to control the effects of client type and other variables in assessing the number and cost of claims.

The second data source was information on the number and types of complaints against engineers lodged with the Board for Professional Engineers and Land Surveyors. One would expect that parties filing insurance claims would differ from those filing complaints with state boards, and that the issues raised and the costs of misconduct would be less serious in Board complaints. Nevertheless, both data sets should flesh out the identity of the consumer of engineering services and offer a chance to determine whether disciplines vary in the type of client served. The first part of this chapter describes the problems associated with accessing insurance data -- possibly the most direct measure of different health and safety impact -- and considers what can be learned from the limited information available. The second part of this chapter analyzes complaint data for California and four comparison states.

Insurance Data

Some of the more important costs of incompetency -- and some of the more important benefits of skill -- in medicine, law or engineering may resist measurement. But the extent to which different engineering branches generate insurance claims, variability in costs associated with events described in those claims, and the cost of liability insurance for engineering firms would seem to be decent, though not perfect, indicators of public harm. With the idea of testing whether practice and title branches can be distinguished in their degree of threat to public health and safety, ISR sought first the average cost of liability insurance for different types of engineers from the California State Department of Insurance.

The response typified other attempts at accessing data that could be used to inform legislative policy decisions. The department does not summarize insurance rates for public use nor will it accept telephone or mail requests that file information be copied and sent. Interested parties must appear in person at a San Francisco office and be prepared to look up by insurance firm their established rates. Since -- in addition to discipline --rates vary by size of firm, the type of projects specialized in, their relative liability exposure as measured by client fees generated, claims history, geographic area and risk management practices, an average rate by discipline would need to be provided by the insurance company or require complicated computations by insurance department staff.

Staffing constraints at the Department of Insurance and more generally at licensing boards and agencies in California and its comparison states are undoubtedly one reason behind the limited access. The maintenance of appropriate and useful records is not a priority in many states and agencies.

ISR then turned to the insurance companies themselves, specifically DPIC and Victor O. Schinnerer, two companies that reportedly insure most of the nation's engineers. DPIC had recently released data on their analysis of 8,687 claims filed between 1996 and 2000, representing $396 million in claims payments. This data was summarized in an article in *Engineering Tim*es.[1] ISR requested and received a power point presentation based on this data that had been presented to a risk management conference for engineering and architectural firms. The power point presentation also included a broader analysis of over 19,000 closed

[1] National Society of Professional Engineers, Volume 24, Number 4, April 2002, page 3 .

claim and loss prevention files from 1989 to 2001, representing $725 million in claim payments. A request for more precise information on the number of claims, claim dollars paid, and fees earned by discipline, type of claim and state was directly refused by Schinnerer and indirectly refused by DPIC, who stopped responding to phone and email messages after providing the publicly available data.

The information provided and described below suggests what might be done with more complete data.

Claims and Claim Dollars Relative to Fees Earned

Table 6.1 compares the proportion of fees earned by specific practice act firms (civil/surveying/environmental, structural, mechanical and electrical), architectural firms, and "other" presumably engineering firms with the proportion of claims generated and claim dollars accounted for by each type of firm. This suggests that civil/surveying/environmental engineering firms have fewer and less expensive claims than the other disciplines relative to their liability exposure as measured by fees generated. Conversely, structural engineering firms account for almost twice as many claims as expected given their proportion of fees generated (11% vs. 6%) and almost three times the proportion of claim dollars (16%). Architecture is the only other described discipline to generate more claims and claim dollars than expected by their amount of exposure (35% of fees generated, but 42% of claims and 44% of claim dollars). Mechanical engineering and the "other" disciplines are proportionately represented across the board, while electrical engineering generates fewer claims and claim dollars than expected (4% of fees generated, but only 2% of claims and 1% of claim dollars). (Table 6.1)

One tentative inference from these comparisons is that structural engineering has a more negative impact on public health and safety than civil and electrical given their liability exposure as measured by client fees. Structural engineers generate more claims and claim dollars relative to their exposure while civil and electrical engineers generate fewer. Mechanical engineering and the "other," presumably title act, disciplines are generally neutral, generating claims and claim dollars in rough proportion to their exposure. Thus, protection of public health and safety could not be used as a basis for practice vs. title protection. Two of the three practice disciplines (civil and electrical) have less impact in terms of insurance claims than their exposure leads us to expect while the number of claims and claim dollars are proportional for mechanical engineering and the title act disciplines.

Types of Damages

The types of damages vary by discipline. Economic loss constitutes the largest group of claims for civil, mechanical and electrical engineering (46%, 51% and 57% respectively). Property damage is the second largest group for these three disciplines (39%, 39% and 28% respectively) with non-construction bodily injury third (10%, 7% and 9%). In contrast, the most frequent type of claim for structural engineering is property damage (47%); economic loss makes up another 40%. Civil and electrical have more non-construction bodily injury claims (10% and 9% respectively compared with 6% and 7% for structural and mechanical). (Table 6.2)

Over half of claims dollars for civil and mechanical engineering firms are in response to claims of economic loss (53% and 56% respectively). In electrical engineering, the proportion of claims dollars are equally split between economic loss and property damage (42% each), while more claim dollars go for property damage than economic loss in structural engineering (45% vs.

41%). Civil, mechanical and electrical require more claim dollars for non-construction bodily injury than structural (13%, 10% and 14% compared with 7%). (Table 6.2)

It is important to note that not all claims arise out of health and safety issues. Contract disputes, fraud, incompetence, and poor management generate claims. DPIC notes four non-technical factors influencing claims, including: negotiation and contracts (13% of claims, 17% of claim dollars), client selection (16% of claims, 18% of claim dollars), project team capabilities (24% of claims, 21% of claim dollars) and communication (27% of claims, 22% of claim dollars). The largest components of project team capabilities are unqualified design staff assigned to project and unqualified project manager.

Suing Parties

All practice act disciplines were more likely to be sued by owners or clients, ranging from a high of 72% for mechanical engineers to a low of 51% for civil. Civil and structural engineers were more apt to sustain third party claims (33% and 25% respectively) than electrical and mechanical engineers (with 21% and 13% third party claims). Although suits by contractors or subcontractors are less frequent for all disciplines, electrical and civil engineers experience these claims somewhat more often than mechanical and structural engineers (15% and 13% vs. 11% for the other two). (Table 6.3)

Owner/client claims are relatively more expensive for electrical engineers than for mechanical and civil engineers. Claims against electrical engineers require 20% more dollars than their proportion of claims suggests while claims against mechanical and civil engineers require only 10% more dollars. Claims by owner/clients against structural engineers require fewer dollars than the proportion of claims suggests (61% of dollars vs. 62% of claims). Third party claims are more expensive for structural and mechanical engineers (26% of dollars vs. 25% of claims for structural engineers and 15% of dollars compared with 13% of claims for mechanical). They are much less costly for civil engineers (27% of dollars but 33% of claims). In suits by contractors or subcontractors, claims are more expensive for civil and structural engineers (14% of dollars vs. 13% of claims for the former and 13% of dollars and 11% of claims for the latter), but much less expensive for mechanical and electrical engineers (6% of dollars for each discipline compared with 11% and 15% of claims respectively). (Table 6.3)

Project Type

The power point presentation described the proportion of claims, dollars and fees accounted for by different project types. The mix of project types varied by discipline. Although not specifically stated, the implication is that the types shown are the most frequently occurring project types for a given discipline. Absent a complete list of project types, it is difficult to test that implication. The inference would be incorrect if the project types shown in graphs for the five disciplines (structural, civil, mechanical, electrical and architectural) are combined into a single list that includes all possibilities. This is because, in some cases, the types shown accounted for half or less of the total claims, dollars or fees for a given discipline. A subdivision of the remaining claims, dollars or fees into the project types omitted from a graph would result in greater proportions than for some included in the graph. It is, therefore, more likely that all possible project types is a much longer list.

Nevertheless, there are some puzzling omissions. One would assume that structural engineers would be sufficiently involved in the construction of highrise buildings to generate at least 2% (the least frequent category for structural engineering firms) of claims against structural engineering firms. Perhaps most of the structural engineering work for high rise buildings occurs within architectural firms. In this study, discipline describes the firm and not the claim. Therefore, a structural claim against an architectural firm would be counted under architecture.

Claims against structural engineering firms are most likely to involve residential and "low-rise" commercial/industrial projects (18% and 12% respectively). The proportion of claims growing out of residential projects is two and a half times the proportion of fees generated by these projects, while the costs involved are one and a half times greater. On the other hand, "low-rise" commercial/industrial buildings generate half as many claims and involve a fourth as many dollars as fees generated by this type of activity. This illustrates a point made by DPIC that client selection is one of the four most important non-technical factors influencing claims. There are fewer claims and even fewer dollars involved given the amount of exposure on commercial/industrial projects; but a lot more claims and somewhat more dollars involved in the more limited exposure on residential projects, with presumably less experienced owner/clients. (Table 6.4)

The pattern is essentially similar for the other practice act disciplines. For civil and electrical engineering firms, residential condos projects -- and for electrical engineering firms only -- residential projects result in far more claims and claim dollars than the fees generated by them. In all four disciplines, "low-rise" commercial/industrial projects generate fewer claims and claim dollars than the fees generated. It appears that the type of project, and by inference, the type of client, is an important factor in claims. Had DPIC shown the parallel table for the "other" disciplines -- that include what California calls the title act disciplines -- it would have shed some light on whether the pattern is any different for these disciplines.[2] Whether or not licensing affects claims cannot be discerned from this data; but it is clear that the type of project and client have a significant impact.

For civil engineering firms, residential projects are a wash with claims and claim dollars matching the amount generated in fees (20%). The projects accounting for the greatest proportion of income (26% from roads and highways) generate far fewer claims and involve even fewer claims dollars (14% and 11% respectively). Conversely, wastewater, sewage and water treatment systems projects are expensive in terms of claims and claim dollars, accounting for three times as many claims dollars as fees (25% of claims dollars, but only 8% of fees generated). Since the clients involved in both types of projects are probably public agencies, it would be useful to know the reasons for the different ratios of claims to fees. These might be discernible from a more in-depth analysis of the data possessed by both insurance companies. Without the companies' cooperation, this isn't an option for this report. (Table 6.4)

Mechanical engineering firms involved in claims receive half of their income from "low-rise" commercial/industrial projects (33%) and construction at schools, colleges and universities (17%). However, their work in the private sector generates far fewer claims and claim dollars (12% and 9% respectively) than the public sector projects associated with education (22% and 23%). Hospitals follow the public sector pattern, generating 8% of fees, but 12% of claims and claim dollars, while malls repeat the private sector pattern, generating fewer (2% and 1% vs. 5% of fees). High-rise projects break the mold, generating 3 times the amount of fees in claims and claim dollars (3% of claims and claim dollars vs. 1% of fees). (Table 6.4)

Electrical engineering firms are far more involved in claims than their proportion of fees leads one to expect. The proportion of claims and claim dollars outweigh fees in all types of projects

[2] ISR requested this data from DPIC but did not receive it.

except "low-rise" commercial/industrial ones. Both public and private sector projects spell trouble for electrical engineering firms. But the types of projects covered include only a third of the fees generated by this type of firm. Without knowing the criteria for inclusion of project types, it is difficult to conclude that electrical engineering firms are at greater risk. DPIC's initial table, "Comparative Claims Experience," presumably including all project types, finds the greatest imbalance between claims, dollars and fees among structural engineers. Their firms generated 6.7% of fees, but accounted for 11.3% of claims and 16.1% of claims dollars. This imbalance is not reflected in the data summarized in Table 6.4 where the project types selected for inclusion suggest a more benign balance of claims and fees: these projects accounted for 56% of the collected fees, but only 53% of claims and 42% of claims dollars. The ratios are similarly benign for civil and mechanical, but quite the reverse for electrical engineering firms *for the projects included in the power point graph*. In the "Comparative Claims Experience" graph, electrical engineering firms have a positive ratio: although they generate 4.2% of fees, they account for 2.1% of claims and 1.0% of claims dollars. (Table 6.4)

What the data do not tell us is how often different types of engineers are sued. No information was provided that allowed us to compute a claim rate for each type of engineer. Without knowing how many engineers in specific disciplines are insured, there is no way to compute a rate of involvement in claims and in so doing determine whether some disciplines generate more than others. The comparison with fees generated is an indirect way of assessing whether a given discipline is more or less involved than their exposure would indicate. But the firms that generate claims may differ in important ways from firms that do not. The unit of analysis is also imprecise. The firm is presumably the unit of analysis; but there is no way to know how many engineers are employed by these firms and what disciplines they may represent.

Complaint Data: California

This section focuses on a data file maintained by the California PELS Board that summarizes complaints lodged with the Board against licensed and unlicensed engineers. This database includes the:

- Opening and closing date of the complaint
- Type of engineering license (or lack of license) held by the subject of the complaint
- Source of the complaint
- Category of alleged violation
- Section of the Business and Professions Code or California Code of Regulations allegedly violated, and
- Closing code for the case.

Cases summarized in this section were opened between 1/7/91 and 10/19/01, covering ten full years and two partial years of complaints lodged with the Board. The number of complaints averaged 249 per year for the full ten-year period, ranging from a low of 180 in 1993/94 to a high of 316 in 1996/97. Complaints are roughly equally distributed between professional engineers and unlicensed persons (43% vs. 39% respectively) with land surveyors accounting for the remaining 18%. (Table 6.5)

Since land surveyors are not included in the Title Act Study, they were removed from the complete complaint data file described in Table 6.5. Cases were also excluded if the subjects were unlicensed persons alleged to have violated only the Professional Land Surveyors Act and no other sections related to engineering. Table 6.6 summarizes the number of subjects licensed in engineering or land surveying, the number who were not licensed in either and the section or code allegedly violated. Strike-outs identify the cases omitted from further analysis.

Engineering discipline. Most of the complaints are against either civil engineers (43%) or unlicensed individuals (45%). (Table 6.7) The number of complaints against civil engineers is unexpected when compared to the discipline distribution of employed engineers in the state. Civil engineers constitute only 15% of the state's engineering work force. Even if the "other" category (18% of the workforce) is assumed to contain mainly civil engineers, they would still be over-represented in the complaint process. (Table 6.8) In contrast, there are very few complaints against electrical and mechanical engineers (1 and 2% respectively) in comparison to their percentage of the work force (30% and 11% respectively). The pattern is similar when the distribution of complaints is compared with the discipline profile of registered engineers. Civil, geotechnical, structural and traffic engineers are significantly over-represented in complaints against registered engineers while electrical, mechanical and the remaining title act disciplines are all under-represented. (Table 6.9)

The fact that the three practice act specialties are employed in different industries may have an effect on complaint rates. Nationally, electrical and mechanical engineers are largely employed in industrial corporations (78 - 80%) while civil engineers are more apt to be employed in engineering and architectural services (51% in 2000). Electrical and mechanical engineers in California have a similar industry profile (with 82% and 76% employed by industrial corporations), and with less individual exposure may generate fewer complaints. California's civil engineers are less likely to be employed in engineering and architectural services (37% vs. 51% nationally) but their involvement in consulting is much greater than electrical and mechanical engineers (6% and 19% respectively). (Table 6.10)

This rationale, however, is not supported by the insurance data discussed earlier in this chapter. Mechanical and electrical engineering firms are more apt to be sued by owner/clients than civil engineering firms (72% and 60% of claims respectively compared with 51% for civil engineers). (Table 6.3) Civil engineering firms are more often sued by third parties (33% vs.13% and 21% for mechanical and electrical engineers). In all likelihood, those who file complaints and those who file insurance claims probably differ. Neither group may accurately reflect the client base of an engineering discipline.

Another possible explanation for varying complaint rates between disciplines is that they engage in different types of projects that may affect exposure to complaints or claims. The insurance claim data provides some information on project type, but the data are incomplete making discipline comparisons difficult. The data indicate the proportion of claims against firms associated with particular disciplines that involve specific types of projects. What is unknown is the proportion of each project type that generates a claim. The only indirect measure is a comparison of the proportion of claims in relationship to the proportion of fees generated by each type of project. Civil engineering firms work on some project types that mechanical and electrical engineering firms apparently do not (roads and highways, wastewater, sewage and water treatment systems). In the former, the proportion of claims is half that of the proportion of fees generated by roads and highway projects. In the latter, the proportion of claims is double the proportion of fees generated. Thus, various project types for a given discipline yield different claims/fee ratios. On the other hand, civil, mechanical and electrical are all involved in building commercial/industrial buildings of nine stories or less and in all three disciplines, the claims/fee ratios are positive -- that is, more fees are earned than claims generated. In other shared project types, the claims/fee ratios are in different directions. Civil engineers are heavily involved in residential projects, but the claims and fees generated are very similar (21% of claims and 20% of fees). For electrical engineers, residential projects are much more damaging -- generating six times the number of claims as fees and 15 times the number of claims dollars. (Table 6.4)

It is therefore difficult to argue that particular types of clients or projects necessarily predict complaints or insurance claims. Other data collected during the course of this study suggest that civil engineering may be a broader discipline, encompassing a range of specialties (water, transportation, environmental, structural, geotechnical) and that the lack of specialization may undermine competence. The violation categories offer some support to this interpretation: a higher percentage of civil engineers are charged with incompetence/negligence than is true for electrical or mechanical engineers (70% vs. 48% and 28% respectively). Geotechnical and structural engineers -- with civil engineering as their initial license -- have a similarly high proportion charged with incompetence/negligence (69% and 75% respectively). Exam pass rates are somewhat consistent with this information. However, both civil *and* electrical have significantly lower pass rates in all or most years between 1997 - 2001 while pass rates for mechanical engineering have been within the norm for the comparison states in all years except the 2001 HVAC/refrigeration exam. Yet there are only 4 complaints lodged against the most numerous category of engineers in the state (electrical).

In short, there is no clear explanation for the concentration of California complaints on civil engineers.

Almost all licensed engineers who are the subject of a complaint hold a single license (95%). Eleven hold multiple practice act licenses (ten, civil and mechanical and one, electrical and mechanical). The remaining 46 combine a title act license with a practice act license or title authority; most of these (36) are traffic engineers or other title disciplines (6) who also hold a civil license. Three control systems engineers have electrical or mechanical licenses and one fire protection engineer has a structural license. (Table 6.11) For the detailed description of disciplines shown in the first panel of Table 6.7, individuals with two licenses are shown in both categories. Since there are so few complaints against engineers in the Title Act disciplines, categories were created as shown in Table 6.12.

Source of complaint. Half of all complaints were initiated by private parties (individual and corporate clients). The Board is the second largest source of complaints, accounting for 39%. Government agencies, licensees and trade organizations make up the rest. Board complaints outnumbered the public's in only two years: 1994/95 and 1997/98. (Table 6.7) In the latter year, an unusual number of complaints were lodged against traffic engineers for engaging in land surveying. (Table 6.7 and 6.25)

The source of the complaint was related to the nature of the complaint as measured by the violation category. The most important issue for public complainants was competence/negligence (56%), while the Board was more concerned with exam subversion (53%) and unlicensed activity (27%). Licensees shared the Board's concern with unlicensed activity (56%) and secondarily with competence/negligence issues (32%), while the reverse was true of "other government agencies" that were more concerned about competence/negligence issues (51%) and less about unlicensed activity (32%). (Table 6.13)

Type of violation. The complaint database contains two types of variables describing the nature of the alleged violation. One applies violation categories and the other uses the sections of the Business and Professions Code or the California Code of Regulations that were allegedly violated. Using the violation categories, the most common alleged violations were competence/negligence (37%), unlicensed activity (24%) and exam subversion (23%). Competence/negligence and unlicensed activity appear to have increased during the 1990s while exam subversion and fraud, deceit and misrepresentation appear to have decreased. (Table 6.14)

Using the code section charged to describe alleged violations, the most common section is §6775 (37%), which involves fraud, negligence or incompetence, breach of contract and conviction of a crime. Most of the complaint subjects (34%) are charged with subsection (b) – regarding fraud, deceit, misrepresentation, negligence, incompetence, and/or breach of contract. (Tables 6.15 and 6.16) Unauthorized practice or use of title in civil, electrical, or mechanical engineering or use of the titles of professional, licensed, registered or consulting engineer (26%) and exam subversion (23%) are the second and third most frequent alleged violations. The only other significant group of cases (14%) is charged with violating the Professional Land Surveyors Act (§8726-8792). (Table 6.15)

Table 6.17 shows the relationship between the two types of violation variables. For cases alleging incompetence/negligence, which is the most sizeable group of cases, it is not uncommon for a second type of alleged violation to be involved. Some of these cases allege both incompetence/negligence and contract issues, and others allege incompetence/negligence as well as fraud, deceit or misrepresentation. Perhaps in response to the fact that cases can involve more than one type of violation, §6775(b), which is the most frequently charged section, was restructured as of January 1, 2001. Three separate subdivisions were created to distinguish (b) fraud, deceit, and/or misrepresentation, (c) negligence and/or incompetence, and (d) breach or violation of contract. But since just 165 of the complaint cases described in this chapter were opened after the change to the section, these were not analyzed separately.

The second most common category of violation is unlicensed activity. Almost all of theses case are charged with §6787. Violation of the professional land surveyors' act is alleged more often in cases involving incompetence/negligence.

Closing code. A violation was identified in almost three out of five complaints (57%), while no violation was found in a fourth of them (28%). (Table 6.18) The Board was unable to pursue 8%, largely for insufficient evidence, and the remaining 10% of cases are not yet closed. When a violation was identified, the most common resolution was obtaining compliance (29%). A Board citation occurred in 6% of the complaints, 12% were referred, either to the Attorney General (9.8%) or District Attorney (2.0%). In two years -- 1992/93 and 1997/98 -- an unusual number of complaints were referred to the Attorney General's office (19% in the earlier year and 25% in the later one). (Table 6.18) These involved an overlap issue between land surveying and several branches of engineering. In 1992/93, civil and geotechnical engineers were charged with the unauthorized practice of land surveying; in 1997/98, traffic engineers were included as well. (Table 6.7 and 6.25)

The closing code varies significantly by source of the complaint and violation category. The largest group of complaints -- those initiated by the public -- are classified most often as no violation (38%) while the second largest group -- those initiated by the Board -- are most likely to result in Board action (66%). In only 11% of complaints initiated by the Board is no violation found. (Table 6.19) Among the four source categories with sufficient numbers for analysis, cases are more likely to remain open if they are filed by licensees (26%) or by an "other government agency" (21%) and least likely to remain open if they are filed by the Board (4.4%). (Table 6.19)

The most common closing code when fraud, competence/negligence or contractual issues are charged is that no violation is found (38%, 37% and 33% respectively). In cases of exam subversion and unlicensed activity, Board action is the most common response (91% and 39% respectively). (Table 6.20)

Complaint Characteristics by Engineering Discipline

Source of complaint. In general, complaints against the practice act disciplines come from the public while those against the title act disciplines and the unlicensed are more likely to come from the Board. The two title authorities (geotechnical and structural) have the highest proportion of complaints generated by the public (89% and 73% respectively), with civil somewhat lower (71%) and electrical still a solid majority (57%). The source of complaints against mechanical engineers is almost equally divided between the Board (48%) and the public (46%). The source of complaints against title act engineers is obscured by the fact that the Board filed 26 of 41 complaints against traffic engineers against a single individual. When these are removed, the public accounts for most complaints filed against title act engineers. (Table 6.21)

Complaint subjects with practice act only licenses were grouped for comparison with title act only subjects, those who had both types of licenses and those who had neither. This clarifies the relationship between type of license and source of the complaint. While the public initiates complaints against practice act only disciplines and practice/title combinations other than traffic (72% and 70% respectively), the Board initiates complaints against civil/traffic engineers (78%) -- including the individual referred to above -- and the unlicensed (65%). Complaints against title act only disciplines are almost equally initiated by the public and Board (45% and 40% respectively).[3] (Table 6.22)

Violation category. The practice and title act disciplines also vary in the type of alleged violation. With the exception of mechanical engineering, competence/negligence issues are the most common in the practice act disciplines and title authorities (with 70% of alleged violations in civil, 48% in electrical, 69% in geotechnical and 75% in structural). Mechanical engineers are unique in the diversity of their alleged violations, which are almost evenly split among unlicensed activity, competence/negligence and fraud. Traffic engineering is the only title act discipline with enough cases to provide meaningful percentages and there, too, competence issues dominate (85%). (Table 6.23)

The disciplines are combined into mutually exclusive categories in Table 6.24. Competence issues dominate among complaint subjects with practice act only licenses and in any combination of practice and title aAct disciplines (practice act only-- 68%, civil and traffic -- 94%, and other practice/title combinations -- 60%). Subjects with title act only licenses are charged most often with unlicensed activity (40%), while the unlicensed are charged about equally with exam subversion (44%) and unlicensed activity (51%). Competence and contractual issues are the least frequent allegations in the title act disciplines (10% each). (Table 6.24)

Code section charged. When the separate disciplines are compared in terms of the specific code section violated, §6775(b) is cited most often, particularly for geotechnical (90%), structural (83%), civil (64%) and electrical (81%) engineers. Alleged violation of §6787 – especially §6787(a) – is much more common among complaints against mechanical engineers than for any other discipline. Section 6775 is still charged in a majority of cases against mechanical engineers (52%) but 36% of complaints against mechanical engineers allege violation of §6787. The charges are concentrated in §6787(a), which involves practice in another discipline (in this case civil or electrical engineering). Traffic engineers are primarily cited for violating the Professional Land Surveyors' Act (73%). A significant percentage (30%) of civil engineers are charged with this section as well. The unlicensed are charged with violating the Board rule against exam subversion (49%), practicing civil, electrical or mechanical engineering (36%) or representing themselves as licensed in these disciplines (12.6%) or as a registered engineer (7.1%). (Table 6.27)

Table 6.28 compares the combined practice and title act disciplines and the unlicensed in terms of the codes allegedly violated. The results are essentially the same as with the individual disciplines. Practice act complaint subjects are most often alleged to have violated §6775 (b) (fraud, deceit, misrepresentation, negligence, incompetence, and/or breach of contract) and the unlicensed are charged with violating §442 (exam subversion) and §6787 (practicing or representing themselves as practice act engineers). (Table 6.28)

Closing code. Complaints against the unlicensed close faster (with 6% still open) than those against geotechnical (21%), structural (16%), mechanical (13%) and civil (12%) engineers. (Table 6.29, top panel) Among the closed cases, violations are identified most often in complaints against the unlicensed (80%), and against traffic (74%), civil (51%), mechanical (48%), structural (39%) and geotechnical (34%) engineers. (Table 6.29, bottom panel)

When the disciplines are combined into mutually exclusive groups, the patterns are similar. The proportion of open complaints against practice act engineers is almost three times higher than

[3] With only 20 cases, the proportions for title act complaint subjects are unreliable.

the proportion among the unlicensed (13.5% vs. 5.8%). (Table 6.30, top panel) Violations are identified most often among the unlicensed (80%) and persons with multiple licenses in civil and traffic engineering (74%), but in slightly less than half (48%) of the closed cases against practice act engineers. Board action is the most common response when violations are identified against the unlicensed (84%), while referral to the Attorney General occurs most often among those with dual licenses in civil and traffic (81%). When violations are identified among practice act engineers, the response is equally split between Board action (40%) and referral to the Attorney General (40%). (Table 6.30)

Comparison of the Discipline Profile of Complaints and Insurance Claims

Complaints filed with state regulatory boards and insurance claims are two separate indices of engineering's effect on public health, safety and welfare. The nature of the harm is presumably less serious where complaints are concerned and some issues, like exam subversion and unlicensed activity, are unique to the regulatory process. Paid claims represent acknowledged damage, whether this involves bodily or economic harm. To make the data sets as comparable as possible, complaint cases involving only exam subversion or unlicensed practice and cases against unlicensed subjects were removed from this part of the analysis. Although the insurance companies do not specifically identify firms that are unlicensed, there may be some included with the "other" disciplines. With these adjustments and recognized limitations, the discipline distribution of complaints and claims was compared.

The discipline profile of complaints is very different from the profile of insurance claims. While most complaints are against civil engineers (80%), 44% of insurance claims are against civil engineering firms -- a proportion that is two and a half times the proportion of employed civil engineers in the U.S (17.3% in 2000).[4] (Table 6.31) In contrast, electrical and mechanical engineers are underrepresented in the complaint population (1.6% and 2.8% respectively), relative to their proportion of the claims population (3.6% and 14.1% respectively) and to their proportion among employed engineers (36.3% for electrical and 13.8% for mechanical). The proportion of insurance claims against mechanical engineers (14.1%) is roughly comparable to their proportion of employed engineers. Another 16% of complaints are against California's title authority disciplines, equally divided between geotechnical and structural engineering. The proportion of claims against structural engineers is more than double the proportion of complaints (19.5% vs. 8.1%). Since OES doesn't separately identify structural engineers, their involvement in claims can't be compared with their proportion in the employed population. Adding their proportion of claims to the proportion for civil engineers (19.5% plus 44.3% or 63.8%) means that claims generated by civil and structural engineers are 3.7 times their proportion among employed engineers. Thus, civil engineering, including structural, appears to pose a greater threat to public health, safety and welfare than electrical or mechanical engineering. (Table 6.31)

The number of complaints filed against engineers in the title act disciplines is lower than expected, given their proportion of employed engineers in California (4.9% of complaints vs. 17.8% in the state). The proportion of claims against all other engineers (including title act disciplines and perhaps some unlicensed firms) is roughly half that of their proportion among employed engineers nationally (18.5% of claims, but 36.2% of all engineers). Thus, in terms of

[4] The claims data provided by DPIC, a firm offering liability insurance to engineering firms nationally, presumably describes claims against engineers throughout the U.S. Assuming that to be the case, the appropriate comparison population would be employed engineers in the U.S. In an earlier section, California complaints are compared with the distribution of employed engineers in the state. DPIC did not respond to a request for clarification of the claims population.

complaints and insurance claims, the title act disciplines pose less of a threat to public health, safety and welfare than civil and structural engineering -- as measured by these indices. (Table 6.31)

Complaint Data: California and Comparison States

Massachusetts and California

Massachusetts is the only discipline-based licensing state that provided complaint data and is therefore the only state where the discipline distribution of complaints and outcomes can be compared. Complaint data provided by Massachusetts for the time period 7/1/83 to 10/1/01 included only closed cases. In California, some types of cases, primarily those including fraud, tend to be resolved sooner. (Table 6.20) On the assumption that there may be similar differences between open and closed cases in Massachusetts, only closed California cases were included in this portion of the analysis.

In addition, California and Massachusetts have each developed different methods of categorizing the outcomes of complaints. These differences should be considered when making comparisons between the two states. Massachusetts' cases can most easily be grouped into cases that are dismissed and those that are not dismissed. California cases are most easily grouped into cases for which no violation is determined to have occurred and those where it is determined that a violation has occurred. Some California cases that were counted as "no violation" for the purpose of computing the percentages presented in Table 6.32 were actually cases that could not be pursued because they were outside the Board's jurisdiction, there was insufficient evidence, or they were unable to locate the subject of the complaint.

Finally, the small number of complaints in Massachusetts means that the percentages are unstable for all but the largest disciplines or categories.

With these caveats, the discipline profile of complaints appears to be remarkably similar in these two states. Complaints in the two states are primarily against civil engineers (40.1% in California and 43.4% in Massachusetts) or the unlicensed (49.2% vs. 36.8%). The other practice act disciplines account for most of the remaining complaints in both states: electrical (1% in California vs. 2.8% in Massachusetts), mechanical (2% vs. 8.3%), structural (3.9% vs. 6%) and geotechnical (3.5% in California and none in Massachusetts). The biggest proportionate difference between the two states is in the proportion of complaints against traffic engineers; California's proportion (1.9%) is almost ten times that in Massachusetts (0.2%). (Table 6.32)

The percent of cases in which a violation was found to have occurred, or was not dismissed, was also fairly consistent between the two states. The major difference between the two was in the treatment of the unlicensed. California found that a violation had occurred in 78.5% of all cases involving the unlicensed while Massachusetts dismissed all but 18.1% of cases against the unlicensed. This may reflect a difference in the two states' methods of handling complaints. In Massachusetts, an Office of Investigations handles complaints for all professions. In the case of unlicensed practice, only the most serious cases are forwarded to the Attorney General. In California, the Board is the investigative agency, with some limited jurisdiction over the unlicensed. It is authorized to issue citations containing an order of abatement or an administrative fine up to $2500 to persons who are not licensed and who are acting in the capacity of a licensee under the Board's jurisdiction. [5] (Table 6.32)

Alleged violation by discipline. The small number of cases in Massachusetts and in the title act disciplines in both states limits the comparisons that can be made in Table 6.33. The proportion of electrical and mechanical engineers charged with unlicensed activity was similar in California and Massachusetts (9.5% and 8.3% for electrical and 27.5% and 22.2% for mechanical), but the proportion of civil engineers with this charge was almost four times greater in Massachusetts than in California (12.7% vs. 3.5%). This disparity may also reflect the advantaged position of civil engineering in California conferred by the practice/title distinction. Fraud was a more frequent alleged violation in all three practice act disciplines and structural engineering in Massachusetts while competence/negligence was more frequent in these disciplines in California. (Table 6.33)

In Massachusetts, most cases are dismissed (80.5%). (Table 6.34) Unlike California, the dismissal rates are virtually the same for the unlicensed and Civil engineers (81.9% and 82.5% respectively) -- the only groups large enough for reliable comparison. Other cases in Massachusetts are settled (6.2%), the license is suspended (3.4%), revoked (2.1%) or voluntarily surrendered (3.0%). (Table 6.34) The widest range of outcomes occurs in cases where fraud, deceit or misrepresentation are charged; and, with the exception of "other" reasons for the complaint, fraud violations are least apt to be dismissed. Those charged with unlicensed activity are the most apt to be dismissed (91.8%). (Table 6.35)

California, Massachusetts and New York

Although New York provided summary data for a ten-year period, the data does not distinguish licensed and unlicensed and, as a generic licensing state, they do not track discipline. Table 6.36 provides rough comparisons between California, Massachusetts and New York on the type of alleged violation, with the most closely related categories in Massachusetts and New York included within the violation categories. Competence/negligence and unlicensed activity were two of the three most common violations in all three states. Fraud was in the top three complaints in California and Massachusetts, while "other" violations were the third most common in New York. Exam subversion was an issue only in California. Licensed engineers were three times as likely to be charged with unlicensed activity in Massachusetts -- a state with 46 licensed disciplines and no hierarchical distinctions between them -- as they were in California (14.2% vs. 4.9%). The proportion of unlicensed *engineers* charged with unlicensed activity was virtually identical in these two states (52.1% in California and 51.9% in Massachusetts). Complaints against the unlicensed in California are concentrated in two violation categories (unlicensed activity and exam subversion). Complaints against this group in Massachusetts are concentrated in unlicensed activity and fraud, but are more dispersed among the full range of allegations. (Table 6.36 and 6.37)

Complaint Rates

Complaint rates by discipline per 100,000 employed engineers. Using OES data for California and Massachusetts, the average number of complaints per 100,000 employed engineers was computed for disciplines licensed in at least one of the two states. Rates for the licensed and unlicensed used all employed engineers, including disciplines not licensed in either state. In both states, there were more complaints against civil engineers than all other

[5] *Plain Language Pamphlet of the Professional Engineers Act and the Board Rules*, Revised 6/99, Section 5, Q6a.

disciplines combined. Complaints against civil engineers were 75% higher in California than in Massachusetts (327 vs. 187 per 100,000 employed engineers). Conversely, there were 141% more complaints against mechanical engineers in Massachusetts than in California. Rates for chemical, electrical and industrial were also higher in Massachusetts, while rates for metallurgical (California) or materials (Massachusetts) engineering was higher in California. The overall rate for complaints against licensed engineers was almost 60% higher in California (44 vs. 28), while that for the unlicensed was more than twice as high in California (43 vs. 16 per 100,000). Total complaints were almost exactly twice as high in California (87 vs. 44 in Massachusetts). (Table 6.38)

The higher complaint rates in California, particularly among the unlicensed, may be related to the state's regulatory structure. California, as a “board” state, vests more control over the licensing and complaint process in the Board, while Massachusetts, as an “agency” state, vests control over complaints in an Office of Investigations that governs all professions. Exercise of the disciplinary and enforcement function both expresses and justifies the Board's authority. Since none of the comparison states were able to provide information regarding complaint source, there is no way to determine whether or not California is unusual in having almost half of all complaints filed by the Board. It would be interesting to know if this is typical of other “board” states. One of the reasons for the high rate of board-initiated complaints in California is its use of exam subversion, a charge that does not appear in the other states. Exam subversion constitutes a majority of board-filed complaints.

Complaint rates per 100,000 registered engineers. Useable complaint data was collected directly from two comparison states that cooperated with ISR's request (Massachusetts and New York). North Carolina provided data that could not be used because it included land surveyors. North Carolina and Texas provided revisions of numbers published in the National Society for Professional Engineers' (NSPE) summary reports. The NSPE numbers for several of the comparison states (California, Massachusetts, New York, Ohio and Texas) were duplicated for fiscal years 97/98 and 99/00 and the NSPE numbers for Texas appeared to be extremely high. When ISR contacted the Texas board, ISR was informed that the numbers reported for Texas included all telephone calls in the number of total complaints. The Texas board then provided ISR with numbers that excluded the phone calls and that were therefore more comparable to the data provided by the other states. The remaining six states, for a variety of reasons, could not provide the information.

Initially, it was hoped that rate comparisons could be extracted from the NSPE summary reports for all of the comparison states. However, only six of the ten comparison states had data reported in the NSPE summary (the four listed above plus Ohio and Florida). The numbers provided by some of these states did not match those published by NSPE. One reason for this may be that although NSPE identifies disciplinary actions as those taken against licensed engineers and enforcement actions as those taken against *unlicensed* engineers, they include unlawful practice complaints, which can involve licensed engineers practicing outside their area of competence, in their summary of "enforcement" actions. Individual states (California and Massachusetts) include unlicensed activity by licensed engineers as a reason for *disciplinary* action, furthering the confusion between unlicensed activity and the licensing status of individuals. This explanation did not explain all of the variation observed between state and NSPE figures. In the end, ISR could not reconcile the numbers provided by the states and those printed in the NSPE reports.

Other variations in state practices make interstate comparisons inexact. States vary in the definition of a fiscal year and one, New York, provided data for the calendar year. Several states, including Massachusetts, code actions taken in response to a complaint while California codes "violations identified" but does not provide a case by case description of the outcome or action taken. Three of the four states provided information on all complaints, while Massachusetts sent information on closed complaints only. Where possible, California's data was adjusted to provide the appropriate comparisons in Table 6.39.

In fiscal year 97/98, California's complaint rate per 100,000 registered engineers was roughly half that of New York and North Carolina and one fourth that of Texas. In 99/00, California's rate was still the lowest, but New York's surpassed Texas, which dropped by more than half. Although lowest in total number of complaints, California was second lowest, after New York, in the number of disciplinary actions per 100,000 registered engineers. Texas has the highest rate of disciplinary actions in both years. (Table 6.39, top panel) California's rate for *closed* complaints was higher than Massachusetts' in three of the four years. The rate of disciplinary actions was much higher in California in all four years. It may be coincidental that the two agency-dominated states (New York and Massachusetts) have the lowest rates of disciplinary actions; but each state has a single investigative agency that deals with complaints against all professions. (Table 6.39)

Complaint rates per 100,000 employed engineers. The rate of complaints against unlicensed subjects was lowest in California in 97/98, but lowest in North Carolina in 99/00. New York was highest in both years. This may be partially explained by their inclusion of illegal practice complaints, which can encompass unlicensed activity by licensed engineers. New York also had the highest rate of enforcement actions against the unlicensed in 97/98 (38.6 per 100,000 employed engineers). California had the highest rate in 1999/2000 (32.2 per 100,000) but the number of enforcement actions for New York and North Carolina was very small. (Table 6.40)

Table 6.1. Percentage Distribution of Number of Claims, Claim Dollars and Client Fees by Discipline, DPIC 1996 - 2000

Engineering Discipline	Number of Claims	Claim Dollars	Client Fees
Civil	25.7%	21.5%	29.0%
Structural	11.3%	16.1%	6.7%
Mechanical	8.2%	7.6%	8.8%
Electrical	2.1%	1.0%	4.2%
Other	10.7%	9.9%	11.8%
Architecture	42.0%	44.0%	39.6%
Total	100.0%	100.0%	100%

Table 6.2. Percentage Distribution of Claims and Claim Dollars for Types of Damages by Engineering Discipline, DPIC 1996 - 2000

		Engineering Discipline[a]			
	Type of Damages	Civil	Structural	Mechanical	Electrical
Number of Claims	Economic loss	46%	40%	51%	57%
	Property damage	39%	47%	39%	28%
	Bodily injury – other	10%	6%	7%	9%
	Bodily injury – construction	3%	6%	2%	4%
	Total[b]	98%	99%	99%	98%
Claims Dollars	Economic loss	53%	41%	56%	42%
	Property damage	29%	45%	31%	42%
	Bodily injury – other	13%	7%	10%	14%
	Bodily injury – construction	3%	6%	3%	3%
	Total[b]	98%	99%	100%	101%

[a] Data on “other” disciplines was not included in the PowerPoint presentation.

[b] Percentages provided in the PowerPoint presentation do not always sum to exactly 100%, most likely this is due to either rounding error or the omission of some types of damages.

Table 6.3. Percentage Distribution of Claims and Claim Dollars for Suing Parties by Engineering Discipline, DPIC 1996 - 2000

		Engineering Discipline[a]			
	Suing Party	Civil	Structural	Mechanical	Electrical
Number of Claims	Contractor or subcontractor	13%	11%	11%	15%
	Third party	33%	25%	13%	21%
	Owner/client	51%	62%	72%	60%
	Total[b]	97%	98%	96%	96%
Claims Dollars	Contractor or subcontractor	14%	13%	6%	6%
	Third party	27%	26%	15%	21%
	Owner/client	56%	61%	79%	72%
	Total[b]	97%	100%	100%	99%

[a] Data on “other” disciplines was not included in the PowerPoint presentation.

[b] Percentages provided in the PowerPoint presentation do not always sum to exactly 100%, most likely this is due to either rounding error or the omission of some categories of suing parties.

Table 6.4. Percentage Distribution of Claims, Claim Dollars and Fees by Project Type and Engineering Discipline, DPIC 1996 - 2000

	Engineering Discipline[a]											
	Structural			Civil			Mechanical			Electrical		
Project Type	Claims	Dollars	Fees	Claims	Dollars	Fees	Claims	Dollars	Fees	Claims	Dollars	Fees
Bridges, trestles	2%	2%	5%	1%	2%	3%						
Correctional										5%	1%	1%
Comm.I/ind <9 stories	12%	7%	26%	6%	4%	8%	12%	9%	33%	14%	16%	21%
High rise, >9 stories							3%	3%	1%			
Hospitals							12%	12%	8%	10%	8%	4%
Malls, retail	4%	4%	5%	4%	2%	5%	2%	1%	5%			
Residential	18%	10%	7%	21%	20%	20%				6%	15%	1%
Residential condos	9%	11%	1%	5%	2%	1%				5%	2%	1%
Residential subdivisions												
Roads, highways				14%	11%	26%						
Schools through grade 12												
Schools, colleges, universities	8%	8%	12%				22%	23%	17%	14%	6%	7%
Wastewater, sewage & water treatment systems				18%	25%	8%						
Total[b]	53%	42%	56%	69%	66%	71%	51%	48%	64%	54%	48%	34%

[a] Data on “other” disciplines was not included in the PowerPoint presentation.

[b] Percentages provided in the PowerPoint presentation sum to much less than 100%, most likely this is due to the exclusion of several project type categories.

Table 6.5. Fiscal Year in which Complaint Case Was Opened by Type of License Held by Subject of Complaint (California)

FY in which case was opened*	Percent of Complaints				*Number of Cases*			
	Professional Engineers	Unlicensed Subjects	Land Surveyors	Total	Professional Engineers	Unlicensed Subjects	Land Surveyors	Total
90/91 (partial)	40.1%	44.1%	15.8%	100.0%	*61*	*67*	*24*	*152*
91/92	42.3%	48.4%	9.3%	100.0%	*132*	*151*	*29*	*312*
92/93	48.6%	39.0%	12.4%	100.0%	*121*	*97*	*31*	*249*
93/94	35.0%	48.9%	16.1%	100.0%	*63*	*88*	*29*	*180*
94/95	42.8%	47.0%	10.2%	100.0%	*101*	*111*	*24*	*236*
95/96	47.3%	41.8%	11.0%	100.0%	*129*	*114*	*30*	*273*
96/97	28.2%	23.1%	48.7%	100.0%	*89*	*73*	*154*	*316*
97/98	45.7%	28.4%	25.9%	100.0%	*106*	*66*	*60*	*232*
98/99	42.9%	46.6%	10.5%	100.0%	*82*	*89*	*20*	*191*
99/00	45.3%	38.4%	16.3%	100.0%	*111*	*94*	*40*	*245*
00/01	53.1%	36.0%	10.9%	100.0%	*137*	*93*	*28*	*258*
01/02 (partial)	61.4%	20.5%	18.1%	100.0%	*51*	*17*	*15*	*83*
Overall	43.4%	38.9%	17.7%	100.0%	*1,183*	*1,060*	*484*	*2,727*

* This table includes all California complaint cases opened between 1/7/91 and 10/19/01. This means the first and last fiscal year categories shown are actually only *partial* fiscal years. The data shown here describes the last six months of FY 90/91 and the first 3.6 months of FY 01/02. These cases were included in the following analysis to help provide a larger and more reliable set of cases.

Table 6.6. Cases Used for Analysis: Category of Code Section Allegedly Violated by Type of License Held by Subject of Complaint (California)

Category of Code Section Allegedly Violated		Subject of Complaint			Total
		Professional Engineers	Unlicensed Subjects	Land Surveyors	
General DCA Provisions		*6*		~~*1*~~	*7*
Board Rules		*18*	*475*	~~*1*~~	*494*
Professional Engineers Act		*865*	*479*	~~*8*~~	*1,352*
Professional Engineers Act and:	General DCA provisions	*2*			*2*
	Board Rules	*2*			*2*
	Professional Land Surveyors Act	*7*	*12*	~~*2*~~	*21*
Professional Land Surveyors Act		*283*	~~*94*~~	~~*472*~~	*849*
Total		*1,183*	*1,060*	~~*484*~~	*2,727*
Cases Used for Analysis		*1,183*	*966*	*0*	*2,149*

Table 6.7. Type of Engineering License Held by Subject of Complaint and Source of Complaint by Fiscal Year in which Case Was Opened (California)

			Fiscal Year in which Case Was Opened											
		Overall	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00	00/01	01/02
Type of engineering license held by subject of complaint[a]	Civil	43.0%	36.4%	38.3%	46.2%	35.8%	38.2%	42.5%	45.3%	50.6%	42.7%	48.7%	41.4%	60.6%
	Agricultural	.2%	.0%	.4%	.0%	.0%	.0%	.0%	.0%	.0%	.6%	1.0%	.0%	.0%
	Control Systems	.4%	1.7%	.4%	.5%	1.4%	.5%	.9%	.0%	.0%	.0%	.0%	.0%	.0%
	Electrical	1.0%	1.7%	1.1%	1.4%	1.4%	1.4%	.0%	.0%	1.2%	1.9%	.5%	.9%	.0%
	Fire Protection	.1%	.0%	.0%	.0%	.0%	.0%	.0%	.6%	.0%	.0%	.0%	.9%	.0%
	Geotechnical	4.2%	5.8%	4.9%	5.7%	2.7%	2.4%	3.5%	2.5%	5.9%	2.5%	3.1%	6.3%	4.5%
	Mechanical	2.1%	3.3%	1.5%	1.9%	.7%	3.4%	2.2%	.6%	.6%	.6%	3.7%	3.6%	4.5%
	Metallurgical	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.5%	.0%	.0%
	Nuclear	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.5%	.0%
	Quality	.2%	.0%	.4%	.0%	.0%	.0%	.0%	.6%	.6%	.6%	.0%	.5%	.0%
	Safety	.1%	.0%	.0%	.0%	.0%	.0%	.4%	.0%	.6%	.0%	.0%	.0%	.0%
	Structural	4.3%	3.3%	3.8%	2.4%	.7%	3.9%	7.0%	6.8%	3.5%	3.2%	3.1%	6.8%	9.1%
	Traffic	1.9%	.8%	.8%	.0%	.7%	.0%	.4%	2.5%	14.7%	1.3%	.5%	1.8%	.0%
	Unlicensed	45.0%	49.6%	50.4%	42.9%	57.4%	51.2%	43.4%	44.7%	37.6%	47.8%	41.9%	38.3%	22.7%
	Number of cases	*2,149*	*121*	*266*	*212*	*148*	*207*	*228*	*161*	*170*	*157*	*191*	*222*	*66*
Category of license held by subject of complaint	Practice Act/Title Authority only	52.0%	47.9%	47.7%	56.6%	40.5%	48.3%	54.8%	51.6%	46.5%	49.7%	56.0%	58.1%	77.3%
	Civil and Traffic	1.7%	.8%	.4%	.0%	.7%	.0%	.4%	2.5%	14.1%	.6%	.5%	.9%	.0%
	Other Practice Act/Title Authority & Title Act	.5%	.8%	.8%	.5%	.0%	.0%	.0%	.6%	1.2%	.6%	1.0%	.0%	.0%
	Title Act only	.9%	.8%	.8%	.0%	1.4%	.5%	1.3%	.6%	.6%	1.3%	.5%	2.7%	.0%
	Unlicensed	45.0%	49.6%	50.4%	42.9%	57.4%	51.2%	43.4%	44.7%	37.6%	47.8%	41.9%	38.3%	22.7%
	Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	Number of cases	*2,149*	*121*	*266*	*212*	*148*	*207*	*228*	*161*	*170*	*157*	*191*	*222*	*66*
Source of complaint	Public (consumer)	50.0%	55.4%	54.1%	58.0%	52.0%	38.2%	53.9%	44.1%	41.2%	52.2%	56.5%	43.7%	51.5%
	Internal (Board)	39.0%	36.4%	39.1%	34.9%	39.2%	50.2%	39.9%	35.4%	53.5%	35.7%	33.5%	36.9%	21.2%
	Other California agency (not DCA)	.1%	.8%	.4%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.5%	.0%	.0%
	Another state (not California)	.1%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.9%	1.5%
	Federal government	.3%	.8%	.4%	.0%	.7%	.0%	.0%	.6%	.0%	.6%	.0%	.5%	.0%
	Other government agency (not State or Federal)	5.4%	6.6%	4.1%	4.2%	6.1%	2.9%	2.2%	8.1%	2.9%	6.4%	7.3%	10.4%	4.5%
	Licensees	3.6%	.0%	.0%	.5%	1.4%	7.7%	1.8%	11.2%	1.2%	3.8%	2.1%	6.3%	16.7%
	Societies/trade organizations	1.1%	.0%	1.9%	2.4%	.7%	.5%	1.8%	.6%	1.2%	1.3%	.0%	.5%	3.0%
	Anonymous	.2%	.0%	.0%	.0%	.0%	.5%	.4%	.0%	.0%	.0%	.0%	.9%	1.5%
	Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	Number of cases	*2,149*	*121*	*266*	*212*	*148*	*207*	*228*	*161*	*170*	*157*	*191*	*222*	*66*

[a] Each complaint case can be coded with up to two types of licenses, so the total percentages for this variable sums to more than 100%

Table 6.8. Compare California's Distribution of Complaints and Employed Engineers

		All California Complaints, 1/7/91-10/19/01		OES Estimated California Workforce, 2000	
		Number of Cases	Percent	*Number of Cases*	Percent
Practice Act	Civil[a]	*965*	44.9%	*33,340*	15.4%
	Electrical	*21*	1.0%	*64,280*	29.7%
	Mechanical	*46*	2.1%	*24,330*	11.2%
Title Authority	Geotechnical	*90*	4.2%		
	Structural	*93*	4.3%		
Title Act	Agricultural	*4*	.2%	*120*	.1%
	Chemical		.0%	*2,030*	.9%
	Control Systems	*9*	.4%		
	Corrosion		.0%		
	Fire Protection	*3*	.1%		
	Industrial		.0%	*20,360*	9.4%
	Manufacturing		.0%		
	Materials[b]	*1*	.0%	*2,270*	1.0%
	Nuclear	*1*	.0%	*1,110*	.5%
	Petroleum		.0%	*940*	.4%
	Quality	*5*	.2%		
	Safety	*2*	.1%		
Unregulated	Aerospace			*21,440*	9.9%
	Biomedical			*890*	.4%
	Health and Safety			*4,800*	2.2%
	Marine			*140*	.1%
	Mining			*810*	.4%
	Other[c]			*39,650*	18.3%
Unlicensed		*966*	45.0%		
Total		*2,149*	N/A	*216,510*	100.0%

[a] OES data for this category also Includes environmental engineers.

[b] Complaints involving registered metallurgical engineers are included under the OES category for materials engineer.

[c] The national OES does not report data for the number of engineers employed in "other" engineering disciplines. This data is only available from each state.

Table 6.9. Compare California's Distribution of Complaints and Registered Engineers

		Complaints Against Registered Engineers 1/7/91-10/19/01		Registered Engineers in California, FY 00/01	
		Number of Cases	Percent	*Number of Cases*	Percent
Practice Act	Civil	*924*	78.1%	*43,710*	51.4%
	Electrical	*21*	1.8%	*8,312*	9.8%
	Mechanical	*46*	3.9%	*14,646*	17.2%
Title Authority	Geotechnical	*90*	7.6%	*865*	1.0%
	Structural	*93*	7.9%	*3,148*	3.7%
Title Act	Agricultural	*4*	.3%	*280*	.3%
	Chemical			*2,121*	2.5%
	Control Systems	*9*	.8%	*2,363*	2.8%
	Corrosion			*488*	.6%
	Fire Protection	*3*	.3%	*865*	1.0%
	Industrial			*845*	1.0%
	Manufacturing			*1,362*	1.6%
	Metallurgical	*1*	.1%	*418*	.5%
	Nuclear	*1*	.1%	*980*	1.2%
	Petroleum			*476*	.6%
	Quality	*5*	.4%	*1,717*	2.0%
	Safety	*2*	.2%	*1,115*	1.3%
	Traffic	*41*	3.5%	*1,372*	1.6%
Total		*1,183*	N/A	*85,083*	100.0%

Table 6.10. Percentage Distribution of California's Employed Engineers[a] by Industry, 1998

		Industry			
		Engineering & Architecture	Government	Corporation	Total
Practice Act Disciplines	Civil, including traffic	36.7%	56.3%	6.9%	100.0%
	Electrical	6.1%	12.3%	81.6%	100.0%
	Mechanical	19.0%	4.7%	76.3%	100.0%
Title Act Disciplines	Chemical	6.7%	.0%	93.3%	100.0%
	Industrial	2.4%	1.6%	96.0%	100.0%
	Metallurgical	.0%	.0%	100.0%	100.0%
	Nuclear	.0%	.0%	100.0%	100.0%
	Petroleum	.0%	.0%	100.0%	100.0%
All Other Disciplines		8.3%	10.8%	81.0%	100.0%

[a] Data from 1998 was taken from State Occupation Employment Statistics Survey.

Table 6.11. Distribution of Licenses Held by Complaint Subjects (California)

			Second License							
		No Second License	Mechan-ical	Agri-cultural	Control Systems	Fire Protection	Quality	Safety	Traffic	Total
Practice Act Disciplines	Civil	872	10	4			1	1	36	924
	Electrical	18	1		2					21
	Mechanical	34			1					35
Title Authorities	Geotechnical	90								90
	Structural	92				1				93
Title Act Disciplines	Control Systems	6								6
	Fire Protection	2								2
	Metallurgical	1								1
	Nuclear	1								1
	Quality	4								4
	Safety	1								1
	Traffic	5								5
Unlicensed		966								966
Total		2,092	11	4	3	1	1	1	36	2,149

Table 6.12. Distribution of Cases in License Categories (California)

	:	Percent	*Number of Cases*
Type of Licenses `Held	Practice Act or Title Authority only	52.0%	*1,117*
	Civil and Traffic	1.7%	*36*
	Other PracticeAct /Title Authority & Title Act	.5%	*10*
	Title Act only	.9%	*20*
	Unlicensed	45.0%	*966*
	Total	100.0%	*2,149*
Number of Licenses Held (for Licensed Engineers only)	One license	95.2%	*1126*
	More than one Practice Act license	.9%	*11*
	PracticeAct /Title Authority & Title Act	3.9%	*46*
	Total	100.0%	*1,183*

Table 6.13. Percentage Distribution of Violation Category by Source of Complaint (California)

	Source of Complaint									
Violation Category	Public (con-sumer)	Internal (Board)	Other California Agency (not DCA)	Other State (not California)	Federal Gov-ernment	Other Gov-ernment Agency	Licensees	Societies/ Trade Orga-nization	Anon-ymous	Total
Contractual	19.7%	.5%	.0%	.0%	16.7%	2.6%	2.6%	.0%	.0%	10.3%
Fraud, deceit, misrepresentation	15.5%	6.9%	33.3%	33.3%	16.7%	12.9%	9.0%	4.2%	.0%	11.7%
Competence/negligence	55.6%	11.9%	33.3%	66.7%	.0%	50.9%	32.1%	75.0%	.0%	37.4%
Exam subversion	.2%	52.9%	.0%	.0%	16.7%	.0%	.0%	.0%	.0%	20.8%
Other	.7%	2.4%	.0%	.0%	.0%	4.3%	2.6%	4.2%	.0%	1.7%
Unlicensed activity	22.0%	26.9%	33.3%	.0%	50.0%	31.9%	56.4%	16.7%	100.0%	25.9%
Number of cases	*1,075*	*839*	*3*	*3*	*6*	*116*	*78*	*24*	*5*	*2,149*

Table 6.14. Percentage Distribution of Violation Category by Fiscal Year in which Case Was Opened (California)

Violation Category	Overall	Fiscal Year in which Case Was Opened 90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00	00/01	01/02
Contractual	10.3%	16.5%	12.8%	22.2%	10.8%	9.7%	6.6%	.0%	2.9%	7.0%	10.5%	11.7%	12.1%
Fraud, deceit, misrepresentation	11.7%	17.4%	22.6%	28.3%	16.9%	12.1%	7.5%	3.7%	3.5%	1.9%	6.8%	5.9%	3.0%
Competence/negligence	37.4%	28.9%	33.5%	34.9%	22.3%	28.0%	43.0%	47.8%	52.4%	40.1%	39.3%	34.2%	54.5%
Exam subversion[b]	22.9%	32.2%	31.6%	27.8%	29.7%	31.9%	18.9%	18.0%	20.6%	19.1%	18.3%	13.1%	.0%
Other	1.7%	.8%	1.1%	.5%	1.4%	.5%	.9%	.6%	2.9%	1.9%	2.6%	3.6%	6.1%
Unlicensed activity	23.8%	19.0%	16.2%	14.6%	26.8%	18.4%	34.2%	29.8%	18.2%	30.6%	23.0%	37.4%	25.8%
Number of cases	*2,149*	*121*	*266*	*212*	*148*	*207*	*228*	*161*	*170*	*157*	*191*	*222*	*66*

[a] Each complaint case can be coded with up to two types of violations so the total percentages for this variable sums to more than 100%

[b] Exam subversion used to be coded in the complaint database in the same category as fraud, deceit and misrepresentation. The current coding system includes it in the same category as other. For all of the analysis presented in this report, exam subversion is broken out into a separate category, based on the alleged violation of Board Rule 442.

Table 6.15. Summary Percentage Distribution of Code Section Allegedly Violated by Fiscal Year in which Case Was Opened (California)

Section of Business and Professions Code or California Code of Regulations Allegedly Violated		Over-all %	Fiscal Year in which Case Was Opened 90/91 %	91/92 %	92/93 %	93/94 %	94/95 %	95/96 %	96/97 %	97/98 %	98/99 %	99/00 %	00/01 %	01/02 %
General DCA Provisions	141. Disciplinary action by foreign jurisdiction; grounds for disciplinary action in state	.4%					.5%	.4%	.6%	1.8%			.5%	1.5%
Board Rules	411. Seal and Signature	.1%											.5%	1.5%
	442. Examination Subversion	22.9%	32.2%	31.6%	27.8%	29.7%	31.9%	18.9%	18.0%	20.6%	19.1%	18.3%	13.1%	
Professional Engineers Act	6730. Evidence of qualifications; registration	.2%										.5%	.9%	1.5%
	6731.1. Civil engineering; additional authority	.0%									.6%			
	6732. Use of seal, stamp or title by unregistered person	.5%					1.0%	.4%	.6%		.6%	1.0%	1.4%	
	6733. Use of stamp of seal when certificate not in force	.1%				.7%						.5%		
	6735. Preparation, signing, and sealing of civil engineering documents	.6%		.4%					2.5%		.6%	1.0%	.9%	3.0%
	6736. Title of structural engineer	.1%							.6%		.6%			1.5%
	6736.1. Soil engineer, soils engineer, or geotechnical engineer	.0%											.5%	
	6737.1. Structure exemption	.0%					.5%							
	6738. Engineering business – business name	1.7%			.5%	1.4%	9.2%	3.1%	.6%	1.2%		.5%	1.4%	
	6749. Written Contracts	.1%											.5%	1.5%
	6755. Examination requirements	.1%				1.4%								
	6764. Seal or stamp	.0%											.5%	
	6775. Complaints against Professional Engineers, including: conviction of a crime; deceit, misrepresentation or fraud; negligence or incompetence; and breach of contract	37.0%	38.8%	32.3%	39.6%	32.4%	34.3%	41.2%	35.4%	33.5%	31.8%	42.4%	38.3%	54.5%
	6787. Acts constituting misdemeanor, include: unauthorized practice or use of title in civil, electrical, mechanical engineering; or use of the titles of professional, licensed, registered, or consulting engineer	25.5%	22.3%	24.1%	16.5%	29.7%	21.7%	27.6%	28.6%	19.4%	28.7%	24.1%	37.4%	24.2%
Professional Land Surveyors Act	8726 -8792 Numerous Business and Professions Codes from the Professional Land Surveyors Act	14.1%	9.1%	14.7%	18.4%	7.4%	6.3%	12.7%	15.5%	23.5%	19.7%	13.6%	10.8%	21.2%
Number of cases		*2,149*	*121*	*266*	*212*	*148*	*207*	*228*	*161*	*170*	*157*	*191*	*222*	*66*

Table 6.16. Detailed Percentage Distribution of Code Section Allegedly Violated by Fiscal Year in which Case Was Opened (California)

Section of Business and Professions Code or California Code of Regulations Allegedly Violated			Over-all %	Fiscal Year in which Case Was Opened: 90/91 %	91/92 %	92/93 %	93/94 %	94/95 %	95/96 %	96/97 %	97/98 %	98/99 %	99/00 %	00/01 %	01/02 %
General DCA Provisions	141.	Disciplinary action by foreign jurisdiction; grounds for disciplinary action in state	.4%					.5%	.4%	.6%	1.8%			.5%	1.5%
Board Rules	411.	Seal and Signature	.1%											.5%	1.5%
	442.	Examination Subversion	22.9%	32.2%	31.6%	27.8%	29.7%	31.9%	18.9%	18.0%	20.6%	19.1%	18.3%	13.1%	
Professional Engineers Act	6730.	Evidence of qualifications; registration	.2%										.5%	.9%	1.5%
	6731.1.	Civil engineering; additional authority	.0%									.6%			
	6732.	Use of seal, stamp or title by unregistered person	.5%					1.0%	.4%	.6%		.6%	1.0%	1.4%	
	6733.	Use of stamp of seal when certificate not in force	.1%				.7%						.5%		
	6735.	Preparation, signing, and sealing of civil engineering documents	.6%		.4%					2.5%		.6%	1.0%	.9%	3.0%
	6736.	Title of structural engineer	.1%							.6%		.6%			1.5%
	6736.1.	Soil engineer, soils engineer, or geotechnical engineer	.0%											.5%	
	6737.1.	Structure exemption	.0%					.5%							
	6738.	Engineering business -- business name	1.7%			.5%	1.4%	9.2%	3.1%	.6%	1.2%		.5%	1.4%	
	6749.	Written Contracts	.1%											.5%	1.5%
	6755.	Examination requirements	.1%				1.4%								
	6764.	Seal or stamp	.0%											.5%	
	6775.	Complaints against Professional Engineers The Board may receive and investigate complaints against registered professional engineers, and make finding thereon. By majority vote, the board may reprove, suspend for a period not to exceed two years, or revoke the certificate of any professional engineer registered under this chapter who:	.3%					.5%	.4%		.6%	1.3%	.5%		
		(a) Has been convicted of a crime substantially related to qualifications, functions and duties of a registered professional engineer	.4%			.5%	.7%	.5%	.4%	1.2%	.6%	.6%			
		(b)* Has been found guilty by the board of fraud, deceit, misrepresentation, negligence, incompetence, and or breach (or violation) of contract	34.0%	37.2%	30.8%	38.7%	28.4%	31.4%	38.6%	29.2%	30.0%	27.4%	38.2%	35.1%	51.5%
		(c)* Has been found guilty of any fraud or deceit in obtaining his or her certificate	.3%		.4%				.9%	1.2%			1.0%		
		(d)* Aids or abets any person in the violation of any provision of this chapter	2.1%	1.7%	2.3%	1.9%	2.0%	2.4%	.9%	3.7%	2.4%	1.3%	1.0%	3.6%	1.5%
		(e)* Violates any provision of this chapter	1.5%		.4%		1.4%	5.3%	.9%	.6%	.6%	2.5%	1.6%	3.2%	1.5%
		Subtotal for § 6775	37.0%	38.8%	32.3%	39.6%	32.4%	34.3%	41.2%	35.4%	33.5%	31.8%	42.4%	38.3%	54.5%
	6787.	Acts constituting misdemeanor Every person is guilty of a misdemeanor who:	.8%				2.0%	1.9%	2.6%		1.2%	.6%	.5%		
		(a) Unless exempt from registration, practices or offers to practice civil, electrical, or mechanical engineering in this state…without legal authorization	17.9%	19.8%	16.9%	13.7%	24.3%	12.1%	16.2%	18.0%	12.4%	19.7%	18.8%	27.9%	15.2%
		(b-d) Misrepresents themselves	3.9%		3.4%	3.8%	4.1%	2.4%	3.5%	7.5%	2.9%	3.2%	8.9%	3.6%	
		(e) Uses an expired, suspended, or revoked certificate issued by the board	1.7%		.8%		.7%	.5%	1.3%		.6%	1.3%		11.7%	1.5%
		(f) Represents himself or herself as, or uses the title of, registered civil, electrical or mechanical engineer	5.9%	.8%	2.3%	.9%	4.7%	4.8%	3.9%	3.1%	6.5%	19.1%	4.2%	14.0%	10.6%
		(g) Unless appropriately registered, manages or conducts as manager…any place of business from which civil, electrical, or mechanical engineering work is done	1.8%		3.0%	2.4%		1.9%			1.2%	1.9%	.5%	4.1%	9.1%
		(h-i) Uses the titles of professional, licensed, registered, or consulting engineer	4.0%	5.8%	6.4%	3.3%	4.1%	2.9%	1.3%	1.2%	2.4%	5.7%	3.7%	5.4%	10.6%
		(j) Violates any provision of this chapter	1.4%		.4%		1.4%	3.4%	1.8%	1.9%	.6%	1.9%	1.0%	2.7%	3.0%
		Subtotal for § 6787	25.5%	22.3%	24.1%	16.5%	29.7%	21.7%	27.6%	28.6%	19.4%	28.7%	24.1%	37.4%	24.2%
Professional Land Surveyors Act	8726 -8792	Numerous Business and Professions Codes from the Professional Land Surveyors Act	14.1%	9.1%	14.7%	18.4%	7.4%	6.3%	12.7%	15.5%	23.5%	19.7%	13.6%	10.8%	21.2%
Number of cases			*2,149*	*121*	*266*	*212*	*148*	*207*	*228*	*161*	*170*	*157*	*191*	*222*	*66*

* §6775 was restructured as of January 1, 200. Three separate subdivisions of the former §6775(b) were created for (b) fraud deceit, and/or misrepresentation, (c) negligence and/or incompetence, and (d) breach or violation of contract. The remaining subdivisions were adjusted to make room for the two new subdivisions -- what was previously c became e, d became f, and e became h. Since most of the cases described in this chapter were opened prior to the restructuring, those cases opened after 1/1/01 were included in the equivalent pre-1/1/01 category to permit comparison with previous years. This was done for all of the tables in this chapter. Subdivisions with an asterisk reflect the earlier wording of the section.

Table 6.17. Percentage Distribution of Code Sections Allegedly Violated by Violation Categories (California)

Section of Business and Professions Code or California Code of Regulations Allegedly Violated			Violation Categories								
			Contractual			Fraud, Deceit, Misrepresentation					
			Only	and Fraud, Deceit, Misrepre-sentation	and Compe-tence/ Neg-ligence	Only	and Compe-tence/ Neg-ligence	Compe-tence/ Neg-ligence	Exam Sub-version	Other	Un-licensed Activity
General DCA Provisions	141.	Disciplinary action by foreign jurisdiction; grounds for disciplinary action in state						.6%		12.5%	
Rules of the Board	411.	Seal and Signature								6.3%	
	442.	Examination Subversion	.8%						100.0%		
Professional Engineers Act	6730.	Evidence of qualifications; registration								9.4%	.2%
	6731.1.	Civil engineering; additional authority								3.1%	
	6732.	Use of seal, stamp or title by unregistered person				1.2%					1.6%
	6733.	Use of stamp of seal when certificate not in force				.6%				3.1%	
	6735.	Preparation, signing, and sealing of civil engineering documents				.6%	1.8%	1.0%		6.3%	.2%
	6736.	Title of structural engineer				.6%					.4%
	6736.1.	Soil engineer, soils engineer, or geotechnical engineer				.6%					
	6737.1.	Structure exemption									.2%
	6738.	Engineering business -- business name	.8%			4.1%		1.6%		6.3%	3.0%
	6749.	Written Contracts	.8%			.6%					
	6755.	Examination requirements									.4%
	6764.	Seal or stamp								3.1%	
	6775.	Complaints against Professional Engineers The Board may receive and investigate complaints against registered professional engineers, and make finding thereon. By majority vote, the board may reprove, suspend for a period not to exceed two years, or revoke the certificate of any professional engineer registered under this chapter who:				.6%		.7%			
		(a) Has been convicted of a crime substantially related to qualifications, functions and duties of a registered professional engineer				1.8%		.3%		6.3%	.2%
		(b)* Has been found guilty by the board of fraud, deceit, misrepresentation, negligence, incompetence, and or breach (or violation) of contract	81.5%	52.0%	68.7%	34.5%	85.5%	67.1%		3.1%	.2%
		(c)* Has been found guilty of any fraud or deceit in obtaining his or her certificate				3.5%					.2%
		(d)* Aids or abets any person in the violation of any provision of this chapter	1.5%			11.7%	12.7%	1.5%		18.8%	
		(e)* Violates any provision of this chapter	3.1%			4.7%		2.2%		18.8%	
		Subtotal for § 6775	82.3%	52.0%	68.7%	52.0%	85.5%	70.0%	.0%	43.8%	.6%
	6787.	Acts constituting misdemeanor Every person is guilty of a misdemeanor who:				1.2%		.1%			2.8%
		(a) Unless exempt from registration, practices or offers to practice civil, electrical, or mechanical engineering in this state…without legal authorization				11.7%		.4%			73.0%
		(b-d) Misrepresents themselves	.8%			10.5%				3.1%	12.7%
		(e) Uses an expired, suspended, or revoked certificate issued by the board				1.2%	5.5%				6.5%
		(f) Represents himself or herself as, or uses the title of, registered civil, electrical or mechanical engineer				6.4%					23.4%
		(g) Unless appropriately registered, manages or conducts as manager…any place of business from which civil, electrical, or mechanical engineering work is done				1.8%				3.1%	6.9%
		(h-i) Uses the titles of professional, licensed, registered, or consulting engineer				19.9%					10.7%
		(j) Violates any provision of this chapter				2.3%		.1%			5.2%
		Subtotal for § 6787	.8%	.0%	.0%	36.8%	5.5%	.6%	.0%	6.3%	95.6%
Professional Land Surveyors' Act	8726 -8792	Numerous Business and Professions Codes from the Professional Land Surveyors' Act	16.9%	48.0%	31.3%	9.9%	14.5%	28.2%		21.9%	4.6%
Number of cases			*130*	*25*	*67*	*171*	*55*	*681*	*492*	*32*	*496*

* §6775 was restructured as of January 1, 2001. Three separate subdivisions of the former §6775(b) were created for (b) fraud deceit, and/or misrepresentation, (c) negligence and/or incompetence, and (d) breach or violation of contract. The remaining subdivisions were adjusted to make room for the two new subdivisions -- what was previously c became e, d became f, and e became h. Since most of the cases described in this chapter were opened prior to the restructuring, those cases opened after 1/1/01 were included in the equivalent pre-1/1/01 category to permit comparison with previous years. This was done for all of the tables in this chapter. Subdivisions with an asterisk reflect the earlier wording of the section.

Table 6.18. Closing Code by Fiscal Year in which Case Was Opened (California)

				Fiscal Year in which Case was Opened											
Closing Code			Overall	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00	00/01	01/02
Not closed			9.9%									3.8%	20.9%	45.9%	97.0%
No violation			25.4%	32.2%	33.5%	26.4%	23.6%	25.6%	34.2%	28.0%	23.5%	23.6%	18.8%	16.7%	
Unable to pursue	No jurisdiction		1.3%			3.8%	4.7%	3.9%	1.3%		.6%			.9%	
	Insufficient evidence		5.1%	8.3%	6.4%	6.6%	5.4%	5.8%	5.3%	6.8%	7.1%	3.8%	2.6%	1.4%	
	Unable to locate subject		.5%			.5%	3.4%	1.0%	.4%	1.2%					
	Complainant dropped complaint		.3%	.8%		.9%	.7%			.6%		.6%	0.5%		
	Subject deceased		.1%				.7%	.5%							
	Non-cooperation of complainant		.2%				.7%	.5%	.4%	.6%		.6%			
	Statute of limitations expired		.1%				.7%		.4%						
	Subtotal unable to pursue		7.7%	9.1%	6.4%	11.8%	16.2%	11.6%	7.9%	9.3%	7.6%	5.1%	3.1%	2.3%	
Violation identified	Resolved or mediated		3.4%		.8%	1.4%	1.4%	1.4%	1.3%	1.2%	2.9%	12.1%	9.4%	6.8%	1.5%
	Violation, but not serious enough to refer		.6%				1.4%	2.4%		.6%		.6%	.5%	.9%	
	Warning letter		3.5%			2.8%	3.4%	6.8%	8.8%	7.5%	4.1%	1.3%	3.1%	1.4%	
	Other		.1%					.5%		.6%					
	Board action	Citation	6.1%	9.1%	19.9%	1.9%		.5%	2.6%	5.0%	3.5%	8.3%	9.4%	5.4%	
		Compliance obtained	28.9%	9.1%	26.7%	31.1%	41.9%	42.0%	34.2%	36.0%	32.4%	35.7%	22.5%	15.8%	
		Disciplinary action (old code)	2.6%	30.6%	3.0%	4.7%									
		Subtotal board action	37.6%	48.8%	49.6%	37.7%	41.9%	42.5%	36.8%	41.0%	35.9%	43.9%	31.9%	21.2%	
	Referred	Referred to Attorney General	9.8%	9.9%	9.8%	18.9%	6.8%	7.2%	7.5%	8.1%	24.7%	6.4%	9.9%	2.3%	1.5%
		Referred to District Attorney	2.0%			.9%	5.4%	1.9%	3.5%	3.7%	1.2%	3.2%	2.1%	1.8%	
		Referred to other agency	.1%											.9%	
		Subtotal referred	11.9%	9.9%	9.8%	19.8%	12.2%	9.2%	11.0%	11.8%	25.9%	9.6%	12.0%	5.0%	1.5%
	Subtotal violation identified		57.0%	58.7%	60.2%	61.8%	60.1%	62.8%	57.9%	62.7%	68.8%	67.5%	57.1%	35.1%	3.0%
Number of cases			*2,149*	*121*	*266*	*212*	*148*	*207*	*228*	*161*	*170*	*157*	*191*	*222*	*66*

Table 6.19. Percentage Distribution of Closing Code by Source of Complaint (California)

Closing Code	Source of Complaint: Public (con-sumer)	Internal (Board)	Other California Agency (not DCA)	Other State (not California)	Federal Gov-ernment	Other Gov-ernment Agency	Licensees	Societies/ Trade Orga-nization	Anon-ymous	Total
Open	11.4%	4.4%	.0%	33.3%	16.7%	20.7%	25.6%	12.5%	60.0%	9.9%
No violation	38.0%	11.0%	.0%	.0%	16.7%	21.6%	20.5%	8.3%	.0%	25.4%
Unable to pursue	11.0%	3.8%	.0%	33.3%	.0%	5.2%	9.0%	8.3%	.0%	7.7%
Resolved or mediated	4.2%	3.0%	.0%	.0%	.0%	1.7%	1.3%	.0%	.0%	3.4%
Violation, but not serious enough to refer	.1%	1.2%	.0%	.0%	.0%	.0%	1.3%	.0%	.0%	.6%
Warning letter	4.2%	2.3%	.0%	.0%	.0%	6.0%	5.1%	.0%	.0%	3.5%
Other	.1%	.0%	.0%	.0%	.0%	.0%	1.3%	.0%	.0%	.1%
Board action	16.7%	65.8%	33.3%	33.3%	66.7%	26.7%	29.5%	62.5%	40.0%	37.6%
Referred to Attorney General	12.6%	6.3%	66.7%	.0%	.0%	12.9%	3.8%	8.3%	.0%	9.8%
Referred to District Attorney	1.5%	2.3%	.0%	.0%	.0%	5.2%	2.6%	.0%	.0%	2.0%
Referred to other agency	.2%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.0%	.1%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Number of cases	*1,075*	*839*	*3*	*3*	*6*	*116*	*78*	*24*	*5*	*2,149*

Table 6.20. Percentage Distribution of Closing Code by Violation Category (California)

Closing Code	Violation Category: Contractual	Fraud, Deceit, Mis-representation	Competence/ Negligence	Exam Subversion	Other	Unlicensed Activity	Total
Open	11.7%	5.2%	13.3%	.0%	25.0%	12.4%	9.9%
No violation	33.3%	37.5%	37.2%	4.5%	16.7%	21.9%	25.4%
Unable to pursue	14.4%	14.3%	8.3%	1.8%	8.3%	7.9%	7.7%
Resolved or mediated	8.1%	1.6%	2.9%	.0%	2.8%	5.2%	3.4%
Violation, but not serious enough to refer	.0%	.0%	.1%	1.8%	.0%	.5%	.6%
Warning letter	3.6%	2.8%	3.9%	.4%	2.8%	5.2%	3.5%
Other	.0%	.0%	.0%	.0%	.0%	.4%	.1%
Board action	14.4%	23.9%	13.6%	90.6%	19.4%	38.6%	37.6%
Referred to Attorney General	14.4%	13.5%	20.5%	.4%	25.0%	.4%	9.8%
Referred to District Attorney	.0%	1.2%	.1%	.4%	.0%	7.2%	2.0%
Referred to other agency	.0%	.0%	.0%	.0%	.0%	.4%	.1%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Number of cases	*222*	*251*	*803*	*447*	*36*	*557*	*2,149*

Table 6.21. Percentage Distribution of Source of Complaint by Type of Engineering License Held by Subject of Complaint (California)

	Type of Engineering License Held by Subject of Complaint													
	Practice Act			Title Authority		Title Act								
Source of Complaint	Civil	Electrical	Mech-anical	Geo-technical	Structural	Agri-cultural	Control Systems	Fire Protection	Metal-lurgical	Nuclear	Quality	Safety	Traffic	Un-licensed
Public (consumer)	70.6%	57.1%	45.7%	88.9%	73.1%	75.0%	44.4%	66.7%	100.0%	100.0%	20.0%	50.0%	24.4%	25.3%
Internal (Board)	15.7%	38.1%	47.8%	7.8%	18.3%	25.0%	55.6%	33.3%			40.0%	50.0%	70.7%	65.4%
Other California agency (not DCA)	.1%													.2%
Another state (not California)	.2%													.1%
Federal government	.2%										20.0%			.3%
Other government agency (not State or Federal)	8.0%	4.8%	2.2%	2.2%	3.2%								2.4%	3.6%
Licensees	3.0%		2.2%		5.4%								2.4%	4.5%
Societies/trade organizations	2.1%		2.2%	1.1%										.3%
Anonymous	.1%										20.0%			.3%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Number of cases	*924*	*21*	*46*	*90*	*93*	*4*	*9*	*3*	*1*	*1*	*5*	*2*	*41*	*966*

Table 6.22. Percentage Distribution of Source of Complaint by License Categories (California)

Source of Complaint	Practice Act Only	Civil & Traffic	Other Practice/Title Authority & Title	Title Act Only	Unlicensed	Total
Public (consumer)	72.3%	19.4%	70.0%	45.0%	25.3%	50.0%
Internal (Board)	15.0%	77.8%	30.0%	40.0%	65.4%	39.0%
Other California agency (not DCA)	.1%	.0%	.0%	.0%	.2%	.1%
Another state (not California)	.2%	.0%	.0%	.0%	.1%	.1%
Federal government	.2%	.0%	.0%	5.0%	.3%	.3%
Other government agency (not State or Federal)	7.2%	2.8%	.0%	.0%	3.6%	5.4%
Licensees	3.0%	.0%	.0%	5.0%	4.5%	3.6%
Societies/trade organizations	1.9%	.0%	.0%	.0%	.3%	1.1%
Anonymous	.1%	.0%	.0%	5.0%	.3%	.2%
Total	100.0%	100.%0	100.0%	100.0%	100.0%	100.0%
Number of cases	*1,117*	*36*	*10*	*20*	*966*	*2,149*

Table 6.23. Percentage Distribution of Violation Category by Type of Engineering License Held by Subject of Complaint (California)

	Type of Engineering License Held by Subject of Complaint													
	Practice Act			Title Authority		Title Act								
Violation Category	Civil	Electrical	Mech-anical	Geo-technical	Structural	Agri-cultural	Control Systems	Fire Protection	Metal-lurgical	Nuclear	Quality	Safety	Traffic	Un-licensed
Contractual	19.3%	9.5%	13.0%	21.1%	17.2%			33.3%					7.3%	.2%
Fraud, deceit, misrepresentation	16.5%	28.6%	23.9%	24.4%	11.8%	50.0%	33.3%	33.3%			20.0%	50.0%		4.9%
Competence/negligence	69.9%	47.6%	28.3%	68.9%	75.3%	50.0%	11.1%	33.3%	100.0%		20.0%	50.0%	85.4%	.7%
Exam subversion	1.1%	4.8%	2.2%		3.2%		22.2%						4.9%	44.4%
Other	2.4%	9.5%	8.7%	1.1%	3.2%		11.1%			100.0%	20.0%		2.4%	.1%
Unlicensed activity	3.8%	9.5%	30.4%	1.1%	3.2%		33.3%				60.0%		7.3%	51.1%
Number of cases	*924*	*21*	*46*	*90*	*93*	*4*	*9*	*3*	*1*	*1*	*5*	*2*	*41*	*966*

Table 6.24. Percentage Distribution of Violation Category by License Categories (California)

Violation Category	Practice Act Only	Civil & Traffic	Other Practice/Title Authority & Title	Title Act Only	Unlicensed	Total
Contractual	19.3%	5.6%	.0%	10.0%	.2%	10.3%
Fraud, deceit, misrepresentation	17.5%	.0%	40.0%	20.0%	4.9%	11.7%
Competence/negligence	67.5%	94.4%	60.0%	10.0%	.7%	37.4%
Exam subversion	1.3%	.0%	10.0%	15.0%	44.4%	20.8%
Other	2.8%	2.8%	.0%	15.0%	.1%	1.7%
Unlicensed activity	4.8%	2.8%	.0%	40.0%	51.1%	25.9%
Number of cases	*1,117*	*36*	*10*	*20*	*966*	*2,149*

Table 6.25. Summary Percentage Distribution of Section Allegedly Violated by Type of Engineering License Held by Subject of Complaint (California)

			Type of License Held by Subject of Complaint													
			Practice Act			Title Authority		Title Act								
Section of Business and Professions Code or California Code of Regulations Allegedly Violated			Civil %	Electrical %	Mechanical %	Geotechnical %	Structural %	Agricultural %	Control Systems %	Fire Protection %	Metallurgical %	Nuclear %	Quality %	Safety %	Traffic %	Unlicensed %
General DCA Provisions	141.	Disciplinary action by foreign jurisdiction; grounds for disciplinary action in state	.6				2.2									
Rules of the Board	411.	Seal and Signature			2.2		1.1									
	442.	Examination Subversion	1.1	4.8	2.2		3.2		22.2						4.9	49.2
Professional Engineers Act	6730.	Evidence of qualifications; registration			4.3							100.0				.1
	6731.1.	Civil engineering; additional authority											20.0			
	6732.	Use of seal, stamp or title by unregistered person	.2													.8
	6733.	Use of stamp of seal when certificate not in force	.2													
	6735.	Preparation, signing, and sealing of civil engineering documents	.8		4.3	1.1	2.2									.1
	6736.	Title of structural engineer	.3													
	6736.1.	Soil engineer, soils engineer, or geotechnical engineer	.1													
	6737.1.	Structure exemption														.1
	6738.	Engineering business -- business name	1.2	4.8	8.7	2.2			11.1						2.4	1.8
	6749.	Written Contracts	.1			1.1										
	6755.	Examination requirements														.2
	6764.	Seal or stamp			2.2											
	6775.	Complaints against Professional Engineers, including: conviction of a crime; deceit, misrepresentation or fraud; negligence or incompetence; and breach of contract	64.3	81.0	52.2	90.0	82.8	100.0	44.4	100.0	100.0	100.0	40.0	100.0	14.6	.4
	6787.	Acts constituting misdemeanor, include: unauthorized practice or use of title in civil, electrical, mechanical engineering; or use of the titles of professional, licensed, registered, or consulting engineer	4.1	9.5	34.8	1.1	4.3		22.2				60.0		4.9	49.7
Professional Land Surveyors' Act	8726 -8792	Numerous Business and Professions Codes from the Professional Land Surveyors' Act	29.5		4.3	8.9	6.5								73.2	1.2
Number of cases			*924*	*21*	*46*	*90*	*93*	*4*	*9*	*3*	*1*	*1*	*5*	*2*	*41*	*966*

Table 6.26. Summary Percentage Distribution of Section Allegedly Violated by License Categories (California)

		Practice Only	Civil & Traffic	Other Practice/Title Authority & Title	Title Only	Unlicensed	Total
General DCA Provisions	141. Disciplinary action by foreign jurisdiction; grounds for disciplinary action in state	.7%					.4%
Rules of the Board	411. Seal and Signature	.2%					.1%
	442. Examination Subversion	1.3%		10.0%	15.0%	49.2%	22.9%
Professional Engineers Act	6730. Evidence of qualifications; registration	.2%			5.0%	.1%	.2%
	6731.1. Civil engineering; additional authority				5.0%		.0%
	6732. Use of seal, stamp or title by unregistered person	.2%				.8%	.5%
	6733. Use of stamp of seal when certificate not in force	.2%					.1%
	6735. Preparation, signing, and sealing of civil engineering documents	1.0%				.1%	.6%
	6736. Title of structural engineer	.3%					.1%
	6736.1. Soil engineer, soils engineer, or geotechnical engineer	.1%					.0%
	6737.1. Structure exemption					.1%	.0%
	6738. Engineering business -- business name	1.5%	2.8%		5.0%	1.8%	1.7%
	6749. Written Contracts	.2%					.1%
	6755. Examination requirements					.2%	.1%
	6764. Seal or stamp	.1%					.0%
	6775. Complaints against Professional Engineers, including: conviction of a crime; deceit, misrepresentation or fraud; negligence or incompetence; and breach of contract	68.8%	16.7%	90.0%	40.0%	.4%	37.0%
	6787. Acts constituting misdemeanor Every person is guilty of a misdemeanor who:	5.4%	2.8%		30.0%	49.7%	25.5%
Professional Land Surveyors' Act	8726 -8792 Numerous Business and Professions Codes from the Professional Land Surveyors' Act	23.3%	77.8%		10.0%	1.2%	14.1%
Number of cases		*1,117*	*36*	*10*	*20*	*966*	*2,149*

Table 6.27. Detailed Percentage Distribution of Section Allegedly Violated by Type of Engineering License Held by Subject of Complaint (California)

			Type of Engineering License Held by Subject of Complaint													
			Practice Act			Title Authority		Title Act								
			Civil	Electrical	Mechanical	Geotechnical	Structural	Agricultural	Control Systems	Fire Protection	Metallurgical	Nuclear	Quality	Safety	Traffic	Unlicensed
			%	%	%	%	%	%	%	%	%	%	%	%	%	%
General DCA Provisions	141.	Disciplinary action by foreign jurisdiction; grounds for disciplinary action in state	.6				2.2									
Rules of the Board	411.	Seal and Signature			2.2		1.1									
	442.	Examination Subversion	1.1	4.8	2.2		3.2		22.2						4.9	49.2
Professional Engineers Act	6730.	Evidence of qualifications; registration			4.3							100.0				.1
	6731.1.	Civil engineering; additional authority											20.0			
	6732.	Use of seal, stamp or title by unregistered person	.2													.8
	6733.	Use of stamp of seal when certificate not in force	.2													
	6735.	Preparation, signing, and sealing of civil engineering documents	.8		4.3	1.1	2.2									.1
	6736.	Title of structural engineer	.3													
	6736.1.	Soil engineer, soils engineer, or geotechnical engineer	.1													
	6737.1.	Structure exemption														.1
	6738.	Engineering business -- business name	1.2	4.8	8.7	2.2			11.1						2.4	1.8
	6749.	Written Contracts	.1			1.1										
	6755.	Examination requirements														.2
	6764.	Seal or stamp			2.2											
	6775.	Complaints against Professional Engineers The Board may receive and investigate complaints against registered professional engineers, and make finding thereon. By majority vote, the board may reprove, suspend for a period not to exceed two years, or revoke the certificate of any professional engineer registered under this chapter who:	.5				1.1									
		(a) Has been convicted of a crime substantially related to qualifications, functions and duties of a registered professional engineer	.6	4.8												.1
		(b)* Has been found guilty by the board of fraud, deceit, misrepresentation, negligence, incompetence, and or breach (or violation) of contract	60.0	52.4	41.3	85.6	77.4	75.0	22.2	66.7	100.0		20.0	100.0	14.6	.3
		(c)* Has been found guilty of any fraud or deceit in obtaining his or her certificate	.3		4.3	1.1			11.1							
		(d)* Aids or abets any person in the violation of any provision of this chapter	3.2	28.6	4.3	2.2	5.4	25.0	11.1							
		(e)* Violates any provision of this chapter	2.1	4.8	8.7	2.2	3.2		11.1	33.3		100.0	20.0			.1
		Subtotal for §6775	64.3	81.0	52.2	90.0	82.8	100.0	44.4	100.0	100.0	100.0	40.0	100.0	14.6	.4
	6787.	Acts constituting misdemeanor Every person is guilty of a misdemeanor who:														1.8
		(a) Unless exempt from registration, practices or offers to practice civil, electrical, or mechanical engineering in this state…without legal authorization	2.3	9.5	23.9	1.1	3.2		22.2				40.0		2.4	35.5
		(b-d) Misrepresents themselves	.3		4.3											8.1
		(e) Uses an expired, suspended, or revoked certificate issued by the board	1.8	9.5	13.0		4.3						20.0		2.4	.7
		(f) Represents himself or herself as, or uses the title of, registered civil, electrical or mechanical engineer	.1		6.5										2.4	12.6
		(g) Unless appropriately registered, manages or conducts as manager…any place of business from which civil, electrical, or mechanical engineering work is done			6.5								20.0			3.5
		(h-i) Uses the titles of professional, licensed, registered, or consulting engineer	1.4	4.8	4.3		1.1						20.0			7.1
		(j) Violates any provision of this chapter	.1		2.2										2.4	2.9
		Subtotal for §6787	4.1	9.5	34.8	1.1	4.3		22.2				60.0		4.9	49.7
Professional Land Surveyors' Act	8726 –8792	Numerous Business and Professions Codes from the Professional Land Surveyors' Act	29.5		4.3	8.9	6.5								73.2	1.2
Number of cases			*924*	*21*	*46*	*90*	*93*	*4*	*9*	*3*	*1*	*1*	*5*	*2*	*41*	*966*

* §6775 was restructured as of January 1, 200. Three separate subdivisions of the former §6775(b) were created for (b) fraud deceit, and/or misrepresentation, (c) negligence and/or incompetence, and (d) breach or violation of contract. The remaining subdivisions were adjusted to make room for the two new subdivisions -- what was previously c became e, d became f, and e became h. Since most of the cases described in this chapter were opened prior to the restructuring, those cases opened after 1/1/01 were included in the equivalent pre-1/1/01 category to permit comparison with previous years. This was done for all of the tables in this chapter. Subdivisions with an asterisk reflect the earlier wording of the section.

Table 6.28. Detailed Percentage Distribution of Code Section Charged by License Categories (California)

Section of Business and Professions Code or California Code of Regulations Allegedly Violated			Practice Only	Civil & Traffic	Other Practice/Title Authority & Title	Title Only	Unlicensed	Total
General DCA Provisions	141.	Disciplinary action by foreign jurisdiction; grounds for disciplinary action in state	.7%					.4%
Rules of the Board	411.	Seal and Signature	.2%					.1%
	442.	Examination Subversion	1.3%		10.0%	15.0%	49.2%	22.9%
Professional Engineers Act	6730.	Evidence of qualifications; registration	.2%			5.0%	.1%	.2%
	6731.1.	Civil engineering; additional authority				5.0%		.0%
	6732.	Use of seal, stamp or title by unregistered person	.2%				.8%	.5%
	6733.	Use of stamp of seal when certificate not in force	.2%					.1%
	6735.	Preparation, signing, and sealing of civil engineering documents	1.0%				.1%	.6%
	6736.	Title of structural engineer	.3%					.1%
	6736.1.	Soil engineer, soils engineer, or geotechnical engineer	.1%					.0%
	6737.1.	Structure exemption					.1%	.0%
	6738.	Engineering business -- business name	1.5%	2.8%		5.0%	1.8%	1.7%
	6749.	Written Contracts	.2%					.1%
	6755.	Examination requirements					.2%	.1%
	6764.	Seal or stamp	.1%					.0%
	6775.	Complaints against Professional Engineers The Board may receive and investigate complaints against registered professional engineers, and make finding thereon. By majority vote, the board may reprove, suspend for a period not to exceed two years, or revoke the certificate of any professional engineer registered under this chapter who:	.5%					.3%
		(a) Has been convicted of a crime substantially related to qualifications, functions and duties of a registered professional engineer	.6%				.1%	.4%
		(b)* Has been found guilty by the board of fraud, deceit, misrepresentation, negligence, incompetence, and or breach (or violation) of contract	63.6%	16.7%	80.0%	15.0%	.3%	34.0%
		(c)* Has been found guilty of any fraud or deceit in obtaining his or her certificate	.5%			5.0%		.3%
		(d)* Aids or abets any person in the violation of any provision of this chapter	3.8%		20.0%			2.1%
		(e)* Violates any provision of this chapter	2.5%			20.0%	.1%	1.5%
		Subtotal for §6775	68.8%	16.7%	90.0%	40.0%	.4%	37.0%
	6787.	Acts constituting misdemeanor Every person is guilty of a misdemeanor who:					1.8%	.8%
		(a) Unless exempt from registration, practices or offers to practice civil, electrical, or mechanical engineering in this state…without legal authorization	3.3%	2.8%		20.0%	35.5%	17.9%
		(b-d) Misrepresents themselves	.4%				8.1%	3.9%
		(e) Uses an expired, suspended, or revoked certificate issued by the board	2.5%	2.8%		5.0%	.7%	1.7%
		(f) Represents himself or herself as, or uses the title of, registered civil, electrical or mechanical engineer	.4%			5.0%	12.6%	5.9%
		(g) Unless appropriately registered, manages or conducts as manager…any place of business from which civil, electrical, or mechanical engineering work is done	.3%			5.0%	3.5%	1.8%
		(h-i) Uses the titles of professional, licensed, registered, or consulting engineer	1.5%			5.0%	7.1%	4.0%
		(j) Violates any provision of this chapter	.2%			5.0%	2.9%	1.4%
		Subtotal for §6787	5.4%	2.8%		30.0%	49.7%	25.5%
Professional Land Surveyors' Act	8726 -8792	Numerous Business and Professions Codes from the Professional Land Surveyors' Act	23.3%	77.8%		10.0%	1.2%	14.1%
Number of cases			*1,117*	*36*	*10*	*20*	*966*	*2,149*

* §6775 was restructured as of January 1, 200. Three separate subdivisions of the former §6775(b) were created for (b) fraud deceit, and/or misrepresentation, (c) negligence and/or incompetence, and (d) breach or violation of contract. The remaining subdivisions were adjusted to make room for the two new subdivisions -- what was previously c became e, d became f, and e became h. Since most of the cases described in this chapter were opened prior to the restructuring, those cases opened after 1/1/01 were included in the equivalent pre-1/1/01 category to permit comparison with previous years. This was done for all of the tables in this chapter. Subdivisions with an asterisk reflect the earlier wording of the section.

Table 6.29. Percentage Distribution of Closing Code by Type of Engineering License Held by Subject of Complaint (California)

Closing Code			Type of Engineering License Held by Subject of Complaint													
			Practice Act			Title Authority		Title Act								
			Civil	Electrical	Mechanical	Geotechnical	Structural	Agricultural	Control Systems	Fire Protection	Metallurgical	Nuclear	Quality	Safety	Traffic	Unlicensed
All cases	Not closed		12.2%		13.0%	21.1%	16.1%					100.0%	20.0%		7.3%	5.8%
	No violation		34.0%	81.0%	37.0%	36.7%	40.9%	50.0%	66.7%	33.3%	100.0%		60.0%		12.2%	12.8%
	Unable to pursue		9.0%	4.8%	8.7%	15.6%	10.8%	25.0%	22.2%						12.2%	5.6%
	Violation identified	Resolved or mediated	3.4%			6.7%	6.5%									3.1%
		Violation, but not serious enough to refer	.1%													1.1%
		Warning letter	3.7%		4.3%	4.4%	4.3%		11.1%							3.1%
		Other														.2%
		Board action	18.1%	9.5%	19.6%	7.8%	5.4%			33.3%			20.0%		14.6%	63.8%
		Referred to Attorney General	19.4%	4.8%	17.4%	7.8%	16.1%	25.0%		33.3%				100.0%	53.7%	
		Referred to District Attorney	.2%													4.2%
		Referred to other agency														.2%
		Subtotal violation identified	44.8%	14.3%	41.3%	26.7%	32.3%	25.0%	11.1%	66.7%	.0%	.0%	20.0%	100.0%	68.3%	75.8%
	Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	Number of cases		*924*	*21*	*46*	*90*	*93*	*4*	*9*	*3*	*1*	*1*	*5*	*2*	*41*	*966*
Closed cases	No violation		38.7%	81.0%	42.5%	46.5%	48.7%	50.0%	66.7%	33.3%	100.0%		75.0%		13.2%	13.6%
	Unable to pursue		10.2%	4.8%	10.0%	19.7%	12.8%	25.0%	22.2%						13.2%	5.9%
	Violation identified	Resolved or mediated	3.8%			8.5%	7.7%									3.3%
		Violation, but not serious enough to refer	.1%													1.2%
		Warning letter	4.2%		5.0%	5.6%	5.1%		11.1%							3.3%
		Other														.2%
		Board action	20.6%	9.5%	22.5%	9.9%	6.4%			33.3%			25.0%		15.8%	67.7%
		Referred to Attorney General	22.1%	4.8%	20.0%	9.9%	19.2%	25.0%		33.3%				100.0%	57.9%	
		Referred to District Attorney	.2%													4.5%
		Referred to other agency														.2%
		Subtotal violation identified	51.0%	14.3%	47.5%	33.8%	38.5%	25.0%	11.1%	66.7%			25.0%	100.0%	73.7%	80.4%
	Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%		100.0%	100.0%	100.0%	100.0%
	Number of cases		*811*	*21*	*40*	*71*	*78*	*4*	*9*	*3*	*1*		*4*	*2*	*38*	*910*

Table 6.30. Percentage Distribution of Closing Code by License Categories (California)

Closing Code			Practice Act Only	Civil & Traffic	Other Practice/Title Authority and Title	Title Act Only	Unlicensed	Total
All cases	Not closed		13.5%	2.8%	.0%	20.0%	5.8%	9.9%
	No violation		36.1%	13.9%	60.0%	35.0%	12.8%	25.4%
	Unable to pursue		9.3%	11.1%	10.0%	15.0%	5.6%	7.7%
	Violation identified	Resolved or mediated	.1%	.0%	.0%	.0%	1.1%	.6%
		Violation, but not serious enough to refer	3.8%	.0%	.0%	.0%	3.1%	3.4%
		Warning letter	3.9%	.0%	.0%	5.0%	3.1%	3.5%
		Other	.0%	.0%	.0%	.0%	.2%	.1%
		Board action	16.6%	13.9%	.0%	15.0%	63.8%	37.6%
		Referred to Attorney General	16.5%	58.3%	30.0%	10.0%	.0%	9.8%
		Referred to District Attorney	.2%	.0%	.0%	.0%	4.2%	2.0%
		Referred to other agency	.0%	.0%	.0%	.0%	.2%	.1%
		Subtotal violation identified	41.1%	72.2%	30.0%	30.0%	75.8%	57.0%
	Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	Number of cases		*1,117*	*36*	*10*	*20*	*966*	*2,149*
Closed cases	No violation		41.7%	14.3%	60.0%	43.8%	13.6%	28.1%
	Unable to pursue		10.8%	11.4%	10.0%	18.8%	5.9%	8.6%
	Violation identified	Resolved or mediated	.1%	.0%	.0%	.0%	1.2%	.6%
		Violation, but not serious enough to refer	4.5%	.0%	.0%	.0%	3.3%	3.8%
		Warning letter	4.6%	.0%	.0%	6.3%	3.3%	3.9%
		Other	.0%	.0%	.0%	.0%	.2%	.1%
		Board action	19.2%	14.3%	.0%	18.8%	67.7%	41.8%
		Referred to Attorney General	19.0%	60.0%	30.0%	12.5%	.0%	10.8%
		Referred to District Attorney	.2%	.0%	.0%	.0%	4.5%	2.2%
		Referred to other agency	.0%	.0%	.0%	.0%	.2%	.1%
		Subtotal violation identified	47.5%	74.3%	30.0%	37.5%	80.4%	63.3%
	Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	Number of cases		*966*	*35*	*10*	*16*	*910*	*1,937*
Cases where violation identified	Resolved or mediated		9.4%	.0%	.0%	.0%	4.1%	6.0%
	Violation, but not serious enough to refer		.2%	.0%	.0%	.0%	1.5%	1.0%
	Warning letter		9.6%	.0%	.0%	16.7%	4.1%	6.1%
	Other		.0%	.0%	.0%	.0%	.3%	.2%
	Board action		40.3%	19.2%	.0%	50.0%	84.2%	66.0%
	Referred to Attorney General		40.1%	80.8%	100.0%	33.3%	.0%	17.1%
	Referred to District Attorney		.4%	.0%	.0%	.0%	5.6%	3.5%
	Referred to other agency		.0%	.0%	.0%	.0%	.3%	.2%
	Total		100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
	Number of cases		*459*	*26*	*3*	*6*	*732*	*1226*

Table 6.31. Compare Discipline Distribution of California Complaints[a] and DPIC Insurance Claims

		California Complaints		DPIC Insurance Claims	
		Percent	*Number of cases*	Percent	*Number of cases*
Practice Act	Civil	79.7%	*881*	44.3%	*2,234*
	Electrical	1.6%	*18*	3.6%	*182*
	Mechanical	2.8%	*31*	14.1%	*712*
Title Authority	Geotechnical	8.1%	*89*		
	Structural	8.1%	*90*	19.5%	*982*
Title Act	Agricultural	.4%	*4*		
	Control Systems	.4%	*4*		
	Fire Protection	.3%	*3*		
	Metallurgical	.1%	*1*		
	Nuclear	.1%	*1*		
	Quality	.3%	*3*		
	Safety	.2%	*2*		
	Traffic	3.3%	*36*		
	Other			18.5%	*930*
	Subtotal	4.9%	*54*	18.5%	*930*
Total[b]		N/A	*1,105*	100.0%	*5,040*

[a] Complaint cases involving only exam subversion or unlicensed practice, as well as cases filed against unlicensed subjects, were removed from this distribution.

[b] Subjects can hold more than one type of license, so the total sums to more than 100%

Table 6.32. Distribution of Complaint Cases and Closing Codes by Discipline for California and Massachusetts

	Percent of cases		*Number of cases*		Percent of cases in which a violation was found (CA) or which were not dismissed (MA))[c]	
	CA[a]	MA[b]	CA	MA	CA	MA
Civil	40.1	43.4	*811*	*189*	17.4	17.5
Chemical	.0	.5	*0*	*2*	N/A	.0
Control Systems	.4	.2	*9*	*1*	11.1	.0
Electrical	1.0	2.8	*21*	*12*	14.3	25.0
Fire Protection	.1	.5	*3*	*2*	66.7	.0
Geotechnical	3.5	.0	*71*	*0*	33.8	.0
Industrial	.0	1.4	*0*	*6*	N/A	33.3
Mechanical	2.0	8.3	*40*	*36*	47.5	30.6
Metallurgical	.0	.0	*1*	*0*	.0	N/A
Quality	.2	.0	*4*	*0*	25.0	N/A
Safety	.1	.0	*2*	*0*	100.0	N/A
Structural	3.9	6.0	*78*	*26*	38.5	26.9
Traffic	1.9	.2	*38*	*1*	73.7	.0
Unlicensed	49.2	36.8	*992*	*160*	78.5	18.1
Overall[d]	N/A	100.0	*2,020*	*275*	63.0	19.5

[a] This table describes all California closed cases opened between 1/1/91 and 10/19/01. This subset of cases was used to provide data comparable to Massachusetts (see following note regarding Massachusetts). Complaints against unlicensed subjects alleged to have violated only the Professional Land Surveyors Act and no other sections related to engineering were intentionally not excluded from this table, in order to provide data comparable to Massachusetts. This means that the number of closed cases California used for comparison with Massachusetts is different than the number of cases described in Tables7.5-7.30.

[b] Massachusetts has a policy of not providing information on open cases. This table describes all Massachusetts closed cases opened between 7/1/83 and 10/1/01.

[c] California and Massachusetts have each developed different methods of categorizing the outcomes of complaints, and these differences should be considered when making comparisons between the two states. Massachusetts cases can most easily be grouped into cases that are dismissed and those that are not dismissed. In Massachusetts most cases of unlicensed practice are resolve through consent agreements or dismissed. Cases of unlicensed practice are infrequently deemed serious enough to pursue criminal prosecution.

California cases can most easily be grouped into cases for which no violation is determined to have occurred and those where it is determined that a violation has occurred. Some California cases which were counted as “no violation” for the purpose of computing the percentages presented in this table were actually cases that could not be pursued because they were outside the Board’s jurisdiction, there was insufficient evidence, or they were unable to locate the subject of the complaint.

[d] The subjects of California complaint cases can hold more than one license, so the total percent sums to more than 100%.

Table 6.33. Category of Alleged Violation by Discipline for California and Massachusetts

		Type of Engineering License Held by Subject of Complaint (Grouped into California's Main Categories)															
		Practice Act			Title Authority		Title Act										
		Civil	Electrical	Mechanical	Geotechnical	Structural	Agricultural	Chemical	Control Systems	Fire Protection	Industrial	Metallurgical	Quality	Safety	Traffic	Unlicensed	All
State	Category of Alleged Violation	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
California	Contractual	19.7	9.5	10.0	21.1	17.9				33.3					5.3	.2	9.7
	Fraud, deceit, misrepresentation	18.2	28.6	25.0	22.5	11.5	50.0		33.3	33.3			25.0	50.0		4.9	11.9
	Competence/negligence	69.5	47.6	32.5	71.8	73.1	50.0		11.1	33.3		100.0	25.0	50.0	86.8	.9	34.6
	Exam subversion	1.2	4.8	2.5		3.8			22.2	33.3					5.3	43.2	22.1
	Unlicensed activity	3.5	9.5	27.5	1.4	2.6			33.3				50.0		5.3	52.1	28.1
	Other	1.8	9.5	7.5	1.4	3.8			11.1				25.0		2.6	.2	1.4
	Number of cases	*811*	*21*	*40*	*71*	*78*	*4*		*9*	*3*		*1*	*4*	*2*	*38*	*993*	*2,020*
Massachusetts	Contractual	8.5		5.6		3.8										8.1	7.4
	Fraud, deceit, misrepresentation	30.2	41.7	44.4		23.1				50	33.3				100	23.1	28.7
	Competence/negligence	29.6	16.7	13.9		38.5		50	100		16.7					6.9	20
	Unlicensed activity	12.7	8.3	22.2		7.7				50	50					51.9	28
	Other	19	33.3	13.9		26.9		50								10.0	15.9
	Total	100	100	100		100		100	100	100	100				100	100	100
	Number of cases	*189*	*12*	*36*		*26*		*2*	*1*	*2*	*6*				*1*	*160*	*435*

Table 6.34. Percentage Distribution for the Outcome of Massachusetts' Complaint Cases by Engineering Discipline

	Type of Engineering License Held by Subject of Complaint										
Outcome	Civil	Chemical	Control Systems	Electrical	Fire Protection	Industrial	Mechanical	Structural	Traffic	Unlicensed	All
License Revoked	3.2%					33.3%	2.8%				2.1%
License Suspended	5.3%			8.3%			8.3%	3.8%			3.4%
Probation	2.1%							7.7%			1.4%
Reprimand	.5%									.6%	.5%
Voluntary Surrender	4.8%						5.6%	3.8%		.6%	3.0%
Case Dismissed	82.5%	100.0%	100.0%	75.0%	100.0%	66.7%	69.4%	73.1%	100.0%	81.9%	80.5%
Settled	1.6%			16.7%			11.1%	7.7%		10.0%	6.2%
Referred										5.6%	2.1%
Consent Agreement								3.8%			.2%
Pending Suit							2.8%			1.3%	.7%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Number of cases	*189*	*2*	*1*	*12*	*2*	*6*	*36*	*26*	*1*	*160*	*435*

Table 6.35. Percentage Distribution for the Outcome of Massachusetts' Complaint Cases by Category of Alleged Violation

	Category of Alleged Violation					
Outcome	Contractual	Fraud, Deceit, Misrepresentation	Competence/ Negligence	Unlicensed Activity	Other	All
License Revoked		5.5%	1.1%		1.5%	2.1%
License Suspended	3.1%	3.9%	3.4%		9.1%	3.4%
Probation		2.3%	3.4%			1.4%
Reprimand		.8%		.8%		.5%
Voluntary Surrender		2.3%	4.6%		9.1%	3.0%
Case Dismissed	81.3%	75.8%	81.6%	91.8%	66.7%	80.5%
Settled	12.5%	8.6%	4.6%	2.5%	7.6%	6.2%
Referred	3.1%	.8%		4.1%	3.0%	2.1%
Consent Agreement					1.5%	.2%
Pending Suit			1.1%	.8	1.5%	.7%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Number of cases	*32*	*128*	*187*	*122*	*66*	*435*

Table 6.36. Percentage Distribution of Type of Alleged Violation by License Status for California, Massachusetts and New York

California Category	Related Massachusetts Categories	Related New York Categories	California Complaints Regarding: Licensed Engineers	California Complaints Regarding: Unlicensed Engineers	California Complaints Regarding: All Engineers	Massachusetts Complaints Regarding: Licensed Engineers	Massachusetts Complaints Regarding: Unlicensed Engineers	Massachusetts Complaints Regarding: All Engineers	New York Complaints Regarding All Engineers
Contractual	Breach of contract	Fee dispute	18.9%	.2%	9.7%	1.8%	1.9%	1.8%	.8%
	Failure to complete work		N/A	N/A	N/A	4.0%	5.6%	4.6%	N/A
	Failure to disclose		N/A	N/A	N/A	.7%	.0%	.5%	N/A
	Unauthorized repair		N/A	N/A	N/A	.4%	.6%	.5%	N/A
	Subtotal	Subtotal	18.9%	.2%	9.7%	6.9%	8.1%	7.4%	.8%
Fraud, deceit, misrepresentation	Misrepresentation	Fraud	18.6%	4.9%	11.9%	24.0%	18.1%	21.8%	8.7%
	Unethical conduct	Fee Splitting/bribery	N/A	N/A	N/A	6.9%	2.5%	5.3%	1.5%
	Overcharging		N/A	N/A	N/A	.7%	.6%	.7%	N/A
	Misleading advertising		N/A	N/A	N/A	.4%	1.3%	.7%	N/A
	Advertising violation	Advertise/improper claim	N/A	N/A	N/A	.0%	.6%	.2%	2.4%
	Subtotal	Subtotal	18.6%	4.9%	11.9%	32.0%	23.1%	28.7%	12.6%
Competence/ negligence	Incompetence	Negligence/incompetence	67.0%	.9%	34.6%	13.1%	3.8%	9.7%	31.3%
	Inferior or improper work	Practice impaired--mental/physical	N/A	N/A	N/A	5.5%	1.9%	4.1%	.1%
	Unprofessional conduct	Recordkeeping	N/A	N/A	N/A	9.1%	1.3%	6.2%	.8%
		Improper supervision	N/A	N/A	N/A	N/A	N/A	N/A	1.0%
	Subtotal	Subtotal	67.0%	.9%	34.6%	27.7%	7.0%	20.0%	33.2%
Unlicensed activity	Operating without a license	Illegal practice--aid/abet	4.9%	52.1%	28.1%	14.2%	51.9%	28.0%	38.5%
Other	Board violation	Violation of Regents penalty	N/A	N/A	N/A	16.4%	4.4%	12.0%	1.5%
	Failure to pay taxes		N/A	N/A	N/A	1.1%	.0%	.7%	N/A
	Criminal conviction	Conviction of crime	N/A	N/A	N/A	1.1%	.0%	.7%	6.6%
	General misconduct	General dissatisfaction	N/A	N/A	N/A	.0%	.6%	.2%	4.6%
		Physical/sexual abuse	N/A	N/A	N/A	N/A	N/A	N/A	.2%
		Refusal of service	N/A	N/A	N/A	N/A	N/A	N/A	.1%
	Other	Other	2.5%	.2%	1.4%	.7%	3.8%	1.8%	1.7%
	Subtotal	Subtotal	2.5%	.2%	1.4%	19.3%	8.8%	15.4%	14.8%
Exam subversion			1.8%	43.2%	22.1%	N/A	N/A	N/A	N/A
Total*			N/A	N/A	N/A	100.0	100.0%	100.0%	100.0%
Number of cases			*1,027*	*993*	*2,020*	*275*	*160*	*435*	*1,443*

* California complaint cases can include more than one type of violation, so their total percentages sum to more than 100%, but Massachusetts and New York complaint cases are categorized with one main type of violation, which means that their total percentage do sum to 100%

Table 6.37. Percentage Distribution of Summary Categories of Alleged Violation by License Status for California, Massachusetts and New York

Category of Alleged Violation:	California Complaints Regarding:			Massachusetts Complaints Regarding:			New York Complaints Regarding All Engineers
	Licensed Engineers	Unlicensed Engineers	All Engineers	Licensed Engineers	Unlicensed Engineers	All Engineers	
Contractual	18.9%	.2%	9.7%	6.9%	8.1%	7.4%	.8%
Fraud, deceit, misrepresentation	18.6%	4.9%	11.9%	32.0%	23.1%	28.7%	12.6%
Competence/negligence	67.0%	.9%	34.6%	27.7%	6.9%	20.0%	33.2%
Unlicensed activity	4.9%	52.1%	28.1%	14.2%	51.9%	28.0%	38.5%
Other	2.5%	.2%	1.4%	19.3%	10.0%	15.9%	14.8%
Exam subversion	1.9%	43.2%	22.1%	N/A	N/A	N/A	N/A
Total[a]	N/A	N/A	N/A	100.0%	100.0%	100.0%	100.0%
Number of cases	*1,027*	*993*	*2,020*	*275*	*160*	*435*	*1,443*

[a] California complaint cases can include more than one type of violation, so their total percentages sum to more than 100%, but Massachusetts and New York complaint cases are categorized with one main type of violation, which means that their total percentage do sum to 100%

Table 6.38. Average Number of Closed Complaints Filed in California and Massachusetts per 100,000 Employed Engineers[a]

	California[c]			Massachusetts[d]		
Disciplines[b]	Average Number of Complaints	Average Number of Employed Engineers	Rate per 100,000 Employed Engineers	Average Number of Complaints	Average Number of Employed Engineers	Rate per 100,000 Employed Engineers
Aerospace	.0	17,753	.0	.0	683	.0
Agricultural	.0	130	.0	.0	0	.0
Chemical	.0	2,717	.0	.1	1,063	9.4
Civil	90.6	27,713	326.9	11.9	6,370	186.8
Electrical	2.4	60,290	4.0	.7	12,436	5.6
Environmental	.0	5,735	.0	.0	2,855	.0
Health and Safety	.3	3,193	9.4	.1	1,000	10.0
Industrial	.3	17,033	1.8	.3	5,500	5.5
Marine	.0	220	.0	.0	80	.0
Materials	.1	1,937	5.2	.0	990	.0
Mechanical	2.7	24,143	11.2	1.9	7,030	27.0
Mining	.0	503	.0	.0	170	.0
Nuclear	.0	1,000	.0	.0	63	.0
Petroleum	.0	897	.0	.0	0	.0
Subtotal for licensed engineers [e]	96.4	217,585	44.3	15.2	54,421	27.9
Unlicensed subjects [e]	92.6	217,585	42.6	8.9	54,421	16.4
Total licensed and unlicensed [e]	189	217,585	86.9	24.1	54,421	44.3

[a] Number of employed engineers is an average of all available years from1998-2000. The number of engineers is not available for all categories for all three years because of changes in the occupational classification system and suppression of confidential information. Data from 1998-2000 was taken from National Occupation Employment Statistics Survey.

[b] Disciplines listed include disciplines licensed in either California or Massachusetts that are covered by the Occupation Employment Statistics Survey.

[c] Separate California licenses were combined to match OES occupational categories. Civil includes: Civil, Traffic, Structural, Geotechnical and multiple licenses that include Civil or Structural (Civil/ Land Surveyor, Civil/ Mechanical, Civil/Quality, Civil/Safety, Civil/Traffic, Structural/Fire). Electrical includes: Electrical, Control Systems and multiple licenses that include Electrical (Electrical/Mechanical, Electrical/Control Systems). Health & Safety includes: Fire Protection, and Safety. Industrial includes Quality. Mechanical includes Mechanical and multiple licenses that include Mechanical (Mechanical/Control Systems).

[d] Separate Massachusetts licenses were combined to match OES occupational categories. Civil includes Civil, Traffic, Construction, Structural and Sanitary. Mechanical includes Mechanical, HVAC, and Acoustical. Electrical includes Electrical and Instrumentation.

[e] Rates for complaints against Licensed, Unlicensed, and Total Licensed and Unlicensed were calculated using total number of employed engineers, including OES occupations not listed in the table.

Table 6.39. Complaint Rates Against Licensed Engineers for California, Massachusetts, New York, North Carolina and Texas

			Number of Complaints	Number of Registered Engineers	Rate of Complaints per 100,000 Registered Engineers[d]	Number of Disciplinary Actions	Rate of Disciplinary Actions per 100,000 Registered Engineers
All Complaints	FY 97/98	California[a]	106	86,396	122.7	69	79.9
		New York[b]	61	25,244	241.6	11	43.6
		North Carolina[c]	31	15,212	203.8	15	98.6
		Texas	225	47,737	471.3	91	190.6
	FY 99/00	California[a]	111	85,734	129.5	52	60.7
		New York[b]	73	26,172	278.9	7	26.7
		North Carolina[c]	25	16,164	154.7	14	86.6
		Texas	97	48,092	201.7	87	180.9
Closed Complaints	FY 94/95	California[a]	101	86,235	117.1	45	52.2
		Massachusetts	15	18,063	83.0	1	5.5
	FY 95/96	California[a]	129	86,219	149.6	52	60.3
		Massachusetts	19	17,736	107.1	3	16.9
	FY 96/97	California[a]	89	87,341	101.9	44	50.4
		Massachusetts	20	18,439	108.5	3	16.3
	FY 97/98	California[a]	106	86,396	122.7	69	79.9
		Massachusetts	20	17,914	111.6	6	33.5

Table 6.40. Complaint Rates Against Unlicensed Subjects for California, New York and North Carolina

		Number of Complaints	Number of Employed Engineers[d]	Rate of Complaints per 100,000 Employed Engineers	Number of Enforcement Actions	Rate of Enforcement Actions per 100,000 Employed Engineers
FY 97/98	California[a]	64	198,440	32.3	48	24.2
	New York[b, e]	42	67,350	62.4	26	38.6
	North Carolina[c]	14	32,050	43.7	8	25.0
FY 99/00	California[a]	80	176,860	45.2	57	32.2
	New York[b, e]	39	58,730	66.4	10	17.0
	North Carolina[c]	5	25,290	19.8	3	11.9

a The number of disciplinary and enforcement actions for California include all cases where a violation was found because the outcome of the case was not available.

b New York provided information for calendar years instead of fiscal years, so data from calendar year 1997 and 1999 were used for fiscal years 1997/1998 and 1999/2000.

c North Carolina's fiscal year is from December of the previous year through November of the following year, so data from 1996/1997 was used for 1997/1998 and data from 1998/1999 was used for 1999/2000.

d Registration data came from state boards. Employment data came from 1998 and 2000 National Occupation Employment Statistics Survey.

e New York provided information for the number of illegal practice complaints rather than the number of complaints against unlicensed engineers.

CHAPTER 7

USES OF LICENSING BY STATE AND LOCAL AGENCIES

Federal, state and local agencies use the licensing system to restrict certain activities to persons with a specific background or set of skills, to define advisory board memberships and to provide restrictive definitions for some specialties within engineering. Examples of prescriptive statements limiting specific activities to a particular type of engineer include[1]:

- A civil engineer shall prepare comprehensive soils and engineering geologic investigations. (Sec.13.03. "G" Surface Mining Operations Districts of the Los Angeles County Code)
- A civil engineer establishes standards for sight distance and riding qualities, prepares soil reports of hillside areas and a preliminary soil report based on testing. (Sec.17.05 Design Standards of the Los Angeles County Code)
- A civil, structural, geotechnical (when the work is supplementary to civil engineering) or electrical engineer or architect prepares, seals and signs plans and specifications. (Sec.93.0206. Plans and Specifications of the Los Angeles County Code)
- A professional engineer shall prepare a report on structural integrity for wireless telecommunication facilities. (Sec.12.21.General Provisions of the Los Angeles County Code)
- A fire protection, mechanical or civil engineer or architect may coordinate and verify all components of the smoke-control system within his or her area of expertise. (Sec.2.6 Smoke Control Systems-Submittal Requirements or the San Francisco Municipal Code)
- A soils, civil or chemical engineer, an engineering geologist, hydrologist, industrial hygienist, or environmental assessor shall determine whether hazardous wastes are likely to cause environmental, health, or safety risks and recommend mitigation reports. (Sec.1228. Applicant's Responsibility Upon Discovery of Hazardous Wastes of the San Francisco Municipal Code)
- A civil, traffic or division engineer directs preparation of "Worksite Traffic Control Plan." (Sec.62.250. Rail Transit Construction Impact of the Los Angeles County Code)
- A petroleum engineer determines the value of proven reserves (Sec.260.140.122.2 Net Worth of the California Code of Regulations)
- A professional engineer certifies that closure is compliant (Sec.66264.143.Financial Assurance for Closure of the California Code of Regulations)

Some examples of restrictive definitions include:

- A city engineer shall be a registered civil engineer with 5 or more years of experience. (Sec.22.341.City Engineer.Qualifications of the Los Angeles County Code)
- A soil engineer shall mean a civil engineer experienced in the application of the principles of soil mechanics or a geotechnical engineer.(Sec.91.220.S of the Los Angeles County Code)

[1] See Appendix D for complete excerpt

- A qualified engineer shall mean a civil engineer. (Sec.64651.66. Qualified Engineer of the California Code of Regulations)

Examples of specifications for advisory board membership include:

- A fire protection engineer shall be a member of the board of examiners for high rise sprinklers. (Sec.4.14 Retroactive sprinkler requirements for existing high-rise buildings of the San Francisco Municipal Code)
- The variance board shall include a mechanical, acoustical, or civil engineer, physician (qualified in physiological effects of noise), audiometrist. (Sec.2910.Variance Board Establishment; Functions; Standards; Procedures of the San Francisco Municipal Code)
- The Building Inspection Commission shall include an architect and structural engineer. (Sec.D3.750-1 Commission; Composition of the San Francisco Municipal Code)
- The Engineering Criteria Review Board shall include a civil engineer, a structural engineer, an architect. (Sec.10271. Membership and Function of Engineering Criteria Review Board of the California Code of Regulations)

The first part of this chapter describes the results of online searches of the California and Federal Code of Regulations and the codes for three of California's largest counties -- Los Angeles, San Diego and San Francisco. The search terms included 16 engineering specialties registered in California and three generic phrases used in these codes (professional engineer, registered professional engineer and licensed professional engineer). The specialties include:

Agricultural Engineer	Manufacturing Engineer
Chemical Engineer	Mechanical Engineer
Civil Engineer	Metallurgical Engineer
Control Systems Engineer	Nuclear Engineer
Electrical Engineer	Petroleum Engineer
Fire Protection Engineer	Soils Engineer
Geotechnical Engineer	Structural Engineer
Industrial Engineer	Traffic Engineer

All titles (Titles 1 through 28) in the California Code of Regulations (CCR) except Title 6 and 24 were searched. (See Appendix E.) Title 24 (the California Building Code) is not available in electronic format. Counts for professional engineers were adjusted so that the same "hit" was not counted twice for professional engineer and registered professional engineer or professional engineer and licensed professional engineer. Mentions or "hits" in Title 16, which includes the Professional Engineer's Act, are included in Table 7.2 but removed from the remaining tables. Title 16 refers almost exclusively to professional engineers (27 references), and to civil and structural engineers (18 and 17 respectively). Petroleum engineers receive a single mention -- the only title act discipline to be mentioned at all in Title 16. (Table 7.1) Appendix F contains a list of the state agencies included in the CCR. Sections listing types of engineers that are subject to the conflict of interest code or those referring to pay schedules are included in the unedited comparisons but omitted from the edited ones. The CCR produces a hit for each mention of a phrase, while the county codes produce a hit for each section of law. To ensure comparability with county codes, duplicate references to the same section and required activity were removed from the CCR file. References in the county codes to engineering rather than engineers were removed as well.[2]

The California State Personnel Board also uses the licensing system to define appropriate qualifications for engineering job class categories. These are job classes resulting from a search of the State Personnel Board's online Classification Information Search System using the term "engineer" and which also had a minimum education requirement of a four-year college degree in engineering. Using this definition, 194 engineering job classes were identified. Education and registration requirements were obtained from the online classification specifications that include qualifications for the job.

The second part of this chapter describes the distribution of engineering job classes and the proportion that require a registered engineer and the proportion of permanent civil service employees in positions requiring registration. This would indicate the relative importance the state places on hiring registered engineers.

Analysis of Federal, State and County Codes

Comparison of Unedited "Hits"

The Federal Code of Regulations (FCR) was too cumbersome to summarize with the same degree of precision applied to the California state and county codes. As a result, a discipline summary of hits in the FCR appears only in Table 7.2. For comparability, state and county code hits in Table 7.2 are unedited, counting multiple mentions in the same section, Title 16 references and references in the county codes to "engineering" rather than "engineers." The remaining tables are based on edited counts as described above.

The most obvious difference between the FCR and California's CCR and county codes is that civil engineers are mentioned far more often in California than they are in the FCR. Between 27% and 41% of the hits in California jurisdiction codes mention civil engineers compared with only 8% of the hits in the FCR. (Table 7.2) Similarly, structural engineers are mentioned between 3 and 6 times more often in California codes than they are in the FCR, with proportions ranging between 8.8% and 17.1% in California compared with 2.8% in the FCR. Geotechnical or soil engineers also appear more often in the California codes, especially in Los Angeles (26%) and San Diego counties (39%), compared with 2.5% of hits in the FCR.

Although mentioned less often, the pattern is the same for electrical and mechanical engineers. They constitute 0.6% of hits in the FCR, but occur much more often in the California codes. Electrical engineers make up between 1.8% and 6.8% of hits in the California jurisdictions while mechanical engineers, with one exception, account for 3.3% to 13.6% of them. San Diego County is the exception; their codes do not mention mechanical engineers.

Chemical, fire protection, petroleum and traffic engineers are the only title act disciplines mentioned in the state and county codes. Fire protection and chemical engineers are mentioned most often in San Francisco (11.4% and 2.3% respectively) while traffic engineers are mentioned more often in Los Angeles and San Diego (15.6% and 5.3%). Petroleum engineers are the only specialty that is mentioned more often in the FCR than in any of the

[2] The CCR does not produce hits for "engineering" when "engineer" is the search term, so the definitions for the title act disciplines in Title 16 are not included.

state's codes (2.8% of FCR hits, but 0.9% of CCR hits and no mention at all in the county codes).

The generic phrase of choice in the FCR is "registered professional engineer" (58% of all hits) whereas in the CCR, the most common term is "professional engineer" (30%). There is much less emphasis on being registered or licensed in the California code (11.4% vs. 63% in the federal code). (Table 7.2)

Comparison of Edited "Hits"

Within California, the most frequently mentioned type of engineer in all four jurisdictions studied was the civil engineer. The number of mentions in county codes ranged from 37% to 45% while the term appeared in 35% of CCR hits. Geotechnical or soils engineers were mentioned almost as often in Los Angeles and San Diego county (32% and 43% respectively), while structural engineers were the second most frequently mentioned specialty in San Francisco and the CCR (15% and 22%). Electrical, mechanical and geotechnical engineers are mentioned with similar frequency in the CCR (5.7%, 4.1% and 3.6% respectively). Electrical engineers received a similar number of hits in San Francisco and Los Angeles counties (3.8% and 3.5%), but none in San Diego. Mechanical engineers were mentioned more often in San Francisco (12%) than in the CCR, but weren't mentioned at all in the other two counties. Fire protection and chemical engineers were the only title act disciplines mentioned in San Francisco (11.5% and 3.8% respectively) and traffic engineers the only one mentioned in Los Angeles (1.8%). No title act disciplines appeared in the San Diego County code. Chemical, petroleum and fire protection engineers are the only title act disciplines mentioned in the CCR (1.6%, 1.6% and 1.0% respectively). (Table 7.3)

Generic titles appear more often in the CCR than in the county codes. In the edited references, the term of choice becomes "registered professional engineer" in both the state and county codes. However, edited references in the CCR identify first, civil engineers (35%), then structural engineers (22%) and third, registered professional engineers (18%). (Table 7.3)

Types of References

Most of the references to engineers are prescriptive statements (90% in the CCR and 84% in the county codes). These define what kind of engineer is required to perform specific tasks. At both the state and county level, a little over a third of these statements specify a civil engineer (36.8% of the references in the CCR and 40% of those in the county codes). Structural engineers and registered professional engineers are each specified in roughly one in five references at the state level, while geotechnical engineers are referred to almost a third of the time in the county codes (32%). Prescriptive statements rarely refer to title act disciplines (3.4% and 3.6% of the state and county codes respectively). (Table 7.4)

Board memberships are prescribed in 6% of the CCR hits and in 8% of those at the county level. At the state level, these primarily refer to structural, electrical and mechanical engineers (20% each with a sample of 10 cites). Civil and structural engineers are more often required on boards at the county level (33% each), with a sample of 9 cites. (Table 7.4)

At the state level, restrictive definitions apply to civil engineers, the two title authorities (geotechnical and structural) and professional engineers (22% each in a sample of 9), while at the county level, all 12 are concentrated in civil and geotechnical engineers. (Table 7.4)

When individual counties are considered, all three focus on civil engineers (with 35% to 43% of prescriptive statements), but Los Angeles and San Diego have similar proportions of prescriptive statements referencing geotechnical engineers (27% and 46% respectively). San Francisco mentions mechanical and fire protection engineers as often as they do geotechnical and structural (10.5% each), while Los Angeles is the only county to reference traffic engineers. (Table 7.5)

Analysis of Registration Requirements in State Personnel Board Engineering Job Classes

Out of 194 job classes specifying an engineer with a four-year college degree in engineering, 40% require that engineer to be licensed. The most common requirement is for a registered civil engineer (39% of the job classes with a registration requirement) with another 25% requiring a registered professional engineer. Registered electrical engineers are required in another 10% of job classes. Other disciplines specifically mentioned are structural, mechanical and industrial. (Table 7.6) In roughly half of the 55 job class categories, none of the job classes require a registered engineer (29 or 53%). Collectively, the categories that do not require a registered engineer account for a little less than half of all job classes (84 out of 194 or 43%). In a fifth of the job categories (11 or 20%), all of the job classes require a registered engineer and in another fifth, over half do. The job categories where all job classes require a registered engineer account for 12% of all positions. Thus, varying proportions of the remaining job classes (45%) require a registered engineer.

Job class categories requiring *100%* registered engineers include bridge, construction, drinking water, hydraulic, industrial, materials and research, mechanical and electrical, reclamation, registrar, seismic and subsidence engineering positions. Many of these positions involve practice act disciplines and their associated areas of expertise. Those requiring *no* registered engineers include air quality, air resources, automotive equipment stands, chemical testing, control, corrosion, energy and mineral resources, equipment, equipment and materials, flammability research test, geologist, hydroelectric power utility, mineral resources, mining, motor vehicle pollution control, petroleum, petroleum drilling, production and reservoir, petroleum and mining appraisal, pipeline safety, process safety, procurement, product, rehabilitation, reservoir, safety, telecommunications, and transportation civil engineering positions. Many of these positions involve title act or unregulated disciplines and their areas of expertise. (Table 7.6)

Table 7.7 describes the number of employees in positions where registration is either required or not required. Almost three-fourths (72%) of employees in engineering job classes are in positions where registration is *not* required. Most of the employees in engineering job classes where registration *is* required are in positions requiring a civil license (19%). (Table 7.7)

In short, most engineers employed by the State of California do not have to be licensed. If they do, the license most often required is in civil engineering.

Table 7.1. "Hits" in Title 16 of California Code of Regulations

Professional Engineer	27
Registered Professional Engineer	1
Licensed Professional Engineer	1
Civil Engineer	18
Geotechnical Engineer	6
Soils Engineer	3
Structural Engineer	17
Electrical Engineer	1
Mechanical Engineer	2
Agricultural Engineer	0
Chemical Engineer	0
Control Systems Engineer	0
Industrial Engineer	0
Fire Protection Engineer	0
Manufacturing Engineer	0
Metallurgical Engineer	0
Nuclear Engineer	0
Petroleum Engineer	1
Traffic Engineer	0

Table 7.2. Unedited References to Types of Engineers in Federal, State and County Codes of Regulation

	California Code of Regulations	San Francisco Municipal Code	Los Angeles County Code	San Diego County Code	Federal Code of Regulations
Professional Engineer	30.4	0.0	5.5	1.8	14.4
Registered Professional Engineer	10.1	2.3	2.8	5.3	57.5
Licensed Professional Engineer	1.3	0.0	0.0	0.0	5.5
Civil Engineer	29.5	40.9	26.6	38.6	7.9
Geotechnical (and Soil) Engineer	2.6	9.1	25.7	38.6	2.5
Structural Engineer	17.1	13.6	11.0	8.8	2.8
Electrical Engineer	3.5	6.8	3.7	1.8	0.6
Mechanical Engineer	3.3	13.6	5.5	0.0	0.6
Agricultural Engineer	0.0	0.0	0.0	0.0	0.0
Chemical Engineer	0.7	2.3	0.0	0.0	0.6
Control Systems Engineer	0.0	0.0	0.9	0.0	0.0
Fire Protection Engineer	0.7	11.4	1.8	0.0	3.0
Industrial Engineer	0.0	0.0	0.9	0.0	0.0
Manufacturing Engineer	0.0	0.0	0.0	0.0	0.0
Metallurgical Engineer	0.0	0.0	0.0	0.0	0.0
Nuclear Engineer	0.0	0.0	0.0	0.0	0.0
Petroleum Engineer	0.9	0.0	0.0	0.0	2.8
Traffic Engineer	0.0	0.0	15.6	5.3	1.7
	100.0	100.0	100.0	100.0	100.0
	n=457	n=44	n=109	n=57	n=471

Table 7.3. Edited References to Types of Engineers in State and Individual County Codes of Regulation

	California Code of Regulations	San Francisco Municipal Code	Los Angeles County Code	San Diego County Code
Professional Engineer	5.7	0.0	5.3	0.0
Registered Professional Engineer	17.6	3.8	5.3	6.1
Licensed Professional Engineer	2.6	0.0	0.0	0.0
Civil Engineer	34.7	38.5	36.8	44.9
Geotechnical (and Soil) Engineer	3.6	11.5	31.6	42.9
Structural Engineer	21.8	15.4	15.8	6.1
Electrical Engineer	5.7	3.8	3.5	0.0
Mechanical Engineer	4.1	11.5	0.0	0.0
Agricultural Engineer	0.0	0.0	0.0	0.0
Chemical Engineer	1.6	3.8	0.0	0.0
Control Systems Engineer	0.0	0.0	0.0	0.0
Fire Protection Engineer	1.0	11.5	0.0	0.0
Industrial Engineer	0.0	0.0	0.0	0.0
Manufacturing Engineer	0.0	0.0	0.0	0.0
Metallurgical Engineer	0.0	0.0	0.0	0.0
Nuclear Engineer	0.0	0.0	0.0	0.0
Petroleum Engineer	1.6	0.0	0.0	0.0
Traffic Engineer	0.0	0.0	1.8	0.0
	100.0	100.0	100.0	100.0
	n=193	n=26	n=57	n=49

Table 7.4. Types of References in State and County Codes of Regulation by Engineering Discipline

	California Code of Regulations	California County Codes Los Angeles, San Francisco, San Diego
Required Member of Board or Minimum Qualifications		
Professional Engineer	10.0	0.0
Civil Engineer	10.0	33.3
Geotechnical (and Soil) Engineer	0.0	11.1
Structural Engineer	20.0	33.3
Electrical Engineer	20.0	0.0
Mechanical Engineer	20.0	11.1
Chemical Engineer	10.0	0.0
Fire Protection Engineer	10.0	11.1
	100.0	100.0
	n=10	n=9
Restrictive Definitions		
Professional Engineer	22.2	0.0
Registered Professional Engineer	11.1	0.0
Civil Engineer	22.2	50.0
Geotechnical (and Soil) Engineer	22.2	50.0
Structural Engineer	22.2	0.0
	100.0	100.0
	n=9	n=12
Prescriptive Statements		
Professional Engineer	4.6	2.7
Registered Professional Engineer	19.0	6.3
Licensed Professional Engineer	2.9	0.0
Civil Engineer	36.8	39.6
Geotechnical (and Soil) Engineer	2.9	31.5
Structural Engineer	21.8	11.7
Electrical Engineer	5.2	2.7
Mechanical Engineer	3.4	1.8
Chemical Engineer	1.1	0.9
Fire Protection Engineer	0.6	1.8
Petroleum Engineer	1.7	0.0
Traffic Engineer	0.0	0.9
	100.0	100.0
	n=174	n=111

Table 7.5. Prescriptive References in State and Individual County Codes of Regulation by Engineering Discipline

	California Code of Regulations	San Francisco Municipal Code	Los Angeles County Code	San Diego County Code
Professional Engineer	4.6	0.0	6.3	0.0
Registered Professional Engineer	19.0	5.3	6.3	6.8
Licensed Professional Engineer	2.9	0.0	0.0	0.0
Civil Engineer	36.8	42.1	35.4	43.2
Geotechnical (and Soil) Engineer	2.9	10.5	27.1	45.5
Structural Engineer	21.8	10.5	18.8	4.5
Electrical Engineer	5.2	5.3	4.2	0.0
Mechanical Engineer	3.4	10.5	0.0	0.0
Chemical Engineer	1.1	5.3	0.0	0.0
Fire Protection Engineer	0.6	10.5	0.0	0.0
Petroleum Engineer	1.7	0.0	0.0	0.0
Traffic Engineer	0.0	0.0	2.1	0.0
	100.0	100.0	100.0	100.0
	n=174	n=19	n=48	n=44

Table 7.6. Summary of California State Personnel Board Engineering Job Class Registration Requirements

Engineering Job Class Category* (in alphabetical order)	Percent of Job Classes with Registration Requirement	Number of Job Classes with Registration Requirement										Number of Job Classes without Registration Requirement	Total Number of Job Classes
		Engineer or PE	PE or Civil	Civil	Civil or Structural	Structural	Electrical	Electrical or Mechanical	Mechanical	Mechanical or Industrial	Industrial		
Air Quality	0%											4	4
Air Resources	0%											1	1
Automotive Equipment Standards	0%											3	3
Bridge	100%			4									4
Chemical Testing	0%											2	2
Civil	55%			5								4	9
Construction	100%			4									4
Control	0%											5	5
Corrosion	0%											2	2
Drinking Water	100%			1									1
Electrical	36%						4					7	11
Electronics	33%						1					2	3
Energy and Mineral Resources	0%											1	1
Equipment	0%											3	3
Equipment and Materials	0%											1	1
Flammability Research Test	0%											1	1
Geologist	0%											5	5
Hazardous Substances	80%	4										1	5
Hydraulic	100%			4									4
Hydroelectric Power Utility	0%											5	5
Industrial	100%									1	1		2
Materials and Research	100%	2	1										3
Mechanical	40%								4			6	10
Mechanical and Electrical	100%							2					2
Mineral Resources	0%											3	3
Mining	0%											1	1

* For the information presented in this and the following table, engineering job classes were defined as those resulting from a search using the term "engineer" in the State Personnel Board's online Classification Information Search System and which also had a minimum education requirement of a four-year college degree in engineering. Using this definition, 194 engineering job classes were identified. Education and registration requirements were obtained from the online classification specifications, which describe essentially similar jobs and include the qualifications for the job. The categories used in this table were constructed by ISR based on the job title in order to show the relative distribution of the classes and their registration requirements.

Table 7.6 (continued). Summary of State Personnel Board Engineering Job Classification Registration Requirements

Engineering Job Class Category (in alphabetical order)	Percent of Job Classes with Registration Requirement	Number of Job Classes with Registration Requirement										Number of Job Classes without Registration Requirement	Total Number of Job Classifications
		Engineer or PE	PE or Civil	Civil	Civil or Structural	Structural	Electrical	Electrical or Mechanical	Mechanical	Mechanical or Industrial	Industrial		
Motor Vehicle Pollution Control	0%											2	2
Oil and Gas	75%	3										1	4
Petroleum	0%											1	1
Petroleum Drilling	0%											1	1
Petroleum Production	0%											1	1
Petroleum Reservoir	0%											1	1
Petroleum Structures	33%				1							2	3
Petroleum and Mining Appraisal	0%											1	1
Pipeline Safety	0%											2	2
Process Safety	0%											3	3
Procurement	0%											3	3
Product	0%											2	2
Reclamation	100%			1								0	1
Registrar	100%	1										0	1
Rehabilitation	0%											2	2
Reservoir	0%											1	1
Safety	0%											22	22
Sanitary	75%	3										1	4
Seismic	100%			1								0	1
Structural	86%			1		5						1	7
Subsidence	100%			1								0	1
Telecommunications	0%											4	4
Transportation	86%	1		5								1	7
Transportation Civil	0%											1	1
Transportation Electrical	50%						3					3	6
Utilities	67%	2										1	3
Waste Management	75%	3										1	4
Water Resources	75%			3								1	4
Water Resources Control	83%		5									1	6
Total	40%	19	6	30	1	5	8	2	4	1	1	117	194

Table 7.7. Distribution of California Permanent Civil Service Employees among Engineering Job Classes with and without Engineering Registration Requirements

		Percent	*Number*
Registration required	Engineer or PE	2.1%	*227*
	Engineer or PE required for advancement to highest pay range	1.2%	*126*
	PE or civil	4.2%	*462*
	Civil	18.9%	*2,065*
	Civil or Structural	.0%	*2*
	Structural	.9%	*99*
	Electrical	.9%	*95*
	Electrical or Mechanical	.0%	*2*
	Mechanical	.1%	*11*
	Industrial or Mechanical	.0%	*1*
	Industrial	.0%	*0*
No registration required		71.7%	*7,833*
Total Employees		100.0%	*10,923*

Information compiled from California State Personnel Board Report 5102, which shows the number of Permanent Civil Services Employees as of 12/31/01.

CHAPTER 8

OVERLAP IN EDUCATIONAL PREPARATION

One of the overarching concerns of the Title Act Study is the amount of overlap in education and job experience of the separate disciplines. Are there sufficient commonalities to justify generic licensing of engineers, as is done in most states, with specialties identified by the type of engineering degree and subsequent work experience or asserted by self-certification? Or, if the commitment to discipline-based licensing is strong, are there sufficient commonalities to eliminate the practice/title distinction and license all disciplines as equal practice act disciplines?

In this report, the overlap issue is being addressed through the analysis of the educational requirements for branches of engineering taught in California universities and through the amount of overlap in NCEES licensing examinations. Overlap in the occupational analyses could not be addressed because of differing methodologies in the collection of this information and the unavailability of data for many disciplines. Since NCEES exams are based on the occupational analyses, analyzing exam outlines offers the most reasonable substitution. This chapter describes the amount of overlapping educational requirements in degree programs at seven California universities. Chapter 10 describes the amount of overlapping exam content using the evaluations of a sample of licensed engineers.

Educational Programs Supporting Regulated and Unregulated Engineering Disciplines

Using the number of 2000 graduates from the 30 California engineering schools, seven universities, accounting for 55% of all engineering graduates, were chosen for the analysis of educational requirements. These schools include: California State Polytechnic University, Pomona; California Polytechnic State University, San Luis Obispo; California State University, San Jose; University of California, Berkeley; University of California, Los Angeles; University of Southern California; and Stanford University. There are 142 Accreditation Board for Engineering and Technology (ABET) accredited engineering programs on the 30 campuses, of which 105 (or 74%) were in the regulated disciplines. The selected schools accounted for 37% of the undergraduate engineering degree programs in the state and 39% of those in the regulated disciplines. Control systems and structural engineering are the only regulated disciplines that lack an undergraduate degree program at the selected schools. In fact, a school not selected for inclusion -- UC San Diego -- offers the only Bachelor's degree program in structural engineering in the state. None of the universities offer an undergraduate degree in control systems. (Table 8.1)

The practice act disciplines are supported by 74 (or 52%) accredited programs throughout the state; all three are offered at each of the seven selected schools. Six title act disciplines are supported by 28 undergraduate programs (or 20%) throughout the state. Chemical and industrial are taught at six of the seven campuses, materials engineering at three, manufacturing at two, and agricultural and nuclear engineering each at a single campus. (Table 8.1) Most or all (75 % to 100%) of the accredited programs in agricultural, industrial, manufacturing, materials and nuclear engineering are offered at the included schools. Between 25% and 46% of accredited programs in the more commonly taught disciplines (chemical, civil, electrical, and mechanical) are found at the seven schools. (Table 8.1)

Options, specializations, or concentrations within majors are another way in which knowledge supporting a particular discipline is transmitted. Options within majors are less important for the practice act disciplines because these are strongly supported by degree programs (44% vs. 52% of degree programs). They are more important for the title act and unregulated disciplines: 27% of the options support title act disciplines, compared with 20% of the degree programs while 29% of the options support unregulated disciplines compared with 25% of degree programs. (Table 8.2) The unregulated disciplines include aerospace, bio- and biomedical, computer, environmental, and management science engineering. (Table 8.3 - 8.5)

Some of the disciplines lacking undergraduate degree programs are supported by graduate degrees at the selected schools. A graduate degree in control systems is offered at six of the seven schools; structural engineering is offered at five, geotechnical at four and transportation engineering at three. Thus, both title authorities and two additional title acts (transportation and control systems) are supported at the graduate level. (Table 8.6)

Degree Requirements

To analyze degree requirements, quarter units were converted to semester units for comparability across institutions. In summarizing the units involved in the undergraduate majors and concentrations, five regulated disciplines were identified (geotechnical, structural, control systems, fire protection and traffic) that are not directly supported— except through limited concentrations— by the undergraduate degree programs at the selected schools. Structural, geotechnical and traffic engineering are treated as specializations within the civil engineering major with an average of 18 units for structural and 13.5 units for the other two sub-disciplines. Control systems is a 13.25 unit specialization within either an electrical engineering or mechanical engineering major. Fire protection is taught at a single location in the U.S., outside California. (Table 8.7)

Non-general education units for an engineering degree vary from a low of 78 at Stanford to a high of 106 at SLO. Degree units are highly variable within some schools -- Berkeley's engineering degree programs vary between 89 and 115 units -- but virtually unvarying within others. All but one program at Pomona requires 89 units; the exception requires 92. Engineering course units also vary by school and discipline. Stanford requires the fewest units in engineering courses (43.9) and SLO the most (68.7). With the exception of Stanford and Berkeley (43.9 and 54.6 units on average), the schools' engineering course units vary between 61.6 (UCLA) and 68.7 (SLO and San Jose). The seven schools require more units in the practice act disciplines than they do in the title act disciplines (64 vs. 57.7). (Table 8.8)

The seven engineering schools varied in the number of degree programs offered in the regulated disciplines. Berkeley offered the greatest variety of engineering degrees (9), with only agriculture excluded. USC and UCLA offered the fewest (5). With the exception of Stanford and Berkeley, the units required for specific degrees are reasonably consistent across the campuses. Degrees in manufacturing, civil and mechanical engineering have the highest engineering course unit requirement (67, 66 and 65 units respectively) while chemical and petroleum engineering have the lowest (51.7 and 51.5 units). The dependence of chemical and petroleum engineering on basic chemistry and its inclusion in support units for all engineering degrees may contribute to the lower number of engineering units for degrees in these two fields. (Table 8.8)

Engineering students must take both engineering coursework as well as supporting classes that are not based in engineering and are not general education courses. Non-general education courses include courses in support subjects such as physics, chemistry and math. The universities vary in the emphasis placed on support units in physics, chemistry and math. An engineering degree at Berkeley, Stanford and UCLA includes more units in these basic subjects, as a proportion of all non-general education units, than the CSU campuses and USC. Physics, chemistry and math make up between 40% and 55% of non-general education units required for the degree at Berkeley, Stanford and UCLA; they make up between 28% and 35% at the CSU campuses and 37% at USC. (Table 8.8)

Many engineering degrees provide for specializations within the degree and, as noted above, these specializations provide the only support at the undergraduate level for the two title authorities and three title act disciplines (control systems, fire protection and traffic). Options, emphases, concentrations or specializations, which are interchangeable terms, require between 11 and 18 units on average, although the range for individual programs varies from 6 to 24. Only two of the regulated disciplines are supported by concentrations at the high end of this range (industrial with a single program requiring 19 units and structural with 4 programs averaging an 18 unit specialization). One school offers a 16-unit materials science minor. The remaining concentrations average 11 to 13.5 units. (Table 8.7)

Educational Overlap

One indicator of the degree of similarity among engineering disciplines is the amount of shared coursework in their undergraduate degree programs. Detailed information on specific course requirements for the engineering degree programs summarized in Table 8.8 was analyzed for the amount of overlap in engineering and support area units. The amount of overlap by school and program is summarized in Tables 8.9, 8.10 and 8.11.

This analysis is thought to be conservative because, for organizational reasons, universities seek to distinguish majors from each other as much as possible. This would have the effect of understating the amount of overlap between disciplines. It is the most "objective" measure of overlap because there is no interpretation or grouping of courses into subject matter categories. Units allocated to specific required and elective courses are counted as overlapping when different degree programs identify the same course requirements by department and course number, title or course description.

The greatest amount of educational overlap occurs between industrial and manufacturing engineering. They share two-thirds (68%) of all non-general education courses (ranging between 64% and 71% at the three schools offering both degrees) and well over half (57%) of all engineering courses (ranging between 55% and 59%). (Table 8.11) Manufacturing and mechanical engineering are ranked second in terms of shared engineering units and third in terms of all engineering and support units, with 51% of all non-general education units in common and 38% of all engineering units in common.

The rankings and average percents are influenced by significant differences among the schools in the amount of overlapping units for some programs. Mechanical and manufacturing engineering are very similar at Berkeley, with 66% of all units and 56% of engineering units in common. They are more distinguished from each other at Pomona and SLO, with 39% and 49% respectively of all units and 25% and 33% of engineering units in common. This variability is expressed by the larger standard deviation (SD=13%) for the proportion of shared units between these majors. Other combinations with more inter-campus variability in the proportion of overlapping units include: chemical and petroleum (SD = 24%), chemical and metallurgical (11%), manufacturing and metallurgical (11%), and civil and metallurgical and civil and mechanical (10% each). Berkeley makes more of a distinction between the chemical and petroleum engineering majors, with 20% of all units and 17% of engineering units in common, than Stanford does, with 55% of all units and 45% of engineering units in common. If overlap were judged on the basis of the Stanford program, chemical and petroleum engineering would rank second in overlapping units. Thus, the variability between universities affects the ranking of overlap among engineering disciplines. (Table 8.10)

Metallurgical engineering is involved in three of the six combinations of majors with the greatest variability in overlapping units. Stanford and Berkeley are partially responsible for this variability because of their high percentages of overlap in all non-general education and engineering units for metallurgical with chemical, civil and mechanical engineering. Metallurgical engineering shares over half of all units with civil (55%) and mechanical (56 - 57%) and almost half of all units (45%) with chemical at these two schools. It also shares over half of all units (56%) with chemical at Pomona and San Jose. It is Berkeley that increases the variability in the metallurgical/chemical combination because of its lower proportion of overlapping courses (30%). Metallurgical engineering also shares 57% of all units with manufacturing at SLO, but a much lower percentage at Pomona and Berkeley. Whether these differences reflect different perceptions of the fields or different emphases within them, or fiscal decisions to support some programs more than others is impossible to tell. (Table 8.10)

Another aspect of overlapping educational requirements is whether the overlap for all units is largely due to overlap in engineering or support area courses. For example, most of the overlap between industrial and manufacturing engineering is in the engineering units rather than the support courses (57% out of the 68% of all overlapping units are in engineering, a ratio of 84%). In general, the combinations with more engineering units are those where engineering units dominate all overlapping units. In the first four and the seventh combinations in Table 8.11, the proportion of overlapping units in engineering courses make up 75 - 85% of all overlapping units in non-general education courses. These combinations include: industrial and manufacturing, manufacturing and mechanical, and mechanical, chemical and manufacturing with petroleum. Other discipline pairings have more shared support units and fewer shared engineering units. For example, overlapping engineering coursework makes up barely half of all overlapping units between mechanical and nuclear (27% out of 52%). Other combinations with similarly low ratios include metallurgical with mechanical (28% out of 47% or 60%), chemical (60%), manufacturing (61%), and civil (52%) as well as civil with mechanical (50%). (Table 8.11)

Educational Background of Engineers

Using the job analysis data files where available and published job analysis reports when they weren't, the educational background of engineers licensed in the regulated fields were summarized in an effort to identify the type of degree that supports the regulated disciplines. Unfortunately, there is no consistency in the framing of questions regarding educational background and therefore the responses are difficult to interpret and compare. Some questionnaires ask for the highest educational level completed but offer different response categories (electrical, manufacturing, mechanical, metallurgical and petroleum vs. structural and traffic) while others ask for the highest engineering degree and its specialty (control systems and agricultural). Yet another variation asks for the specialty that best describes the Bachelor's degree (manufacturing and metallurgical). All three seek a single answer. Job analysis questionnaires in other disciplines (chemical, industrial, and civil) seek multiple responses to the question: "What educational degrees do you hold?" Although job analysis questionnaires typically restrict responses to registered or licensed engineers, small numbers of unregistered engineers responded to these questions. (Tables 8.12a, b, and e)

Most engineers have at least a Bachelor's degree. Significant proportions have graduate degrees (30% or more in all but petroleum and traffic engineers). (Tables 8.12a - d) Based on the job analysis surveys, more metallurgical, structural and agricultural engineers have graduate degrees in engineering than any other disciplines studied (74%, 57% and 56% respectively). (Tables 8.12a-d).

The number of programs available in various disciplines undoubtedly influences the educational background that leads into an area of practice. For example, only three of the seven schools selected for study in California offer degrees in manufacturing. This may not be unusual nationally since almost half (46.5%) of manufacturing engineers have degrees in mechanical engineering and only 8.2% have degrees in manufacturing. (Table 8.12e) In contrast, six of California's seven selected schools offer degrees in metallurgical engineering, and nationally, 65.8% of metallurgical engineers have degrees in metallurgical engineering. Other common backgrounds for metallurgical engineers are chemical and materials engineering (8.6% each). (Table 8.12e) Similarly, control systems engineers are most often educated in electrical (42.2%), mechanical (21.1%) and chemical (14.2%) engineering. Only 9% of control systems engineers nationwide have a specialty in control systems associated with their highest engineering degree. (Table 8.12f)

Most (76% or more) agricultural, chemical, civil, electrical, mechanical and metallurgical engineers have Bachelor's degrees from an ABET-accredited program. Somewhat fewer, but still a solid majority, of industrial (70%), manufacturing (65%) and petroleum (60%) engineers graduated from ABET accredited programs. (Table 8.13)

Table 8.1. ABET Accredited Engineering Programs in California (Accreditation Period Ending September 30, 2001)

		Cal Poly		California State University												University of California																Total # of Programs	7 Study Schools	
	Caltech	SLO	Pomona	Chico	Fresno	Fullerton	Humboldt	Long Beach	Los Angeles	Northridge	Sacramento	San Diego	San Francisco	San Jose	Berkeley	Davis	Irvine	Los Angeles	Riverside	San Diego	Santa Barbara	Santa Cruz	Harvey Mudd	Loyola Marymount	NPS	UOP	Univ. of San Diego	Santa Clara Univ.	USC	Stanford		# of Programs	% of Programs
Aeronautical Engineering																									✓						1	0	0%
Aeronautical Science and Engineering																✓															1	0	0%
Aerospace Engineering		✓	✓									✓		✓			✓	✓											✓		7	5	71%
Architectural Engineering		✓																													1	1	100%
Astronautical Engineering																									✓						1	0	0%
Bioengineering																				✓											1	0	0%
Biological Systems Engineering																✓															1	0	0%
BioResource and Agriculture Engineering		✓	--											--	--			--											--	--	1	1	100%
Chemical Engineering	✓	--	✓					✓						✓	✓	✓	✓	✓	✓	✓	✓								✓	✓	13	6	46%
Civil & Environmental Engineering															✓																21	7	33%
Civil Engineering		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓						✓		✓		✓	✓	✓			
Computer Engineering		✓		✓				✓			✓			✓		✓	✓					✓				✓		✓			10	2	20%
Computer Science & Engineering															✓	✓		✓													3	2	67%
Electrical and Electronic(s) Engineering											✓																				28	7	25%
Electrical Engineering	✓	✓	✓		✓	✓		✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓	✓			
Electrical Engineering/Materials Science and Engineering																✓																	
Electrical/Electronic(s) Engineering				✓																													
Engineering										✓													✓								2	0	0%
Engineering and Applied Science	✓																														1	0	0%
Engineering Physics																										✓					1	0	0%
Environmental Engineering		✓															✓		✓										✓		4	2	50%
Environmental Resources Engineering							✓																								1	0	0%
Geomatics Engineering					✓																										1	0	0%
Industrial & Systems Engineering														✓				--											✓		7	6	86%
Industrial Engineering		✓	✓		✓										✓			--												✓			
Manufacturing Engineering		✓	✓											--	⦸			--											--	--	2	2	100%
Materials Engineering		✓	⦸											✓				✓													4	3	75%
Materials Science & Engineering															⦸	✓														⦸			
Mechanical Engineering		✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			✓	✓	✓		✓	✓	✓	25	7	28%
Mechatronics Engineering				✓																											1	0	0%
Nuclear Engineering		--	--											--	✓			--											--	--	1	1	100%
Structural Engineering		--	--											--	--			--		✓									--	--	1	0	0%
Surveying Engineering		--	--		✓									--	--			--											--	--	2	1	50%
Surveying Option in Civil Engineering		--	✓											--	--			--											--	--			
Total for Regulated Disciplines	2	7	7	3	5	3	0	4	3	3	3	3	3	6	6	6	4	5	3	4	3	0	0	3	2	3	1	3	5	5	105	41	39%
Total for All Disciplines	3	11	8	5	6	3	1	5	3	4	4	4	3	8	7	10	7	7	4	5	3	1	1	3	4	5	1	4	7	5	142	53	37%

Note: The seven study schools and disciplines regulated in California are shaded. The symbol "✓ " is used to indicate that a program is accredited. For study schools, the symbol "⦸" is used to indicate that a program is not accredited and "—" is used to indicate the school does not offer a program in that discipline.

Table 8.2 Summary of Undergraduate Options/Specializations/Concentrations

	Pomona	SLO	San Jose	Stanford	Berkeley	UCLA	USC	Total	Percent
Options/Specializations/Concentrations in Disciplines Not Regulated in California	5	8	8	10	9	3	12	55	29.3
Options/Specializations/Concentrations in California Practice Act Disciplines	15	9	8	9	11	7	24	83	44.1
Options/Specializations/Concentrations in California Title Act Disciplines	4	8	3	9	11	7	8	50	26.6
Total	24	25	19	28	31	17	44	188	100.0

Table 8.3. Undergraduate Options/Specializations/Concentrations in Disciplines *Not Regulated* in California

Degree	Option/Specialization/Concentration	Pomona	SLO	San Jose	Stanford	Berkeley	UCLA	USC
Aeronautics and Astronautics					✓			
Aerospace Engineering	General	✓					✓	✓
	Aerodynamics and Propulsion			✓				
	Aeronautic		✓					
	Astronautics		✓					✓
	Dynamics and Control			✓				
	Structures			✓				
Applied Mechanics								✓
Bioengineering (areas of specialization under review)						✓		
Biomedical Engineering	General							✓
	Biochemical Engineering							✓
Computational Engineering Science						✓		
Computer Engineering			✓	✓				
Computer Engineering and Computer Science	Advanced Circuit Design							✓
	Multimedia and Graphics							✓
	Software Systems							✓
	Theory							✓
Computer Science	General		✓		✓		✓	✓
	Manufacturing Engineering							✓
Computer Science and Engineering	General						✓	
	Computer Science (Option IV)					✓		
Computer Systems Engineering					✓			
Construction Engineering Technology		✓						
Earth Resource Engineering	General					✓		
	Environmental Engineering					✓		
	Mineral Engineering					✓		
Electronics and Computer Engineering Technology		✓						
Engineering Mathematics and Statistics						✓		
Engineering Physics						✓		
Engineering Technology	Environmental	✓						
	General Mechanical & Manufacturing	✓						
Environmental Engineering			✓		✓			✓
Environmental Engineering Science						✓		
General Engineering	General			✓				
	Bioengineering		✓					
	Biomedical Engineering		✓					
	Environmental Health & Safety Engineering			✓				
	Individualized Course of Study		✓					
	Microelectronics Process Engineering			✓				
	Software and Information Engineering			✓				
Management Science and Engineering	Financial and Decision Engineering				✓			
	Operations Management				✓			
	Operations Research				✓			
	Technology and Organizations				✓			
	Technology and Policy				✓			
Product Design					✓			

Table 8.4. Undergraduate Options/Specializations/Concentrations in California *Practice Act* Disciplines

Discipline	Degree	Option/Specialization/Concentration		Pomona	SLO	San Jose	Stanford	Berkeley	UCLA	USC
Civil Engineering	Civil Engineering	General Civil Engineering		✓	✓	✓		✓	✓	✓
		Building Science								✓
		Construction Engineering								✓
		Construction Engineering and Management						✓		
		Environmental and Water Resources Engineering				✓				
		Environmental and Water Studies					✓			
		Environmental Engineering		✓				✓		✓
		GeoEngineering						✓		
		Geotechnical			✓					
		Structural Engineering			✓			✓		✓
		Structural Engineering and Applied Mechanics				✓				
		Structures and Construction					✓			
		Surveying Engineering		✓						
		Transportation			✓			✓		
		Transportation, Construction & Geotechnical Engineering				✓				
		Water Resources Engineering			✓					✓
Electrical Engineering	Electrical and Computer Engineering	Communications, Networks and Systems (Option II)						✓		
		Computer Systems (Option III)						✓		
		Electronics (Option I)						✓		
		General (Option V)						✓		
	Electrical Engineering	General				✓			✓	
		Biomedical Engineering							✓	
		Communication and Signal Processes		✓						
		Communication, Control and Signal Processing	Control Systems							✓
			Digital Signal Processing							✓
			Modern Communication Systems							✓
			Robotics							✓
			Systems							✓
			Communication Networks							✓
		Computer Engineering							✓	
		Computer Engineering	Computer Architecture and Organization							✓
			Computer Networks							✓
			Hardware/Software							✓

Note: Shaded areas indicate programs that will be included in coursework analysis.

Table 8.4. (Continued) Undergraduate Options/Specializations/Concentrations in California *Practice Act* Disciplines

Discipline	Degree	Option/Specialization/Concentration		Pomona	SLO	San Jose	Stanford	Berkeley	UCLA	USC
Electrical Engineering (continued)	Electrical Engineering (continued)	Computer Hardware					✓			
		Computer Software					✓			
		Computer Systems		✓						
		Computers								✓
		Control and Robotic		✓						
		Controls					✓			
		Electromagnetics and Energy Conversion	Energy Conversion							✓
			Energy Conversion: Lasers							✓
		Electronic			✓					
		Electronic Devices and Circuits	Electronic Circuits							✓
			Integrated Circuits							✓
		Electronics					✓			
		Fields and Waves					✓			
		General SPE		✓						
		Illumination Engineering		✓						
		Instrum. Biomed Ocean		✓						
		Manufacturing Engineering								✓
		Microelectronics		✓						
		Power			✓					
		Power Systems		✓						
		Radio Frequency Systems		✓						
		Signal Processing and Communication					✓			
Mechanical Engineering	Mechanical Engineering	General		✓	✓		✓	✓		✓
		Design and Manufacturing							✓	
		Dynamics and Control							✓	
		Energy (Thermal/Fluid Sciences)		✓						
		Fluids and Thermal Engineering							✓	
		Manufacturing Engineering								✓
		Mechanical Design		✓		✓				
		Mechatronics			✓	✓				
		Petroleum Engineering								✓
		Thermal/Fluids				✓				

Note: Shaded areas indicate programs that will be included in coursework analysis.

Table 8.5. Undergraduate Options/Specializations/Concentrations in California *Title Act* Disciplines

Discipline	Degree	Option/Specialization/Concentration	Pomona	SLO	San Jose	Stanford	Berkeley	UCLA	USC
Agricultural	BioResource & Agricultural Engineering			✓					
Chemical	Chemical Engineering	General	✓		✓	✓		✓	✓
		Applied Chemistry					✓		
		Applied Physics					✓		
		Biochemical Engineering							✓
		Bioengineering						✓	
		Biomedical Engineering						✓	
		Biotechnology					✓		
		Chemical Processing					✓		
		Environmental						✓	
		Environmental Engineering							✓
		Environmental Technology					✓		
		Manufacturing Engineering							✓
		Materials Science					✓		
		Petroleum Engineering							✓
		Polymer Science							✓
		Semiconductor Manufacturing						✓	
Industrial	Industrial and Systems Engineering	General			✓				✓
		Manufacturing Engineering							✓
	Industrial Engineering		✓	✓					
	Industrial Engineering and Operations Research						✓		
	Management Science and Engineering	Industrial Engineering				✓			
Manufacturing	Manufacturing Engineering	General	✓	✓			✓		
		Manufacturing Process Engineering		✓					
		Manufacturing Systems		✓					
		Mechatronics Manufacturing		✓					
		Metrology		✓					
Metallurgical	Materials Engineering	General	✓	✓	✓			✓	
		Electronic Materials						✓	
	Materials Science and Engineering	General					✓		
		Chemical Engineering				✓			
		Chemistry				✓			
		Electrical Engineering				✓			
		Mechanical Engineering				✓			
		Physics				✓			
		Self-Defined Option				✓			
Nuclear	Nuclear Engineering						✓		
Petroleum	Earth Resource Engineering	Petroleum Engineering					✓		
	Petroleum Engineering					✓			

Note: Shaded areas indicate programs that will be included in coursework analysis. This table includes some degree programs that are not accredited.

Table 8.6 Summary of Selected Graduate Program Specializations**

	Pomona	SLO	San Jose	Stanford*	Berkeley*	UCLA	USC	Total
Structural	1		1	1	1	1		5
Geotechnical			1	1	1	1		4
Transportation		1	1		1			3
Control Systems	1		1		1	2	1	6

* Numbers for Geotechnical include a Geomechanics program at Stanford and a Geoengineering program at Berkeley.

** For complete listing of Graduate program specializations see Appendix G.

Table 8.7. Undergraduate Engineering Degree Programs and Specialties* at Seven Study Schools by Discipline and Type of Regulation

Type of Regulation	Discipline	Number of Schools Offering Degree in Discipline	Total Units Required in Engineering Topics**	Number of Specialties in Regulated Disciplines	Description of Specialty Area	Units Required in Specialty Area**	
						Average	Range
Practice Act	Civil	7	65.6	0			
	Geotechnical	0	--	2	Specialization for Civil Engineering majors	13.5	12-15
	Structural	0	--	4	Specialization/emphasis for Civil Engineering majors	18	12-24
	Electrical	7	61.3	1	Option for Material Science Engineering majors	6	--
	Mechanical	7	65.1	1	Option for Material Science Engineering majors	6	--
Title Act	Agriculture	1	62.0	0			
	Chemical	6	51.7	1	Option for Material Science Engineering majors	6	--
	Control	0	--	4	Specialty/certificate for Electrical or Mechanical Engineering majors	13.25	7-22
	Fire Protection	0	--	0			
	Industrial	5	59.8	1	Concentration for Management Science Engineering majors	19	--
	Manufacturing	3	67.3	2	Specialization/emphasis for various Engineering majors	11	8-14
	Metallurgical	6	56.8	1	Materials Science minor with various Engineering majors	16	--
	Nuclear	1	55.0	0			
	Petroleum***	3	51.5	1	Option for Earth Resources Engineering majors	17	--
	Traffic	0	--	2	Specialization for Civil Engineering majors	13.5	12-15

* The term specialty is used in this table to describe options, concentrations and areas of emphasis.

** Units from Universities on quarter systems have been converted to semester units.

*** For the sake of completeness degree programs in petroleum engineering are included in the table even though they are not ABET accredited.

Table 8.8. Units Required for Engineering Degrees by School

		Pomona	SLO	San Jose	Stanford	Berkeley	UCLA	USC	Average
All Units (Excluding General Education Courses)	Agricultural	--	105	--	--	--	--	--	105.0
	Chemical	89	--	102	89	115	108	105	101.3
	Civil	89	108	106	77	94	98	104	96.6
	Electrical	92	104	103	78	96	104	106	97.6
	Industrial	89	107	98	76	89	--	102	93.5
	Manufacturing	89	106	--	--	99	--	--	73.5
	Mechanical	89	107	102	74	89	106	103	95.7
	Metallurgical	89	105	98	75	115	99	--	96.8
	Nuclear	--	--	--	--	91	--	--	91.0
	Petroleum	--	--	--	76	104	--	--	90.0
	Average	89.4	106.0	101.5	78.0	99.0	103.0	104.0	
Engineering Course Units	Agricultural	--	62	--	--	--	--	--	62.0
	Chemical	57	--	58	38	53	51	53	51.6
	Civil	70	70	76	49	60	62	72	65.6
	Electrical	70	68	73	43	44	65	66	61.3
	Industrial	59	72	69	45	51	--	63	59.8
	Manufacturing	68	70	--	--	64	--	--	67.3
	Mechanical	67	71	72	48	57	69	72	65.1
	Metallurgical	60	68	64	46	42	61	--	56.8
	Nuclear	--	--	--	--	55	--	--	55.0
	Petroleum[a]	--	--	--	38	65	--	--	51.5
	Average	64.4	68.7	68.7	43.9	54.6	61.6	65.2	
Average Supporting Units[b]		25.0	37.3	32.8	34.1	44.4	41.4	38.8	
Average % Supporting Units[c]		28.0	35.2	32.3	43.7	54.6	40.2	37.0	
Average Number of Engineering Units for Degrees Supporting Title Act Disciplines[d]									57.7
Average Number of Engineering Units for Degrees Supporting Practice Act Disciplines[e]									64.0

[a] For the sake of completeness degree programs in petroleum engineering are included in the table even though they are not ABET accredited.

[b] Supporting Units are the number on non-general education units required other than engineering units.

[c] Average percent of Supporting Units is equal to the average number of supporting units divided by the average number of all non-general education units.

[d] Degrees supporting Title Act Disciplines are Agricultural, Chemical, Industrial, Manufacturing, Metallurgical, Nuclear, and Petroleum.

[e] Degrees supporting Practice Act Disciplines are Civil, Electrical, and Mechanical.

Table 8.9. Overlapping Units (Excluding General Education Courses) Required for Engineering Degrees by School

Degrees		All Units							Engineering Units						
		Pomona	SLO	San Jose	Stanford	Berkeley	UCLA	USC	Pomona	SLO	San Jose	Stanford	Berkeley	UCLA	USC
Agricultural	Civil		46							11					
Agricultural	Electrical		37							7					
Agricultural	Industrial		43							8					
Agricultural	Manufacturing		44							10					
Agricultural	Mechanical		39							9					
Agricultural	Metallurgical		44							10					
Chemical	Civil	20		35	34	27	45	35	2		14	11	0	10	4
Chemical	Electrical	19		32	27	28	34	35	0		11	2	0	2	3
Chemical	Industrial	27		33	37	30		31	7		12	10	6		4
Chemical	Manufacturing	25				34			5				10		
Chemical	Mechanical	24		35	36	38	45	27	5		14	13	10	10	0
Chemical	Metallurgical	50		56	37	34	47		26		23	11	6	11	
Chemical	Nuclear					37							9		
Chemical	Petroleum				45	22						17	10		
Civil	Electrical	17	37	35	22	27	43	43	0	9	9	2	0	11	13
Civil	Industrial	23	47	41	34	28		31	4	13	14	13	0		8
Civil	Manufacturing	31	52			33			11	17			5		
Civil	Mechanical	27	46	53	41	36	57	33	11	16	28	16	5	22	3
Civil	Metallurgical	28	49	38	42	40	54		10	16	14	16	6	21	
Civil	Nuclear					37							3		
Civil	Petroleum				28	31						9	12		
Electrical	Industrial	21	36	38	24	30		30	2	8	12	3	6		5
Electrical	Manufacturing	19	39			24			0	11			0		
Electrical	Mechanical	17	37	39	20	31	47	34	0	11	9	3	3	15	3
Electrical	Metallurgical	19	40	39	22	28	41		0	9	14	2	0	11	
Electrical	Nuclear					31							3		
Electrical	Petroleum				17	15						0	3		
Industrial	Manufacturing	57	76			65			35	41			34		
Industrial	Mechanical	29	43	42	35	37		24	11	13	16	15	9		1
Industrial	Metallurgical	31	49	37	37	31			11	15	12	13	3		
Industrial	Nuclear					35							7		
Industrial	Petroleum				28	28						7	12		
Manufacturing	Mechanical	35	52			62			17	23			34		
Manufacturing	Metallurgical	35	60			39			14	26			11		
Manufacturing	Nuclear					37							9		
Manufacturing	Petroleum					34							18		
Mechanical	Metallurgical	36	48	39	42	43	58		17	16	14	18	11	25	
Mechanical	Nuclear					47							15		
Mechanical	Petroleum				33	36						13	20		
Metallurgical	Nuclear					46							10		
Metallurgical	Petroleum				29	35						8	15		
Nuclear	Petroleum					35							15		

Table 8.10. Percent Overlap by School*

Degrees		All Units								Engineering Units							
		Pomona	SLO	San Jose	Stanford	Berkeley	UCLA	USC	Average	Pomona	SLO	San Jose	Stanford	Berkeley	UCLA	USC	Average
Agricultural	Civil		43%						43%		17%						17%
Agricultural	Electrical		35%						35%		11%						11%
Agricultural	Industrial		41%						41%		12%						12%
Agricultural	Manufacturing		42%						42%		15%						15%
Agricultural	Mechanical		37%						37%		14%						14%
Agricultural	Metallurgical		42%						42%		15%						15%
Chemical	Civil	22%		34%	41%	26%	44%	33%	33%	3%		21%	25%	0%	18%	6%	12%
Chemical	Electrical	21%		31%	32%	27%	32%	33%	29%	0%		17%	5%	0%	3%	5%	5%
Chemical	Industrial	30%		33%	45%	29%		30%	34%	12%		19%	24%	12%		7%	15%
Chemical	Manufacturing	28%				32%			30%	8%				17%			13%
Chemical	Mechanical	27%		34%	44%	37%	42%	26%	35%	8%		22%	30%	18%	17%	0%	16%
Chemical	Metallurgical	56%		56%	45%	30%	45%		46%	44%		38%	26%	13%	20%		28%
Chemical	Nuclear					36%			36%					17%			17%
Chemical	Petroleum				55%	20%			37%				45%	17%			31%
Civil	Electrical	19%	35%	33%	28%	28%	43%	41%	33%	0%	13%	12%	4%	0%	17%	19%	9%
Civil	Industrial	26%	44%	40%	44%	31%		30%	36%	6%	18%	19%	28%	0%		12%	14%
Civil	Manufacturing	35%	49%			34%			39%	16%	24%			8%			16%
Civil	Mechanical	30%	43%	51%	54%	39%	56%	32%	44%	16%	23%	38%	33%	9%	34%	4%	22%
Civil	Metallurgical	31%	46%	37%	55%	38%	55%		44%	15%	23%	20%	34%	12%	34%		23%
Civil	Nuclear					40%			40%					5%			5%
Civil	Petroleum				37%	31%			34%				21%	19%			20%
Electrical	Industrial	23%	34%	38%	31%	32%		29%	31%	3%	11%	17%	7%	13%		8%	10%
Electrical	Manufacturing	21%	37%			25%			28%	0%	16%			0%			5%
Electrical	Mechanical	19%	35%	38%	26%	34%	45%	33%	33%	0%	16%	12%	7%	6%	22%	4%	10%
Electrical	Metallurgical	21%	38%	39%	29%	27%	40%		32%	0%	13%	20%	4%	0%	17%		9%
Electrical	Nuclear					33%			33%					6%			6%
Electrical	Petroleum				22%	15%			19%				0%	6%			3%
Industrial	Manufacturing	64%	71%			69%			68%	55%	58%			59%			57%
Industrial	Mechanical	33%	40%	42%	47%	42%		23%	38%	17%	18%	23%	32%	17%		1%	18%
Industrial	Metallurgical	35%	46%	38%	49%	30%			40%	18%	21%	18%	29%	6%			19%
Industrial	Nuclear					39%			39%					13%			13%
Industrial	Petroleum				37%	29%			33%				17%	21%			19%
Manufacturing	Mechanical	39%	49%			66%			51%	25%	33%			56%			38%
Manufacturing	Metallurgical	39%	57%			36%			44%	22%	38%			21%			27%
Manufacturing	Nuclear					39%			39%					15%			15%
Manufacturing	Petroleum					33%			33%					28%			28%
Mechanical	Metallurgical	40%	45%	39%	56%	42%	57%		47%	27%	23%	21%	38%	22%	38%		28%
Mechanical	Nuclear					52%			52%					27%			27%
Mechanical	Petroleum				44%	37%			41%				30%	33%			32%
Metallurgical	Nuclear					45%			45%					21%			21%
Metallurgical	Petroleum				38%	32%			35%				19%	28%			24%
Nuclear	Petroleum					36%			36%					25%			25%

* Percent overlap was computed by dividing the sum of units for courses required for both degrees by the average number units required for the two degrees (excluding general education course requirements).

Table 8.11 Percent Overlap (in Rank Order for Engineering Units)

		# of Schools Offering Both Degrees	All Units		Engineering Units		Rank		Percent of Engineering Units per Total Units
			Average	SD	Average	SD	All Units	Engineering Units	
Industrial	Manufacturing	3	68%	4%	57%	2%	1	1	84%
Manufacturing	Mechanical	3	51%	13%	38%	16%	3	2	75%
Mechanical	Petroleum	2	41%	5%	32%	2%	13	3	78%
Chemical	Petroleum	2	37%	24%	31%	20%	21	4	84%
Mechanical	Metallurgical	6	47%	8%	28%	8%	4	5	60%
Chemical	Metallurgical	5	46%	11%	28%	13%	5	6	61%
Manufacturing	Petroleum	1	33%		28%		31	7	85%
Mechanical	Nuclear	1	52%		27%		2	8	52%
Manufacturing	Metallurgical	3	44%	11%	27%	9%	7	9	61%
Nuclear	Petroleum	1	36%		25%		24	10	69%
Metallurgical	Petroleum	2	35%	5%	24%	6%	27	11	69%
Civil	Metallurgical	6	44%	10%	23%	9%	8	12	52%
Civil	Mechanical	7	44%	10%	22%	13%	9	13	50%
Metallurgical	Nuclear	1	45%		21%		6	14	47%
Civil	Petroleum	2	34%	4%	20%	1%	29	15	59%
Industrial	Petroleum	2	33%	6%	19%	3%	34	16	58%
Industrial	Metallurgical	5	40%	8%	19%	8%	16	17	48%
Industrial	Mechanical	6	38%	8%	18%	10%	20	18	47%
Agricultural	Civil	1	43%		17%		10	19	40%
Chemical	Nuclear	1	36%		17%		23	19	47%
Civil	Manufacturing	3	39%	8%	16%	8%	17	21	41%
Chemical	Mechanical	6	35%	8%	16%	11%	28	22	46%
Agricultural	Metallurgical	1	42%		15%		11	23	36%
Agricultural	Manufacturing	1	42%		15%		12	24	36%
Manufacturing	Nuclear	1	39%		15%		18	25	38%
Chemical	Industrial	5	34%	6%	15%	7%	30	26	44%
Civil	Industrial	6	36%	8%	14%	10%	25	27	39%
Agricultural	Mechanical	1	37%		14%		22	28	38%
Industrial	Nuclear	1	39%		13%		19	29	33%
Chemical	Manufacturing	2	30%	3%	13%	6%	39	30	43%
Chemical	Civil	6	33%	8%	12%	10%	32	31	36%
Agricultural	Industrial	1	41%		12%		14	32	29%
Agricultural	Electrical	1	35%		11%		26	33	31%
Electrical	Industrial	6	31%	5%	10%	5%	38	34	32%
Electrical	Mechanical	7	33%	8%	10%	8%	35	35	30%
Civil	Electrical	7	33%	8%	9%	8%	36	36	27%
Electrical	Metallurgical	6	32%	8%	9%	9%	37	37	28%
Electrical	Nuclear	1	33%		6%		33	38	18%
Electrical	Manufacturing	3	28%	8%	5%	9%	41	39	18%
Civil	Nuclear	1	40%		5%		15	40	13%
Chemical	Electrical	6	29%	5%	5%	6%	40	41	17%
Electrical	Petroleum	2	19%	5%	3%	4%	42	42	16%

Table 8.12a. Educational Degrees Held by Chemical, Civil, Electrical, Industrial, Manufacturing, Mechanical, Metallurgical and Petroleum Engineers

	Chemical[ac]		Civil[c]		Electrical[b]		Industrial[a]		Manufacturing[b]		Mechanical**		Metallurgical[b]		Petroleum[b]	
What educational degrees do you hold?	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%
Missing					*157*	8.7%			*22*	4.0%	*109*	6.4%			*71*	28.6%
No degree	*2*	.9%	*4*	0.6%	*7*	.4%	*4*	2.0%	*15*	2.7%	*8*	.5%				
Associate Degree	*8*	3.5%	*31*	4.4%	*5*	.3%	*15*	7.4%	*23*	4.2%	*5*	.3%			*2*	.8%
Four-Year Engineering Technology Degree	*3*	1.3%	*14*	2.0%	*20*	1.1%	*3*	1.5%	*20*	3.7%	*28*	1.6%				
Bachelor's Degree in Science-Related Field	*16*	7.0%	*45*	6.4%	*9*	.5%	*19*	9.3%	*19*	3.5%	*9*	.5%			*2*	.8%
Bachelor's Degree in Engineering	*182*	80.2%	*508*	72.6%	*859*	47.6%	*154*	75.5%	*168*	30.7%	*899*	52.7%	*39*	21.2%	*108*	43.6%
Master's Degree in Another Field	*28*	12.3%	*43*	6.1%	*130*	7.2%	*60*	29.4%	*91*	16.6%	*136*	8.0%	*8*	4.4%	*11*	4.4%
Master's Degree in Engineering	*70*	30.8%	*316*	45.1%	*467*	25.9%	*62*	30.4%	*108*	19.7%	*410*	24.1%	*40*	21.7%	*37*	14.9%
Doctorate in Another Field	*1*	.4%	*4*	0.6%	*11*	.6%	*3*	1.5%	*13*	2.4%	*12*	.7%	*4*	2.2%	*2*	.8%
Doctorate in Engineering	*21*	9.3%	*36*	5.1%	*125*	6.9%	*14*	6.9%	*59*	10.8%	*88*	5.2%	*93*	50.5%	*15*	6.0%
Other	*2*	.9%	*19*	2.7%	*14*	.8%	*1*	5.0%	*10*	1.8%	*1*	.1%				
Total	*227*	146.6%	*700*	145.7%	*1804*	100.0%	*204*	168.9%	*548*	100.0%	*1705*	100.0%	*184*	100.0%	*248*	100.0%

Table 8.12b. Highest Engineering Degree for Agricultural and Control Systems Engineers

	Agricultural		Control Systems	
Highest Engineering Degree	*N*	%	*N*	%
None	*7*	.7%	*28*	3.4%
Associate's	*3*	.3%	*21*	2.6%
Bachelor's	*400*	42.2%	*475*	58.2%
Master's	*261*	27.6%	*200*	24.5%
Doctorate	*269*	28.4%	*82*	10.0%
Did not respond	*7*	.7%	*10*	1.2%
Total	*947*	100.0%	*816*	100.0%

Table 8.12c. Highest Educational Level Completed by Traffic Engineers

	Traffic	
Highest Educational Level Completed	*N*	%
High school/some college	*26*	6.2%
BS in civil, transportation, or traffic engineering	*174*	41.6%
BS/BA in field other than civil, transportation, or traffic engineering	*36*	8.6%
MS in civil, transportation, or traffic engineering	*140*	33.5%
MS/MA in field other than civil, transportation, or traffic engineering	*25*	6.0%
Doctorate in engineering	*9*	2.2%
Doctorate in field other than engineering	*2*	.5%
No response	*6*	1.4%
Total	*418*	100.0%

Table 8.12d. Highest Level of Education for Structural Engineers

	Structural	
Highest Level of Education	*N*	%
Missing	*1*	.1%
On the job training	*3*	.4%
BS Civil/Structural/Architecture Engineering	*285*	39.6%
BS in another field	*6*	.8%
MS/PHD Civil Engineering	*75*	10.4%
MS/PHD Structural Engineering	*330*	45.9%
MS/PHD Other Engineering	*6*	.8%
MS/PHD another field	*11*	1.5%
Other	*2*	.3%
Total	*719*	100.0%

Table 8.12e. Bachelor's Degree Program for Manufacturing and Metallurgical Engineers

	Manufacturing[b]		Metallurgical[b]	
Which best describes Bachelor's?	*N*	%	*N*	%
Missing	*52*	9.5%	*4*	2.1%
Aeronautical/Aerospace Engineering	*12*	2.2%		
Agricultural Engineering	*7*	1.3%		
Chemical Engineering	*7*	1.3%	*16*	8.6%
Civil Engineering	*7*	1.3%	*2*	1.1%
Computer Engineering	*1*	.2%		
Electrical Engineering	*39*	7.1%		
Engineering Management	*6*	1.1%		
Engineering Mechanics	*10*	1.8%	*4*	2.1%
Engineering Physics/Engineering Science	*11*	2.0%	*5*	2.7%
Forest Engineering	*1*	.2%		
General Engineering	*3*	.6%	*1*	.5%
Industrial Engineering	*54*	9.9%		
Manufacturing Engineering	*45*	8.2%		
Materials Engineering	*3*	.6%	*16*	8.6%
Mechanical Engineering	*255*	46.5%	*12*	6.4%
Metallurgical Engineering	*19*	3.5%	*123*	65.8%
Naval Architecture & Marine Engineering	*2*	.4%		
Systems Engineering	*1*	.2%		
Welding Engineering	*2*	.4%		
Other	*11*	2.0%	*4*	2.1%
Total	*548*	100.0%	*183*	100.0%

Table 8.12f. Specialty of Highest Engineering Degree for Control Systems Engineers

	Control Systems	
Specialty of Highest Engineering Degree	*N*	%
Chemical	*116*	14.2%
Civil	*16*	2.0%
Control Systems	*75*	9.2%
Electrical	*344*	42.2%
Mechanical	*172*	21.1%
Other	*62*	7.6%
Did not respond	*31*	3.8%
Total	*816*	100.0%

[a] Registered engineers only [b] Highest educational achievement [c] Choose all that apply

Table 8.13: Job Analysis Report Information on ABET Accredited Programs
Bachelor's degree from ABET accredited program

	Agricultural		Chemical*		Civil		Electrical		Industrial		Manufacturing		Mechanical		Metallurgical		Petroleum	
	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%	N	%
Missing	3	0.3%	1	0.4%	2	0.3%	118	6.5%			28	5.1%	56	3.3%			71	28.6%
Yes	851	89.9%	181	79.7%	538	76.9%	1546	85.7%	143	70.1%	356	65.0%	1514	88.3%	152	81.3%	148	59.7%
No	40	4.2%	5	2.2%	41	5.9%	41	2.3%	11	5.4%	40	7.3%	32	1.9%	11	5.9%	20	8.1%
DK	37	3.9%	38	16.7%	110	15.7%	99	5.5%	42	20.6%	100	18.3%	103	6.0%	24	12.8%	9	3.6%
No bachelor's degree	16	1.7%	2	0.9%	9	1.3%			8	3.9%	24	4.4%	8	0.5%				
Total	947	100.0%	227	99.9%	700	100.0%	1804	100.0%	204	100.0%	548	100.0%	1713	100.0%	187	100.0%	248	100.0%

* ECPD/ABET
No information in Control Systems, Geotechnical, Nuclear, Structural, or Traffic Engineering Job Analysis Reports

CHAPTER 9

DISCIPLINE TASK PROFILES

The National Council of Examiners for Engineering and Surveying (NCEES) oversees the design and administration of licensing exams in various engineering disciplines. Exams are updated periodically and are based on the surveys of practicing engineers regarding the frequency and/or importance of their job tasks. NCEES employs private consulting firms to design, administer and analyze these job analysis surveys. Reports typically summarize demographic and professional characteristics of the respondents and summary measures on the frequency and importance of each task. ISR obtained the job analysis data files for 6 disciplines (agricultural, electrical, mechanical, metallurgical, petroleum and structural) and printed reports for 9 disciplines (chemical, civil, control systems, geotechnical, industrial, manufacturing, nuclear, special civil and traffic) where the raw data was not available. In some cases the consulting firms considered the data proprietary and refused to make it available for analysis. NCEES does not maintain this raw data.

In ISR's judgment, a more detailed analysis of the job analysis data could be used to strengthen the exams and maintenance of succeeding analyses of a single discipline could be used to track changes in the field. The latter would be useful to engineering educators and to the professional organizations as well as those involved in exam preparation.

While these job analyses are designed for use in creating licensing exams, in this report the data provide a profile of the types of knowledges and activities that define each engineering discipline. The tables in this chapter highlight those items that are ranked as important or critical for each engineering discipline.

Job Analysis Data and Reports

Several different firms with differing approaches perform the analyses of the discipline specific tasks and knowledges that are used in the creation of licensing exams. Each of the practice and title act disciplines have been analyzed, except for nuclear engineering for which a comparable job analysis has not been performed due to the small number of examinees, and fire protection engineering for which the report was not complete at the time of this study. The results of these analyses are presented in the following tables. The job analyses that were made available for this analysis in the summer of 2001 varied in the following ways: 1) number and specificity of items, 2) items representing tasks, skills, and/or knowledges, 3) ratings of importance or of criticality, 4) and range of scales. Access to the data from these analyses also varied and when raw data was not provided, reliance on the way data is officially reported was necessary. Some reports did not include results for the whole sample, but instead reported results for subgroups. Most reports included mean scores, but some did not include standard deviations or other data that would allow standard deviations to be calculated.

The tables attempt to present the data in the most comparable form as is possible. Items with average ratings that exceed a critical threshold are included in the tables. The critical threshold is set by the job analysis report in most cases and it varies due to the differences in the scales used. For scales of 0 to 4, the cutoff is a score of 2.5, while with scales of 0 to 5 the cutoff is a score of 3.5. These are the midpoints between ratings of moderately important and very important in most cases (the language varies slightly among the job analyses). For two of the job analyses, special civil and traffic, the cutoff point is lowered to 3 on a 0 to 5 scale because there are so few items that reached the standard cutoff level.

Practice Act Disciplines

Civil engineering. The job analysis of civil engineering is a general survey with 50 items and low levels of specificity in which respondents were asked to rate each item's importance on a scale of 0 to 4. The job analysis instrument was created and administered by the National Council of Examiners for Engineering and Surveying (NCEES) in 1989. Table 9.1 identifies the tasks rated as important in this analysis. No variability data are available for this discipline. The items that are considered important are mostly general in nature, such as ability to communicate and knowledge of ethics. Several items in the structural area are also rated as important to the practice of civil engineering. Due to the structure of this survey, which asked the engineers to rank a relatively small number of items that are general in nature, the profile of civil engineering that emerges is limited. Table 9.2 lists the important items on the Special Civil engineering discipline analysis that informs the Special Civil engineering exam required of all civil engineers who are seeking licensure in California. This survey was developed and administered by CTB/McGraw Hill in 1997, and it asks respondents to rate the importance of 22 task and 109 knowledge items on a scale of 1 to 5, and items that are not at all important are not rated. The cut off point for inclusion in Table 9.2 was lowered to 3 because there were very few tasks and knowledges with average ratings of 3.5 or higher. This job analysis provides considerable detail that is specific to the practice of civil engineering. It is divided into the tasks and knowledges that are necessary for two components of civil engineering: engineering surveying and seismic principles.

There appears to be some relationship between the degree of importance and the amount of variability in the ratings of importance for a particular item. Those items that have the highest average importance ratings are more likely to be the items with the least variability. This indicates a high level of agreement among civil engineers that these tasks are very important to their occupation. Multiple items in the areas of engineering surveying field measurements, engineering surveying calculations, and engineering surveying office procedures have high importance ratings and low levels of variability. The items with the most variability are all seismic principles knowledge items, which are rated as important but not most important for the civil engineering profession.

Civil engineers must take additional exams if they wish to use the title of geotechnical or structural engineer, and detailed job surveys are administered to engineers in these disciplines. Table 9.3 illustrates the critical job tasks measured by the job analysis for geotechnical engineering. This job analysis was developed and administered by the Office of Examination Resources at the California Department of Consumer Affairs in 1994 and it asks respondents to rate how critical 68 task and 77 knowledge items are on a scale of 0 to 5. While many items are rated as critical, the most critical task and knowledge items are mostly in the areas of reconnaissance and project planning and analyses and development of conclusions and recommendations. Standard deviation measures are not available for this analysis, so the variability of the responses is not known.

The results for structural engineers are provided in Table 9.4. The Office of Examination Resources at the California Department of Consumer Affairs produced this analysis in 1997 and respondents were asked to rate the importance of 51 task and 108 knowledge items on a scale of 0 to 5. These results indicate that the most important job tasks and knowledges are in the areas of selection of structural systems, design of structural elements, and structural analysis procedures. The items with the highest importance ratings are, again, the items with the least variability.

Electrical engineering. The inquiry into the important knowledges associated with electrical engineering was produced by NCEES in conjunction with the Chauncey Group International in 2000. Respondents rate the importance of 58 breadth knowledge items on a scale of 0 to 4. Table 9.5 shows that the highest ranked items in this analysis are found in many categories, but the majority are in the area of electric circuits. The standard deviation scores indicate that the highest ranked items have the least variable responses while the lower rated items are more likely to have higher standard deviations, indicating lower levels of agreement about the importance of these items.

Mechanical engineering. A detailed study of mechanical engineering tasks and knowledges, developed and administered by NCEES in cooperation with the Chauncey Group International in 1999, provides an insight into the important requirements for this engineering discipline. Respondents were asked to rate the importance of 64 task and 75 knowledge items on a scale of 0 to 4. Table 9.6 shows that the area with the highest ranked items is general knowledge, such as relevant engineering terminology, fluid mechanics, heat transfer principles, and ethics. The most important items have the lowest standard deviation scores, as found in the other analyses, indicating a high level of agreement among mechanical engineers that these tasks and knowledges are important to their occupation.

Title Act Disciplines

Agricultural engineering. The job analysis for agricultural engineering, produced and administered by NCEES in conjunction with the Chauncey Group International in 2000, asks respondents to rate the importance of 68 task and 97 knowledge items on a scale of 0 to 4. Table 9.7 indicates that the most important items are in the areas of soil and water, structures and environment, and core tasks and knowledges. This analysis shows that agricultural engineers agree that a wide range of tasks and knowledges are important to their occupation.

Chemical engineering. The job analysis for chemical engineering is similar in design to the basic civil engineering analysis, and was also produced by the National Council of Examiners for Engineering and Surveying (NCEES) in 1989. The survey had 39 general items for the participating engineers to evaluate for importance on a scale of 0 to 4. Those items in Table 9.8 that ranked as most important were communication, chemistry, and mass and energy balances. No measures of variability were provided for these average importance scores, so level of agreement among respondents is unknown.

Control systems engineering. The University Research Corporation analyzed the activities and requirements of the control systems engineering profession for the Instrument Society of America and NCEES in 1991. Respondents for this study were asked to rate the importance of 240 items on a scale of 0 to 5. Table 9.9 shows that many activities and professional requirements are considered to be important by control systems engineers. The most important items are in the area of conceptual design and definition of controls systems, control strategies, and documentation. Standard deviations for the mean importance scores were not provided, so no conclusions regarding the variability of responses can be made.

Industrial engineering. The NCEES administered a job analysis for industrial engineers in 1989. As in the other analyses performed by NCEES, this study asked respondents to rate the importance of 43 general knowledges, skills, and abilities on a scale of 0 to 4. Table 9.10 indicates that most of the items rated as important are general, such as ethics, engineering economics, and communication, software, and statistics. The items that are more specific to industrial engineering and that rank most important are management principles and cost analysis. No standard deviation scores were provided for the mean importance ratings, so nothing can be concluded regarding the variability of the responses.

Manufacturing engineering. The Chauncey Group International with NCEES analyzed the knowledge areas associated with the manufacturing engineering profession in 1999. This job analysis was unique because it did not include items that the vast majority of manufacturing engineers agree are common or fundamental to their discipline. The instrument contained only items that were of questionable importance. The results in Table 9.11, therefore, may provide a partial profile of manufacturing engineering. Respondents were asked to rank the importance of 70 knowledge items on a scale of 0 to 4. Table 9.11 indicates that the items ranked as important for manufacturing engineering are in the areas of product/process design and materials application, manufacturing process applications and operation, production system and equipment design, and quality. The two items ranking most important also had the lowest standard deviation scores, indicating a high level of agreement that these are indeed important knowledges for the manufacturing engineering profession.

Metallurgical engineering. The Chauncey Group International with NCEES also performed the study of metallurgical engineering in 2000. Respondents were asked to rate the importance of 133 knowledges using a scale of 0 to 4. The important knowledge areas indicated in Table 9.12 include general knowledge, extractive metallurgy, physical metallurgy, mechanical metallurgy, and materials. Only a few items are rated as most important and they are in the general knowledge and material testing areas. There is not a strong relationship between the variability of the responses and the importance ratings in this analysis, which may indicate that the importance of particular tasks varies by job setting or some other factor.

Petroleum engineering. Petroleum engineering was studied by the Chauncey Group International with NCEES in 1999. Table 9.13 indicates that petroleum engineers rate many of the 25 task and 65 knowledge items as important on a scale of 0 to 4. The areas with the most items of importance are common knowledges, drilling, completion, production and facilities, reservoir, and formation evaluation. The highest rated items are more likely to have the lowest standard deviation scores, indicating higher levels of agreement in respondents' ratings.

Traffic engineering. The traffic engineering job analysis was developed and administered by the Office of Examination Resources at the California Department of Consumer Affairs in 1999 and it asks respondents to rate how important 66 task and 102 knowledge items are on a scale of 0 to 5. The cut off point for inclusion in Table 9.14 was lowered to 3 because there were very few tasks and knowledges with average ratings of 3.5 or higher. Table 9.14 shows that several task and knowledge items are rated as important by respondents. The most important items are mostly in the knowledge areas of circulation, trip generation, parking and land use and traffic controls. The report did not provide any standard deviation data.

Summary

The job analyses vary considerably by discipline, but each study provides a source for understanding the important tasks, skills, and knowledges that are important for that profession. The variability of ratings is generally greater for those items that have a lower average rating, indicating a general lack of agreement about less important items among practitioners of the occupation, while the highest rated items often had the least variability indicating high levels of agreement about more important ones. Each table provides a profile of a licensed engineering discipline in California.

Comparability between disciplines is limited by variations in the goals, methodologies, and analytical techniques used by the separate disciplines in the design of their job analysis survey. Some disciplines provide a very brief and general description of important tasks and knowledges in their discipline, while others seek to provide a more extensive and detailed description of their field. Most focus on the most common tasks performed by practitioners in their discipline; one discipline (manufacturing) omits the more common tasks and focuses on less widely shared tasks in newly developing or unusual applications of the discipline. The surveys themselves vary in the number and specificity of items, in the scale used and in the type of rating requested (for example, importance or criticality). They also differ in the measurement of educational background and job experience and in whether unlicensed engineers are included in the sample. Published reports on the results vary in the descriptive statistics used and in how the sample is grouped for analysis. Some describe the sample as a whole while others describe only subgroups within the sample. No effort is made to profile the variations in tasks in different job settings or by engineers with different levels of experience. Thus, these differences in approach undermine the usefulness of the job analyses for the measurement of overlap between engineering disciplines.

Table 9.1. Items Rated Important on the Civil Engineering Occupation Analysis

			Importance Score (0-4)	Score, Most Important (3 or Higher)	S. D. Most Variable NA*	S.D. Least Variable NA*
A. Ethics	1)	Canon of Ethics of Professional or Technical Society	2.6			
	2)	Rules of Professional Conduct of State Registration Board	2.7			
B. Engineering Economics	1)	Engineering Economics	2.5			
C. Communication	1)	Oral Communications	3.4	3.4		
	2)	Written Communications	3.4	3.4		
	3)	Drawing and Graphics	3.1	3.1		
D. Physical and Engineering Sciences	1)	Statics	2.8			
E. Computer Science	1)	Software	2.5			
F. Codes and Standards	1)	Codes and Standards	3.1	3.1		
G. Structural	1)	Loadings	2.9			
	2)	Structural Analysis	3.0	3.0		
	3)	Member Design	2.9			
	4)	Construction Techniques/Equipment/Materials	2.8			

*Standard deviation data not provided.

Table 9. 2. Items Rated Important on the Special Civil Engineering Occupation Analysis

Engineering Surveying Tasks		Importance Score (1-5)*	Score, Most Important (3.5 or higher)	S.D., Most Variable NA**	S.D., Least Variable NA**
A. Engineering Surveying Equipment and Field Calculations	1) Recognize the Purposes of Different Types of Surveys	3.22			
	2) Practice within the Laws Regulating Engineering Surveying........	3.18			
	3) Recognize Common Construction Surveying Methods and Procedures	3.28			
B. Engineering Surveying Field Measurements	1) Perform the Measurement of Horizontal Distances............	3.13			
	2) Perform the Measurement of Elevations from Leveling.......	3.16			
C. Engineering Surveying Calculations	1) Perform Basic Geometric and Trigonometric Calculations..	3.84	3.84		
	2) Determine the Properties of a Horizontal Curve..................	3.26			
	3) Determine the Properties of a Vertical Curve......................	3.22			
	4) Perform Leveling Calculations from Field Data to Determine Elevations........	3.18			
	5) Perform Rectangular Coordinate System Calculations	3.17			
	6) Perform Calculations to Determine Quantities of Construction Materials	3.57	3.57		
D. Engineering Surveying Office Procedures	1) Recognize Information from Legal Boundary and Easement Data Pertinent to Engineering Surveying Projects	3.28			
	2) Recognize the Use of Datums for Horizontal and Vertical Control........	3.38			
	3) Prepare Topographic And Planimetric Maps.......................	3.16			
	4) Interpret Existing Maps	3.78	3.78		
Engineering Surveying Knowledges		**Importance Score (1-5)***	**Score, Most Important (3.5 or higher)**	**S.D., Most Variable**	**S.D., Least Variable**
A. Engineering Surveying Equipment and Field Activities	1) General Methods and Procedures of Control Surveys	3.09			1.11
	2) General Methods and Procedures of Construction Surveys	3.25			1.08
	3) General Methods and Procedures of Topographic Surveys	3.24			1.09
	4) Accuracy of Measurements Made with Survey Equipment .	3.09			
	5) Scope of Practice of Engineering Surveying as Defined by the Professional Engineers Act and the Scope of Practice of Land Surveying as defined by the Professional Land Surveyors Act	3.20			
	6) Construction Layout Requirements to Enable the Contractor to Construct the Project....................................	3.43			
	7) Horizontal Curve Layout	3.21			
	8) Horizontal and Vertical Curve Layout.................................	3.30			
	9) Line and Grade Layout	3.38			
	10) Potential Conflicts with Underground Utilities......................	3.80	3.80		
	11) Location, Orientation, and Terminology for Construction Staking	3.26			
	12) Offset Distance Computations	3.13			
	13) Roadway Layout..	3.18			
B. Engineering Surveying Field Measurements	1) Definitions of Leveling Terminology	3.36			
	2) Procedure for Sighting the Telescope and Reading the Rod........	3.01			

*Importance scores of 3 or higher used as cutoff; not comparable to other tables.

** Standard deviation data not provided for task items.

Table 9. 2. (continued) Items Rated Important on the Special Civil Engineering Occupation Analysis

Engineering Surveying Knowledges		Importance Score (1-5)*	Score, Most Important (3.5 or higher)	S.D., Most Variable	S.D., Least Variable
C. Engineering Surveying Calculations	1) Properties of a Right Triangle	3.82	3.82		1.08
	2) General Trigonometric Formulas	3.80	3.80		1.08
	3) Properties of an Oblique Triangle	3.47			
	4) Trigonometric Relationships to Determine the Area of a Polygon	3.30			
	5) Geometric Properties and Equations of a Circular Curve	3.27			
	6) Circular Curve Deflections	3.01			
	7) Procedure for Locating a Point on a Curve	3.10			
	8) Procedure for Calculating Stations for the Point of Intersection, Beginning of Curve, and End of Curve	3.29			
	9) Procedure for Calculating the Intersection of a Curve and a Straight Line	3.08			
	10) Geometric Properties and Equations of a Parabola	3.00			
	11) Procedure for Calculating a Vertical Curve	3.20			
	12) Procedure for Calculating Vertical Curves from Tangent Offsets of Grade Lines	3.03			
	13) Procedure for Calculating Intermediate Points	3.03			
	14) Procedure for Calculating the Highest or Lowest Point	3.15			
	15) Procedure for Calculating the Rate of Gradient	3.08			
	16) Procedure for Calculating Profile Grade and Elevations on the Tangents	3.17			
	17) Procedures for Calculating Distances from Coordinates	3.27			
	18) Procedures for Calculating Bearings or Azimuths from Coordinates	3.17			
	19) Coordinate Geometry Relationships	3.18			
	20) Procedures for Calculating an Area from Rectangular Coordinates	3.13			
	21) Methods for Calculating Volumes of Materials	3.64	3.64		1.09
	22) Procedures for Calculating Volume by Average-End-Area Method Including Using Cross-Sections	3.47			
	23) Procedures for Calculating Volume by Prismoidal Method	3.04			
D. Engineering Surveying Office Procedures	1) Procedure for Plotting Profiles	3.07			
	2) Procedure for Plotting Cross-Sections	3.10			
	3) Procedure for Plotting Field Points and Data	3.06			
	4) Applications of Stationing	3.29			
	5) Relationship Between Grade Lines and Cross-Sections	3.25			
	6) Standard Formats and Terminology of Legal Descriptions	3.06			
	7) Purpose of Control Monuments	3.18			
	8) Different Types of Horizontal Datums	3.09			
	9) Different Types of Vertical Datums	3.14			
	10) Purposes and Types of Bench Mark Systems	3.20			
	11) Contour Intervals	3.48			1.09
	12) Methods to Plot Contours from Field Information	3.20			
	13) Methods for Interpolating Contours	3.32			1.12
	14) Map Scales	3.88	3.88		1.04
	15) Common Conventions of Map Orientation	3.69	3.69		1.04

*Importance scores of 3 or higher used as cutoff; not comparable to other tables.

** Standard deviation data not provided for task items.

Table 9. 2. (continued) Items Rated Important on the Special Civil Engineering Occupation Analysis

Engineering Surveying Knowledges		Importance Score (1-5)*	Score, Most Important (3.5 or higher)	S.D., Most Variable	S.D., Least Variable
D. Engineering Surveying Office Procedures	16) Standard Map Symbols	3.55	3.55		1.04
	17) Characteristics and Purposes of Different Types of Maps	3.74	3.74		1.04
	18) Purpose of Geographic Information System (GIS)	3.04			1.08

Seismic Principles Tasks		Importance Score (1-5)*	Score, Most Important (3.5 or higher)	S.D., Most Variable NA**	S.D., Least Variable NA**
A. Seismic Data and Seismic Design Criteria	1) Understand Earthquake Data that Influence Design of Projects	3.58	3.58		
	2) Understand Geotechnical Issues that May Influence Design of Projects	3.74	3.74		
	3) Recognize Design Performance Goals for a Project	3.56	3.56		
	4) Recognize Laws, Codes, and Standards Governing Seismic Design	3.64	3.64		
B. Seismic Characteristics of Engineered Systems	1) Determine Appropriate Seismic Resisting Structural System	3.36			
	2) Recognize Seismic Performance and Damage Vulnerability of Structures	3.28			
	3) Understand Methods for Seismic Strengthening of Existing Structures	3.25			
	4) Recognize the Requirements for Lifelines	3.08			
	5) Understand Requirements for Earth Structures	3.20			
C. Seismic Forces	1) Determine Structural Characteristics Required to Calculate Seismic Design Forces	3.31			
	2) Determine UCB Seismic Design Forces for Buildings	3.22			
	3) Determine Seismic Forces for Elements of Structures, Non-Structural Components, and Equipment	3.04			
D. Seismic Analysis Procedures	1) Determine the Distribution of Forces to Structural Elements Based on Their Rigidities	3.10			
E. Seismic Design	1) Understand the Detailing Requirements that are Critical for Seismic Performance	3.31			
	2) Recognize the Need for Construction Quality Monitoring and Inspection of the Seismic Design Aspects of the Project	3.42			

Seismic Principles Knowledges		Importance Score (1-5)*	Score, Most Important (3.5 or higher)	S.D., Most Variable	S.D., Least Variable
A. Seismic Data and Seismic Design Criteria	1) Earthquake Accelerographs, Response Spectra, and Ground Acceleration	3.05			
	2) Geologic Seismic Hazards and Geotechnical Data That Affect Design, Including Liquefaction, Slope Stability, Settlement, and Faulting	3.73	3.73		1.12
	3) UBC Site Coefficient	3.20			
	4) Soil Structure Interaction, Including the Effective Natural Period of the Structure and the Expected Period of the Seismic Ground Motion	3.16			
	5) Lateral Seismic Earth Pressure on Retaining Structures	3.41			
	6) Seismic Design Philosophy of the UBC	3.16			
	7) Seismic Performance Levels such as Life Safety, Operational, Fully Functional	3.33			
	8) Practice Law, Responsible Charge Criteria, Practice Within Area of Competency	3.38			
	9) The UBC and the California Building Coded for New Construction	3.42			

*Importance scores of 3 or higher used as cutoff; not comparable to other tables.

** Standard deviation data not provided for task items.

Table 9. 2. (continued) Items Rated Important on the Special Civil Engineering Occupation Analysis

Seismic Principles Knowledges		Importance Score (1-5)*	Score, Most Important (3.5 or higher)	S.D., Most Variable	S.D., Least Variable
B. Seismic Characteristics of Engineered Systems	1) Different Structural Systems and Their Design Parameters	3.21			
	2) Performance Characteristics of Different Structural Systems	3.19			
	3) Effects of Ductility, Damping, Redistribution, and Redundancy on Seismic Performance	3.00			
	4) Types of Construction with Poor Seismic Performance	3.30			
	5) Effects of Overstress on Seismic Structural Components or Systems	3.01			
	6) Methods and Effects of Adding Overall Strength	3.07			
	7) Methods and Effects of Strengthening Weak-Links in Structural Systems	3.06			
	8) Earthquake Design Requirements for Power, Communications, Natural Gas, Liquid Fuels, Water, and Sewage Systems	3.03			
	9) Seismic Loading for Retaining Structures and Tunnels	3.15			
	10) Seismic Requirements for Landfills, Cuts and Fills, Engineered Grading, etc.	3.06			
C. Seismic Forces	1) Mass and Stiffness	3.12		1.41	
	2) UBC Static Force Procedures	3.14		1.46	
	3) Choice and Application of RW Factor	3.05		1.48	
	4) UBC Design Base Shear Using Z, I, C, W, S, T, and Rw Factors	3.19		1.50	
	5) Vertical Distribution of the UBC Forces	3.06		1.48	
	6) UBC Static Force Determination Procedures	3.01		1.43	
D. Seismic Analysis Procedures	1) Methods Used to Calculate Rigidities of Structural Elements, Including the Effects of Fixed, Pinned, or Semi-Rigid Member End Conditions	3.05		1.45	
	2) Distribution of Seismic Forces Based on Rigidity	3.06		1.46	
	3) Diaphragm Chord Forces, Drag Forces, and Diaphragm Shear	3.06		1.49	
	4) Methods to Distribute Shear Forces to Structural Elements	3.05		1.48	
E. Seismic Design	1) Seismic Detailing and Inherent Seismic Performance Characteristics for Steel	3.11		1.46	
	2) Seismic Detailing and Inherent Seismic Performance Characteristics for Concrete	3.19		1.45	
	3) Requirements for Horizontal and Vertical Seismic Forces	3.22		1.43	
	4) Requirements for Ties and Continuity, Collectors or Drags	3.02		1.46	
	5) Requirements for Anchorage of Concrete and Masonry Walls	3.21		1.46	
	6) Construction Materials	3.39			
	7) Construction Requirements for the Placement of Materials for the Lateral Load Resisting Elements	3.24			
	8) Testing, Special Inspection, and Structural Observation Requirements	3.19			

*Importance scores of 3 or higher used as cutoff; not comparable to other tables.

** Standard deviation data not provided for task items.

Table 9.3. Items Rated Critical on the Geotechnical Engineering Occupation Analysis

Tasks		Criticality Score (0-5)	Score, Most Critical (4 or higher)	S.D., Most Variable NA*	S.D., Least Variable NA*
A. Reconnaissance and Project Planning	1) Identify Potential Geotechnical Issues That May Influence Design of the Proposed Project	4.38	4.38		
	2) Determine Scope of Project Based on Client's Site Development Plans and Special Regulatory Requirements	4.11	4.11		
	3) Formulate Proposal or Work Plan for Field Exploration, Laboratory Testing, Analyses, or Preparation of Geotechnical Recommendations for the Proposed Project	4.02	4.02		
	4) Gather Relevant Data about Subsurface conditions at the Site by Reviewing Available Site Information	3.85			
	5) Identify Project Parameters Based on Discussion with Design Team and Consideration of Proposed Type of Structure, Structure Size, Site Used, Loading Conditions, and Site Grading	3.94			
B. Field Exploration	1) Determine Adequacy of Field Exploration Program for Proposed Project by Assessing Results of Field Exploration Program	3.92			
	2) Perform Subsurface Exploration and Sampling to Evaluate Subsurface Strata and Groundwater Conditions	4.02	4.02		
	3) Prepare Logs of Explorations to Include Field Descriptions of Soils, Details of Exploration and Sampling Operations, and Groundwater Conditions	3.57			
C. Laboratory Testing	1) Determine Shear Strength Parameters from Results of Laboratory Strength Testing	3.95			
	2) Determine Engineering Properties of Soil by Evaluating Results of Soil Classification Tests	3.69			
	3) Determine Soil Compressibility Parameters from Results of Laboratory Consolidation Testing	3.87			
	4) Classify Soil from Results of Laboratory Testing	3.58			
	5) Determine Expansion Characteristics of Soil From Results of Laboratory Expansion Testing	3.69			
D. Analyses and Development of Conclusions and Recommendations	1) Formulate Recommendations Regarding Slope Stability Based on Project Requirements, Analyses Performed, and Field and Laboratory Data	4.28	4.28		
	2) Formulate Recommendations for Shallow Foundation Design Based on Project Requirements, Analyses Performed, and Field and Laboratory Data	4.05	4.05		
	3) Formulate Recommendations for Site Grading Based on Project Requirements, Analyses Performed, and Field and Laboratory Data	3.87			
	4) Formulate Recommendations Regarding Site Settlement or Collapse Potential Based on Project Requirements, Analyses Performed, and Field and Laboratory Data	4.13	4.13		
	5) Formulate Recommendations for Earth Retention Systems Based on Project Requirements, Analyses Performed, and Field and Laboratory Data	3.90			
	6) Formulate Recommendations for Deep Foundation Design Based on Project Requirements, Analyses Performed, and Field and Laboratory Data	4.00	4.00		
	7) Formulate Recommendations Regarding Soil Expansion or Swell Potential Based on Project Requirements, Analyses Performed, and Field and Laboratory Data	3.78			
	8) Determine Risk and Safety Factors in Preparation of Design Recommendations	3.64			
	9) Formulate Recommendations for Liquefaction Based on Project Requirements, Analyses Performed, and Field and Laboratory Data	3.72			

* Standard deviation data not provided

Table 9.3. (continued) Items Rated Critical on the Geotechnical Engineering Occupation Analysis

Tasks		Criticality Score (0-5)	Score, Most Critical (4 or higher)	S.D., Most Variable NA*	S.D., Least Variable NA*
D. Analyses and Development of Conclusions and Recommendations	10) Formulate Recommendations for Subdrain Systems Based on Project Requirements, Analyses Performed, and Field and Laboratory Tests	3.54			
	11) Formulate Recommendations Regarding Temporary Excavations and Shoring Based on Project Requirements, Analyses Performed, and Field and Laboratory Data	3.54			
	12) Formulate Recommendations Regarding Ground Improvement or Ground Modification Based on Project Requirements, Analyses Performed, and Field and Laboratory Data	3.58			
	13) Develop Remedial Recommendations based on Analysis of Post-Construction Distress	3.57			
E. Report Preparation/Documentation	1) Document Recommendations Based on Geotechnical Findings and Conclusions in a Formal Written Report	4.47	4.47		
	2) Document Conclusions Based on Geotechnical Findings in a Formal Written Report	4.37	4.37		
	3) Describe Project Scope and Purpose of Work in a Formal Written Report	3.86			
	4) Describe Results of Document Review, Reconnaissance, Field Exploration, Laboratory Testing, and Analyses in a Formal Written Report	3.98			
	5) Describe Site Plan, Logs of Filed Exploration, Soil Profiles/Cross-Sections, and Laboratory Test Data in a Formal Written Report	3.75			
	6) Document Limitations of the Findings of the Geotechnical Investigation in a Formal Written Report	3.67			
	7) Describe Guideline Specifications for Geotechnical Aspects of the Proposed Project Based on Geotechnical Findings in a Formal Written Report	3.54			
F. Document Review, Construction Monitoring, and Post-Construction Observation	1) Assess Compliance with Geotechnical Recommendations by Reviewing Plans and Specifications	4.06	4.06		
	2) Assess Compliance with Geotechnical Aspects of Specifications by Observing and Testing Construction Activities	3.92			

Knowledges		Criticality Score (0-5)	Score, Most Critical (4 or higher)	S.D., Most Variable NA*	S.D., Least Variable NA*
A. Reconnaissance and Project Planning	1) Current “Standard of Care” for Geotechnical Investigations	4.04	4.04		
	2) Methodologies to Gather information Relevant to Site and Project Plan	4.00	4.00		
	3) Methodologies to Develop a Scope of Work for Geotechnical Investigation	4.00	4.00		
	4) Geotechnical Engineering Principles that Affect Geotechnical Planning	4.00	4.00		
	5) Techniques to Review and Interpret Existing Data for the Site	4.00	4.00		
	6) Geotechnical Requirements for Different Types of Construction	3.99			
	7) Effects of Local Geologic Hazards on Project Planning	3.93			
	8) Exploration Methodologies that Affect Project Work Plan	3.62			
B. Field Exploration	1) Field Exploration Methods to Evaluate Subsurface Conditions	4.15	4.15		
	2) Conditions that Affect Geotechnical Field Sampling Techniques	3.97			
	3) Field Methods to Document Site Conditions and Log Subsurface Conditions	3.92			
	4) Methodologies to Evaluate Soil Behavior in Field Investigations	3.83			

* Standard deviation data not provided

Table 9.3. (continued) Items Rated Critical on the Geotechnical Engineering Occupation Analysis

Knowledges		Criticality Score (0-5)	Score, Most Critical (4 or higher)	S.D., Most Variable NA*	S.D., Least Variable NA*
B. Field Exploration	5) Purposes for Different Field Sampling Techniques	3.81			
	6) Factors That May Alter the Work Plan During Field Investigation	3.80			
	7) Factors That Influence the Validity of In Situ Test Results	3.76			
	8) Different Types of Field Sampling Techniques	3.73			
C. Laboratory Testing Program	1) Procedures to Obtain Shear Strength Parameters from the Results of Laboratory Testing	3.92			
	2) Laboratory Tests to Classify Soil	3.89			
	3) Laboratory Tests that may Alter Work Plan	3.58			
D. Analysis and Development of Conclusions and Recommendations	1) Impact of Geotechnical Recommendations on Proposed Construction	4.43	4.43		
	2) Techniques to Characterize the Engineering Properties of the Subsurface Strata by Integration of Field and Laboratory Data	4.20	4.20		
	3) Impact of Results from the Static Slope Stability Analyses on Proposed Site Uses	4.11	4.11		
	4) Impact of Results from the Consolidation Settlement Analysis on Proposed Site Uses	4.03	4.03		
	5) Procedures to Determine if Field and Laboratory Data are Within Geotechnical Limits	3.99			
	6) Process for Evaluating Feasibility of Alternate Solutions in Geotechnical Investigations	3.99			
	7) Impact of Results from the Liquefaction Analysis on Proposed Site Uses	3.90			
	8) Impact of Results from the Distortion/Deformation Settlement Analysis on Proposed Site Uses	3.85			
	9) Impact of Results form the Analyses of Bearing capacity of Shallow Foundations on Proposed Site Uses	3.77			
	10) Impact of Results from the Soil Expansion Analysis on Proposed Site Uses	3.76			
	11) Impact of Results from the Analyses to Evaluate Suitability of fill Materials on Proposed Site Uses	3.71			
	12) Impact of Results from the Analyses of Axial Capacity of Deep Foundations on Proposed Site Uses	3.62			
	13) Impact of Results from the Static Lateral Earth Pressures Analysis on Proposed Site Uses	3.62			
	14) Effects of Regulatory Requirements on Formulation of Recommendations and Specifications	3.57			
	15) Procedures to Determine Risk and Safety Factors for Incorporation into Design Recommendations	3.55			
	16) Methods to Evaluate Post-Construction Distress	3.53			
	17) Methods to Evaluate Geologic Hazards On Site Based On Field and Laboratory Data	3.53			
E. Report Preparation/Documentation	1) Major Components of Geotechnical Investigation Reports	4.14	4.14		
	2) Limitations of the Geotechnical Investigation	4.06	4.06		
	3) Major Elements of File and Laboratory Documentation	3.79			
F. Document Review, Construction Monitoring, and Post-construction Monitoring	1) Factors to Consider When Reviewing Plans and Specification for Geotechnical Issues	4.17	4.17		
	2) Techniques to Remedy Unanticipated Geotechnical Conditions Encountered During Construction	4.08	4.08		
	3) Methods to Verify that Project Construction Conforms to Geotechnical Plans and Specifications	3.98			
	4) Methods to Interpret Observations and instrumentation Data During Construction	3.64			
	5) Required Components to Document Construction and Post-Construction Observations and Monitoring	3.56			

* Standard deviation data not provided.

Table 9.4. Items Rated Important on the Structural Engineering Occupation Analysis

Tasks		Importance Score (0-5)	Score, Most Important (4 or higher)	S.D., Most Variable	S.D., Least Variable
A. Determination of Design Criteria Based on Site Conditions	1) Analyze Site Specific Design Criteria and Design Codes to Identify Loads on the Structure	3.87			
	2) Determine Foundation and Structural Design Requirements Based on Information in Geotechnical Reports	3.95			
B. Selection of Structural Systems	1) Determine Project Specific Criteria by Using Applicable Codes	3.94			
	2) Select Economically Feasible Structural System	3.52			
	3) Select the Structural System to Meet Wind and Seismic Performance Requirements	4.33	4.33		
C. Determination of Forces and Analysis of Structures	1) Determine Dead and Live Loads for Structural Systems from Plans	4.21	4.21		
	2) Determine Forces Due to Wind	3.89			
	3) Determine Forces Due to Earth and Hydrostatic Pressures	3.71			
	4) Determine Governing Load Combinations for Design of Structure	4.22	4.22		
	5) Analyze Lateral Force Resisting System to Determine Deflections and Member Forces	4.23	4.23		
	6) Perform Seismic Analysis using Static Procedures	4.31	4.31		.96
	7) Determine Forces, Stresses, and Deflections of Horizontal Diaphragms	3.65			
	8) Verify Accuracy of Computer-Generated Output by Hand Calculations	3.72			
D. Design of Structural Elements	1) Design Structural Elements and Connections Using Steel	3.94			
	2) Design Structural Elements and Connections Using Concrete	3.96			
	3) Design Structural Elements and Connections using Wood	3.67		1.47	
	4) Design Structural Elements and Connections using Masonry	3.53		1.42	
	5) Design Structural Elements and Connections to meet Special Seismic Requirements	4.09	4.09		
	6) Design Horizontal Diaphragm Members and Their Connection Details	3.86			
	7) Design Connections Between Structural Elements and Foundation	4.09	4.09		
	8) Design Foundation Systems	4.00	4.00		
E. Construction Documents	1) Provide Member Sizes, Dimensions and Details to Prepare Structural Drawings for Construction	4.15	4.15		
	2) Prepare Seismic Force Resisting System Details for Structural Drawings	4.27	4.27		
	3) Prepare Specifications, and Testing and Inspection Requirements for Structural Systems to Satisfy Design Criteria	3.59		1.41	
F. Construction Administration	1) Review Shop Drawings and Submittals for Complex Details or Changes to Ensure Compliance with Design Criteria	3.69			
	2) Resolve Structural Issues that Occur During Construction	4.16	4.16		
G. Investigation, Evaluation, Retrofitting, and Renovation	1) Prepare Construction Documents for Structural Upgrades/Retrofit to Improve Performance of the Structure	3.50		1.45	

Table 9.4. (continued) Items Rated Important on the Structural Engineering Occupation Analysis

Knowledges		Importance Score (0-5)	Score, Most Important (4 or higher)	S.D., Most Variable	S.D., Least Variable
A. Determination of Design Based on Site Conditions	1) Effect of Wind and Seismic Factors on Design of Structural Systems	4.53	4.53		.86
	2) Effect of Jurisdiction on Applicable Building Codes and Design Requirements	3.55			
B. Selection of Structural Systems	1) Code Requirements Pertaining to the Configuration of a Structural System to Resist Effects of Horizontal Torsional Moments	3.51			
	2) Code Requirements Pertaining to Design of a Structural System to Resist Effects of Lateral Forces	4.46	4.46		.88
	3) Code Requirements Pertaining to Minimum Uniform and Concentrated Dead and Live Floor Loads to Consider in Floor Design	3.92			
	4) Code Requirements Pertaining to Minimum Uniform and Concentrated Dead and Live Roof Loads to Consider in Roof Design	3.86			
	5) Code Requirements Pertaining to Criteria for Allowable Deflection of Structural Members	3.72			
	6) Design and Performance of Reinforced Concrete Structures	3.91			
	7) Design and Performance of Structural Steel Structures	4.14	4.14		.99
	8) Design and Performance of Timber Structures	3.69		1.47	
	9) Structural Behavior Under Seismic Loads	4.50	4.50		.86
C. Structural Analysis Procedures	1) Code-Prescribed Static Lateral Force Analysis Procedures to Determine Design Base Shear	4.36	4.36		
	2) Effect of Wind Loads on Structural Design	4.05	4.05		
	3) Code-Prescribed Static Lateral Force Analysis Procedures to Determine Vertical Distribution of Seismic Forces	4.12	4.12		
	4) Code-Prescribed Static Lateral Force Analysis Procedures to Determine Limitations of Story Drift	3.78			
	5) Techniques to Interpret Computer-Generated Structural Analysis Output	3.69			
	6) Non-Computer Methods to Verify Accuracy of Computer-Generated Structural Analysis Output	3.66			
	7) Code Prescribed Procedures to Analyze Diaphragms	3.63			
D. Design of Structural Elements	1) Standards for Material Properties and Specifications	3.63			
	2) Code Requirements Pertaining to Working Stress Design to Accommodate Different Load Combinations	3.82			
	3) Code Requirements Pertaining to Load Factors and Load Combinations for Strength Design in Concrete Construction	4.01	4.01		
	4) Code Requirements Pertaining to Anchorage of a Structural System to Resist Uplift and Sliding Forces	3.99			
	5) Code Requirements Pertaining to Discontinuous Lateral Force Resisting Elements	3.55			
	6) Design Procedures for Steel Moment Frames	3.76			
	7) Design Procedures for Steel Moment Connections	3.86			
	8) Design Procedures for Steel Baseplates	3.54			
	9) Design Procedures for Steel Columns	3.80			
	10) Design Procedures for Steel Beam-Columns	3.73			
	11) Design Procedures for Steel Beams	3.93			
	12) Design Procedures for Steel Bracing	3.78			
	13) Design Procedures for Simple, Rigid, Welded, and Bolted Connections	3.93			
	14) Design Procedures for Concrete Foundations	3.96			
	15) Design Procedures for Concrete Flexural Members	3.82			

Table 9.4. (continued) Items Rated Important on the Structural Engineering Occupation Analysis

Knowledges		Importance Score (0-5)	Score, Most Important (4 or higher)	S.D., Most Variable	S.D., Least Variable
D. Design of Structural Elements	16) Design Procedures for Concrete Compression Members ...	3.75			
	17) Design Procedures for Concrete Flexural-Compression Members ...	3.68			
	18) Design Procedures for Concrete Shear Walls ...	3.77			
	19) Standards for Concrete Reinforcing Bar Details ...	3.76			
	20) Design Procedures for Plywood Diaphragms ...	3.63		1.47	
	21) Design Procedures for Wood Shear Walls ...	3.63		1.51	
	22) Design Procedures for Bolted, Nailed Connections in Wood Design ...	3.63		1.45	
E. Investigation, Evaluation, Retrofitting, and Renovation	1) Different Types of Strengthening Systems to Improve Structural Capacity ...	3.51			

Table 9.5. Items Rated Important on the Electrical Engineering Occupation Analysis

		Importance Score (0-4)	Score, Most Important (3 or higher)	S.D., Most Variable	S.D., Least Variable
A. Professionalism and Engineering Economics	1) Engineering Economics	2.87			
	2) Ethics	3.48	3.48		.79
	3) Professional Practice	2.92			
B. Management and Instrumentation	1) Analog to Digital/Digital to Analog Conversion	2.50			
	2) Grounding	3.24	3.24		.86
C. Electric Circuits	1) Ohm's Law	3.79	3.79		.52
	2) Coulomb's Law	3.12	3.12		
	3) Faraday's Law	3.13	3.13		
	4) Kirchhoff's Laws, Current Law/Nodal Analysis	3.43	3.43		.84
	5) Kirchhoff's Laws, Voltage Law/Mesh Analysis	3.40	3.40		.85
	6) Thevenin's Theorem	3.12	3.12		
	7) Norton's Theorem	3.01	3.01		
	8) Superposition	2.93			
	9) Source Transformation	2.69		1.09	
	10) Dependent Sources	2.54		1.11	
	11) Sinusoidal Steady State Analysis, Phasor Transforms	2.95			
	12) Sinusoidal Steady State Analysis, Diagrams	2.98			
	13) Sinusoidal Steady State Analysis, Operators	2.79			
	14) Sinusoidal Steady State Analysis, Power and Energy Calculations	3.42	3.42		.85
	15) Transient Analysis	2.86			
	16) Fourier Analysis	2.54		1.10	
	17) Transfer Functions	2.54		1.11	
	18) Complex Impedence	3.02	3.02		
	19) Laplace Transforms	2.51		1.12	
	20) Mutual Inductance	2.76			
D. Electronics, Electronic Circuits and Components	1) Solid State Device Characteristics and Ratings	2.56			
E. Electrical and Electronic Materials	1) Conductivity/Resisitivity	3.10	3.10		.87
	2) Thermal Characteristics	2.82			
	3) Electric Shock and Burns	2.89			
	4) General Public Safety	3.29	3.29		
	5) Semiconductors	2.53			
F. Electric and Magnetic Field Theory and Applications	1) Electrostatic Effects	2.51			
G. Computer Systems and Engineering	1) Logic Functions	2.62		1.10	
H. Control Systems	1) Feedback System Stability	2.58		1.08	
	2) Frequency Response	2.59			
I. Rotating Machines and Electromagnetic Devices	1) AC and DC Machines	2.97			
	2) Transformers	3.18	3.18		
J. Communications and Signal Processing	1) Signal to Noise Ratio	2.54		1.10	
K. Transmission and Distribution	1) Voltage Regulation	3.08	3.08		
	2) Power Factor Correction	3.06	3.06		

Table 9.6: Items Rated Important on the Mechanical Engineering Occupation Analysis

			Importance Score (0-4)	Score, Most Important (3 or higher)	S.D. Most Variable	S.D. Least Variable
A. Machine Design and Materials Tasks	1)	Select Pressure Vessels	2.56			
	2)	Select Mechanisms (e.g., linkages, gears, cams, bearings, etc)	2.50			
	3)	Design or Analyze Structures and Frames	2.64		1.12	
B. Hydraulics and Fluids Tasks	1)	Select Fans	2.71			
	2)	Design or Analyze Pumps	2.60			
	3)	Select Pumps	3.05	3.05		
	4)	Design or Analyze Piping Systems	3.07	3.07		
	5)	Design or Analyze Duct Systems	2.75			
	6)	Design of Analyze Hydraulic Components	2.52			
	7)	Select Hydraulic Components	2.83			
	8)	Select Pneumatic Components	2.56			
	9)	Select Air Compressors or Air System Accessories	2.53			
C. Energy Conversion/ Power Systems Tasks	1)	Select Power System Components	2.54		1.10	
D. HVAC and Refrigeration	1)	Design or Analyze HVAC Systems	2.61		1.13	
	2)	Select HVAC Systems	2.70		1.10	
	3)	Select HVAC Components	2.65		1.10	
	4)	Select Refrigeration Components	2.53		1.11	
	5)	Calculate Heating and Cooling Loads	3.09	3.09		
	6)	Calculate Refrigeration Loads	2.82		1.11	
	7)	Estimate Energy Usage	2.91			
E. Fire Protection Tasks	1)	Perform Hydraulic Calculations	2.57		1.18	
F. Codes and Standards Tasks	1)	Interpret and Utilize Codes and Standards	3.33	3.33		
G. General Knowledges	1)	Relevant Engineering Terminology	3.35	3.35		.72
	2)	Materials Properties	2.92			.83
	3)	Fluid Mechanics	3.16	3.16		.75
	4)	Heat Transfer Principles	3.18	3.18		.75
	5)	Mass Transfer Principles	2.77			
	6)	Economic Analyses	2.79			
	7)	Project Management	2.70			
	8)	Ethics	3.32	3.32		
	9)	General Knowledge of Regulations and Laws	2.82			.88
	10)	Relevant Industry and Company Design Standards	2.95			.88
H. Machine Design and Materials Knowledges	1)	Strength of Materials	3.13	3.13		
	2)	Fatigue Theory	2.61			
	3)	Statics and Dynamics	3.13	3.13		
	4)	Welding	2.51			
	5)	Pressure Vessels	2.66			

Table 9.6: (continued) Items Rated Important on the Mechanical Engineering Occupation Analysis

			Importance Score (0-4)	Score, Most Important (3 or higher)	S.D. Most Variable	S.D. Least Variable
I. Hydraulics and Fluids Knowledges	1)	Compressible Flow	2.54			
	2)	Incompressible Flow	2.81			
	3)	Stress Analysis	2.81			
	4)	Hydraulic Pumps	2.58			
J. Energy Conversion/Power Systems Knowledges	1)	Thermodynamic Cycles	2.94			
	2)	Thermodynamic Properties	3.02	3.02		
	3)	Energy Balances	3.07	3.07		
	4)	Pumps/Compressors	2.78			
K. HVAC and Refrigeration Knowledges	1)	Psychrometrics	2.85		1.10	
	2)	Thermodynamics	3.14	3.14		
	3)	Cooling/Heating Cycles	2.77			
	4)	Water Distribution Systems	2.51			
L. Codes and Standards Knowledges	1)	ASTM	2.55			
	2)	NFPA	2.54			
	3)	ASME	2.69			

Table 9.7. Items Rated Important on the Agricultural Engineering Occupation Analysis

Tasks			Importance Score (0-4)	Score, Most Important (3 or higher)	S.D. Most Variable	S.D. Least Variable
A. Soil and Water	1)	Analyze Hydraulic Data	3.05	3.05	.95	
	2)	Design Irrigation Systems	2.75			
	3)	Design Drainage Systems	2.87			
	4)	Design Water Control Structures	3.06	3.06		
	5)	Design Erosion Control Structures	2.94			
	6)	Design and Inspect Earthen Structures	3.08	3.08		
	7)	Design Watershed Remediation and Restoration	2.58			
	8)	Design for Land Application of Solid and Liquid Waste	2.80			
	9)	Develop Best Management Practices for Soil and Water Conservation and Waste Management	2.95			
B. Power and Machinery	1)	Design Machinery Systems	3.04	3.04		
	2)	Design Power Hydraulic Systems	2.82			
	3)	Design and Utilize Electrical Power Systems	2.74			
	4)	Design and Select Power Transmission Systems	2.63			
	5)	Design and Select Traction and Tillage Systems	2.50			
C. Processing and Handling of Biological Products	1)	Design Hydration and Conditioning Systems	2.59			
	2)	Design Physical Separations	2.55			
	3)	Design and Select Materials Handling Systems	2.80			
D. Structures and Environment	1)	Design/Analyze Agricultural and Related Light Commercial Structures	2.95			
	2)	Design/Analyze Animal and Greenhouse Production and Product Storage Systems	2.81			
	3)	Design/Analyze Structural Systems	2.99			
	4)	Design/Analyze Ventilation Systems	2.89			
	5)	Design/Analyze Waste Storage and Treatment Facilities	3.07	3.07		
	6)	Assess Interaction of the Designed Facility with Plant/ Animal/Product Being Housed, Stored, or Processed	2.76			
	7)	Design/Analyze Storage, Handling, and Containment Systems for Hazardous Materials	2.74		1.03	
E. Biological Systems	1)	Analyze/Identify Properties of Plants/Animals to Optimize the Health/Quality/Sustainability of the Product	2.60		.99	
	2)	Design/Analyze Biological Processes	2.54			
	3)	Design/Analyze Agricultural Production Systems	2.60			
	4)	Assess Environmental Impact of Processes/Facilities	2.90			
	5)	Design/Restore/Preserve Ecological Systems	2.64		.96	
F. Core Tasks	1)	Characterize the Engineering Properties of Materials	2.86			
	2)	Characterize Fluid and Thermal Flow Through Porous Media	2.57			
	3)	Calculate Energy and Power Requirements	3.09	3.09		
	4)	Calculate and Interpret Mass Balances	2.93			
	5)	Calculate and Interpret Energy Balances	2.89			
	6)	Analyze Load-Carrying Elements	2.96			

Table 9.7. (continued) Items Rated Important on the Agricultural Engineering Occupation Analysis

Tasks			Importance Score (0-4)	Score, Most Important (3 or higher)	S.D. Most Variable	S.D. Least Variable
F. Core Tasks	7)	Analyze Air Vapor Mixtures	2.50		.95	
	8)	Analyze Fluid Flow Systems	2.82			
	9)	Conduct and/or Interpret Statistical Analyses	2.69			
	10)	Conduct and Interpret Construction and Topographic Surveys	2.69		.95	
	11)	Interpret Model Results	2.81			
	12)	Interpret Laboratory Test Results	2.95			
	13)	Interpret Graphical and Tabular Engineering Data and Information	3.13	3.13		
	14)	Design Processes and Procedures Based on Human Factors, Ergonomics, Health and Personal Protection	2.87			
	15)	Develop Clear, Logical, and Accurate Plans and Specifications	3.42	3.42		.73
	16)	Design Pumping Systems	2.58			
	17)	Design Control Systems	2.64			
	18)	Evaluate Products and Processes for Conformance and Specifications	2.86			
	19)	Diagnose and Recommend Solutions to Technical Problems	2.98			
	20)	Conduct Failure Analysis	2.70			
	21)	Evaluate Risks to Community Health, Safety, and Exposure	2.95			
	22)	Supervise Construction and Fabrication	2.75			
	23)	Understand and Interpret Risk Analyses	2.69			
	24)	Perform Economic Analyses	2.68			
	25)	Determine Ethical Conduct	3.19	3.19		
	26)	Review/Interpret/Apply Available Information	3.14	3.14		
	27)	Determine Requirements of Codes and Standards	3.05	3.05		
	28)	Prepare Procedures and Standard Practices	2.51			
	29)	Report Technical Information to Professional and Lay Audiences	2.98			

Knowledges			Importance Score	Score, Most Important	S.D. Most Variable	S.D. Least Variable
A. Soil and Water	1)	Hydrology	3.27	3.27		
	2)	Principles of Soil Physics	2.86			
	3)	Soil Mechanics	2.74			
	4)	Evapotranspiration	2.52			
	5)	Open Channel Hydraulics	3.14	3.14		
	6)	Hydrogeology	2.70			
	7)	Principles of Nutrient Management/Loading Rates in Soils	2.58			
	8)	Principles of Irrigation	2.89			
	9)	Principles of Surface and Subsurface Drainage	2.89			
	10)	Sediment Transport	2.76			
	11)	Erosion Control and Slope Stabilization	3.06	3.06		
B. Power and Machinery	1)	Agricultural Mechanization	2.85			
	2)	Machine/Commodity Interactions	2.69			
	3)	Machine/Soil Interactions	2.62			
	4)	Machine Component Design	2.92			
	5)	Understand Stress/Strain Relationships	3.19	3.19		
	6)	Materials Selection	2.99			

Table 9.7. (continued) Items Rated Important on the Agricultural Engineering Occupation Analysis

Knowledges			Importance Score	Score, Most Important	S.D. Most Variable	S.D. Least Variable
B. Power and Machinery	7)	Fatigue Analysis	2.76			
	8)	Stability Analysis	2.97			
	9)	Internal Combustion Engines	2.58			
	10)	Electrical Circuit Analysis	2.79			
	11)	Hydraulic Power Circuits	2.86			
	12)	Power Requirement Analysis	2.92			
	13)	Mechanical Power Transmission	2.88			
C. Processing and Handling of Biological Products	1)	Fundamental Physical Chemistry	2.72			
	2)	Mass Transfer Between Phases	2.51			
	3)	Bulk Solids Characterization	2.63			
	4)	Principles of Unit Operations	2.60			
	5)	Compatibility of Biological Materials	2.59			
	6)	Standards, Codes, and Regulations	2.87			
D. Structures and Environment	1)	Structural Loads and Standards	3.38	3.38		.77
	2)	Structural Analysis	3.21	3.21		
	3)	Provisions of Structural Materials Design Specification/Codes	3.02	3.02		
	4)	Standards for Post-Frame Building Design	2.68			
	5)	Steady State Heat and Mass Balances	2.58			
	6)	Ventilation Rate Requirements	2.83			
	7)	Ventilation System Requirements	2.85			
	8)	Insulation Requirements	2.72			
	9)	Moisture Control Standards for Building Construction	2.61			
D. Structures and Environment	10)	Air Quality Standards/Requirements in Agricultural Buildings/Confined Spaces for Humans, Animals, Plants and Produce	2.89			
	11)	Functional and Space Requirements for Agricultural Production Facilities	2.55			
	12)	Electrical Wiring/Lighting Devices	2.71			
	13)	Requirements for Hazardous Materials Storage Facilities	2.83		.96	
	14)	Construction Materials	2.91			
E. Biological Systems	1)	Ergonomics	2.52			
	2)	Environmental Assessment Techniques	2.66			
	3)	Awareness of Ecological Processes	2.66			
F. Core Knowledge	1)	Applied Mathematics	3.23	3.23		
	2)	Statistics	2.93			
	3)	Statics and Dynamics	3.25	3.25		.77
	4)	Fluid Mechanics	3.32	3.32		.69
	5)	Thermodynamics	2.97			
	6)	Psychrometric Processes	2.71			
	7)	Heat Transfer	2.80			
	8)	Strength of Materials and Structural Mechanics	3.26	3.26		.73
	9)	General Mass and Energy Balances	2.79			
	10)	Water Relationships	2.73			
	11)	Pump Principles	2.74			
	12)	Fan Principles	2.57			
	13)	Sensors, Instrumentation, and Control Circuits	2.68			
	14)	Engineering Economics Analysis	2.86			

Table 9.7. (continued) Items Rated Important on the Agricultural Engineering Occupation Analysis

Knowledges			Importance Score	Score, Most Important	S.D. Most Variable	S.D. Least Variable
F. Core Knowledge	15)	Knowledge of Ethics	3.32	3.32		
	16)	The Role of Codes, Regulations, and Standards in Professional Practice	3.17	3.17		
	17)	Applicable Codes, Regulations, and Standards in Specific Areas of Practice	3.10	3.10		
	18)	Procedure and Specification Documentation	2.90			

Table 9.8. Items Rated Important on the Chemical Engineering Occupation Analysis

			Importance Score (0-4)	Score, Most Important (3 or Higher)	S. D. Most Variable NA*	S.D. Least Variable NA*
A. Ethics	1)	Canon of Ethics of Professional or Technical Society	2.5			
B. Engineering Economics	1)	Engineering Economics	2.8			
C. Communication	1)	Oral Communications	3.5	3.5		
	2)	Written Communications	3.5	3.5		
	3)	Drawing and Graphics	2.6			
D. Physical and Engineering Sciences	1)	Chemistry	3.0	3.0		
	2)	Thermal Science	2.6			
	3)	Fluid Mechanics	2.8			
E. Computer Science	1)	Software	2.7			
F. Material Science	1)	Chemical Properties	2.7			
G. Other						
	1)	Measurement and Instrumentation	2.7			
	2)	Codes and Standards	2.7			
	3)	Mass and Energy Balances	3.2	3.2		
	4)	Applied Thermodynamics	2.8			
	5)	Applied Fluid Mechanics	2.8			
	6)	Heat Transfer	2.9			
	7)	Mass Transfer	2.7			
	8)	Chemical Process Control	2.9			
	9)	Chemical Process Design	2.9			
	10)	Chemical Equipment Design	2.7			

*Standard deviation data not provided.

Table 9.9. Items Rated Important on the Control Systems Engineering Occupation Analysis

Professional Activities		Importance Score (0-5)	Score, Most Important (4 or higher)	S.D., Most Variable NA*	S.D., Least Variable NA*
A. Conceptual Design/Definition of Control Systems	1) Study Potential Control System Application to Define Control System Objectives and Functions	4.32	4.32		
	2) Prepare Specifications of Control System Performance Needed to meet Application Objectives	4.16	4.16		
	3) Specify Kinds and Locations of Sensors and Switches Needed as Inputs for Control System Functions	3.89			
	4) Specify Kinds and Locations of Control Actions or Outputs Needed to Achieve System Objectives	4.02	4.02		
B. Control Strategies	1) Develop Control Strategies to Achieve Application Objectives	4.16	4.16		
	2) Apply Basic Control Techniques	4.09	4.09		
	3) Apply Advanced Control Techniques	3.76			
	4) Evaluate Performance of Existing Control Systems	3.66			
	5) Troubleshoot Existing Control Systems to Correct Malfunctions or Poor Performance and Achieve System Objectives	3.84			
C. Logical/Sequential Control Systems	1) Specify Functions for Logical/Sequential Control Systems	3.61			
D. Digital Computer Applications	1) Design (or Configure) Distributed Control Systems	3.55			
E. Control Valves, Actuators and Final Elements	1) Select Final Elements to Implement Control Strategies	3.83			
	2) Calculate Control Valve Size	3.53			
	3) Select Control Valve Type and Characteristics	3.61			
F. Safety and Relief Valves	1) Analyze Processes to Define Risks and Most Likely Failures	3.59			
	2) Analyze Processes to Determine Type of Safety System Needed	3.58			
	3) Ensure Compliance with Applicable Government, Industry, Owner, and Good-Practice Safety Standards or Laws	3.85			
	4) Check Safety System Design to Ensure Protection Against All Significant Hazards	3.81			
	5) Determine Where Safety and Relief Valves are Needed	3.54			
	6) Define Process Conditions which will Initiate Alarms or Shutdowns	3.65			
G. Alarm/Shutdown Switches	1) Ensure Compliance of Switch Selection and Settings with Applicable Codes	3.55			
H. Flow Measurement	1) Select Proper Flowmeter For Application	3.86			
	2) Determine Process Characteristics and Flow Measurement Range from Process Flow Diagrams	3.69			
I. Other Measurements	1) Select Appropriate Devices to Measure Temperature, Level, Pressure, Speed, Position, etc., as Needed to Satisfy System Requirements	3.87			
J. Data Transmission and Communication Networks	1) Select Appropriate Media for Transmission of Plant Data for Control and Information Functions	3.84			
	2) Select Proper Ranges for Transmitters from Process Data	3.71			
	3) Select Transmitters to Suit Hazardous Areas	3.69			
K. Operator Interface, Panels, and Displays	1) Design Emergency Shutdown Systems	3.84			
L. Project Management	1) Review System Design for Compliance with Functional Requirements and Applicable Codes	3.90			
	2) Write Control System Specifications and Requests for Proposals or Quotations	3.75			
	3) Evaluate Proposals, Quotations or Bids	3.75			
	4) Select Vendors	3.53			
	5) Review Vendor Drawings for Completeness and Compliance with Specifications	3.53			

*Standard deviation data not provided

Table 9.9. (continued) Items Rated Important on the Control Systems Engineering Occupation Analysis

Professional Activities		Importance Score (0-5)	Score, Most Important (4 or higher)	S.D., Most Variable NA*	S.D., Least Variable NA*
L. Project Management	6) Train Junior Engineers in Accomplishing Tasks Performed by Control Systems Engineers	3.64			
	7) Coordinate with Other Engineering Disciplines and Various Crafts During Construction, Installation, Checkout, Commissioning and Startup	4.02	4.02		
	8) Plan and Supervise System Checkout and Commissioning	3.55			
	9) Test the Completed System as a Unit at the Installation Site	3.79			
	10) Make Field Changes to Correct Errors and Omissions	3.74			
	11) Adjust Control System Parameters Based on Performance in the Plant	3.76			
	12) Modify the Configuration or Programming of Digital Devices as Required During Startup	3.60			
M. Documentation	1) Read and Understand Process Flow Diagrams	4.31	4.31		
	2) Prepare, Read and Understand Piping and Instrument Drawings	4.30	4.30		
	3) Prepare, Read and Understand Instrument Loop Diagrams Using Various Symbols	4.25	4.25		
	4) Prepare, Read and Understand Flow Charts for Computer Programs	3.51			
	5) Prepare, Read and Understand Ladder-Type Diagrams for Relay and Logic Schematics	3.85			
	6) Read and Understand Electrical One-Line Diagrams	3.51			
	7) Update Drawings and Other Documentation to Reflect Changes to the System and Ensure the Availability of Correct Information on the Current System Structure and Parameters	3.61			
N. Applications	1) Design and Implement Control Systems for Continuous Processes	4.02	4.02		
	2) Design and Implement Control Systems for Batch Processes	3.94			
	3) Design and Implement Control Systems for Energy Conservation and Transmission Systems	3.87			
	4) Design and Implement Control Systems for Strip, Sheet and Fiber Processes	3.68			
	5) Design and Implement Control Systems for Distributed Processes	3.69			

Professional Requirements		Importance Score (0-5)	Score, Most Important (4 or higher)	S.D., Most Variable NA*	S.D., Least Variable NA*
A. Ethics	1) Canon of Ethics of Professional or Technical Society	3.83			
	2) Rules of Professional conduct of State Registration Board	3.90			
B. Communication	1) Oral Communication	3.62			
	2) Written Communication	3.79			
	3) Drawings and Graphics	3.63			
C. Codes and Standards	1) Codes and Standards	3.58			
D. Fundamentals of Measurement	1) Fundamentals of Measurement	3.85			
E. Knowledges	1) Sensor Selection	3.64			
	2) Valves and Final Elements	3.57			
	3) Controllers/Modes/Tuning	3.77			
	4) Digital Control Systems	3.66			
	5) Discrete Logic and Sequencing	3.60			
	6) Alarms	3.53			
	7) Interlocks	3.66			
	8) Control System Analysis	3.77			
	9) Process Dynamics	3.65			

*Standard deviation data not provided.

Table 9.10. Items Rated Important on the Industrial Engineering Occupation Analysis

			Importance Score (0-4)	Score, Most Important (3 or Higher)	S. D. Most Variable NA*	S.D. Least Variable NA*
A. Ethics	1)	Canon of Ethics of Professional or Technical Society	2.7			
	2)	Rules of Professional Conduct of State Registration Board	2.6			
B. Engineering Economics	1)	Engineering Economics	3.1	3.1		
C. Communication	1)	Oral Communications	3.5	3.5		
	2)	Written Communications	3.6	3.6		
	3)	Drawing and Graphics	2.8			
D. Mathematics and Statistics	1)	Probability and Statistics	2.7			
E. Computer Science	1)	Software	2.7			
F. Other						
	1)	Management Principles	3.1	3.1		
	2)	Work Methods and Management Techniques	2.7			
	3)	Manufacturing Processes	2.7			
	4)	Systems Design/Analysis	2.7			
	5)	Statistical Quality Control	2.6			
	6)	Cost Analysis	3.1	3.1		
	7)	Optimization Methods	2.5			

*Standard deviation data not provided.

Table 9.11. Items Rated Important on the Manufacturing Engineering Occupation Analysis

		Importance Score (0-4)	Score, Most Important (3 or higher)	S.D., Most Variable	S.D., Least Variable
A. Product/Process Design, Materials Application	1) Metals	3.01	3.01		.73
	2) R&D, Prototyping, Testing	2.61			
	3) Design/Concurrent Engineering	2.86			
	4) Design for X (Mfg/Assm/Maint/etc)	2.87			
	5) Engineering Graphics	2.73			
	6) Engineering Design Analysis	2.76			
	7) Cost Engineering/Analysis	2.92			.76
	8) Tolerance Analysis/GD&T	2.66			
	9) Process Design, Development, and Producibility	3.08	3.08		.72
B. Manufacturing Process Applications and Operation	1) Material Removal Processes	2.69			
	2) Fabrication Processes	2.74			.75
	3) Joining and Assembly Processes	2.77			.78
C. Production System and Equipment Design	1) Tool and Equipment Selection	2.79			
	2) Machine Design	2.56		1.05	
	3) Production System Design	2.69			
	4) Process Planning	2.77			.77
	5) Capacity Planning	2.51			
	6) Cost Justification	2.98			.74
	7) Safety, Health, and OSHA	2.80			
D. Automated Systems and Control	1) CAD/CAM/CIM Systems	2.71			
E. Quality	1) Probability and Statistics	2.51		.99	
	2) Statistical Control Methods	2.56			
	3) Process and Equipment Capability Analysis	2.60			
F. Manufacturing Management	1) Project Management	2.97			
	2) Business/Engineering Ethics	2.84		1.01	

Table 9.12. Items Rated Important on the Metallurgical Engineering Occupation Analysis

		Importance Score (0-4)	Score, Most Important (3 or higher)	S.D., Most Variable	S.D., Least Variable
A. General	1) Mathematics; Arithmetic Calculations	3.35	3.35		.84
	2) Mathematics; Algebraic Calculations	3.13	3.13		
	3) Statistics; Data Analysis	2.65			
	4) Physical/Engineering Sciences; Phase Equilibria	2.55			
B. Extractive Metallurgy Fundamentals	1) Mass Balance	2.50		1.29	
	2) Thermodynamics	2.51		1.24	
C. Extractive Metallurgy Processes	1) Material Balances	2.54		1.26	
D. Physical Metallurgy Fundamentals-Structure of Metals	1) Crystalline Properties of Metals; Elastic Deformation	2.69			
	2) Crystalline Properties of Metals; Plastic Deformation	2.83			
	3) Crystalline Properties of Metals; Strengthening Mechanisms	2.88			
	4) Annealing of Metals; Recovery-Recrystallization	2.71			
	5) Annealing of Metals; Grain Growth	2.70			
	6) Metallography; Microstructure/Macrostructure	3.17	3.17		
	7) Physical Chemistry; Phase Diagrams	2.81			
	8) Physical Chemistry; Phase Diagrams; Solidification	2.60			
	9) Physical Chemistry; Phase Diagrams; Transformations	2.73			
	10) Physical Chemistry; Solid Solutions	2.55			
	11) Electrochemistry of Metals; Corrosion Mechanisms	2.89			
E. Mechanical Metallurgy	1) Mechanical Fundamentals; States of Stress	2.68			
	2) Yielding of Metals	2.87			
	3) Theories of Fracture; Fracture Mechanisms	2.99			
	4) Theories of Fracture; Fracture Mechanisms; Fracture Mechanics	2.71			
	5) Theories of Fracture; Fatigue	2.90			
F. Fabrication and Mechanical Processing	1) Joining	2.55			
	2) Joining; Welding	2.71			.90
G. Materials Processing Procedures	1) Thermal Treatment of Alloys; Ferrous Alloys; Hardenability	2.96			
	2) Thermal Treatment of Alloys; Ferrous Alloys; Austenitizing	2.82			
	3) Thermal Treatment of Alloys; Ferrous Alloys; Hardening	2.95			.87
	4) Thermal Treatment of Alloys; Ferrous Alloys; Tempering Embrittlement	2.50			
	5) Thermal Treatment of Alloys; Non-Ferrous Alloys; Annealing	2.71			
	6) Thermal Treatment of Alloys; Non-Ferrous Alloys; Age Hardening	2.77			
	7) Surface Modification	2.52			
H. Alloy Selection	1) Ferrous; Material Properties; Mechanical	2.96			
	2) Ferrous; Specifications; Chemical	2.65			
	3) Non-Ferrous; Material Properties; Mechanical	2.75			
I. Material Testing	1) Mechanical Testing; Tensile	3.14	3.14		
	2) Mechanical Testing; Hardness	3.02	3.02		
	3) Mechanical Testing; Fatigue	2.83			
	4) Mechanical Testing; Fracture Toughness	2.71			

Table 9.13. Items Rated Important on the Petroleum Engineering Occupation Analysis

Tasks		Importance Score (0-4)	Score, Most Important (3 or higher)	S.D., Most Variable	S.D., Least Variable
A. Drilling	1) Understand and Use Well or Project Objectives to Design Well	3.06	3.06		
	2) Prepare Drilling Cost Estimates	2.72		1.13	
	3) Design Wells and Develop Drilling Plans	2.84		1.12	
	4) Provide Surveillance on Wells Being Drilled and Optimize Drilling Performance	2.61		1.09	
	5) Evaluate Completed Wells for Improvements in Drilling	2.74		1.13	
B. Completion, Production and Facilities	1) Determine the Optimum Production Profile for a Given Well/Field	3.07	3.07		
	2) Design the Various Elements of, and Prepare Cost Estimates for Well Completion, Recompletion, and Remedial Work	3.02	3.02	1.07	
	3) Design Cost Estimates for Subsurface Production String and Assembly	2.60		1.09	
	4) Manage the Execution of Well Completion, Recompletion or Remedial Work	2.56		1.06	
C. Reservoir	1) Prepare Reservoir Description	2.80			
	2) Analyze Reservoir Fluids Behavior	2.67			
	3) Estimate Reserves/Contingent Resources	3.34	3.34		
	4) Analyze and Monitor Reservoir Performance	3.34	3.34		
	5) Predict Future Reservoir Performance	3.19	3.19		
	6) Design and Implement Field Development Projects	2.86			
	7) Manage the Reservoir for Optimal Value	3.28	3.28		
D. Formation Evaluation	1) Determine the Formation Evaluation Data Required for Well/Project	2.82			
	2) Interpret/Integrate Results of Formation Evaluation Data	2.99			

Knowledges		Importance Score (0-4)	Score, Most Important (3 or higher)	S.D., Most Variable	S.D., Least Variable
A. Common Knowledge	1) Principles of Mathematics and the Physical Sciences	2.95			
	2) Petroleum Engineering Terminology	3.54	3.54		.66
	3) Relevant Industry and Company Design Standards	3.02	3.02		
	4) Relevant Industry Regulatory/Environmental Law	2.70			
	5) Industry and/or Company Provided Technical Software/Informational Databases	2.91			
	6) Project Management Techniques	2.81			
	7) Geoscience Principles	2.95			
	8) Risk Analysis/Contingency Planning	2.85			
	9) Surveillance/Optimization Techniques	2.85			
	10) Economic Principles	3.26	3.26		
	11) Multi-Disciplinary Team Participation	3.17	3.17		
	12) Professionalism Including Ethics and Due Diligence	3.41	3.41		.73
B. Drilling	1) Tubulars	2.92			
	2) Cementing	2.86			
	3) Drilling Fluids	2.86			
	4) Drill String	2.64			
	5) Drilling Mechanics	2.78			
	6) Hydraulics	2.84			
	7) Directional/Horizontal Drilling	2.68			
	8) Well Control/BOP	2.96		1.05	
	9) Bits	2.56			

Table 9.13. (continued) Items Rated Important on the Petroleum Engineering Occupation Analysis

Knowledges		Importance Score (0-4)	Score, Most Important (3 or higher)	S.D., Most Variable	S.D., Least Variable
C. Completion, Production and Facilities	1) Proper Lift Mechanism Selection Given a Set of Well Conditions	3.03	3.03		
	2) Sucker Rod Pumping Systems	2.56			
	3) Well and Completion Systems Including Nodal Analysis	3.09	3.09		
	4) Inflow Performance curve Analysis	3.11	3.11		
	5) Production Logging	2.65			
	6) 2D Sand Fracture Treatments	2.54			
	7) Matrix Acid Treatments	2.56			
	8) Tubing and Downhole Equipment	2.81			
	9) Remedial/Recompletion Operations	3.04	3.04		
	10) Selections of Piping to Accommodate Flow Rate, Total Pressure and Pressure Drop Considerations	2.83			
D. Reservoir	1) Reservoir Geoscience	2.81			
	2) Oil/Gas Reservoir Performance	3.38	3.38		.70
	3) Methods to Determine Net Pay	3.07	3.07		.76
	4) Phase Behavior/Reservoir Fluids	2.81			
	5) Single/Multiphase Flow in Porous Media	2.85			
	6) Methods for Estimating Reserves and Recoveries	3.54	3.54		.71
	7) Reservoir Development Techniques	3.13	3.13		.77
	8) Water/Gas Injection	2.71			
	9) Reservoir Simulation Techniques	2.62			
E. Formation Evaluation	1) Physical Measurements	2.61			
	2) Derivation of Properties from Formation Evaluation Data Including Lithology, Mechanical Rock Properties, fluid Properties and Borehole Dimensions	2.82			
	3) Lithology	2.73			
	4) Fluid Properties	2.81			.78
	5) Logging Methods	2.95			.78
	6) Well Testing	2.98			

Table 9.14. Items Rated Important on the Traffic Engineering Occupation Analysis

Tasks		Importance Score (0-5)*	Score, Most Important (3.5 or higher)	S.D., Most Variable NA**	S.D., Least Variable NA**
A. Circulation, Trip Generation, parking, and Land Use	1) Recommend Roadway Mitigations Based on Forecast of Transportation Demands to Improve Level of Service	3.20			
B. Level of Service and Capacity	1) Evaluate Traffic Volume Data to Determine Infrastructure Design	3.07			
	2) Evaluate Development Projects for On- and Off-Site Geometrics to Determine Operational Efficiency and Safety of Traffic Flow	3.05			
C. Transportation Facilities Design	1) Develop Intersection Channelization Plans to Facilitate Movements of Vehicles and Pedestrians	3.10			
	2) Develop Plans for Roadway Signing and Striping to Facilitate Movements of Traffic	3.28			
D. Traffic Controls	1) Identify Need for Traffic Control Device Modifications Based on Accident Rates, Traffic Volumes, and Changes in Traffic Patterns	3.16			
	2) Specify Signs, Markings, and Delineators to Regulate, Warn, and Guide Motorists	3.31			
E. Traffic Flow	1) Recommend Corrective Measures to Reduce Accident Potential/Occurrences	3.30			

Knowledges		Importance Score (0-5)*	Score, Most Important (3.5 or higher)	S.D., Most Variable NA**	S.D., Least Variable NA**
A. Circulation, Trip Generation, Parking and Land Use	1) Techniques for Calculating Level of Service of Roadways and Intersections	3.40			
	2) Warrants that Define Minimum Requirements for Installation of Traffic Controls	3.68	3.68		
	3) Relationship Between Roadway Classification or Intersection Geometrics and Carrying Capacity	3.29			
	4) Techniques for Mitigating Traffic Impacts	3.51	3.51		
	5) Roadway Features that Affect Capacity	3.39			
B. Transportation Facilities Design	1) Relationship Between Motorist Characteristics and Sight Distance Requirements	3.36			
	2) Methods for Applying Roadway Design Elements	3.33			
	3) Effect of Vehicle Turning Radii for Vehicle Classifications in Determining Roadway Characteristics	3.13			
	4) Channelization Standards for Intersections to Regulate Traffic Movement	3.29			
	5) Standards for the Identification and Placement of Signing and Striping Elements	3.70	3.70		
	6) Standards for Guiding Traffic through Construction and Maintenance Zones	3.24			
C. Traffic Signals and Lighting	1) Relationship Between Traffic Flow and the Development of Signal Timing Plans	3.00			
	2) Interaction Between Time, Space, and the Movement of Vehicles Through Intersections	3.03			
	3) Standards that Apply to the Selection of Signal Type and Placement	3.10			
	4) Procedures for Applying Warrants/Standards used to Justify the Implementation of Traffic Control Devices	3.73	3.73		
	5) Relationship Between Signal Phasing and the Control of Right-of-Way through Intersections	3.35			
D. Traffic Controls	1) Relationship Between Cycle Length, Splits, and Offsets	3.00			
	2) Standards for Determining Intersection Signal Timing Based on Traffic and Pedestrian Requirements	3.15			
	3) Effects of Phasing on Signal Timing	3.27			
	4) Relationship Between Signal Timing/Phasing and Accident Mitigation	3.06			
	5) Elements to be Evaluated When Performing Traffic Control Studies	3.02			

* Importance scores of 3 or higher used as cutoff; not comparable to other tables.

** Standard deviation data not provided.

Table 9.14. I(continued) tems Rated Important on the Traffic Engineering Occupation Analysis

Knowledges		Importance Score (0-5)*	Score, Most Important (3.5 or higher)	S.D., Most Variable NA**	S.D., Least Variable NA**
	6) Procedures for Conducting and Interpreting Traffic Engineering Studies	3.56	3.56		
	7) Measures that Remedy Safety and Operational Deficiencies	3.56	3.56		
	8) Laws, Regulations, and Guidelines Pertaining to Traffic	3.84	3.84		
E. Traffic Flow	1) Measures for Optimizing Traffic Flow	3.14			
	2) Types of Pavement Striping Based on Roadway Characteristics and Prevailing Conditions	3.09			
	3) Knowledge of Methods for Identifying Hazardous Traffic Locations/Conditions	3.14			
	4) Traffic Engineering Measures for Improving Roadway Safety	3.64	3.64		
	5) Methods for Evaluating the Effectiveness of Safety Improvement Measures	3.07			
	6) Relationship Between Roadway Characteristics and Accident Potential	3.32			

* Importance scores of 3 or higher used as cutoff; not comparable to other tables.

** Standard deviation data not provided.

CHAPTER 10

OVERLAP IN NCEES EXAM OUTLINE CONTENT

The job analyses described in the preceding chapter are designed for use in developing licensing exams. The job analysis for each discipline is carried out in its own unique way, and ISR's effort to use this data to measure overlap across disciplines revealed that these independent approaches create inconsistencies and limitations that prevent the data from being useful for the purpose of measuring overlap. This led to the decision to instead analyze NCEES exam outlines for possible overlap between engineering disciplines.

In theory, the exams are based on what engineers do. However, job tasks for engineers from the same discipline may vary with the job setting. In spite of this variety, the job analysis reports generally provide means and standard deviations for the frequency and criticality of tasks for the sample as a whole rather than separately for a limited number of job settings. Moreover, most job analyses omit unlicensed engineers, which means that, for disciplines with low registration rates, they may not reflect what a majority of engineers do.[1] There is no way to know how well the exam content reflects what licensed and unlicensed engineers really do in a variety of job settings. As a result, conclusions based on the analysis of overlap in exam content may differ from those that might be derived from the analysis of actual overlapping job tasks -- if comparable job analysis data were available for all engineering disciplines.

The analysis described in this chapter is based on the exam specifications maintained by NCEES on their website (www.ncees.org).[2] For each discipline, NCEES provides an outline of the exam content along with the approximate percentage of the exam devoted to each topic. NCEES indicates that "the knowledge areas specified in these outlines are examples of the kinds of knowledge required for the exams, but they are not exclusive or exhaustive categories." Clearly, these outlines were not designed for the type of analysis performed here, but they presented the best available opportunity to examine overlapping knowledge between disciplines. Some of the outlines are very detailed, while others are much more brief. The most detailed, with 92 items, is the outline for the electronics, controls, and communication depth module of the electrical and computer engineering exam. At the other end of the scale, the outline for fire protection engineering contains just 23 items. Because differences in the format of the outlines directly affected the ability of experts reviewing them to make informed comparisons, the level of detail contained in each outline should be considered in interpreting the results presented in this chapter. Another important point, brought up by a number of experts reviewing the exam outlines, is that although disciplines may require similar knowledge, the application of this knowledge may be quite different.

Methodology

Selection of subject matter experts. On the assumption that a discipline's practitioners would be the best judges of what material is subsumed in a subject matter area, ISR selected a sample of experts, representing nine engineering disciplines, to review exam outlines for pairs of disciplines. The disciplines chosen -- civil, electrical, mechanical, chemical, control systems,

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[1] The job analyses for civil, chemical, control systems, industrial and mechanical engineering include both licensed and unlicensed engineers.

[2] The material provided to subject matter experts for comparing the exam outlines is included in Appendix H.

fire protection, industrial, manufacturing and nuclear -- represent disciplines with NCEES exams that have the greatest number of registrants in California.

Subject matter experts were chosen from three lists supplied by the Board. The first was a database of Enforcement Technical Experts, consisting of 98 civil engineers, 40 mechanical engineers and 32 electrical engineers. The second was a list of electrical engineers from the Board's Technical Advisory Committee (TAC). And the third was a list of 38 title act Subject Matter Experts (SMEs). All but three of the title act SMEs were contacted. The three who were not contacted specialized in areas that are no longer being examined. A random sample of 15 experts from each discipline was chosen from the lists of civil, mechanical and electrical engineers. The list of experts within each discipline was ordered by license number, providing a rough measure of years of experience as a licensed engineer. Each list was divided into three equal strata and a systematic sample of five experts was selected from each stratum, producing an initial sample of 15 experts from each practice act discipline.

The object was to have roughly equal numbers of experts from each pair of disciplines review the exam outlines. For example, for the comparison between civil and mechanical engineering exam outlines, roughly half should be licensed civil engineers and half should be licensed mechanical engineers. All experts were asked to indicate which disciplines they felt comfortable comparing. Mechanical engineers, on average, tended to choose to work with fewer disciplines. It therefore became necessary to draw an additional sample of mechanical engineers. A delayed response from some mechanical engineers led to more invitations to participate. This also increased the number of mechanical engineers in the final sample. The same sampling procedures were followed for this supplemental sample selection. Table 10.2 summarizes the number of experts from different disciplines that reviewed each pair of exam outlines.

As a result of the oversampling of mechanical engineers, there were more expert pairs comparing mechanical engineering with all other disciplines than there were for other discipline pairs (11 to 15 paired comparisons with mechanical engineering vs. 6 to 9 between all others discipline pairs).

The participation rate was roughly comparable for all disciplines except electrical engineering. Between 56% and 81% of civil, mechanical and title act SMEs contacted participated compared with 40% of electrical engineers from both sources.[3] (Table 10.1)

Table 10.3 summarizes the mix of backgrounds of experts reviewing each of the discipline pairs. An effort was made to have half of the reviewers for a given discipline pair be licensed or recognized as an expert in one of the disciplines and half in the other. This occurred in 11 of 21 comparisons, counting 4/3 or 5/4 type splits as roughly half. Greater disparities in favor of the practice act disciplines occurred in ten of the comparisons -- six of them involving mechanical engineering -- while two favored title act disciplines (nuclear over civil and electrical).

Measurement of overlapping exam content. In order to understand how exam content overlap was calculated, it’s helpful to take an example and work through each of the steps in the process. For reasons that will be discussed later in this section, the comparison between the industrial engineering exam and the computers depth module of the electrical and computer engineering exam is a particularly useful example. Table 10.4 shows the exam outline for industrial engineering. There are six major sections, each comprising between 12% and 25% of

[3] Electrical engineers were chosen from two source lists. The numbers responding from each list were combined into a single response rate of 40% (3 of 10 and 3 of 5 = 6 out of 15 or 40%).

the exam. Within each section more detailed topics are shown. Since subject matter experts were asked to compare outlines using the most detailed information available, the percent of the exam devoted to a section was distributed equally among these individual topics. For example, there are seven topics within the Facilities section, which comprises 25% of the exam, so each topic in this section is allocated 1/7th of 25%, or 3.57%.

Table 10.4 also shows the percent of experts who identified overlapping topics on the two exam outlines. There were eight experts who compared these two outlines. None of the experts felt that the topics included in the Facilities section (1A-G) and the Production and Inventory Systems section (3A-G) of the industrial exam were covered anywhere in the computers depth module. Several topics (robotics, value engineering, human-machine interfacing, quality aspects of design, and productivity) were identified by just one expert (12.5%) as being covered on the computers depth module.

Not surprisingly, the only consensus regarding overlap concerns section 6 of the industrial exam outline – Management and Computer Information Systems. Seven of the experts (or 87.5%) said that computer systems analysis and design (6E on the industrial exam outline) was covered on the computers depth module. And six experts felt that specification of computer equipment and computer communication protocols (6F-G) from the industrial exam were covered on the computers depth module.

Multiplying the percent of the exam that each item contributes by the percent of experts who identified an equivalent item on the comparison exam produces a measure which reflects the relative importance of a topic on the outline, as well as the degree of agreement between the experts. This weighted percent overlap is shown in the last column of Table 10.4. A total of 6% of the content on the industrial exam is covered on the computers depth module.

Table 10.5 is based on the same expert review summarized in Table 10.4, but it reverses the direction of the overlap and shows the computations for measuring the percent of computers depth module content that is included on the industrial engineering exam. A much larger percent of the computers depth module content (28.86%) is covered on the industrial engineering exam.

Each pair of comparisons produces two different measures of overlap. Often the two measures are remarkably similar. This particular pair of comparisons was selected as an example because the difference between the two measures is so extreme. The measures describe a situation in which knowledge of management and computer information systems is a relatively minor part of the knowledge required by the industrial engineering exam. Since the computers module requires much more specialized knowledge of computers than the industrial exam, an engineer prepared only to pass the industrial exam would have difficulty passing the computers module. For industrial engineers, computers are a tool, not the focus of what they do. An engineer prepared to pass the computers module would appear to be well prepared to pass one section of the industrial exam, but would not necessarily have any knowledge of other more heavily emphasized areas required by the industrial exam.

Degree of Overlap between Disciplines

Overlap between practice act disciplines. Table 10.6 ranks the 148 discipline comparisons from the greatest amount of overlap to the least. Since there are two measures of overlap for each pair of comparisons, they are ordered according to the average amount of overlap. Most of the comparisons above the median (averaging 4.4% overlap) are practice/title act comparisons (57/74 or 77%), while more of those below the median are practice/practice act comparisons (47/74 or 64%). In other words, there is more overlap between the title and practice disciplines than there is between the practice disciplines. In the lowest 20%, only 6 of 30 comparisons involve title and practice disciplines; 80% are combinations of practice act disciplines. Conversely, in the top 20%, only 3 of 30 comparisons involve two practice act disciplines; 90% are practice/title comparisons.

Twenty of the 30 comparisons with the least amount of overlap (1% or less) involve paired portions of the civil and electrical exams. Electrical and mechanical are also very dissimilar; 13 of 16 comparisons between the two are in the lower half of the ranking. On the other hand, there is much more overlap between civil and mechanical engineering; 14 of 24 comparisons between the two disciplines are in the upper half of the distribution. Overlap between these disciplines is greatest between the structural depth module and three mechanical exam modules (machine design, thermal & fluids systems, and breadth). The overlap between the structural and machine design modules is a balanced one: a fifth of each exam is found on the other one. In contrast, more content from the structural module appears on the mechanical breadth module than the reverse (17.6% vs. 11.1%). The same thing is true for overlap between the structural and the thermal & fluids systems modules. More content from the structural module appears on the thermal & fluids systems module (15.7%) and less material from thermal & fluids systems appears on the structural module (6.8%). It appears that the structural module is more specialized than the mechanical breadth and thermal & fluids systems modules. This suggests that someone with the knowledge required to pass the structural module would be better prepared for the mechanical breadth and thermal & fluids systems modules than the reverse.

There is also a significant amount of overlap between the civil and mechanical breadth modules (8.9% and 13.6%) and between the civil breadth and mechanical machine design modules (9.2% and 14.9%). The water resources and environmental modules both overlap with the mechanical breadth and thermal & fluids systems modules. The overlap between the water resources and mechanical breadth modules is 7.4% and 11.8%, for water resources and thermal & fluid systems it is 8.5% and 12.9%, for environmental and mechanical breadth it is 3.4% and 12.8%, and for environmental and thermal & fluids systems it is 4.1% and 14.3%. In each of these cases, a higher percentage of material on the mechanical exam appears on the civil exam than the reverse. (Table 10.7) It appears that in this instance, some of the mechanical modules are more specialized compared to the civil modules. This suggests that someone with the knowledge required to pass these mechanical modules would be better prepared for particular civil modules than the reverse.

The independence of exam content for two of the three pairs of practice act disciplines (between electrical and both civil and mechanical) strongly supports their separate disciplinary boundaries. But it also calls into question the one-directional allowable overlap of civil engineers into the other disciplines, particularly electrical engineering. Based on exam content, neither discipline should be engaged in the incidental practice of the other's responsibilities. There is a stronger case for bi-directional overlap between mechanical and civil engineering than there is for overlap in any direction between electrical and either civil or mechanical. (Table 10.6)

Overlap between practice and title act disciplines. The greatest amount of overlapping exam content between practice and title act disciplines occurs with modules on the mechanical (17 out of the top 30) and electrical (6 out of the top 30) exams. Overlaps involving mechanical exams are largely concentrated in the top 15. The title acts disciplines with the greatest amount of overlap are chemical (6 out of 30), control systems (5), fire protection (5), industrial (4) nuclear (4), and manufacturing (3). Chemical and control systems are concentrated in the top 15, while fire protection is concentrated in the lower half of the top 30. The remaining 3 in the top 30 are pairings between civil and mechanical, two practice act disciplines. (Tables 10.6 and 10.7)

Looking at the top 30 comparisons with the greatest amount of average overlap, the chemical exam overlaps with four mechanical and two civil exams. The control systems exam overlaps with three mechanical and two electrical exams, while fire protection overlaps with three mechanical and two civil exams. The industrial exam overlaps more with the electrical (3) than mechanical modules (1), while nuclear does the reverse, overlapping more with mechanical (3) than electrical (1). All three of manufacturing's overlapped pairings are with mechanical exam modules. (Table 10.7)

Practice act discipline exam content makes up a higher percentage of the title act discipline exams in 8 of the top 30 comparisons, while title act content makes up a higher percentage of the practice act exams in 10 comparisons. In another nine, the amount of overlap is comparable (within 3% points) in both directions. The remaining three comparisons are between two practice act disciplines. In over half of the 30 comparisons, the proportion of overlapping content exceeds 20% for one or both exams. In the four pairings of chemical and mechanical in the top 30, the overlap is between 28% and 40%, with two equally balanced and the others weighted toward chemical. The extent of overlapping exam content between these two disciplines argues against the current licensing system that permits one directional overlap by mechanical engineers into chemical engineering, prohibiting the reverse. In the cases of unbalanced overlap, the content from the chemical exam makes up a higher proportion of the mechanical exam than the reverse -- suggesting that the chemical engineering exam requires more specialized knowledge than the mechanical modules. (Table 10.6)

Percentage of title acts' exam content covered on practice acts' exams. From the perspective of the title acts, most of the overlap with practice act discipline exams is on the mechanical breath and depth modules. Roughly a third of the chemical exam is covered on the mechanical breadth and depth modules, especially the HVAC & refrigeration and thermal & fluids systems modules. A slightly smaller percentage (20.9%) of the chemical exam content is found in the civil environmental depth module. Almost a fifth of the control systems, fire protection and manufacturing exams are covered on the mechanical breadth module (19%, 17.5% and 16.7% respectively) and the thermal & fluids systems module (16.9%, 17.0% and 14.7% respectively). Fire protection has a similar degree of overlap with the civil breadth module (16.4%). In addition, a fourth of the control systems and fire protection exam content is covered by the HVAC & refrigeration module and a third of the manufacturing exam content is found on the machine design module. (Table 10.8)

Percentage of practice acts' exam content covered on title acts' exams. From the perspective of civil engineering, most of the overlap with other discipline exams is in the environmental, structural and water resources depth modules. A fourth of the environmental module is found on the chemical exam and 15% is covered on the industrial exam. The water resources module also overlaps with the chemical exam (15.24%). Finally, material making up 16% to 21% of the structural module is found on the mechanical breadth module and two of mechanical depth modules (machine design and thermal & fluids systems). (Table 10.9)

From the perspective of electrical engineering, most of the overlap with other discipline exams is in control systems, industrial and nuclear. Between 17% and 29% of the electrical breadth, computers and power modules are found on the industrial exam (17%, 29% and 22% respectively). Roughly a fifth of the computers and electronics modules are found on the control systems exam (24% and 22% respectively). A similar percentage of the electronics module is found on the nuclear exam (22%). (Table 10.10)

From the perspective of mechanical engineering, most of the overlap in exam content is with the title act disciplines, especially chemical. Roughly a third of the content on the mechanical breadth, HVAC & refrigeration and thermal & fluids systems modules are found on the chemical exam. A similar proportion of the machine design module is found on the manufacturing exam, along with 16% of the mechanical breadth module. Approximately a fifth of the mechanical breadth, HVAC & refrigeration and thermal & fluids systems modules are found on the control systems exams. A similar proportion of the thermal & fluids systems module is found on the nuclear exam. Finally, roughly 15% of the machine design and thermal & fluids systems modules are found on the industrial exam and a similar percentage of the mechanical breadth module on the nuclear exam. The one noticeable overlap with a practice act discipline occurs with the civil structural depth module -- 22% of the machine design module appears on the structural module. (Table 10.11)

Overlap reflected in dual licenses. Areas of significant overlap described above are also reflected in discipline combinations found among those with dual licenses. The two title act disciplines with the highest percentages of dual licenses were not included in the exam outline comparisons because of either limited numbers of licensees (agricultural engineering with 20% holding a civil license and 4% a mechanical license) or the absence of an NCEES exam (traffic engineering with 36% holding a civil license). Discipline combinations with the greatest amount of overlap in exam content that also had significant numbers of dual licenses include: nuclear (15% had a mechanical license), control systems (7% had an electrical license and 5%, a mechanical license), fire protection (7% had a mechanical license and 4% a civil license), metallurgical (4% had a mechanical license), industrial (3% had a mechanical license) and chemical (3% had a mechanical license).

Consistent with the lack of overlap in exam content and the one-directional overlap permitted by the regulatory structure, less than 1% of civil engineers had dual licenses involving the other practice act disciplines and less than 1% of electrical engineers had a civil license as well. Between 1 and 2% of mechanical engineers had licenses in civil and electrical.

The order in which dual licenses were obtained is also of interest. Of those with dual licenses, a slight majority of the practice act engineers obtained their civil license first (55% and 54% for electrical and mechanical engineers). For the title act disciplines with meaningful numbers of cases, most of those with dual licenses obtained the civil first, ranging from 69% for agricultural engineers to 97% for fire protection. Control systems engineers with electrical and mechanical licenses also obtained the practice license first; 75% obtained the electrical and 53% the mechanical before obtaining the control systems license. The same was true for fire protection and nuclear engineers with mechanical licenses; 77% and 57% respectively obtained the practice license first. Only chemical engineers obtained the mechanical license second (84%). (Table 10.13)

Nature of Overlapping Content

Where significant overlap in exam content exists, it is of interest to consider more specifically what these exams have in common. Up to this point, this chapter has focused on the relative amount of overlap between pairs of exams. But now that the analysis is shifting to the more detailed location of this overlap, the most useful measure is the percent of experts who identified overlap between two particular exam areas.

ISR chose to explore in more depth those pairings where the proportion of overlapping content exceeded 15% on at least one of the paired exams. This decision rule led, coincidentally, to a more detailed comparison of overlapping content for 30 pairings of exam modules. The discipline pairings are described in Table 10.14. While most of the pairings in the top 30 -- ranked in terms of the average amount of overlap on the two paired exam modules -- are included in this part of the analysis, some fell out because they didn't meet the 15% threshold on at least one exam and others not in the top 30 were included because they did. There are two more pairings of industrial with practice act disciplines and two fewer pairings involving fire protection. One of the nuclear pairings fell out, while an additional pair of civil and mechanical made the cut.

Chemical engineering and practice act exam modules. The subject matter experts identified similarities between the Fluids and Heat Transfer sections of the chemical exam and several sections of the thermal & fluids systems module. Half or more of the 11 experts found overlap between these two sections of the chemical exam and the Engineering Principles, Hydraulic System Components, Power Plant Components and Systems Applications sections of the thermal & fluids systems module. The Engineering Principles section of the thermal & fluids systems module also overlapped with chemical exam sections on Mass and Energy Balances, Thermodynamics and Plant Design. The System Applications section of the thermal & fluids systems module overlaps with the chemical exam section on Thermodynamics. (Table 10.15)

Some of the same areas on the chemical exam (HeatTransfer, Fluids, Thermodynamics and to a lesser extent Mass and Energy Balances, Mass Transfer and Plant Design) overlapped with the HVAC & refrigeration module. This was particularly true of the Principles, Equipment and Materials and Systems Applications sections. These sections make up most of the HVAC & refrigeration module and the corresponding areas, most of the chemical engineering exam.

Most of the experts saw significant overlap between five of the seven areas on the chemical exam and the Supportive Knowledges and System Applications sections of the machine design module. However, these sections make up only 21% of this module. Slightly less than half of the experts saw similarities in the chemical exam section on Plant Design and the more important Engineering Principles portion of the machine design module.

A majority of experts saw overlap between the Heat Transfer, Fluids and Plant Design sections of the chemical exam and the General Knowledge, Codes and Standards topic area, specifically the Engineering Principles or Fundamentals of Engineering Practice portions, of the mechanical breadth module. The other part of this module with significant overlap was in the Energy Conversion/Power Systems Knowledge area, which overlapped with Mass and Energy Balances, Fluids and Thermodynamics on the chemical exam. (Table 10.15)

Finally, portions of the chemical exam outline overlapped with sections of the water resources and environmental topics on the environmental and water resources modules of the civil engineering exam. All experts agreed that the Fluids section of the chemical exam overlapped with Hydraulics on the Water Resources sections of the two civil depth modules. Others, ranging from 43% to 71%, saw comparability between the Plant Design section of the chemical exam and the water and wastewater treatment, biology and solid/hazardous waste sections of the two civil engineering depth modules. A similar proportion (43%) saw similarities between the chemical exam section on Thermodynamics and the environmental module section on Wastewater Treatment. (Table 10.15)

Control systems engineering and practice act exam modules. Different parts of the control systems exam overlap with various sections of the mechanical and electrical modules. Between 93% and 100% of 14 experts agreed that overlap occurs between the control systems exam sections on Valves & Final Elements and Process Dynamics and the HVAC & refrigeration and thermal &fluids systems module sections on Engineering Principles. There is also significant agreement that the same sections of the control systems exam overlap the Engineering Principles (79% and 86%) and Analysis of Systems & Components (57%) portions of the mechanical breadth module. Together, the two control systems sections make up 20% of that exam; the identified sections on the mechanical depth modules make up similar proportions of those exams (19% and 22%) while the Engineering Principles section on the breadth module is 15%. In short, there is widespread agreement among 14 experts concerning overlapping content on substantial sections of the control systems and mechanical engineering exams. (Table 10.16)

A secondary area of overlap involves the control systems exam sections on Documentation and the Economics of Control. Most experts (79%) perceived similarities between Economics of Control and the Supportive Knowledges section of the HVAC & refrigeration module, the Engineering Principles section of the thermal & fluids systems module, and the Fundamental Engineering Practice section of the mechanical breadth module. However, Economics of Control makes up only 2% of the control systems exam. Documentation, making up 8% of that exam, also overlaps with the Fundamental Engineering Practice section of the mechanical breadth module and with the Development and Applications section of the electrical engineering computers depth module, which makes up almost a fourth of that exam. The control systems exam section on Codes and Standards (10% of that exam) is seen as similar to parallel sections on the electronics module and mechanical breadth module -- sections that are less important on those exams (4%) -- and to the Application Supportive Knowledge section of the thermal & fluids systems module, where the topic is given more importance (8%). (Table 10.16)

Almost half of the experts believed that the most important section of the control systems exam, Discrete Logic, Interlocks, Alarms and Sequencing (18%) overlapped with the similarly weighted (16%) computers module section on Digital Electronics. The same proportion of experts saw a connection between the control systems exam section on Digital Control Systems (8% of the exam) and the computers module section on System Software (12% of the exam). (Table 10.16)

Roughly half also saw similarities between the control systems exam sections on Analog & Digital Data Transmission and the electronics depth module sections on Communication & Signal Processing and Telecommunications, as well as the computers depth module section on Networks. Over half also perceived that Sensors, an important area on control systems' exam (16%), overlapped with Measurement and Instrumentation on the electronics depth module (4%) and Equipment and Materials on the HVAC & refrigeration module (37%). (Table 10.16)

Thus, the more significant overlaps involving control systems occurred: 1) between the control systems exam section on Valves & Final Elements and the mechanical exam sections on Engineering Principles and Fundamentals; 2) between the control systems section on Sensors and the HVAC & refrigeration module section on Equipment and Materials, and; 3) between the control systems section on Discrete Logic, etc. and the computer depth module section on Digital Electronics. (Table 10.16)

Fire protection engineering and practice act exam modules. Although a few experts saw overlap in many sections of these pairings, the only areas with significant agreement (43% or more) involved the Building systems section of the fire protection exam and portions of the structural depth module (Materials and Design Criteria), the mechanical breadth module (Applications of Machine Design and Materials Knowledge) and the thermal & fluids systems module (Engineering Principles). (Table 10.17)

Industrial engineering and practice act exam modules. The two most significant sections of the industrial exam, Facilities and Manufacturing, each make up 25% of the exam content. Overlap for the industrial exam section on Manufacturing is concentrated in mechanical engineering – both in the machine design module section on Systems Applications and Supportive Knowledges, and in the thermal & fluids systems module section on Engineering Principles. Overlap for the industrial exam section on Facilities is more dispersed -- in the environmental module section on Solid/Hazardous Waste, in the electrical breadth module section on Transmission and Distribution, and in the power depth module sections on Measurement, Instrumentation and Statistics, System Analysis and Power System Performance. (Table 10.18)

Material on the industrial exam section on Management (13% of the exam) overlaps with topics of moderate importance on the computers depth module -- Systems, System Software, and Networks. Quality Assurance, an area of comparable strength on the industrial exam (12%), overlaps with an area of moderate importance on the machine design module (Supportive Knowledges), and an area of less importance on the electrical breadth module (Safety and Reliability). (Table 10.18)

Manufacturing engineering and practice act exam modules. The only practice act discipline exam that overlaps with the manufacturing exam is mechanical engineering. In terms of weights on the respective exams, the most important areas of overlap involve manufacturing exam sections on Product/Process Design and Production, Systems and Control sections (21% and 17% respectively). These sections overlap with the thermal & fluids systems module section on Engineering Principles, the machine design module section on Systems Applications, and the mechanical breadth module section on Fundamental Engineering Practice. Between 64% and 79% of 14 experts agree on these areas of overlap. (Table 10.19)

Similar levels of agreement occurred in other less important areas. The manufacturing exam section on Management overlaps with the mechanical breadth exam section on Fundamental Engineering Practice, as well as the machine design module section on Supportive Knowledges and the thermal & fluids systems module section on Engineering Principles.

Manufacturing exam sections on Quality and Fabrication, Joining & Assembly also overlap with machine design module sections on Supportive Knowledges. Materials Engineering and Applications, an area of limited importance (6%) on the manufacturing exam, overlaps with the Engineering Principles section of three of the mechanical exam modules. The Engineering Principles section is 43% of the machine design module, 22% of the thermal & fluids systems module, and 15% of the mechanical breadth module. Finally, areas of limited importance on both exams – the manufacturing exam section on Materials Engineering & Applications (6%) and the machine design module section on Applications (6%) -- overlap. (Table 10.19)

Nuclear engineering and practice act exam modules. Two important parts of the nuclear exam (Power Systems and Fuel & Waste Management-- 25% and 20% respectively) overlap with important sections of the thermal & fluids systems module (Engineering Principles, Systems Applications and Power Plant Components). These same sections of the nuclear exam overlap with parallel, but less heavily weighted, parts of the mechanical breadth exam (Engineering Principles, Fundamental Engineering Practice and Analysis of Systems and Components). (Table 10.20)

A less heavily weighted section of the nuclear exam, Measurements and Instruments (15%), overlaps with less important sections of the electronics module -- Measurement and Instrumentation (4%), Control System Fundamentals (10%) and Control System Design/Implementation (6%). (Table 10.20)

Mechanical and civil modules. Engineering Principles is major section of the machine design module, with 43% of the exam content. This section overlaps with the Structural section of the civil breadth module (20% of that exam) and with the structural depth module section on Materials and Failure Analysis. Areas of less importance on the machine design module -- System Applications (13%) and Supportive Knowledges (18%) – overlap, respectively, with the Structural and Water Resources sections of the civil breadth exam. (Table 10.21). In addition to the important overlap between the Mechanics of Materials and Failure Analysis on the structural module and the machine design module just described, the same areas overlap with the less important Supportive Knowledges section of the thermal & fluids systems module. (Table 10.22)

Table 10.1 Contact and Participation Rates for Subject Matter Experts Reviewing NCEES Exam Outlines

			Enforcement Technical Experts[c]			Electrical Engineering TAC	Title Act Subject Matter Experts[d]	All
			Civil	Mechanical	Electrical			
Percent	Ability to contact	Unable to contact[a]	40%	35%	33%	0%	26%	31%
		Contacted	60%	65%	67%	100%	74%	69%
		Total	100%	100%	100%	100%	100%	100%
	Outcome for those contacted	Contacted but unable to participate[b]	11%	5%	20%	0%	8%	9%
		Left messages, but calls not returned	0%	5%	40%	0%	0%	7%
		Invitation to participate sent	33%	20%	10%	20%	8%	16%
		Comparison documents sent	0%	5%	0%	20%	4%	4%
		Participated	56%	65%	30%	60%	81%	64%
		Total	100%	100%	100%	100%	100%	100%
Number	Ability to contact	Unable to contact[a]	6	11	5	0	9	31
		Contacted	9	20	10	5	26	70
		Total	15	31	15	5	35	101
	Outcome for those contacted	Contacted but unable to participate[b]	1	1	2		2	6
		Left messages, but calls not returned		1	4			5
		Invitation to participate sent	3	4	1	1	2	11
		Comparison documents sent	0	1	0	1	1	3
		Participated	5	13	3	3	21	45
		Total	9	20	10	5	26	70

[a] Non-working phone number, ill or deceased.

[b] Some experts felt they were not qualified to participate because they were retired, while other were not able to take on the additional work.

[c] For the purpose of this study, the Board made available their database of Enforcement Technical Experts, which consisted of 98 Civil Engineers, 40 Mechanical Engineers, and 32 Electrical Engineers. A random sample of 15 experts was drawn from each discipline. The list of experts within each discipline was ordered by license number, which provides a rough measure of years of experience as a licensed engineer, and divided into three equal strata. A systematic sample of five experts was selected from each stratum, producing an initial sample of 15 experts from each discipline. For reasons described in the following paragraph, it became necessary to draw an additional sample of Mechanical Engineers. The same sampling procedures were followed for this supplemental sample selection.

The objective was to have roughly equal numbers of experts from each pair of disciplines review the exam outlines. For example, for the comparison between Civil and Mechanical Engineering exam outlines, ideally half the reviewers should be licensed Civil Engineers and half should be licensed Mechanical Engineers. All experts were asked to indicate which disciplines they felt comfortable working with. Mechanical engineers, on average, tended to choose to work with fewer disciplines, thus the need to select more of them.

[d] The Board provided a list of 38 Title Act Subject Matter Experts. Three of these experts were not contacted because their areas of knowledge were not currently being examined. Table 10.3 shows the licensing and expertise for all of the experts.

Table 10.2 Number of Experts who Reviewed Each Pair of Exam Outlines

	Civil	Electrical & Computer	Mechanical
Electrical & Computer	9		
Mechanical	14	13	
Chemical	7	7	11
Control Systems	6	7	14
Fire Protection	7	7	13
Industrial	9	8	13
Manufacturing	8	6	14
Nuclear	6	6	15

Table 10.3. Selection Criteria for Experts Comparing Pairs of NCEES Exam Outlines

		Civil				Electrical & Computer				Mechanical			
		No special knowledge	Current license in discipline	Board designated expert	Total	No special knowledge	Current license in discipline	Board designated expert	Total	No special knowledge	Current license in discipline	Board designated expert	Total
Electrical & Computer	No special knowledge		5		5								
	Current license in discipline	3			3								
	Board-designated expert			1	1								
	Total	3	5	1	9								
Mechanical	No special knowledge		5		5		6		6				
	Current license in discipline	5	2	1	8	5			5				
	Expired license in discipline			1	1			1	1				
	Board-designated expert							1	1				
	Total	5	7	2	14	5	6	2	13				
Chemical	No special knowledge		3		3		3		3		7		7
	Current license in discipline	4			4	4			4		2	2	4
	Total	4	3		7	4	3		7		9	2	11
Control	No special knowledge		4		4		4		4	1	11		12
	Current license in discipline	2			2	2			2	2			2
	Board-designated expert							1	1				
	Total	2	4		6	2	4	1	7	3	11		14
Fire	No special knowledge		4		4		4		4		10		10
	Current license in discipline	1			1			1	1			1	1
	Expired license in discipline	1			1	1			1	1			1
	Board-designated expert	1			1	1			1			1	1
	Total	3	4		7	2	4	1	7	1	10	2	13
Industrial	No special knowledge		5		5		4		4		9		9
	Current license in discipline	1			1	1			1	1			1
	Board-designated expert	3			3	2		1	3	2		1	3
	Total	4	5		9	3	4	1	8	3	9	1	13
Manufacturing	No special knowledge		5		5		3		3		11		11
	Board-designated expert	3			3	2		1	3	3			3
	Total	3	5		8	2	3	1	6	3	11		14
Nuclear	No special knowledge		2		2		1		1		9		9
	Current license in discipline	3			3	3			3	3			3
	Expired license in discipline	1			1	1			1	1			1
	Board-designated expert							1	1	1	1		2
	Total	4	2		6	4	1	1	6	5	10		15

Table 10.4. Computation of Percent of Industrial Engineering Exam Content
Covered on the Computers Depth Module of the Electrical and Computer Engineering Exam

			Approximate Percentage of Examination	Percent of Experts Identifying Overlap	Weighted Percent Overlap
1. Facilities (25%)	A.	Site selection	3.57%		
	B.	Plant layout	3.57%		
	C.	Equipment	3.57%		
	D.	Material handling and waste management systems	3.57%		
	E.	Packaging equipment	3.57%		
	F.	Capacity analysis	3.57%		
	G.	Power service and other utility requirements	3.57%		
2. Manufacturing (25%)	A.	Products	3.13%		
	B.	Manufacturing processes	3.13%		
	C.	Maintenance procedures	3.13%		
	D.	Operations sequencing	3.13%		
	E.	Machine grouping	3.13%		
	F.	Robotics	3.13%	12.5%	.39%
	G.	Automation	3.13%		
	H.	Value engineering	3.13%	12.5%	.39%
3. Production and Inventory Systems (12%)	A.	Forecasting	1.71%		
	B.	Production scheduling	1.71%		
	C.	Project scheduling	1.71%		
	D.	Production control	1.71%		
	E.	Resource planning	1.71%		
	F.	Logistics	1.71%		
	G.	Distribution	1.71%		
4. Work Systems and Ergonomics (13%)	A.	Measuring work	2.17%		
	B.	Methods analysis	2.17%		
	C.	Incentive and other payment plans	2.17%		
	D.	Workplace design	2.17%		
	E.	Human-machine interfacing	2.17%	12.5%	.27%
	F.	Industrial hygiene and safety	2.17%		
5. Quality Assurance (12%)	A.	Quality assurance plans	2.40%		
	B.	Reliability analysis	2.40%		
	C.	Control procedures	2.40%		
	D.	Capability analysis	2.40%		
	E.	Quality aspects of design	2.40%	12.5%	.30%
6. Management and Computer/ Information Systems (13%)	A.	Organization design	1.86%		
	B.	Staffing plans	1.86%		
	C.	Productivity	1.86%	12.5%	.23%
	D.	Human resources	1.86%		
	E.	Computer systems analysis and design	1.86%	87.5%	1.63%
	F.	Specification of computer equipment	1.86%	75.0%	1.39%
	G.	Computer communication protocols	1.86%	75.0%	1.39%
Total			100.00%	N=8	5.99%

Percentages shown in parentheses in the first column are the approximate percentage of the examination provided by NCEES in the exam outline.

Table 10.5. Computation of Percent of the Computers Depth Module of the Electrical and Computer Engineering Exam Content Covered on the Industrial Engineering Exam

				Approximate Percentage of Examination	Percent of Experts Identifying Overlap	Weighted Percent Overlap
1. General Computer Systems (10%)	A. Interpretation of Codes and Standards (4%)	1) IEEE Standards		2.00%	37.5%	.75%
		2) ISO Standards		2.00%	37.5%	.75%
	B. Micro-processor Systems (6%)	1) Number Systems and Codes		1.00%	25.0%	.25%
		2) Microprocessor Systems	a) Components	1.00%	25.0%	.25%
			b) Control Applications	1.00%	37.5%	.38%
			c) Math Applications	1.00%	25.0%	.25%
			d) Programmable Logic Controllers	1.00%	25.0%	.25%
			e) Real-time Operations	1.00%	37.5%	.38%
2. Hardware (45%)	A. Digital Electronics (16%)	1) Memory Devices		1.60%	12.5%	.20%
		2) Medium Scale Integration Devices		1.60%	12.5%	.20%
		3) Programmable Logic Devices and Gate Arrays		1.60%	12.5%	.20%
		4) Tristate Logic		1.60%	12.5%	.20%
		5) Digital Electronic Devices		1.60%	12.5%	.20%
		6) Logic Components	a) Properties	1.60%	12.5%	.20%
			b) Fan-In, Fan-Out	1.60%	12.5%	.20%
			c) Propagation Delay	1.60%	12.5%	.20%
		7) Large Scale Integration		1.60%	12.5%	.20%
		8) Analog to Digital and Digital to Analog Conversion		1.60%	12.5%	.20%
	B. Design and Analysis (19%)	1) Clock Generation/Distribution		1.27%	12.5%	.16%
		2) Memory Interface		1.27%	12.5%	.16%
		3) Processor Interfacing		1.27%	12.5%	.16%
		4) Asynchronous Communication		1.27%	12.5%	.16%
		5) Metastability		1.27%	12.5%	.16%
		6) Races and Hazards		1.27%	12.5%	.16%
		7) State Transition Tables		1.27%	12.5%	.16%
		8) State Transition Diagrams		1.27%	12.5%	.16%
		9) Algorithmic State Machine Charts		1.27%	12.5%	.16%
		10) Timing Diagrams		1.27%	12.5%	.16%
		11) Synchronous State Machines		1.27%	12.5%	.16%
		12) Asynchronous State Machines		1.27%	12.5%	.16%
		13) Pipelining and Parallel Processing		1.27%	12.5%	.16%
		14) Fault Tolerance		1.27%	12.5%	.16%
		15) Sampling Theory		1.27%	12.5%	.16%
	C. Systems (10%)	1) Digital Signal Processor Architecture		1.67%	62.5%	1.04%
		2) Design for Testability		1.67%	87.5%	1.46%
		3) Computer Architecture		1.67%	62.5%	1.04%
		4) Mass Storage Devices		1.67%	62.5%	1.04%
		5) Input/Output Devices		1.67%	75.0%	1.25%
		6) Central Processing Unit Architecture		1.67%	75.0%	1.25%

Percentages shown in parentheses in the first and second columns are the approximate percentage of the examination provided by NCEES in the exam outline.

Table 10.5. (continued) Computation of Percent of the Computers Depth Module of the Electrical and Computer Engineering Exam Content Covered on the Industrial Engineering Exam

				Approximate Percentage of Examination	Percent of Experts Identifying Overlap	Weighted Percent Overlap
3. Software (35%)	A. System Software (12%)	1) Computer Security		2.40%	37.5%	.90%
		2) Real-Time Operating Systems		2.40%	50.0%	1.20%
		3) Error Detection and Control		2.40%	37.5%	.90%
		4) Drivers		2.40%	37.5%	.90%
		5) Time Critical Scheduling		2.40%	25.0%	.60%
	B. Development/ Applications (23%)	1) Computer Control and Monitoring		1.10%	25.0%	.27%
		2) Software Lifecycle	a) Requirements Definition	1.10%	25.0%	.27%
			b) Specification	1.10%	25.0%	.27%
			c) Design	1.10%	25.0%	.27%
			d) Implementation and Debugging	1.10%	25.0%	.27%
			e) Testing	1.10%	37.5%	.41%
			f) Maintenance and Upgrade	1.10%	12.5%	.14%
		3) Fault Tolerance		1.10%	25.0%	.27%
		4) Modeling and Simulation		1.10%	50.0%	.55%
		5) Software Pipelining		1.10%	12.5%	.14%
		6) Human Interface Requirements		1.10%	25.0%	.27%
		7) Software Design Methods and Documentation	a) Structured Programming	1.10%	12.5%	.14%
			b) Top Down or Bottom Up Programming	1.10%	12.5%	.14%
			c) Successive Refinement	1.10%	12.5%	.14%
			d) Programming Specifications	1.10%	12.5%	.14%
			e) Program Testing	1.10%	25.0%	.27%
			f) Structure Diagrams	1.10%	12.5%	.14%
			g) Recursion	1.10%	12.5%	.14%
		8) Object Oriented Design		1.10%	12.5%	.14%
		9) Data Structures	a) Internal	1.10%	12.5%	.14%
			b) External	1.10%	12.5%	.14%
4. Networks (10%)	A. Networks	1) Protocols	a) TCP/IP	1.67%	75.0%	1.25%
			b) Ethernet	1.67%	75.0%	1.25%
		2) Computer Networks	a) OSI Model	1.67%	37.5%	.63%
			b) Network Topology	1.67%	37.5%	.63%
			c) Network Technology	1.67%	37.5%	.63%
			d) Network Security	1.67%	37.5%	.63%
Total				100.00%	N=8	28.86%

Percentages shown in parentheses in the first and second columns are the approximate percentage of the examination provided by NCEES in the exam outline.

Table 10.6. Percent of Overlapping Content Among Practice and Title Discipline Exam Outlines (in Average Rank Order)

* Comparison Between Practice Act Disciplines	1st Discipline	2nd Discipline	Percent of 2nd Discipline's Exam Content Found on the 1st	Percent of 1st Discipline's Exam Content Found on the 2nd	Rank on 1st%	Rank on 2nd%	Average Rank Order
	Mechanical HVAC Module	Chemical	39.7%	39.9%	1	1	1
	Mechanical Breadth Module	Chemical	33.7%	34.0%	3	2	2.5
	Mechanical Thermal and Fluids Systems Module	Chemical	38.1%	31.1%	2	3	2.5
	Mechanical Machine Design Module	Manufacturing	32.3%	30.5%	4	4	4
	Electrical Electronics Module	Control Systems	30.7%	21.7%	5	10	7.5
	Civil Environmental Depth Module	Chemical	20.9%	24.1%	10	6	8
*	Civil Structural Depth Module	Mechanical Machine Design Module	21.7%	20.5%	9	13	11
	Mechanical HVAC Module	Control Systems	24.3%	19.0%	8	15	11.5
	Mechanical Breadth Module	Control Systems	19.0%	19.3%	11	14	12.5
	Mechanical Thermal and Fluids Systems Module	Control Systems	16.9%	20.6%	14	12	13
	Mechanical Breadth Module	Manufacturing	16.7%	16.0%	15	19	17
	Mechanical Thermal and Fluids Systems Module	Nuclear	13.9%	21.4%	26	11	18.5
	Mechanical Machine Design Module	Chemical	27.5%	10.8%	6	33	19.5
	Electrical Computers Depth Module	Control Systems	12.3%	23.5%	33	7	20
	Mechanical Breadth Module	Nuclear	15.6%	15.1%	18	24	21
	Mechanical Machine Design Module	Industrial	14.0%	16.4%	25	18	21.5
	Mechanical Thermal and Fluids Systems Module	Manufacturing	14.7%	13.1%	21	27	24
	Mechanical Breadth Module	Fire Protection	17.5%	10.1%	12	38	25
*	Civil Structural Depth Module	Mechanical Breadth Module	11.1%	17.6%	36	16	26
	Civil Water Resources Depth Module	Chemical	13.1%	15.2%	29	23	26
	Civil Structural Depth Module	Fire Protection	15.3%	10.7%	19	34	26.5
	Mechanical Thermal and Fluids Systems Module	Fire Protection	17.0%	9.3%	13	41	27
	Electrical Electronics Module	Nuclear	7.5%	22.0%	48	8	28
	Electrical Computers Depth Module	Industrial	6.0%	28.9%	53	5	29
	Electrical Breadth Module	Industrial	9.6%	17.3%	42	17	29.5
	Civil Water Resources Depth Module	Fire Protection	14.3%	10.2%	23	37	30
	Mechanical HVAC Module	Nuclear	14.4%	10.1%	22	39	30.5
	Mechanical HVAC Module	Fire Protection	26.9%	6.6%	7	54	30.5
*	Civil Breadth Module	Mechanical Machine Design Module	14.9%	9.2%	20	42	31
	Electrical Power Module	Industrial	5.9%	21.9%	54	9	31.5
	Electrical Breadth Module	Manufacturing	12.6%	11.0%	32	32	32
	Mechanical Thermal and Fluids Systems Module	Industrial	8.7%	15.3%	44	22	33
*	Civil Structural Depth Module	Mechanical Thermal and Fluids Systems Module	6.8%	15.7%	49	20	34.5
	Civil Breadth Module	Chemical	11.4%	10.6%	35	35	35
*	Civil Breadth Module	Mechanical Breadth Module	13.6%	8.9%	27	43	35
	Mechanical Breadth Module	Industrial	9.3%	12.0%	43	28	35.5

Table 10.6. (continued) Percent of Overlapping Content Among Practice and Title Discipline Exam Outlines (in Average Rank Order)

* Comparison Between Practice Act Disciplines	1st Discipline	2nd Discipline	Percent of 2nd Discipline's Exam Content Found on the 1st	Percent of 1st Discipline's Exam Content Found on the 2nd	Rank on 1st%	Rank on 2nd%	Average Rank Order
	Civil Breadth Module	Fire Protection	16.4%	6.6%	16	55	35.5
	Electrical Breadth Module	Control Systems	9.8%	11.5%	41	31	36
*	Civil Water Resources Depth Module	Mechanical Thermal and Fluids Systems Module	12.9%	8.5%	30	46	38
	Civil Environmental Depth Module	Industrial	5.5%	15.4%	60	21	40.5
	Electrical Breadth Module	Nuclear	6.2%	11.5%	51	30	40.5
	Civil Environmental Depth Module	Fire Protection	16.1%	5.5%	17	66	41.5
	Civil Water Resources Depth Module	Control Systems	5.6%	13.1%	58	26	42
	Electrical Breadth Module	Fire Protection	10.1%	8.6%	40	45	42.5
*	Civil Water Resources Depth Module	Mechanical Breadth Module	11.8%	7.4%	34	51	42.5
	Mechanical HVAC Module	Industrial	4.9%	13.5%	64	25	44.5
*	Civil Breadth Module	Mechanical Thermal and Fluids Systems Module	8.6%	8.4%	45	47	46
	Mechanical Machine Design Module	Nuclear	11.0%	6.6%	37	56	46.5
*	Electrical Breadth Module	Mechanical Breadth Module	5.4%	10.5%	61	36	48.5
	Electrical Breadth Module	Chemical	4.6%	11.9%	70	29	49.5
	Mechanical Machine Design Module	Fire Protection	10.2%	5.7%	39	62	50.5
	Electrical Power Module	Fire Protection	8.1%	6.3%	47	57	52
*	Civil Environmental Depth Module	Mechanical Thermal and Fluids Systems Module	14.3%	4.1%	24	81	52.5
	Civil Transportation Depth Module	Fire Protection	13.4%	4.6%	28	78	53
	Mechanical Machine Design Module	Control Systems	10.4%	5.0%	38	71	54.5
	Civil Breadth Module	Industrial	4.9%	8.4%	64	47	55.5
	Civil Environmental Depth Module	Control Systems	6.5%	5.5%	50	64	57
	Civil Transportation Depth Module	Industrial	4.8%	7.4%	66	50	58
*	Civil Environmental Depth Module	Mechanical Breadth Module	12.8%	3.4%	31	86	58.5
	Civil Environmental Depth Module	Manufacturing	3.8%	9.9%	78	40	59
	Civil Environmental Depth Module	Nuclear	8.5%	4.9%	46	72	59
	Electrical Computers Depth Module	Manufacturing	4.8%	6.7%	66	53	59.5
	Mechanical HVAC Module	Manufacturing	5.9%	5.5%	54	65	59.5
	Civil Breadth Module	Control Systems	6.1%	5.4%	52	67	59.5
	Electrical Power Module	Manufacturing	3.5%	8.9%	82	44	63
*	Civil Water Resources Depth Module	Mechanical HVAC Module	4.8%	6.2%	68	58	63
*	Electrical Breadth Module	Mechanical Thermal and Fluids Systems Module	3.7%	7.5%	80	49	64.5
*	Civil Transportation Depth Module	Mechanical Breadth Module	5.7%	4.9%	57	73	65
*	Electrical Power Module	Mechanical Thermal and Fluids Systems Module	4.6%	5.7%	71	60	65.5
	Civil Water Resources Depth Module	Industrial	4.1%	5.6%	75	63	69
*	Civil Transportation Depth Module	Mechanical Thermal and Fluids Systems Module	4.7%	4.8%	69	74	71.5
*	Civil Environmental Depth Module	Mechanical HVAC Module	5.8%	3.0%	56	88	72

Table 10.6. (continued) Percent of Overlapping Content Among Practice and Title Discipline Exam Outlines (in Average Rank Order)

* Comparison Between Practice Act Disciplines	1st Discipline	2nd Discipline	Percent of 2nd Discipline's Exam Content Found on the 1st	Percent of 1st Discipline's Exam Content Found on the 2nd	Rank on 1st%	Rank on 2nd%	Average Rank Order
	Civil Breadth Module	Manufacturing	4.4%	4.8%	73	74	73.5
	Electrical Power Module	Control Systems	5.0%	4.0%	63	84	73.5
	Civil Breadth Module	Nuclear	5.6%	2.8%	58	90	74
*	Civil Water Resources Depth Module	Mechanical Machine Design Module	2.8%	5.8%	90	59	74.5
	Civil Structural Depth Module	Industrial	3.6%	5.1%	81	70	75.5
*	Civil Geotechnical Depth Module	Mechanical Machine Design Module	4.6%	4.2%	71	80	75.5
	Civil Structural Depth Module	Manufacturing	3.4%	5.2%	83	69	76
	Electrical Electronics Module	Chemical	1.3%	7.2%	104	52	78
	Electrical Electronics Module	Fire Protection	5.3%	1.3%	62	101	81.5
	Civil Transportation Depth Module	Control Systems	2.0%	5.2%	96	68	82
	Civil Transportation Depth Module	Chemical	2.8%	4.3%	88	79	83.5
*	Civil Geotechnical Depth Module	Mechanical Breadth Module	2.5%	4.7%	92	76	84
	Electrical Computers Depth Module	Fire Protection	4.0%	2.5%	76	92	84
	Electrical Computers Depth Module	Chemical	1.1%	5.7%	109	61	85
	Electrical Power Module	Nuclear	2.2%	4.6%	94	77	85.5
	Civil Geotechnical Depth Module	Fire Protection	4.0%	1.8%	76	96	86
*	Civil Transportation Depth Module	Mechanical HVAC Module	2.8%	3.3%	88	87	87.5
*	Civil Breadth Module	Mechanical HVAC Module	3.1%	2.9%	86	89	87.5
*	Civil Environmental Depth Module	Mechanical Machine Design Module	3.4%	2.7%	84	91	87.5
*	Electrical Breadth Module	Mechanical HVAC Module	3.7%	1.7%	79	97	88
*	Civil Transportation Depth Module	Mechanical Machine Design Module	2.0%	4.1%	96	82	89
*	Electrical Breadth Module	Mechanical Machine Design Module	3.3%	1.9%	85	95	90
	Civil Geotechnical Depth Module	Industrial	1.5%	4.1%	102	82	92
*	Electrical Power Module	Mechanical Breadth Module	2.7%	2.0%	91	93	92
	Electrical Electronics Module	Industrial	1.7%	1.9%	101	94	97.5
*	Electrical ECC Depth Module	Mechanical HVAC Module	2.1%	1.4%	95	100	97.5
*	Electrical Power Module	Mechanical HVAC Module	1.9%	1.5%	99	98	98.5
*	Civil Geotechnical Depth Module	Mechanical Thermal and Fluids Systems Module	.9%	3.7%	113	85	99
*	Civil Structural Depth Module	Mechanical HVAC Module	2.0%	1.0%	98	102	100
	Civil Water Resources Depth Module	Manufacturing	2.3%	.7%	93	112	102.5
	Civil Transportation Depth Module	Manufacturing	1.2%	1.5%	107	99	103
	Electrical Computers Depth Module	Nuclear	1.8%	.8%	100	108	104
*	Electrical ECC Depth Module	Mechanical Thermal and Fluids Systems Module	4.3%	.1%	74	134	104
	Electrical Power Module	Chemical	1.2%	1.0%	107	103	105
*	Electrical ECC Depth Module	Mechanical Breadth Module	2.9%	.3%	87	123	105
*	Electrical Power Module	Mechanical Machine Design Module	1.3%	.6%	105	113	109

Table 10.6. (continued) Percent of Overlapping Content Among Practice and Title Discipline Exam Outlines (in Average Rank Order)

* Comparison Between Practice Act Disciplines	1st Discipline	2nd Discipline	Percent of 2nd Discipline's Exam Content Found on the 1st	Percent of 1st Discipline's Exam Content Found on the 2nd	Rank on 1st%	Rank on 2nd%	Average Rank Order
	Civil Structural Depth Module	Nuclear	.8%	.9%	116	104	110
*	Electrical Computers Depth Module	Mechanical HVAC Module	1.2%	.5%	106	115	110.5
	Electrical Electronics Module	Manufacturing	.7%	.9%	119	105	112
*	Civil Structural Depth Module	Electrical Computers Depth Module	.9%	.7%	113	111	112
*	Civil Transportation Depth Module	Electrical Breadth Module	.7%	.8%	120	106	113
*	Civil Structural Depth Module	Electrical Power Module	1.1%	.4%	110	117	113.5
	Civil Geotechnical Depth Module	Manufacturing	.4%	.8%	122	106	114
*	Electrical Computers Depth Module	Mechanical Breadth Module	.7%	.7%	118	110	114
*	Civil Water Resources Depth Module	Electrical Power Module	1.1%	.4%	110	120	115
	Civil Geotechnical Depth Module	Control Systems	.9%	.4%	115	116	115.5
*	Civil Environmental Depth Module	Electrical Power Module	1.1%	.3%	110	123	116.5
	Civil Structural Depth Module	Chemical	.3%	.7%	127	109	118
*	Electrical ECC Depth Module	Mechanical Machine Design Module	1.5%	.1%	103	134	118.5
	Civil Geotechnical Depth Module	Chemical	.3%	.6%	127	114	120.5
*	Civil Transportation Depth Module	Electrical Computers Depth Module	.4%	.4%	124	117	120.5
*	Civil Geotechnical Depth Module	Mechanical HVAC Module	.5%	.3%	121	122	121.5
*	Civil Structural Depth Module	Electrical Electronics Module	.3%	.4%	130	117	123.5
	Civil Water Resources Depth Module	Nuclear	.4%	.2%	122	127	124.5
*	Civil Water Resources Depth Module	Electrical Electronics Module	.3%	.4%	130	120	125
*	Electrical Computers Depth Module	Mechanical Thermal and Fluids Systems Module	.8%	.1%	117	133	125
*	Civil Environmental Depth Module	Electrical Electronics Module	.3%	.3%	130	123	126.5
*	Civil Transportation Depth Module	Electrical Electronics Module	.3%	.2%	126	127	126.5
*	Civil Breadth Module	Electrical Computers Depth Module	.3%	.3%	129	126	127.5
*	Electrical Computers Depth Module	Mechanical Machine Design Module	.3%	.2%	125	130	127.5
*	Civil Transportation Depth Module	Electrical Power Module	.1%	.2%	135	127	131
*	Civil Environmental Depth Module	Electrical Breadth Module	.2%	.2%	133	131	132
*	Civil Breadth Module	Electrical Breadth Module	.2%	.1%	133	132	132.5
	Civil Structural Depth Module	Control Systems	.0%	.0%	136	136	136
	Civil Geotechnical Depth Module	Nuclear	.0%	.0%	136	136	136
	Civil Transportation Depth Module	Nuclear	.0%	.0%	136	136	136
*	Civil Geotechnical Depth Module	Electrical Breadth Module	.0%	.0%	136	136	136
*	Civil Structural Depth Module	Electrical Breadth Module	.0%	.0%	136	136	136
*	Civil Water Resources Depth Module	Electrical Breadth Module	.0%	.0%	136	136	136
*	Civil Environmental Depth Module	Electrical Computers Depth Module	.0%	.0%	136	136	136
*	Civil Geotechnical Depth Module	Electrical Computers Depth Module	.0%	.0%	136	136	136
*	Civil Water Resources Depth Module	Electrical Computers Depth Module	.0%	.0%	136	136	136

Table 10.6. (continued) Percent of Overlapping Content Among Practice and Title Discipline Exam Outlines (in Average Rank Order)

* Comparison Between Practice Act Disciplines	1st Discipline	2nd Discipline	Percent of 2nd Discipline's Exam Content Found on the 1st	Percent of 1st Discipline's Exam Content Found on the 2nd	Rank on 1st%	Rank on 2nd%	Average Rank Order
*	Civil Breadth Module	Electrical Electronics Module	.0%	.0%	136	136	136
*	Civil Geotechnical Depth Module	Electrical Electronics Module	.0%	.0%	136	136	136
*	Civil Breadth Module	Electrical Power Module	.0%	.0%	136	136	136
*	Civil Geotechnical Depth Module	Electrical Power Module	.0%	.0%	136	136	136

Table 10.7. Number of Discipline Pairs with the Greatest Average Overlap in Exam Content

		Civil	Mechanical	Electrical & Computer	Total
Title Act Disciplines	Control Systems		3	2	5
	Chemical	2	4		6
	Industrial		1	3	4
	Nuclear		3	1	4
	Manufacturing		3		3
	Fire Protection	2	3		5
	Total	4	17	6	27
Practice Act Disciplines	Civil				
	Mechanical	3			
	Electrical & Computer				
	Total	3	0	0	30

Table 10.8 Percent of Title Act Discipline Exam Content Covered on Practice Act Discipline Exams

			Title Act Disciplines					
Practice Act Disciplines			Chemical	Control Systems	Fire Protection	Industrial	Manufacturing	Nuclear
Civil	Breadth Module		11.4%	6.1%	16.4%	4.9%	4.4%	5.6%
	Depth Modules	Environmental	20.9%	6.5%	16.1%	5.5%	3.8%	8.5%
		Geotechnical	.3%	.9%	4.0%	1.5%	.4%	.0%
		Structural	.3%	.0%	15.3%	3.6%	3.4%	.8%
		Transportation	2.8%	2.0%	13.4%	4.8%	1.2%	.0%
		Water Resources	13.1%	5.6%	14.3%	4.1%	2.3%	.4%
Electrical & Computer	Breadth Module		4.6%	9.8%	10.1%	9.6%	12.6%	6.2%
	Depth Modules	Computers	1.1%	12.3%	4.0%	6.0%	4.8%	1.8%
		Electronics, Controls, and Communication	1.3%	30.7%	5.3%	1.7%	.7%	7.5%
		Power	1.2%	5.0%	8.1%	5.9%	3.5%	2.2%
Mechanical	Breadth Module		33.7%	19.0%	17.5%	9.3%	16.7%	15.6%
	Depth Modules	HVAC and Refrigeration	39.7%	24.3%	26.9%	4.9%	5.9%	14.4%
		Machine Design	27.5%	10.4%	10.2%	14.0%	32.3%	11.0%
		Thermal and Fluids Systems	38.1%	16.9%	17.0%	8.7%	14.7%	13.9%

Table 10.9 Percent of Civil Exam Content Covered on Other Exams

			Civil Exams					
				Depth Modules				
			Breadth Module	Environmental	Geotechnical	Structural	Transportation	Water Resources
Electrical & Computer	Breadth Module		.13%	.16%	.00%	.00%	.83%	.00%
	Depth Modules	Computers	.28%	.00%	.00%	.69%	.41%	.00%
		Electronics, Controls, and Communication	.00%	.33%	.00%	.41%	.21%	.37%
		Power	.00%	.33%	.00%	.41%	.21%	.37%
Mechanical	Breadth Module		8.93%	3.40%	4.68%	17.57%	4.90%	7.35%
	Depth Modules	HVAC and Refrigeration	2.86%	3.00%	.34%	1.03%	3.30%	6.16%
		Machine Design	9.17%	2.72%	4.24%	20.54%	4.05%	5.77%
		Thermal and Fluids Systems	8.44%	4.08%	3.65%	15.72%	4.81%	8.54%
Title Act Disciplines	Chemical		10.60%	24.14%	.58%	.71%	4.28%	15.24%
	Control Systems		5.40%	5.52%	.42%	.00%	5.20%	13.13%
	Fire Protection		6.58%	5.47%	1.79%	10.70%	4.55%	10.18%
	Industrial		8.44%	15.41%	4.05%	5.13%	7.44%	5.62%
	Manufacturing		4.81%	9.88%	.83%	5.19%	1.47%	.68%
	Nuclear		2.75%	4.92%	.00%	.93%	.00%	.21%

Table 10.10 Percent of Electrical Exam Content Covered on Other Exams

			Electrical & Computer Exams			
				Depth Modules		
			Breadth Module	Computers	Electronics, Controls, and Communication	Power
Civil	Breadth Module		.22%	.27%	.00%	.00%
	Depth Modules	Environmental	.22%	.00%	.25%	1.07%
		Geotechnical	.00%	.00%	.00%	.00%
		Structural	.00%	.93%	.25%	1.07%
		Transportation	.67%	.39%	.31%	.11%
		Water Resources	.00%	.00%	.25%	1.07%
Mechanical	Breadth Module		10.46%	.70%	.33%	2.00%
	Depth Modules	HVAC and Refrigeration	1.66%	.49%	1.40%	1.48%
		Machine Design	1.85%	.18%	.07%	.59%
		Thermal and Fluids Systems	7.50%	.08%	.07%	5.73%
Title Act Disciplines	Chemical		11.94%	5.70%	7.15%	.96%
	Control Systems		11.47%	23.47%	21.73%	3.95%
	Fire Protection		8.58%	2.48%	1.33%	6.32%
	Industrial		17.31%	28.86%	1.91%	21.89%
	Manufacturing		11.00%	6.67%	.88%	8.89%
	Nuclear		11.54%	.80%	21.95%	4.64%

Table 10.11 Percent of Mechanical Exam Content Covered on Other Exams

			Mechanical Exams			
				Depth Modules		
			Breadth Module	HVAC and Refrigeration	Machine Design	Thermal and Fluids Systems
Civil	Breadth Module		13.56%	3.09%	14.88%	8.62%
	Depth Modules	Environmental	12.77%	5.84%	3.37%	14.28%
		Geotechnical	2.53%	.48%	4.57%	.93%
		Structural	11.09%	1.98%	21.74%	6.77%
		Transportation	5.73%	2.80%	2.00%	4.70%
		Water Resources	11.76%	4.79%	2.76%	12.93%
Electrical & Computer	Breadth Module		5.41%	3.68%	3.33%	3.67%
	Depth Modules	Computers	.73%	1.22%	.32%	.77%
		Electronics, Controls, and Communications	2.89%	2.12%	1.46%	4.31%
		Power	2.68%	1.85%	1.26%	4.57%
Title Act Disciplines	Chemical		33.97%	39.90%	10.77%	31.11%
	Control Systems		19.34%	18.96%	4.99%	20.59%
	Fire Protection		10.10%	6.63%	5.66%	9.28%
	Industrial		11.96%	13.49%	16.35%	15.31%
	Manufacturing		16.04%	5.49%	30.47%	13.07%
	Nuclear		15.12%	10.09%	6.56%	21.41%

Table 10.12. Overlap in California Licenses

Discipline	Total number of licensed engineers in discipline	Number of engineers in discipline who also have: A civil engineering license	An electrical engineering license	A mechanical engineering license	Percent of engineers in discipline who also have: A civil engineering license	An electrical engineering license	A mechanical engineering license
Civil	44,135	--	33	231	--	.1%	.5%
Electrical	8,444	33	--	144	.4%	--	1.7%
Mechanical	14,878	231	144	--	1.6%	1.0%	--
Agricultural	257	52	1	9	20.2%	.4%	3.5%
Chemical	2,012	22	3	61	1.1%	.1%	3.0%
Control Systems	2,324	19	167	111	.8%	7.2%	4.8%
Fire Protection	807	35	5	60	4.3%	.6%	7.4%
Industrial	845	8	2	28	.9%	.2%	3.3%
Manufacturing	1,340	1	2	23	.1%	.1%	1.7%
Metallurgical	423	1	1	16	.2%	.2%	3.8%
Nuclear	877	7	8	132	.8%	.9%	15.1%
Petroleum	473	5		7	1.1%		1.5%
Traffic	1,401	497	11	6	35.5%	.8%	.4%
Subtotal without civil	34,081	911	--	--	2.7%	--	--
Subtotal without electrical	69,772	--	377	--	--	.5%	--
Subtotal without mechanical	63,338	--	--	828	--	--	1.3%
Total	78,216	--	--	--	--	--	--

The initial data provided included current licenses issued up through January 25, 2002. It was later realized that this data inadvertently excluded chemical engineers, so data for chemical engineering licenses includes licenses issued up through June 26, 2002.

Engineers with more than one license were identified based on *exact* matches on both name and address information or exact matches on address information and two out of the three name components (first, middle, last). This second criteria was used to include individual whose name was recorded in a slightly different manner for one license than it was for another. The most common example of this is where one license shows a full middle name but the other shows just an initial.

Table 10.13. Sequence in which California Engineering Licenses were Issued, for those with a License in More than One Discipline

		Sequence for those with a civil engineering license and a license in another discipline				Sequence for those with an electrical engineering license and a license in another discipline				Sequence for those with a mechanical engineering license and a license in another discipline			
		Civil license issued:				Electrical license issued:				Mechanical license issued:			
	Other license	First	Second	Both issued at same time	Total	First	Second	Both issued at same time	Total	First	Second	Both issued at same time	Total
Percent	Civil	--	--	--	--	45.5%	54.5%		100.0%	45.5%	53.7%	.9%	100.0%
	Electrical	54.5%	45.5%		100.0%	--	--	--	--	42.4%	52.8%	4.9%	100.0%
	Mechanical	53.7%	45.5%	.9%	100.0%	52.8%	42.4%	4.9%	100.0%	--	--	--	--
	Agricultural	69.2%	30.8%		100.0%	100.0%			100.0%	44.4%	55.6%		100.0%
	Chemical	40.9%	59.1%		100.0%	66.7%	33.3%		100.0%	16.4%	83.6%		100.0%
	Control Systems	73.7%	26.3%		100.0%	75.4%	24.6%		100.0%	53.2%	46.8%		100.0%
	Fire Protection	97.1%	2.9%		100.0%	80.0%		20.0%	100.0%	76.7%	23.3%		100.0%
	Industrial	62.5%	37.5%		100.0%	100.0%			100.0%	75.0%	25.0%		100.0%
	Manufacturing	100.0%			100.0%	50.0%	50.0%		100.0%	43.5%	56.5%		100.0%
	Metallurgical		100.0%		100.0%	100.0%			100.0%	43.8%	56.3%		100.0%
	Nuclear	85.7%	14.3%		100.0%	100.0%			100.0%	56.8%	34.1%	9.1%	100.0%
	Petroleum	80.0%	20.0%		100.0%					85.7%	14.3%		100.0%
	Traffic	87.1%	12.5%	.4%	100.0%	81.8%	18.2%		100.0%	66.7%	33.3%		100.0%
	Total	75.1%	24.5%	.4%	100.0%	65.0%	32.9%	2.1%	100.0%	49.3%	48.2%	2.5%	100.0%
Number	Civil	--	--	--	--	15	18		33	105	124	2	231
	Electrical	18	15		33	--	--	--	--	61	76	7	144
	Mechanical	124	105	2	231	76	61	7	144	--	--	--	--
	Agricultural	36	16		52	1			1	4	5		9
	Chemical	9	13		22	2	1		3	10	51		61
	Control Systems	14	5		19	126	41		167	59	52		111
	Fire Protection	34	1		35	4		1	5	46	14		60
	Industrial	5	3		8	2			2	21	7		28
	Manufacturing	1			1	1	1		2	10	13		23
	Metallurgical		1		1	1			1	7	9		16
	Nuclear	6	1		7	8			8	75	45	12	132
	Petroleum	4	1		5					6	1		7
	Traffic	433	62	2	497	9	2		11	4	2		6
	Total	684	223	4	911	245	124	8	377	408	399	21	828

Table 10.14. Summary of Exams with More than Fifteen Percent Overlap in Content

Practice Act Discipline Exams	Module	Percent of :	Title Act Discipline Exams						Civil Engineering Exams	
			Chemical	Control Systems	Fire Protection	Industrial	Manufacturing	Nuclear	Breadth Module	Structural Module
Civil Engineering Exam	Environmental	Column exam content on row exam	21%			6%				
		Row exam content on column exam	24%			15%				
	Structural	Column exam content on row exam			15%					
		Row exam content on column exam			11%					
	Water Resources	Column exam content on row exam	13%							
		Row exam content on column exam	15%							
Electrical & Computer Engineering Exam	Breadth	Column exam content on row exam				10%				
		Row exam content on column exam				17%				
	Computers	Column exam content on row exam		12%		6%				
		Row exam content on column exam		24%		29%				
	Electronics, Controls and Communication	Column exam content on row exam		31%				8%		
		Row exam content on column exam		22%				22%		
	Power	Column exam content on row exam				6%				
		Row exam content on column exam				22%				
Mechanical Engineering Exam	Breadth	Column exam content on row exam	34%	19%	18%		17%	16%		18%
		Row exam content on column exam	34%	19%	10%		16%	15%		11%
	HVAC and Refrigeration	Column exam content on row exam	40%	24%						
		Row exam content on column exam	40%	19%						
	Machine Design	Column exam content on row exam	28%			14%	32%		19%	21%
		Row exam content on column exam	11%			16%	31%		15%	22%
	Thermal and Fluids Systems	Column exam content on row exam	38%	17%	17%	9%	15%	14%		16%
		Row exam content on column exam	31%	21%	9%	15%	13%	21%		7%

Exams with less than 15% overlap are not shown in this table (Geotechnical and Transportation Depth Modules of the Civil Engineering exam). The only overlap between Practice Act discipline exams was between civil and mechanical engineering.

Table 10.15. Percent of Experts Identifying Overlap Between Sections of the Chemical Engineering Exam and Exams with Noteworthy (15%+) Overlap

					Chemical Engineering Exam						
					(20%)	(15%)	(15%)	(10%)	(15%)	(10%)	(15%)
Exam	Module	% of Exam	Topic		Mass and Energy Balances	Heat Transfer	Fluids	Thermo-dynamics	Mass Transfer	Kinetics	Plant Design
Civil Engineering Exam (N=7)	Environmental Depth Module	(65%)	Environmental	Wastewater Treatment	29%		29%	43%	14%	14%	71%
				Biology							43%
				Solid/Hazardous Waste	29%	29%			14%		71%
				Ground Water and Well Fields							14%
		(10%)	Geotechnical	Subsurface Exploration and Sampling							
				Engineering Properties of Soils							
				Soil Mechanics Analysis							
		(25%)	Water Resources	Hydraulics	29%	14%	100%				14%
				Hydrology		29%					14%
				Water Treatment			14%				43%
	Water Resources Depth Module	(65%)	Water Resources	Hydraulics	29%	14%	100%				14%
				Hydrology		29%					14%
				Water Treatment			14%				43%
		(25%)	Environmental	Wastewater Treatment	14%		14%		14%		43%
				Biology							43%
				Ground Water and Well Fields							
		(10%)	Geotechnical	Subsurface Exploration and Sampling							
				Engineering Properties of Soils							
				Soil Mechanics Analysis							
Mechanical Engineering Exam (N=11)	Breadth Module	(15%)	General Knowledge, Codes & Standards	Engineering Principles	27%	91%	73%	27%	18%		36%
		(11%)		Fundamental Engineering Practice						9%	55%
		(4%)		Interpretation of Codes and Standards						18%	
		(11%)	Machine Design & Materials Knowledge	Principles							18%
		(6%)		Applications		9%					46%
		(9%)	Hydraulics & Fluids	Principles			36%				
		(8%)		Applications			27%				9%
		(10%)	Energy Conversion/Power Systems Knowledge	Principles	36%	27%		73%			9%
		(8%)		Analysis of Systems and Components	55%	18%	73%	18%	9%		9%
		(18%)	HVAC and Refrigeration Knowledge		9%	18%	9%	64%	18%		
	HVAC & Refrigeration Depth Module	(15%)	Fundamentals	Psychometrics				18%	64%		9%
		(19%)		Principles	55%	91%	82%	100%	27%		9%
		(37%)	Equipment and Materials		9%	64%	82%	73%	9%	9%	64%
		(21%)	Applications	Systems Applications		46%	46%	36%	18%		18%
		(8%)		Supportive Knowledges							46%
	Machine Design Depth Module	(43%)	Engineering Principles			9%	9%	9%		9%	46%
		(36%)	Components								
		(13%)	Applications	System Applications						18%	55%
		(8%)		Supportive Knowledges	55%	91%	73%	82%	27%		36%
	Thermal & Fluids Systems Depth Module	(22%)	Fundamentals	Engineering Principles	55%	91%	82%	91%	27%		55%
		(11%)		Supportive Knowledges		9%	9%	18%	18%		18%
		(14%)	Components	Hydraulic System Components			55%				9%
		(20%)		Power Plant Components	9%	73%	73%	9%	18%		9%
		(25%)	Applications	Systems Applications	18%	64%	73%	64%	18%	9%	9%
		(8%)		Application Supportive Knowledge						18%	

Percentages in parentheses in column and row headings indicate the percent of the exam that NCEES allocates to the topic.

Table 10.16. Percent of Experts Identifying Overlap Between Sections of the Control Systems Engineering Exam and Exams with Noteworthy (15%+) Overlap

					Control Systems Engineering Exam										
					(16%)	(6%)	(14%)	(6%)	(6%)	(6%)	(8%)	(18%)	(10%)	(8%)	(2%)
Exam	Module	% of Exam	Topic		Sensors	Analog & Digital Data Trans-mission	Valves & Final Elements	Process Dynamics	Control System Analysis	Controllers/ Modes/ Tuning	Digital Control Systems	Discrete Logic, Interlocks, Alarms and Se-quencing	Codes & Standards	Docu-mentation	Economics of Control
Electrical & Com-puter Engi-neering Exam (N=7)	Computers Depth Module	(4%)	General Computer Systems	Interpretation of Codes & Standards							14%		14%	14%	
		(6%)		Microprocessor Systems							29%				
		(16%)	Hardware	Digital Electronics							14%	43%		14%	
		(19%)		Design and Analysis							14%	29%		14%	
		(10%)		Systems							14%	14%		14%	
		(12%)	Software	System Software							43%				
		(23%)		Development/Applications							29%			43%	
		(10%)	Networks			57%									
	Electronics, Controls and Commu-nication Depth Module	(4%)	General Electrical Engineer-ing Know-ledge	Measurement & Instrumentation	57%										
		(2%)		Interpretation of Codes & Standards		14%						14%	57%	29%	
		(4%)		Computer Systems								29%			
		(10%)	Electronics	Electric Circuit Theory											
		(7%)		Electric and Magnetic Field Theory and Applications											
		(18%)		Electronic Components & Circuits								14%		14%	
		(10%)	Controls	Control System Fundamentals				29%	86%	14%	29%			14%	
		(6%)		Control System Design/Implementation				14%	57%	71%	43%				
		(9%)		Stability					71%	29%					
		(15%)	Commu-nications	Communication & Signal Processing		43%		14%							
		(8%)		Noise and Interface		14%									
		(7%)		Telecommunications		57%									

Percentages in parentheses in column and row headings indicate the percent of the exam that NCEES allocates to the topic

Table 10.16. (continued) Percent of Experts Identifying Overlap Between Sections of the Control Systems Engineering Exam and Exams with Noteworthy (15%+) Overlap

					Control Systems Engineering Exam										
					(16%)	(6%)	(14%)	(6%)	(6%)	(6%)	(8%)	(18%)	(10%)	(8%)	(2%)
Exam	Module	% of Exam	Topic		Sensors	Analog & Digital Data Trans-mission	Valves & Final Elements	Process Dynamics	Control System Analysis	Controllers/ Modes/ Tuning	Digital Control Systems	Discrete Logic, Interlocks, Alarms and Se-quencing	Codes & Standards	Docu-mentation	Economics of Control
Mech-anical Engineer-ing Exam (N=14)	Breadth Module	(15%)	General Know-ledge, Codes & Standards	Engineering Principles			79%	86%							
		(11%)		Fundamental Engineering Practice	21%	29%				7%		7%	29%	57%	79%
		(4%)		Interpretation of Codes & Standards								7%	50%		
		(11%)	Machine Design & Materials Knowledge	Principles											
		(6%)		Applications									7%		
		(9%)	Hydraulics & Fluids	Principles			29%	14%							
		(8%)		Applications											
		(10%)	Energy Conversion /Power Systems Knowledge	Principles				21%	7%						
		(8%)		Analysis of Systems & Components				57%							
		(18%)	HVAC & Refrigeration Knowledge				7%	21%							
	HVAC & Refrig-eration Depth Module	(15%)	Funda-mentals	Psychrometrics			7%	7%							
		(19%)		Principles			100%	100%	7%						
		(37%)	Equipment & Materials		57%	21%	36%	14%	29%	29%	14%	21%	7%		
		(21%)	Appli-cations	Systems Applications			21%	14%				7%	29%		
		(8%)		Supportive Knowledges			7%								79%
	Thermal & Fluids Systems Depth Module	(22%)	Funda-mentals	Engineering Principles			93%	100%	7%						79%
		(11%)		Supportive Knowledges			7%						7%		
		(14%)	Com-ponents	Hydraulic System Components	7%		14%	7%	14%	21%		7%			
		(20%)		Power Plant Components				21%							
		(25%)	Appli-cations	Systems Applications			21%	29%							
		(8%)		Application Supportive Knowledge								7%	50%		

Percentages in parentheses in column and row headings indicate the percent of the exam that NCEES allocates to the topic

Table 10.17. Percent of Experts Identifying Overlap Between Sections of the Fire Protection Engineering Exam and Exams with Noteworthy (15%+) Overlap

					Fire Protection Engineering Exam							
					(12%)	(13%)	(12%)	(13%)	(12%)	(13%)	(12%)	(13%)
					Planning and Design of:							
Exam	Module	% of Exam	Topic		Water Supplies	Building Systems	Water-Based Suppression Systems	Non Water-Based Suppression Systems	Detection and Alarm Systems	Fire Prevention	Imple-mentation & Monitoring of Fire Prevention	Research and Development of Hazard and Risk Analysis
Civil Engineering Exam (N=7)	Structural Depth Module	(65%)	Structural	Loadings								
				Analysis								
				Mechanics of Materials		14%						
				Materials		43%				14%		
				Member Design								
				Failure Analysis	14%	29%						14%
				Design Criteria	14%	57%	14%		14%	29%	14%	
		(25%)	Geotechnical	Subsurface Exploration and Sampling								
				Soil Mechanics Analysis								
				Shallow Foundations								
				Deep Foundations								
				Earth Retaining Structures								
		(10%)	Transportation	Construction	14%							
Mechanical Engineering Exam (N=13)	Breadth Module	(15%)	General Knowledge, Codes & Standards	Engineering Principles	8%	39%	8%	8%	8%	15%		8%
		(11%)		Fundamental Engineering Practice	15%	23%	31%	23%	23%	15%	15%	
		(4%)		Interpretation of Codes and Standards	8%	15%		8%				
		(11%)	Machine Design & Materials Knowledge	Principles		8%						
		(6%)		Applications		46%	8%	8%		15%	15%	
		(9%)	Hydraulics & Fluids	Principles								
		(8%)		Applications	15%						8%	
		(10%)	Energy Conversion/Power Systems Knowledge	Principles		8%					8%	8%
		(8%)		Analysis of Systems and Components		8%					8%	
		(18%)	HVAC and Refrigeration Knowledge									
	Thermal & Fluids Systems Depth Module	(22%)	Fundamentals	Engineering Principles	8%	46%	23%	8%	15%	15%	8%	8%
		(11%)		Supportive Knowledges		8%		8%			15%	
		(14%)	Components	Hydraulic System Components	15%						8%	
		(20%)		Power Plant Components		8%						
		(25%)	Applications	Systems Applications	31%	8%	15%	15%		8%	8%	
		(8%)		Application Supportive Knowledge	8%	15%		8%				

Percentages in parentheses in column and row headings indicate the percent of the exam that NCEES allocates to the topic

Table 10.18. Percent of Experts Identifying Overlap Between Sections of the Industrial Engineering Exam and Exams with Noteworthy (15%+) Overlap

					Industrial					
					(25%)	(25%)	(12%)	(13%)	(12%)	(13%)
Exam	Module	% of Exam	Topic		Facilities	Manu-facturing	Production & Inventory Systems	Work Systems	Quality Assurance	Manage-ment
Civil Engineering Exam (N=9)	Environmental Depth Module	(65%)	Environmental	Wastewater Treatment	33%					
				Biology	22%				33%	
				Solid/Hazardous Waste	56%			11%		
				Ground Water and Well Fields	11%				11%	
		(10%)	Geotechnical	Subsurface Exploration and Sampling	11%					
				Engineering Properties of Soils						
				Soil Mechanics Analysis						
		(25%)	Water Resources	Hydraulics						
				Hydrology	11%					
				Water Treatment	33%					
Electrical & Computer Engineering Exam (N=8)	Breadth Module	(6%)	Basic Electrical Engineering	Professionalism and Engineering Economics	13%	38%		13%		38%
		(6%)		Safety and Reliability				100%	88%	
		(24%)		Electric Circuits	13%					
		(3%)		Electric and Magnetic Field Theory and Applications						13%
		(6%)		Digital Logic						13%
		(14%)	Electronics, Electronic Circuits and Components	Components						
		(6%)		Electrical and Electronic Materials						
		(15%)	Controls and Communications Systems							
		(12%)	Power	Transmission and Distribution	50%					
		(8%)		Rotating Machines and Electromagnetic Devices	38%					
	Computers Depth Module	(4%)	General Computer Systems	Interpretation of Codes and Standards						38%
		(6%)		Microprocessor systems		13%				38%
		(16%)	Hardware	Digital Electronics						13%
		(19%)		Design and Analysis						13%
		(10%)		Systems						88%
		(12%)	Software	System Software						50%
		(23%)		Development/Applications		13%		13%	13%	38%
		(10%)	Networks							75%
	Power Depth Module	(5%)	General Power Engineering	Measurement, Instrumentation and Statistics	50%				38%	
		(2%)		Special Applications	38%					
		(8%)		Codes and Standards	25%				13%	
		(15%)	Circuit Analysis	Analysis						
		(8%)		Devices and Power Electronic Circuits	13%					
		(5%)		Electric and Magnetic Fields and Applications	13%					
		(18%)	Rotating Machines and Electromagnetic Devices	Rotating Machines	25%	13%				
		(9%)		Electromagnetic Devices	25%	13%				
		(15%)	Transmission and Distribution	System Analysis	50%					
		(6%)		Power System Performance	50%					
		(9%)		Protection	38%					
		(25%)	Applications	Systems Applications	39%					
		(8%)		Application Supportive Knowledge	8%				8%	

Percentages in parentheses in column and row headings indicate the percent of the exam that NCEES allocates to the topic

Table 10.18. (continued) Percent of Experts Identifying Overlap Between Sections of the Industrial Engineering Exam and Exams with Noteworthy (15%+) Overlap

					Industrial					
					(25%)	(25%)	(12%)	(13%)	(12%)	(13%)
Exam	Module	% of Exam	Topic		Facilities	Manu-facturing	Production & Inventory Systems	Work Systems	Quality Assurance	Manage-ment
Mechanical Engineering Exam (N=13)	Machine Design Depth Module	(43%)	Engineering Principles		31%	8%				
		(36%)	Components		15%					
		(13%)	Applications	Systems Applications	15%	46%		8%	8%	8%
		(18%)		Supportive Knowledges	23%	77%	31%		62%	23%
	Thermal & Fluids Systems Depth Module	(22%)	Fundamentals	Engineering Principles	23%	46%	31%	8%		23%
		(11%)		Supportive Knowledges	15%	8%		8%		
		(14%)	Components	Hydraulic System Components	15%					8%
		(20%)		Power Plant Components	23%					
		(25%)	Applications	Systems Applications	39%					
		(8%)		Application Supportive Knowledge	8%				8%	

Percentages in parentheses in column and row headings indicate the percent of the exam that NCEES allocates to the topic

Table 10.19. Percent of Experts Identifying Overlap Between Sections of the Manufacturing Engineering Exam and Exams with Noteworthy (15%)+ Overlap

					Manufacturing Engineering Exam									
					(6%)	(21%)	(9%)	(8%)	(6%)	(3%)	(17%)	(10%)	(15%)	(5%)
					Product Process Design, Materials Applications		Manufacturing Processes				Production Systems, Controls & Equipment Design			
Exam	Module	% of Exam	Topic		Materials Engineering & Applications	Product/ Process Design	Material Removal	Fabrication, Joining & Assembly	Forming	Finishing	Production, Systems & Control	Equipment Design	Quality	Manufacturing Management
Mechanical Engineering Exam (N=14)	Breadth Module	(15%)	General Knowledge, Codes & Standards	Engineering Principles	57%		7%		7%	7%				
		(11%)		Fundamental Engineering Practice	7%	79%					71%			100%
		(4%)		Interpretation of Codes and Standards		7%					7%	7%		
		(11%)	Machine Design & Materials Knowledge	Principles	43%	14%						21%		
		(6%)		Applications	57%	7%	7%	43%		7%		21%		
		(9%)	Hydraulics & Fluids	Principles	29%	21%								
		(8%)		Applications	14%									
		(10%)	Energy Conversion/Power Systems Knowledge	Principles										
		(8%)		Analysis of Systems and Components										
		(18%)	HVAC and Refrigeration Knowledge											
	Machine Design Depth Module	(43%)	Engineering Principles		64%	36%	7%		7%	7%		21%		
		(36%)	Components					43%				21%		
		(13%)	Applications	Systems applications		79%					64%	36%	7%	
		(8%)		Supportive Knowledges	43%	71%	14%	79%	36%	29%	29%	29%	71%	86%
	Thermal & Fluids Systems Depth Module	(22%)	Fundamentals	Engineering Principles	64%	79%	7%		7%	7%	64%			86%
		(11%)		Supportive Knowledges	43%	36%		43%				21%		
		(14%)	Components	Hydraulic System Components	14%									
		(20%)		Power Plant Components										
		(25%)	Applications	Systems Applications	14%	14%								
		(8%)		Application Supportive Knowledge		7%					7%	7%		

Percentages in parentheses in column and row headings indicate the percent of the exam that NCEES allocates to the topic

Table 10.20. Percent of Experts Identifying Overlap between Sections of the Nuclear Engineering Exam and Exams with Noteworthy (15%+) Overlap

					Nuclear Engineering Exam				
					(25%)	(20%)	(20%)	(20%)	(15%)
Exam	Module	% of Exam	Topic		Nuclear Power Systems	Nuclear Fuel and Waste Management	Nuclear Radiation Protection/ Radiation Shielding	Nuclear Criticality/ Kinetics/ Neutronics	Nuclear Measurements and Instruments
Electrical & Computer Engineering Exam (N=6)	Electronics, Controls and Commu-nication Depth Module	(4%)	General Electrical Engineering Knowledge	Measurement and Instrumentation					67%
		(2%)		Interpretation of Codes and Standards					17%
		(2%)		Computer Systems					17%
		(10%)	Electronics	Electric Circuit Theory					17%
		(7%)		Electric and Magnetic Field Theory and Applications					
		(18%)		Electronic Components and Circuits					33%
		(10%)	Controls	Control System Fundamentals					50%
		(6%)		Control System Design/Implementation					83%
		(9%)		Stability					33%
		(15%)	Communications	Communication and Signal Processing					
		(8%)		Noise and Interface					17%
		(7%)		Telecommunications					
Mechanical Engineering Exam (N=15)	Breadth Module	(15%)	General Knowledge, Codes & Standards	Engineering Principles	53%	13%			
		(11%)		Fundamental Engineering Practice	7%	60%	47%		27%
		(4%)		Interpretation of Codes and Standards	7%		7%		
		(11%)	Machine Design & Materials Knowledge	Principles	7%				
		(6%)		Applications	20%	7%			
		(9%)	Hydraulics & Fluids	Principles	27%				
		(8%)		Applications	20%				
		(10%)	Energy Conversion/ Power Systems Knowledge	Principles	33%				
		(8%)		Analysis of Systems and Components	60%				
		(18%)	HVAC and Refrigeration Knowledge						
	Thermal & Fluids Systems Depth Module	(22%)	Fundamentals	Engineering Principles	93%	60%			
		(11%)		Supportive Knowledges	20%				
		(14%)	Components	Hydraulic System Components	20%				
		(20%)		Power Plant Components	67%				
		(25%)	Applications	Systems Applications	53%				
		(8%)		Application Supportive Knowledge	7%		7%		

Percentages in parentheses in column and row headings indicate the percent of the exam that NCEES allocates to the topic

Table 10.21. Percent of Experts Identifying Overlap Between Sections of the Machine Design Depth Module of the Mechanical Engineering Exam and Exams with Noteworthy (15%+) Overlap

					Machine Design Depth Module of Mechanical Engineering Exam			
					(43%)	(36%)	(13%)	(18%)
							Applications	
Exam	Module	% of Exam	Topic		Engineering Principles	Components	Systems applications	Supportive Knowledges
Civil Engineering Exam (N=14)	Breadth Module	(20%)	Environmental					7%
		(20%)	Geotechnical		7%			
		(20%)	Structural		71%	7%	50%	14%
		(20%)	Transportation					29%
		(20%)	Water Resources		29%			71%
	Structural Depth Module	(65%)	Structural	Loadings	43%		7%	
				Analysis	21%		36%	
				Mechanics of Materials	50%	14%	21%	
				Materials	7%			14%
				Member Design	14%	7%		
				Failure Analysis	64%		21%	
				Design Criteria			29%	
		(25%)	Geotechnical	Subsurface Exploration and Sampling				
				Soil Mechanics Analysis	7%			
				Shallow Foundations				
				Deep Foundations				
				Earth Retaining Structures				
		(10%)	Transportation	Construction				29%

Percentages in parentheses in column and row headings indicate the percent of the exam that NCEES allocates to the topic

Table 10.22. Percent of Experts Identifying Overlap Between Sections of the Structural Depth Module of Civil Engineering Exam and Exams with Noteworthy (15%+) Overlap

					Structural Depth Module of Civil Engineering Exam												
					(65%)							(25%)					(10)
					Structural							Geotechnical					Trans-portation
Exam	Module	% of Exam	Topic		Loadings	Analysis	Mech-anics of Materials	Materials	Member Design	Failure Analysis	Design Criteria	Sub-surface Explor-ation & Sampling	Soil Mech-anics Analysis	Shallow Foun-dations	Deep Foun-dations	Earth Retain-ing Struc-tures	Con-struction
Mechanical Engineering Exam (N=14)	Breadth Module	(15%)	General Knowledge, Codes & Standards	Engineering Principles			14%						7%				
		(11%)		Fundamental Engineering Practice							14%						29%
		(4%)		Interpretation of Codes and Standards							29%						
		(11%)	Machine Design & Materials Knowledge	Principles	43%	21%	50%	7%	14%	64%							
		(6%)		Applications	36%		7%	14%		14%				7%			
		(9%)	Hydraulics & Fluids	Principles													
		(8%)		Applications													
		(10%)	Energy Conversion/ Power Systems Knowledge	Principles													
		(8%)		Analysis of Systems and Components													
		(18%)	HVAC and Refrigeration Knowledge														
	Thermal & Fluids Systems Depth Module	(22%)	Fundamentals	Engineering Principles			14%						7%				29%
		(11%)		Supportive Knowledges	43%	21%	50%	21%	14%	71%							
		(14%)	Components	Hydraulic System Components													
		(20%)		Power Plant Components													
		(25%)	Applications	Systems Applications													
		(8%)		Application Supportive Knowledge							2%						

Percentages in parentheses in column and row headings indicate the percent of the exam that NCEES allocates to the topic

CHAPTER 11

SUMMARY OF FINDINGS

In defining the Title Act Study in SB2030, the California Legislature specified a series of tasks that, together, would lead to recommendations for change in licensing the state's engineers. These tasks included:

- Meeting with representatives of the engineering branches and other professional groups.
- Examining the types of services provided by different branches of engineering.
- Reviewing and analyzing educational requirements for the separate engineering disciplines.
- Identifying the amount of overlap between engineering disciplines.
- Reviewing alternative methods of regulation in other states and assessing the impact these regulations would have if adopted in California.
- Describing the manner in which local and state agencies utilize regulations and statutes to regulate engineering work.
- Recommend changes to existing laws regulating engineers after considering how these changes may affect the health, safety and welfare of the public.

ISR assembled as much information pursuant to these tasks as possible within the time available. Some of the information necessary to fully satisfy the legislative requests outlined above was either proprietary (e.g., job analyses performed by private firms for NCEES, insurance rates and claims data for different types of engineers), not publicly available (e.g., national and state pass rates for NCEES exams), or inadequately defined and administered (e.g., state data on complaints against engineers). The unavailability of good information on a profession with significant impact on the public health, safety and welfare limits accountability in the exercise of that profession. Lack of accountability itself threatens the public's health, safety and welfare.

Underlying these tasks were several overarching concerns. The first was the amount of overlap between engineering disciplines regulated in California. Overlap occurs in the coursework required for degrees in different branches of engineering, in the work that employed engineers perform (formally measured through NCEES sponsored job analyses), in the NCEES exams used in licensing engineers that are based on job analyses, and in state regulatory structures that either permit or disallow the performance of work outside areas defined by educational preparation, the NCEES exams taken and/or subsequent work experience. The second overarching concern was whether there were sufficient distinctions between California's practice and title act disciplines to justify maintenance of its existing and unique regulatory structure. No other state allows unlicensed persons to practice any branch of engineering. Only California licenses use of a title, but permits unregulated practice of all but three engineering disciplines (civil, electrical and mechanical). The third concern was whether this regulatory structure adequately protects the public health, safety and welfare and whether a differential impact on public health, safety and welfare, if any, might be one justification for the practice/title distinction.

Significant findings from the analysis of educational requirements, job task profiles, examination outlines, pass rates, engineering employment and registration patterns, exemptions, complaints and insurance claims are summarized in the most appropriate section corresponding to the three overarching concerns.

Comparisons with ten other states and analysis of the treatment of engineering disciplines in California state and county codes (the California Code of Regulations (CCR) and those for Los Angeles, San Diego and San Francisco counties) and the Federal Code of Regulations (FCR) were used to create a context for understanding California's licensing system. Results from this analysis contribute to an understanding of the findings in each of the following sections.

Overlap (Commonalities Between Engineering Disciplines)

Overlapping Practice

Like law and medicine, engineering shares a body of knowledge that forms the basis for specializations covered in undergraduate and graduate programs or internships, residencies and informal apprenticeships. Medicine is at the more formalized end of a continuum defining specializations -- with internships and residencies built into the licensing process and board certifications in specialty areas. Although national exams are available for 17 engineering disciplines, the formal recognition of specialties within engineering varies by state. Most states have "generic" licensing, registering those who passed the Fundamentals of Engineering and at least one specialty exam as "Professional Engineers." In these states, professional engineers may practice any type of engineering, as long as they are competent through education or experience. This self-certified competence is only questioned after errors have occurred and a professional engineer is required to demonstrate an appropriate level of competency. "Discipline-based" licensing is used primarily in 16 smaller and more rural states and territories that recognize between six (Rhode Island) and 46 (Massachusetts) engineering specialties. These include: Hawaii, Alaska, Arizona, Nevada, Wyoming, Guam and the Mariana Islands. California and Massachusetts are the only large states to use "discipline-based" licensing with California recognizing 15 specialties. Most of these states define the specialty in terms of the subject matter of the comparable NCEES exam.

Generic licensing states do not attempt to regulate who does what in engineering except through the complaint and enforcement process. Discipline-based licensing states vary in the degree to which they regulate overlapping practice between disciplines -- work that is "incidental" or "supplemental" to the "normal" work of a specific type of engineer. Rhode Island allows no overlapping practice even though it provides no discipline definitions. Massachusetts, which also lacks discipline definitions, allows engineers to work outside their specialty with Board approval. Guam is the only jurisdiction besides California that restricts the *direction* of overlapping practice for some disciplines.

Allowable one-directional overlap by the practice act disciplines into title act areas, by civil engineers into mechanical and electrical, and prohibition of the reverse, is unique to California. With the exception of civil engineering, the purview of California's recognized disciplines is defined in Rules of the Board for Professional Engineers and Land Surveyors. In contrast, civil engineering is thoroughly defined, and mechanical and electrical engineering identified as other practice disciplines, in the Professional Engineers Act. These definitions specifically restrict the title act disciplines from practicing civil, electrical or mechanical engineering -- and the latter two from engaging in civil engineering -- while permitting the practice act disciplines to engage in any engineering activities as long as they are "incidental" or "supplementary" to work in their branch of engineering. Thus, a hierarchy is established among the practice act disciplines and between the practice and title act disciplines that is reflected in placement in the Business and Professions Code vs. Board Rules, in allowable one-directional overlap, and in a complaint process that primarily protects the practice act disciplines.

Commonalities in Educational Requirements

All engineers share a core of non-general education support units in physics, chemistry and math. At the seven selected California universities, these support units make up between a quarter (28%) and more than a half (55%) of all non-general education units required for an engineering degree. An engineering degree at Berkeley, Stanford and UCLA includes more units in these basic subjects than the CSU campuses and USC. Physics, chemistry and math make up between 40% and 55% of non-general education units required for the degree at Berkeley, Stanford and UCLA, between 28% and 35% at the CSU campuses, and 37% at USC.

Industrial and manufacturing engineering have the highest percentage of overlapping engineering and related support units. These disciplines share two-thirds (68%) of all non-general education courses (ranging between 64% and 71% at the three schools offering both degrees) and well over half (57%) of all engineering courses (ranging between 55% and 59%). Manufacturing and mechanical engineering are ranked second in terms of shared engineering units and third in terms of all engineering and support units, with 51% of all non-general education units in common and 38% of all engineering units in common.

Also ranking high in the proportion of shared engineering and all non-general education units is metallurgical with both mechanical and chemical engineering. Metallurgical shares 47% of all units with mechanical and 46% with chemical and 28% of engineering units with each of them.

Some disciplines share a much higher percentage of engineering units than they do in the support areas. Petroleum shares almost a third of its engineering units with mechanical and chemical -- the third and fourth highest of all discipline pairs -- but a relatively lower proportion of all units (41% and 37% respectively), ranking 13th and 21st among all discipline pairs. These disciplines differ more in their support areas. In contrast, nuclear and mechanical engineering are ranked second in the proportion of all units shared (52%), but 8th in the proportion of shared engineering units (27%).

NCEES Examination Outlines

Subject matter experts assisted ISR in comparing NCEES exam outlines for 21 discipline pairs: civil, mechanical and electrical with each other and six title act disciplines (chemical, control systems, fire protection, industrial, manufacturing and nuclear).

The first step in the analysis was to compute the percent of the title acts' exam content found on the separate modules of the practice act exams. Then the process was reversed and the percent of the practice acts' exam content found on the title act exams was computed. The second step was to rank the percent of overlap from each perspective, ranking all 148 combinations of breadth and depth modules and exams in terms of the average of the two. Finally, specific areas of overlap were described for combinations where an overlap of 15% or more existed.

There is much more similarity between practice and title acts disciplines than there is among practice act disciplines. Almost all (90%) of the 30 discipline pairs with the greatest amount of overlap are practice/title combinations. Conversely, most (80%) of the 30 discipline pairs with the least amount of overlap are practice/practice combinations. Twenty of these involve paired portions of the civil and electrical exams, with overlapping content of 1% or less. Electrical and mechanical are also very dissimilar.

On the other hand, civil and mechanical engineering are much more alike -- 14 of 24 comparisons between the two are in the upper half of the distribution. Overlap between the structural depth module and mechanical's breadth and thermal and fluids systems modules favor civil engineering. That is, material from the mechanical exams constitutes a higher percentage of the civil exams than the reverse. In seven other combinations, material from the civil exams constitutes a higher percentage of the mechanical modules, suggesting that, in these areas, mechanical engineers might be better prepared.

From the perspective of the title acts, most of the overlap with practice act discipline exams is on the breath and depth modules of the mechanical engineering exam. Roughly a third of the chemical exam is covered on the breadth and each of the depth modules of the mechanical engineering exam, especially the HVAC and refrigeration and the Thermal and Fluids Systems sections. Similarly, a third of the manufacturing exam is covered by the machine design depth module of the mechanical exam and a fourth of the control systems and fire protection exams by the HVAC and refrigeration depth module. Between 15% and 20% of the control systems, fire protection and manufacturing exams are found on the breadth and thermal and fluids systems depth modules.

From the perspective of civil engineering, most of the overlap with other discipline exams is in the environmental, structural and water resources depth modules. A fourth of the environmental depth module is found on the chemical exam and 15% on the industrial exam. The water resources depth module also overlaps with the chemical exam (15.24%). Mechanical engineering also shares the highest proportion of exam content with chemical engineering. Roughly a third of the mechanical breadth module and the HVAC/refrigeration and thermal and fluids systems depth modules are found on the chemical exam. A similar proportion of the machine design depth modules is found on the manufacturing exam. Most of electrical engineering's overlap with other discipline exams is with control systems, industrial and nuclear. The most notable overlap between practice act disciplines occurs between mechanical's machine design and the structural depth modules: 21% to 22% of each appears on the other exam.

The independence of exam content for two of the three pairs of practice act disciplines (between electrical and both civil and mechanical) strongly supports their separate disciplinary boundaries. But it also calls into question the one-directional allowable overlap of civil engineers into the other disciplines, particularly electrical engineering. Based on exam content, neither discipline should be engaged in the incidental practice of the other's responsibilities. There is a stronger case for bi-directional overlap between mechanical and civil engineering than there is for overlap in any direction between electrical and either civil or mechanical.

In addition, the extent of overlapping exam content between chemical and mechanical engineering argues against the current licensing system that permits one directional overlap by mechanical engineers into chemical engineering, prohibiting the reverse. In the cases of unbalanced overlap, a higher proportion of material from the chemical exam appears on the mechanical exam than the reverse -- suggesting that chemical engineers might be better prepared in these areas of the exam.

Distinctions between Practice and Title Act Disciplines

Introduction

The licensing of engineers in California began with civil engineers in 1929, prohibiting those not licensed from *practicing* civil engineering. In 1947, chemical, electrical, mechanical and petroleum engineering were licensed with *titl*e protection, prohibiting others from using the title of their discipline, but permitting anyone to practice it. The recognition of additional disciplines in the 1960s and 70s reflected either growth in scientific knowledge (nuclear engineering), the application of engineering principles to new areas (agricultural, fire protection, corrosion and traffic engineering), or the new 20th century focus on the social organization of production (control systems, manufacturing, industrial, quality and safety engineering). In the late 1960s, electrical and mechanical engineering were converted to practice protection while the disciplines of the 1970s were given title protection only. Structural and geotechnical engineering were defined as title authorities, an amalgam of practice and title protection. Licensed civil engineers may take additional exams to use the titles of structural or geotechnical engineer; but they may practice either type of engineering with their civil license.

It is a reasonable question whether there are clear and sufficient differences between the branches of engineering to justify differential treatment of the various disciplines. No other state allows unlicensed persons to practice any branch of engineering and most states of any size do not even distinguish the branches, offering licensing as a "Professional Engineer" to those completing a prescribed set of exams. When this question was posed at the Forum on Engineering Licensing 2002 and on DCA's website announcing the forum, participants and others offering public comment could not identify any criteria that distinguish practice and title disciplines other than the legal distinctions that have arisen with the historical development of engineering in this state.

ISR tested for differences between practice and title Act disciplines in the analysis of each data set examined in the course of the Title Act Study. Some differences may be less relevant to a decision to retain or eliminate the practice/title distinction; but they round out the picture of engineering education, employment and licensing and the nature of regulatory support and enforcement. Key differences are summarized below.

Education

- There are 74 accredited undergraduate programs supporting the practice act disciplines (52%) and 28 supporting six title act disciplines (20%) throughout the state. The six include agricultural, chemical, industrial, manufacturing, materials and nuclear engineering. Some disciplines lacking undergraduate degree programs are supported by graduate degrees at the selected schools. Graduate degrees are offered in two other title act disciplines, control systems and transportation engineering and in the two title authorities, structural and geotechnical engineering. Fire protection is taught out of state at a single location in the U.S.

- Options, specializations, or concentrations within majors are another way in which knowledge supporting a particular discipline is transmitted. Options within majors are less important for the practice act disciplines because these are strongly supported by degree programs (44% of options vs. 52% of degree programs). They are more important for the title act and unregulated disciplines: 27% of the options support title act disciplines, compared with 20% of the degree programs while 29% of the options support unregulated disciplines compared with 25% of degree programs. Options, emphases, concentrations or specializations, which are interchangeable terms, require between 11 and 18 units on average, although the range for individual programs varies from 6 to 24.

- Degrees in manufacturing, civil and mechanical engineering have the highest engineering course unit requirement (67, 66 and 65 units respectively) while chemical and petroleum engineering have the lowest (51.7 and 51.5 units). The dependence of chemical and petroleum engineering on basic chemistry and its inclusion in support units for all engineering degrees may contribute to the lower number of engineering units for degrees in these two fields. The seven schools require more units in the practice act disciplines than they do in the title act disciplines (64 vs. 57.7).

- Stanford requires the fewest units in engineering courses (43.9) and SLO the most (68.7). With the exception of Stanford and Berkeley (43.9 and 54.6 units on average), the schools' engineering course units vary between 61.6 (UCLA) and 68.7 (SLO and San Jose).

Pass Rates

Pass rates on NCEES examinations in California and the comparison states were obtained and described over a five-year period (1997 to 2001). In addition to the Fundamentals of Engineering (FE) exam, results were obtained for the following engineering disciplines: agricultural, chemical, civil and its five depth exams, control systems, electrical, fire protection, industrial manufacturing, mechanical and its three depth exams, metallurgical, nuclear and petroleum. Since the analysis focuses on relative differences between individual states, standard normal scores (z-scores) were computed to describe each state's distance from the weighted pass rate for the ten states combined. The higher the z-score the further a state's pass rate is from the rate for the combined states. A negative value indicates a lower than average pass rate while a positive value indicates a higher one.

- Some states are consistently above average in their pass rates on the FE exam, while others are consistently below. California's pass rate was at least nine standard deviations below the mean for ten comparison states in each of the five years, far and away the lowest among the comparison states.

- Pass rates on the FE exam are higher in "board-dominated" states and lower in "agency-dominated" ones.

- California and the other discipline-based licensing state with pass rate data are many standard deviations below the average pass rate on the FE exam while the generic licensing states are significantly above average.

- In California, the fundamentals and civil exams appear to work as screening devices for those seeking licensing. Although California's z-scores on the general civil exam are not as low as they are on the fundamentals exam, they are still significantly below average, varying between three and nine standard deviations below the mean for the ten states. A similar pattern is observed on the transportation depth exam that began in 2000 and to a lesser extent on the water resources depth exam that began in the same year. On all other civil depth exams -- and indeed, almost all other specialty exams -- California pass rates are very close to the average.

- The HVAC and refrigeration depth exam was one of the exceptions to the general observation that California pass rates on the specialty exams were in the normal range. On this exam, the pass rate was two standard deviations below the average for seven states. However, California was close to the average for the comparison states on the overall exam in mechanical engineering.

- The other major exception to California's generally average pass rates on the specialty exams was its performance on the electrical engineering exam. Pass rates on this exam were significantly below average in four of the five years surveyed.

Registration

Registration rates were computed by dividing the number of registered engineers by the number of employed engineers as estimated by the Occupation Employment Statistics (OES) survey, jointly sponsored by the U.S. Bureau of Labor Statistics (BLS) and State Employment Security Agencies (SESAs). In California, registration rates were computed by discipline even though they are unreliable for the less numerous (e.g., agricultural and chemical) and less specialized (e.g., civil) disciplines due to sampling and measurement problems.

Roughly half of employed engineers in California are registered (48%). For ten of the comparison states, registration rates varied between 44% (Texas) and 68% (New Jersey). Three states (New Jersey, North Carolina and Ohio) are grouped at the high end of this range, with registration rates between 64% and 68%. The remaining states are grouped at the low end of the range, between 44% (Texas) and 49% (Illinois). Rhode Island, with 60% of its engineers in government employment, is anomalous in having only 9.5% registered.

Agricultural, chemical and civil engineering are the three disciplines where the number registered is greater than the number estimated to be employed in the state (2.33, 1.54 and 1.04 respectively registered for every one employed). Nuclear and mechanical engineers have the next highest registration rates, with 88% and 60% respectively. Roughly half of all petroleum engineers in California are registered. Rates are lowest for materials (18%), electrical (13%) and industrial (4%).

Thus, there were no systematic differences between the practice and title act disciplines in registration rates. One practice discipline, civil engineering, had one of the highest rates, while another, electrical, had one of the lowest. Similarly, title act disciplines were found throughout the range.

Employment

Collectively, the three practice act disciplines account for 63.8% of all employed engineers in the nation, with industrial engineering the only other branch with double-digit percentages. In 2000, the OES survey found that, nationally, persons employed as electrical engineers outnumbered mechanical and civil by 1.7 to 1. Discipline-based states averaged 2.5 electrical engineers for every mechanical engineer and 2.4 for every civil engineer; comparable ratios in generic states are 1.6 for both mechanical and civil.

Discipline-based states have 42% more engineers than generic licensing states (519 vs. 365 per 100,000 population). They have almost twice as many electrical engineers per 100,000 population, 25 - 30% more mechanical and industrial engineers, but roughly the same number of civil engineers. California, however, has the highest rate of civil engineers (84 per 100,000) of any of the comparison states, which range between 42 and 78 per 100,000. The newer and more specialized branches of engineering (aerospace, biomedical, environmental) are also more common in the discipline-based states.

In 2000, engineers nationally were primarily employed by industrial corporations (69%), with 20% in engineering and architectural services and 11% in government employment. In contrast to the other disciplines, civil engineers were much more apt to be employed in engineering and architectural services than in government or private industry (50.6% vs. 29.4% and 20% respectively). California diverged significantly from the national pattern. Government employed over half of its civil engineers (56%) and only 37% were engaged in engineering and architectural services.

Job Classes

One way to understand the uses of licensing and the role of practice and title disciplines is to summarize registration and other requirements for the 194 job classes in state employment that specify an engineer with a four-year college degree in engineering. An online review found that 40% of 194 job classes required a licensed engineer. Among the jobs requiring licensing, 39% specified that the occupant must be a registered *civil engineer*, while another 25% required a registered *professional engineer*. Another 10% specified a registered *electrical engineer*. Other disciplines specifically mentioned were industrial, mechanical and structural.

The 194 job classes are grouped into 55 job class categories that relate more closely to specific engineering disciplines or the activity areas in which their skills are applied (e.g., automotive equipment standards, hazardous substances, hydroelectric power utility). In roughly half of the 55 job class categories, none of the job classes require a registered engineer (29 or 53%). In a fifth of the job categories (11 or 20%), all of the job classes require a registered engineer and in another fifth, over half do. The job categories where all job classes require a registered engineer account for 12% of all positions.

Job class categories requiring *100%* registered engineers include bridge, construction, drinking water, hydraulic, industrial, materials and research, mechanical and electrical, reclamation, registrar, seismic and subsidence engineering positions. Many of these positions involve practice act disciplines and their associated areas of expertise. Those requiring *no* registered engineers include air quality, air resources, automotive equipment standards, chemical testing, control, corrosion, energy and mineral resources, equipment, equipment and materials, flammability research test, geologist, hydroelectric power utility, mineral resources, mining, motor vehicle pollution control, petroleum, petroleum drilling, production and reservoir, petroleum and mining appraisal, pipeline safety, process safety, procurement, product, rehabilitation, reservoir, safety, telecommunications, and transportation civil engineering positions. Many of these positions involve title act or unregulated disciplines and their areas of expertise.

As of 12/31/01, there were 10,923 employees in the 194 job classes requiring an engineer. Almost three-fourths (72%) of these employees are in positions where registration is *not* required. Most of the employees in engineering job classes where registration *is* required are in positions requiring a civil license (19%). In short, most engineers employed by the State of

California do not have to be licensed. If they do, the license most often required is in civil engineering.

Codes

The Federal and California Code of Regulations (FCR and CCR) and three California county codes (Los Angeles, San Diego and San Francisco) were searched online for references to all of the engineering disciplines and combinations of the generic terms of registered or licensed professional engineer.

The most common term in the FCR is "registered professional engineer" (58% of all hits). Over three-fourths of all mentions of engineers in the FCR refer to professional engineers rather than specific disciplines. In the CCR, the two most common terms are "professional engineer" (30.4%), without any modifier, and "civil engineer" (29.5%). Only 8% of hits in the FCR identify civil engineers. There is much less emphasis on being registered or licensed in the California code (11.4% vs. 63% in the federal code).

Chemical, fire protection, petroleum and traffic engineers are the only title act disciplines mentioned in the state and county codes (3.4% and 3.6% respectively of all hits). Petroleum engineers are the only specialty that is mentioned more often in the FCR than in any of the state's codes.

Within California, the most frequently mentioned type of engineer in all four jurisdictions studied was the civil engineer. Geotechnical engineers were mentioned almost as frequently in Los Angeles and San Diego counties, while structural engineers were the second most commonly specified in San Francisco and at the state level. Generic titles appear more often in the CCR than in the county codes.

Most of the references to engineers are prescriptive statements (90% in the CCR and 84% in the county codes), requiring the involvement of an engineer in a specified activity.

Complaints

ISR analyzed twelve years (1990/91 through 2001/02) of complaint data collected by DCA and the BPELS to determine whether there were any consistent differences between practice and title act disciplines in the frequency and nature of complaints, their source, or the Board's response. A second purpose was to explore whether the differences, if any, had any implications for protection of public health, safety and welfare -- implications that are discussed in the next section of this summary chapter.

Most of the complaints are against either civil engineers (43%) or unlicensed individuals (45%). There are very few complaints against electrical and mechanical engineers (1 and 2% respectively). This distribution of complaints is not representative of the distribution of employed engineers in the state. Civil engineers constitute 15% of the state's engineering work force, electrical and mechanical engineers 30% and 11% respectively. Even if all of OES' "other engineers" category was assumed to be civil engineers (18% of the work force), civil engineers would be over-represented in the complaint process. Geotechnical, structural and traffic engineers are also significantly over-represented in complaints against registered engineers while the remaining title act disciplines are all under-represented.

Several explanations for the over-representation of civil engineers, including geotechnical and structural, have been put forward. The first is the varying employment locations of different branches of engineering. More civil engineers are employed in "engineering and architectural services" (37% in California) than electrical or mechanical engineers (6% and 19% respectively). Industrial corporations employ most electrical and mechanical engineers (82% and 76% compared with 7% of civil engineers). Almost all title act engineers are employed by industry. Although differential exposure to clients probably contributes to the over-representation of civil engineers in the complaint population, it is not the whole story.

Civil engineers are also over-represented, and electrical and mechanical engineers under-represented, in the claims population relative to their proportions in the engineering work force -- although more claims than complaints are filed against electrical and mechanical engineers. But, in the claims data, more mechanical and electrical than civil engineering firms are sued by clients (72% and 60% respectively vs. 51% for civil). Civil engineering firms are more likely to be sued by third parties (33% vs. 13% and 21% for mechanical and electrical engineers). Suits against corporations or government agencies for negligent or incompetent engineering practices are not in any available database. But the claims data suggest that injured third parties are an important source of claims and that factors other than exposure to clients affect what types of engineers are held accountable.

Another such factor suggested by the claims data is the type of projects engineering firms are engaged in. However, different project types engaged in by a single discipline can generate positive and negative claims/fee ratios and the same project type engaged in by multiple disciplines can generate different claims/fee ratios for the separate disciplines. For example, civil engineering firms had positive ratios for their work on roads and highways, generating fewer claims and claim dollars than they earned in fees, but a negative ratio for work on wastewater, sewage and water treatment systems. Civil engineering firms engaged in residential projects came out even -- generating similar proportions of claims and fees -- while, for electrical engineers, residential projects were much more damaging -- generating six times the number of claims as fees.

The weakness in the claims data is that there is no measure of the rate of claims relative to the number of firms covered; the only norming variable available for the number and dollar value of claims is the total fees generated by the firms sued. In addition, comparing the distribution of *firms* to the distribution of *employed engineers* is inexact.

Another possible explanation for the apparent over-representation of civil engineers in the complaint and claims populations is that, for whatever reason, incompetence may be more common in this branch of engineering. Both the complaint and pass rate data provide some support for this interpretation. In the complaint population, a higher proportion of civil, structural and geotechnical engineers are charged with incompetence/negligence than is true for electrical or mechanical engineers (70%, 75% and 69% vs. 48% and 28% respectively). Pass rates for civil engineers in California have been significantly lower than the average for the comparison states, while those for mechanical engineering have, with one exception, been within the norm. However, pass rates for electrical engineers have been lower in most years and yet there are only 4 complaints lodged against them. Although it is those who pass these exams and become licensed who are involved in the complaints, the difficulty in passing them may reflect a broader range of topics in civil and electrical engineering. Civil has five depth areas that are covered on the breadth exam. In addition, candidates for licensing in civil engineering must take an additional exam in "special civil" the following day. This lack of specialization in the discipline --

and a regulatory structure that permits this discipline to practice other disciplines as well -- may undermine competence among civil engineers.

That the regulatory structure may be a factor in complaints of incompetence/negligence against civil engineers in California is suggested by the comparison with complaint data in Massachusetts. While the proportion of electrical and mechanical engineers charged with unlicensed activity was similar in the two states (10% and 8% for electrical and 28% and 22% for mechanical in California and Massachusetts respectively), the proportion of civil engineers charged with unlicensed activity was almost four times greater in Massachusetts (12.7% vs. 3.5%). Massachusetts prohibits overlapping practice without prior Board approval between any of its 46 disciplines while California permits one-directional incidental overlap for civil engineers into any discipline and for electrical and mechanical into any discipline except civil engineering. This may help to explain another difference between the two states: while, in Massachusetts, fraud was a more frequent alleged violation in all three practice act disciplines and structural engineering, competence/negligence was more frequent in these disciplines in California.

Another affect of the regulatory structures in Massachusetts and California can be seen in who gets charged with unlicensed activity. While the proportion of *unlicensed engineers* charged with unlicensed activity was virtually identical in these two states (52.1% in California and 51.9% in Massachusetts), *licensed engineers* in Massachusetts -- a state with 46 licensed disciplines and no hierarchical distinctions between them -- were three times as likely to be charged with unlicensed activity as they were in California (14.2% vs. 4.9%).

Complaints against the title act disciplines were rare in both states. In California, the title act disciplines accounted for 17.8% of employed engineers in the state, but only 4.9% of complaints. The title act disciplines and other engineers were also under-represented in the claims population, making up 18.5% of claims, but 36.2% of the nation's employed engineers.

In California, processing time, identifying a violation, and Board actions varied between practice act engineers and the unlicensed. The proportion of open complaints against practice act engineers is almost three times higher than among the unlicensed (13.5% vs. 5.8%). Violations are identified most often among the unlicensed (80%) and persons with multiple licenses in civil and traffic engineering (74%), but in slightly less than half (48%) of the closed cases against practice act engineers. Board action is the most common response when violations are identified against the unlicensed (84%), while referral to the Attorney General occurs most often among those with dual licenses in Civil and Traffic (81%). When violations are identified among practice act engineers, the response is equally split between Board action (40%) and referral to the Attorney General (40%).

Health and Safety

One of the legislatively defined goals for the Title Act Study was to consider how changes to existing laws regulating engineers would affect the public health, safety and welfare. To assess this requires some measure of the degree to which the public health, safety and welfare are affected by the current licensing system. The positive impacts of engineering and its products on quality of life and economic prosperity are not at issue in regulating this profession. Determining relative differences in the potential for harm among engineering branches would be one way to justify licensing distinctions between them. Measuring the potential for harm was the challenge. Errors in the design of buildings, roads, bridges and products are not tracked by any state or federal agency and the resolution of legal avenues of redress are often private (e.g., out-of-court settlements and insurance claims). ISR located two data sources that offered a limited opportunity to assess differential impacts on public health and safety: DCA's data base on complaints against engineers and a power point presentation on insurance claims compiled by DPIC, one of the two largest insurers of engineers in the U.S.

Complaints

In terms of complaints and insurance claims, the title act disciplines appear to pose less of a threat to public health, safety and welfare than civil and structural engineering -- *as measured by these indices*. Mechanical and electrical engineering are even more under-represented than the title act disciplines in the generation of complaints and insurance claims. Therefore, differential impact on public health and safety does not support the current grouping of practice and title act disciplines.

The complaint process serves to protect the public through enforcement actions against engineers and the maintenance of a fair examination system. How well it does this is difficult to judge. California has the lowest complaint rate per 100,000 registered engineers among the four states with comparable information (an average of 126 per 100,000 for California compared with 179 to 337 for New York, North Carolina and Texas). Is this because California engineers are more ethical and competent, or because the complaint process is more cumbersome and not well publicized? Private parties (individual and corporate clients) initiate half of all complaints. The Board is the second largest source of complaints, accounting for 39%.

In general, complaints against the practice act disciplines come from the public while those against the unlicensed are more likely to come from the Board. While the public is primarily responsible for complaints against practice act only disciplines and practice/title combinations when a single traffic engineer generating multiple Board complaints is removed, the Board initiates complaints against the unlicensed (65%). The public and the Board each generate roughly half of all complaints against title act engineers (45% and 40% respectively).

How quickly complaints are resolved and what happens when they are depends upon the complaint subject's discipline. The proportion of open complaints against practice act engineers is almost three times higher than the proportion among the unlicensed (13.5% vs. 5.8%). Violations are identified most often among the unlicensed (80%) and persons with multiple licenses in civil and traffic engineering (74%), but in slightly less than half (48%) of the closed cases against practice act engineers. Board action is the most common response when violations are identified against the unlicensed (84%), while referral to the Attorney General occurs most often among those with dual licenses in civil and traffic (81%). When violations are identified among practice act engineers, the response is equally split between Board action (40%) and referral to the Attorney General (40%).

The violation alleged also influences the outcome of a complaint. The most common closing code when fraud, competence/negligence or contractual issues are charged is that no violation is found (38%, 37% and 33% respectively). In cases of exam subversion and unlicensed activity, Board action is the most common response (91% and 39% respectively). Thus, cases brought by the Board are more likely to result in an enforcement action (66% of the time), while the largest group of complaints -- those brought by the public -- lead more often to a finding of "no violation" (38% of the time).

Complaints in Other States

The discipline profile of complaints in Massachusetts confirms results from California. Complaints in both states are primarily against civil engineers (40.1% in California and 43.4% in Massachusetts) or the unlicensed (49.2% vs. 36.8%). The other practice act disciplines account for most of the remaining complaints in both states: electrical (1% in California vs. 2.8% in Massachusetts), mechanical (2% vs. 8.3%), structural (3.9% vs. 6%) and geotechnical (3.5% in California and none in Massachusetts).
The complaint rates for mechanical, electrical, chemical and industrial engineering were higher in Massachusetts while those for metallurgical or materials and traffic engineering were higher in California.

The overall rate for complaints against licensed engineers was almost 60% higher in California (44 vs. 28), while that for the unlicensed was more than twice as high in California (43 vs. 16 per 100,000). Total complaints were almost exactly twice as high in California as in Massachusetts (87 vs. 44).

The major difference between the two states was in the treatment of the unlicensed. Massachusetts dismissed all but 18% of cases involving the unlicensed while California found that a violation had occurred in 79% of such cases. The higher complaint rates in California, particularly among the unlicensed, and the states' response to cases against the unlicensed, may be related to the states' regulatory structure. California, as a "board" state, vests more control over the licensing and complaint process in the Board, while Massachusetts, as an "agency" state, vests control over complaints in an Office of Investigations that governs all professions. Exercise of the disciplinary and enforcement function both expresses and justifies the California Board's authority.

Claims

When the number and cost of insurance claims among engineering disciplines are compared against their exposure as measured by client fees generated, structural engineers appear to have a more negative impact on the public health and safety. They generate roughly twice the proportion of claims and claim dollars as client fees while civil and electrical engineers generate less. Mechanical engineering and the "other," presumably title act, disciplines are generally neutral, generating claims and claim dollars in rough proportion to their exposure.

Thus, protection of public health and safety does not appear to be a justification for practice vs. title protection. Two of the three practice disciplines (civil and electrical) have less impact in terms of insurance claims than their exposure leads us to expect while the number of claims and claim dollars are proportional for mechanical engineering and the title act disciplines. When claims involvement is compared to the proportion of employed engineers, civil joins structural in being over-represented, but the two other practice act disciplines and the title act disciplines are under-represented. Either way, mechanical and electrical engineering appear to have less impact on public health and safety and more clearly in common with the title acts than civil engineering.

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Appendix A. Disciplines Licensed by Massachusetts

Acoustical	Heating & Ventilation/ Air Conditioning
Aeronautical/ Aerospace	Industrial
Aeronautical	Instrumentation
Agricultural	Mechanical
Architectural Marine	Marine
Architectural	Metallurgical
Aerospace	Mining/ Mineral
Astronautical	Manufacturing
Civil	Material
Ceramic	Naval Architecture
Chemical	Nuclear
Construction	Plumbing
Corrosion	Petroleum
Control Systems	Plastics
Electrical	Quality
Electronic	Railroad
Environmental	Sanitary
Engineering Plastics	Safety
Fire Protection	Structural
Geological	Systems
Geodetic	Traffic
Geotechnical	Transportation
Highway	Textile

Appendix B: ISR Interview with Ten Comparison States on Regulatory Model and Request for Data

Registration data 1994/95 through 00/01:
1. We are requesting information on the number of registered engineers for each year from 1994/95 through 2000/01. If the number of registered engineers by discipline (based on the specialty exam) is available, we would prefer to have that information.

Exemptions:
2. Are there subgroups of engineers who are exempt from licensing? Which are they?

Exams:
1. How is your Engineer in Training (EIT) exam structured?
Does it have a breadth and depth section?
Which specialties are covered in the depth section?
____
____
____
____

2. We are requesting data from 1993 - 2001.
We need the number taking exams,
The cut points,
And the pass rates by exam type. (EIT, PE exams including specialties)

3. We would like to confirm the educational background and years of experience that your state requires people to have before taking the exam. Our research indicates that your state requires… [insert required educational background and years of experience to take exam from state codes, pull out info before calling] Is this correct?

We are looking at the division of responsibilities between an appointive licensing Board and the State Agency that oversees Licensing of engineers. We have a few questions about who is responsible for what. [Boards are appointive; Agencies are full-time staff.]

1. First, who is responsible for hiring Board staff?

   a. Totally the Board's responsibility
   b. Totally the Agency's responsibility
   c. Shared responsibility: Board initiated, Agency approval required
   d. Shared responsibility: Agency initiated, Board approval required
   e. The Board is staffed by the Agency
   f. Other_____________________________________

2. Who is responsible for hiring Agency staff?

   a. Totally the Board's responsibility
   b. Totally the Agency's responsibility
   c. Shared responsibility: Board initiated, Agency approval required
   d. Shared responsibility: Agency initiated, Board approval required

3. Who makes decisions about office location, purchasing and procedures?

   a. Totally the Board's responsibility
   b. Totally the Agency's responsibility
   c. Shared responsibility: Board initiated, Agency approval required
   d. Shared responsibility: Agency initiated, Board approval required

4. Who maintains the financial records for licensing? (license and registration fees)

   a. Totally the Board's responsibility
   b. Totally the Agency's responsibility
   c. Shared responsibility: Board initiated, Agency approval required
   d. Shared responsibility: Agency initiated, Board approval required

5. Are all Board expenditures covered by license and registration fees or are some covered by the state's general fund monies?

   a. License and registration fees only
   b. Fees and state general fund money

6. (If some state funding) Roughly what proportion of the Board's budget is contributed by the state?_____________________

7. Are all State Agency expenditures covered by license and registration fees or are some covered by the state's general fund monies?
   a. License and registration fees only
   b. Fees and state general fund money

8. (If some state funding) Roughly what proportion of the Agency's budget is contributed by the state?___________________

9. Does the state develop its own exams or does it use only NCEES exams?

   a. state develops its own exams
   b. state uses only NCEES exams
   c. state use a combination of NCEES & its own exams

10. Who's responsible for the preparation of exams?

   a. Totally the Board's responsibility
   b. Totally the Agency's responsibility
   c. Shared responsibility: Board initiated, Agency approval required
   d. Shared responsibility: Agency initiated, Board approval required
   e. State uses NCEES exams only.

11. What exams does the state administer? That is, do you offer a single exam to all engineers, or must licensees take an exam in a specialty area? In which specialties do you test?

____
____
____
____
____

12. Does the license specify a specialty area or discipline, or does it say "professional engineer"?

   a. Specified
   b. Professional Engineer only
   c. Mixed (specify____________________________________)

13. Does the seal specify a specialty area or does it say "professional engineer"?

   a. Specified
   b. Professional Engineer only
   c. Mixed (specify____________________________________)

14. Who sets the cut score of passing grade?

   a. Totally the Board's responsibility
   b. Totally the Agency's responsibility
   c. Shared responsibility: Board initiated, Agency approval required
   d. Shared responsibility: Agency initiated, Board approval required

15. Who conducts and grades exams?

   a. Totally the Board's responsibility
   b. Totally the Agency's responsibility
   c. Shared responsibility: Board initiated, Agency approval required
   d. Shared responsibility: Agency initiated, Board approval required

16. Who sets qualifications for people taking the exams?

    a. Totally the Board's responsibility
    b. Totally the Agency's responsibility
    c. Shared responsibility: Board initiated, Agency approval required
    d. Shared responsibility: Agency initiated, Board approval required

17. Who collects the fees for exams?

    a. Totally the Board's responsibility
    b. Totally the Agency's responsibility
    c. Shared responsibility: Board initiated, Agency approval required
    d. Shared responsibility: Agency initiated, Board approval required

18. Who collects the fees for renewal of registration?

    a. Totally the Board's responsibility
    b. Totally the Agency's responsibility
    c. Shared responsibility: Board initiated, Agency approval required
    d. Shared responsibility: Agency initiated, Board approval required

19. Who answers inquiries from licensees and the public?

    a. Totally the Board's responsibility
    b. Totally the Agency's responsibility
    c. Shared responsibility: Board initiated, Agency approval required
    d. Shared responsibility: Agency initiated, Board approval required

20. Who prepares and mails applications for licensing and renewal?

    a. Totally the Board's responsibility
    b. Totally the Agency's responsibility
    c. Shared responsibility: Board initiated, Agency approval required
    d. Shared responsibility: Agency initiated, Board approval required

21. Who issues licenses?

    a. Totally the Board's responsibility
    b. Totally the Agency's responsibility
    c. Shared responsibility: Board initiated, Agency approval required
    d. Shared responsibility: Agency initiated, Board approval required

22. Who handles complaints?

    a. Totally the Board's responsibility
    b. Totally the Agency's responsibility
    c. Shared responsibility: Board initiated, Agency approval required
    d. Shared responsibility: Agency initiated, Board approval required

23. Who disciplines licensees?

a. Totally the Board's responsibility
b. Totally the Agency's responsibility
c. Shared responsibility: Board initiated, Agency approval required
d. Shared responsibility: Agency initiated, Board approval required

24. How are complaints against unlicensed individuals handled? What are the penalties? What agency or court has jurisdiction over unlicensed practice?

____
____
____
____
____
____

Complaint Data:

1. Do you log information on complaints in a computer database?

2. Would it be possible to obtain a copy of the complaint data for 1991-2001?

3. We will also need copy of the codebook for your complaint database.

4. (If complaint data is not available,) Would you have summaries of the data (frequencies) for all variables? What years are available? We would like summaries for 1991-2001.

Appendix C: Request for Consent of Release of Pass Rates

Memorandum

State of California
Department of Consumer Affairs

Date: November 6, 2002

To: Natalie Lowe, Florida Board
Thelma Barrington, Illinois Board
Deborah Milliken, Massachusetts Board
Arthur Russo, New Jersey Board
Jane Blair, New York Board
Andrew L. Ritter, North Carolina Board
Mark T. Jones, Ohio Board
Shirley S. Klinger, Pennsylvania Board
Lois Marshall, Rhode Island Board
Victoria J.L. Hsu, Texas Board

From: **Board for Professional Engineers and Land Surveyors**
Cindi Christenson, P.E. (916) 263-2285

Subject: Request for consent of release of pass rates

An independent study, mandated by the legislature, regarding the California Board's licensing structure is being performed by the Institute of Social Research (ISR). A part of this study is the comparison of California to 10 states which are similar to California in several aspects. One part of the study consists of comparing California pass rates with the pass rates in each of your states. ISR was advised that some or most of you do not retain pass rates statistics and that such data was available from the NCEES. I have contacted NCEES and they will release it with your consent. We would really appreciate your cooperation in this matter and are requesting that you consent to the release of this data by filling out the information below and faxing it back to my attention. I realize that this information is sensitive and the published report will contain only how California ranks amongst the 10 states and will not include a table that has state specific pass rate data.

Thanks again.

The State Board of ____ consents to allowing its pass rates released by the NCEES to the Institute of Social Research. In consenting to this release we understand that our state specific data will not be published in the final report.

____
Authorized Signature

Please fax to: Cindi Christenson FAX (916) 263-2221

Appendix D. Examples of Code Sections

San Francisco Municipal Code

Sec.2.6 Smoke Control Systems-Submittal Requirements
"2. Special Inspection must be overseen and coordinated by one of the following *when approved by the Fire Department and the Department of Building Inspection*:
* Design Engineers of Record may fulfill the special inspection roll on projects that they have designed;
* An approved California Registered Fire Protection Engineer with smoke management commissioning experience may coordinate and verify all components of the smoke-control system within his or her area of expertise, or;
* An approved California Registered Mechanical or Electrical Engineer with building or smoke management commissioning experience may coordinate and verify all components of the smoke-control system within his or her area of expertise. "

Sec.4.14 Retroactive sprinkler requirements for existing high-rise buildings
"403.24.7.1 Members. Six of the nine members of the Board shall be the same persons and with the same terms as those appointed to the Board of Examiners pursuant to Section 105.1 of this code. ((One member of the Board shall be a licensed plumbing contractor, and shall be the same person and with the same term as the plumbing contractor member of the Board of Examiners - Plumbing, appointed pursuant to Section 105.1 of the San Francisco Plumbing Code. The two additional members of the Board shall be a)) The three remaining members of the Board shall consist of two registered fire protection engineers and ((a)) one representative of owners of buildings subject to the requirements of this section and shall be appointed by the Building Inspection Commission pursuant to the provisions of Section 105.1 of this code. The following shall constitute ex officio members of the Board, without vote and without compensation: the Chief of the Bureau of Fire Prevention and Investigation, and the Director of the Department of Building Inspection who shall act as Secretary of the Board." (sic)

Sec 1228. Applicant's Responsibility Upon Discovery of Hazardous Wastes.
"Unless Section 1227 is applicable, if the soil sampling and analysis report indicates that hazardous wastes are present in the soil, the applicant shall submit a site mitigation report prepared by a qualified person to the Director.
(a) For the purposes of this Section, a qualified person is defined as one or more of the following who is registered or certified by the State of California: soil engineer, civil engineer, chemical engineer, engineering geologist, geologist, hydrologist, industrial hygienist or environmental assessor.
(b) The site mitigation report shall contain the following information:
(1) A determination by the qualified person as to whether the hazardous wastes in the soil are causing or are likely to cause significant environmental or health and safety risks, and if so, recommend measures that will mitigate the significant environmental or health and safety risks caused or likely to be caused by the presence of the hazardous waste in the soil. If the report recommends mitigation measures it shall identify any soil sampling and analysis that it recommends the project applicant conduct following completion of the mitigation measures to verify that mitigation is complete;
(2) A statement signed by the person who prepared the report certifying that the person is a qualified person within the meaning of this Section and that in his or her judgment either no mitigation is required or the mitigation measures identified, if completed, will mitigate the significant environmental or health and safety risks caused by or likely to be caused by the hazardous wastes in the soil;
(3) Complete the site mitigation measures identified by the qualified person in the site mitigation report; and
(4) Complete the certification required by Section 1229. (Added by Ord. 35-99, App. 3/12/99) "

Sec.2910. Variance Board Establishment; Functions; Standards; Procedures.
"There is hereby created a Variance Board consisting of five members; one shall be qualified by training and experience in the field of acoustics or acoustical engineering; one shall be qualified by training, experience, and registration in the field of mechanical engineering; one shall be qualified by training, experience, and licensing in the field of architecture or civil engineering; one shall be a physician qualified in the field of physiological effects of noise; and one shall be a qualified audiometrist. Its functions shall be

to evaluate all applications for variance from the requirements of this Article with respect to noises emitted from truck-mounted waste or garbage loading and/or compacting equipment, and from fixed sources, and to grant said variances with respect to time for compliance, subject to such terms, conditions and requirements as it may deem reasonable to achieving compliance with the provisions of this Article. Each such variance shall set forth in detail the approved method of achieving compliance and a time schedule for its accomplishment. In determining the reasonableness of the terms of any proposed variance, said Board shall consider the magnitude of nuisance caused by the offensive noise, the uses of property within the area of impingement by the noise, the time factors related to study, design, financing and construction of remedial work, the economic factors related to age and useful life of equipment, and the general public interest and welfare. Any variance granted by said Board shall be by resolution and shall be transmitted to the Director of Public Health for enforcement. (Added by Ord. 274-72, App. 9/20/72) "

Sec.D3.750-1 Commission; Composition.
"The Department of Building Inspection shall be under the management of a Building Inspection Commission consisting of seven members. Four members shall be appointed by the mayor for a term of two years; provided that the respective terms of office of those first appointed shall be as follows: two for one year, and two for two years from the effective date of this section. Three members shall be appointed by the President of the Board of Supervisors for a term of two years; provided that the respective terms of office of those first appointed shall be as follows: three for one year from the effective date of this section. The initial appointments shall be made no later than fifteen days after the effective date of this section, and the commission's management shall begin no later than forty-five days after the effective date of this section. Vacancies occurring in the offices of appointive members, either during or at expiration of term, shall be filled by the electoral office that made the appointment. The four mayoral appointments shall be comprised of a structural engineer, a licensed architect, a residential builder, and a representative of a community- based non-profit housing development corporation. The three Supervisorial appointments shall be comprised of a residential tenant, a residential landlord, and a member of the general public. The members of the commission shall serve without compensation."

<u>Los Angeles County Code</u>

Sec.12.21.General Provisions
"(3) Structural Integrity Report. A Structural Integrity Report from a professional engineer licensed in the State of California documenting the following:
(i) Tower height and design, including technical, engineering, economic, and other pertinent factors governing selection of the proposed design;
(ii) Total anticipated capacity of the structure, including number and types of antennas which can be accommodated;
(iii) Failure characteristics of the tower and demonstration that site and setbacks are of adequate size to contain debris in the event of failure; and
(iv) Specific design and reconstruction plans to allow shared use. (This submission is required only in the event that the applicant intends to share use of the facility by subsequent reinforcement and reconstruction of the WTF.)"

Sec.17.05 Design Standards
"J. Hillside Areas. Design requirements for subdivisions in hillside areas shall meet the grading standards established by the Board of Public Work and the grading regulations established by Article I, Chapter 9of this Code. Such requirements may also include providing soil reports prepared by a Registered Civil Engineer specializing in Soil Mechanics and/or reports on geological investigations."

Sec.22.341.City Engineer, Qualifications.
"The City Engineer shall be a Registered Civil Engineer with not less than five years of professional work experience."

Sec.62.250.Rail Transit Construction Impact.
"12. Worksite Traffic Control Plan. A Worksite Traffic Control Plan may be required by the Review Committee, which includes a drafted, 1" = 40' scale plan delineating base conditions, construction impact areas, site-specific detour operations, including traffic striping, pavement and curb markings, traffic control signs, signals, delineators, barricades, and traffic management requirements, at a precise level of detail. A Worksite Traffic Control Plan may be required where street work necessitates that motorists travel in paths for several days that conflict with permanent striping. The Worksite Traffic Control Plan and Traffic Circulation Plan, if required, shall be prepared under the direction of a Traffic Engineer or a Civil Engineer experienced in the preparation of Traffic Control Plans and registered in the State of California, and shall have the signed approval of the Division Engineer in Charge of Rail Transit Division, Department of Transportation, prior to the issuance by the Department of Public Works of the appropriate permit. "

Sec.91.220.S.
"Soil Engineer shall mean a civil engineer duly licensed by the State of California who is experienced in the application of the principles of soil mechanics in the investigation, evaluation and design of civil works involving the use of earth materials and who is approved by the Department, or a geotechnical engineer licensed by the State of California."

Sec.93.0206. Plans and Specifications
"(a) Plans and specifications required by the provisions of Subsection (b) of this Section shall be prepared by and bear the signature and registration number of a State of California Civil Engineer, Structural or Geotechnical Engineer (when the work is supplementary to Civil Engineering work), Electrical Engineer or Licensed Architect."

Sec.1303."G"Surface Mining Operations Districts.
"(a) A comprehensive soils engineering and engineering geologic investigation report prepared by a registered civil engineer and a certified engineering geologist, who shall not be employees of the applicant. The report shall indicate the type and features of Overburden and Minerals expected to be extracted and Mining Waste generated by the proposed Surface Mining Operations, and recommendations relative to setbacks, slopes, and excavations."

<u>California Code of Regulations</u>

TITLE 10. Investment \ Chapter 3. Commissioner of Corporations \ Subchapter 2. Corporate Securities \ Article 4. Standards for the Exercise of the Commissioner's Authority \ Subarticle 11. Oil and Gas Interests \ §260.140.122.2. Net Worth.
"b) In determining the general partner's net worth, the value of proven reserves, as determined by an independent petroleum engineer, of oil, gas and other minerals owned by a general partner may be used. Notes and accounts receivables from all programs, interests in all programs, and all contingent liabilities will be scrutinized carefully to determine the appropriateness of their inclusion in the net worth computation."

TITLE 14. Natural Resources \ Division 5. San Francisco Bay Conservation and Development Commission \ Chapter 2. The Commission, the Staff, and the Advisory Review Boards \ Article 7. Advisory Boards \ §10271. Membership and Function of Engineering Criteria Review Board.
"The Engineering Criteria Review Board shall consist of not more than eleven (11) members, including at least one (1) geologist, one (1) civil engineer specializing in soils, one (1) structural engineer, and one (1) architect. The Board shall advise the Commission on problems relating to the safety of fills and of structures on fills."

TITLE 22. Social Security \ Division 4. Environmental Health \ Chapter 17. Surface Water Treatment\ Article 1. General Requirements and Definitions \ §64651.66. Qualified Engineer.
"“Qualified engineer” means a Civil Engineer, registered in the State of California, with 3 years experience in water treatment design, construction, operation, and watershed evaluations.

TITLE 22. Social Security \ Division 4.5. Environmental Health Standards for the Management of Hazardous Waste \ Chapter 14. Standards for Owners and Operators of Hazardous Waste Transfer, Treatment, Storage, and Disposal Facilities \ Article 8. Financial Requirements \ §66264.143. Financial Assurance for Closure.

"(1) Within 60 days after receiving certifications from the owner or operator and an independent professional engineer, registered in California, that final closure has been completed in accordance with the approved closure plan, the Department shall notify the owner or operator in writing that they are no longer required by this section to maintain financial assurance for final closure of the facility, unless the Department has reason to believe that final closure has not been in accordance with the approved closure plan. The Department shall provide the owner or operator a detailed written statement of any such reason to believe that closure has not been in accordance with the approved closure plan."

Appendix E. Titles included in the California Code of Regulations

Title 1.	General Provisions
Title 2.	Administration
Title 3.	Food and Agriculture
Title 4.	Business Regulations
Title 5.	Education
Title 6.	Governor [No regulations filed]
Title 7.	Harbors and Navigation
Title 8.	Industrial Relations
Title 9.	Rehabilitative and Developmental Services
Title 10.	Investment
Title 11.	Law
Title 12.	Military and Veterans Affairs
Title 13.	Motor Vehicles
Title 14.	Natural Resources
Title 15.	Crime Prevention and Corrections
Title 16.	Professional and Vocational Regulations
Title 17.	Public Health
Title 18.	Public Revenues
Title 19.	Public Safety
Title 20.	Public Utilities and Energy
Title 21.	Public Works
Title 22.	Social Security
Title 23.	Waters
Title 24.	Building Standards are not published on CCR website
Title 25.	Housing and Community Development
Title 26.	Toxics
Title 27.	Environmental Protection
Title 28.	Managed Health Care

ACCOUNTANCY, BOARD OF
ACUPUNCTURE BOARD
ADMINISTRATIVE HEARINGS, OFFICE OF
ADMINISTRATIVE LAW, OFFICE OF
AGING, CALIFORNIA DEPARTMENT OF
AGRICULTURAL LABOR RELATIONS BOARD
AIR RESOURCES BOARD
ALCOHOL AND DRUG PROGRAMS, DEPARTMENT OF
ALCOHOLIC BEVERAGE CONTROL APPEALS BOARD
ALCOHOLIC BEVERAGE CONTROL, DEPARTMENT OF
ALLOCATION BOARD, STATE
ALTERNATIVE ENERGY AND ADVANCED TRANSPORTATION SOURCE FINANCING AUTHORITY
APPRENTICESHIP STANDARDS, DIVISION OF
ARBITRATION CERTIFICATION PROGRAM
ARCHITECT, DIVISION OF THE STATE
ARCHITECTS BOARD, CALIFORNIA
ARTS COUNCIL, CALIFORNIA
ATHLETIC COMMISSION
AUCTIONEER COMMISSION
AUTOMOTIVE REPAIR, BUREAU OF
BANKING DEPARTMENT, STATE
BARBERING AND COSMETOLOGY, BUREAU OF
BEHAVIORAL SCIENCES, BOARD OF
BOATING AND WATERWAYS, DEPARTMENT OF
BUSINESS, TRANSPORTATION AND HOUSING AGENCY
CALIFORNIA SCIENCE CENTER
CEMETERY AND FUNERAL BUREAU
CHILD SUPPORT SERVICES, DEPARTMENT OF
CHIROPRACTIC EXAMINERS, BOARD OF
COASTAL COMMISSION, CALIFORNIA
COASTAL CONSERVANCY, STATE
COLLECTION AND INVESTIGATIVE SERVICES, BUREAU OF
COLORADO RIVER BOARD OF CALIFORNIA
COMMUNITY COLLEGES, CALIFORNIA
COMMUNITY SERVICES AND DEVELOPMENT, DEPARTMENT OF
CONSERVATION, DEPARTMENT OF
CONSUMER AFFAIRS, DEPARTMENT OF
CONTRACTORS' STATE LICENSE BOARD
CONTROLLER, STATE
CORPORATIONS, DEPARTMENT OF
CORRECTIONS, BOARD OF
CORRECTIONS, CALIFORNIA DEPARTMENT OF
COSMETOLOGY, BOARD OF
COURT REPORTERS' BOARD OF CALIFORNIA
DELTA PROTECTION COMMISSION
DENTAL BOARD OF CALIFORNIA
DEVELOPMENTAL SERVICES, DEPARTMENT OF
DISPUTE RESOLUTION ADVISORY COUNCIL
ECONOMIC OPPORTUNITY, DEPARTMENT OF
EDUCATION, CALIFORNIA DEPARTMENT OF
EDUCATIONAL FACILITIES AUTHORITY
ELECTRONIC AND APPLIANCE REPAIR, BUREAU OF
EMERGENCY MEDICAL SERVICES AUTHORITY
EMERGENCY SERVICES, OFFICE OF
EMPLOYMENT DEVELOPMENT DEPARTMENT
ENERGY COMMISSION, CALIFORNIA
ENVIRONMENTAL AFFAIRS AGENCY
ENVIRONMENTAL HEALTH HAZARD ASSESSMENT, OFFICE OF
ENVIRONMENTAL PROTECTION AGENCY (Cal-EPA), CALIFORNIA
EQUALIZATION, STATE BOARD OF
EXPOSITION AND STATE FAIR, CALIFORNIA
FAIR EMPLOYMENT AND HOUSING, DEPARTMENT OF
FAIR EMPLOYMENT AND HOUSING COMMISSION
FAIR POLITICAL PRACTICES COMMISSION
FINANCIAL INSTITUTIONS, DEPARTMENT OF
FIRE MARSHAL, OFFICE OF THE STATE
FISH AND GAME, DEPARTMENT OF
FISH AND GAME COMMISSION
FOOD AND AGRICULTURE, DEPARTMENT OF
FORESTRY AND FIRE PROTECTION
FORESTRY AND FIRE PROTECTION, CALIFORNIA DEPARTMENT OF
FRANCHISE TAX BOARD
FUNERAL DIRECTORS AND EMBALMERS, BOARD OF
GAMBLING CONTROL, DIVISION OF
GAMBLING CONTROL COMMISSION, CALIFORNIA
GENERAL SERVICES, DEPARTMENT OF
GEOLOGISTS AND GEOPHYSICISTS, BOARD FOR
GUIDE DOGS FOR THE BLIND, STATE BOARD OF
HEALTH FACILITIES FINANCING AUTHORITY, CALIFORNIA
HEALTH AND HUMAN SERVICES AGENCY, CALIFORNIA
HEALTH PLANNING AND DEVELOPMENT, OFFICE OF STATEWIDE
HEALTH SERVICES, DEPARTMENT OF
HEARING AID DISPENSERS BUREAU
HIGHWAY PATROL, DEPARTMENT OF CALIFORNIA
HOME FURNISHINGS AND THERMAL INSULATION, BUREAU OF
HORSE RACING BOARD, CALIFORNIA
HOUSING AND COMMUNITY DEVELOPMENT, DEPARTMENT OF
HOUSING FINANCE AGENCY, CALIFORNIA
INDUSTRIAL DEVELOPMENT FINANCING ADVISORY COMMISSION, CALIFORNIA
INDUSTRIAL MEDICAL COUNCIL
INDUSTRIAL RELATIONS, DEPARTMENT OF
INDUSTRIAL WELFARE COMMISSION
INSURANCE, DEPARTMENT OF
JUSTICE, DEPARTMENT OF
LABOR STANDARDS ENFORCEMENT, DIVISION OF
LABOR STATISTICS AND RESEARCH, DIVISION OF
LANDS COMMISSION, STATE
LANDSCAPE ARCHITECTS TECHNICAL COMMITTEE
LIBRARY, CALIFORNIA STATE
LOCAL AGENCY DEPOSIT SECURITY, ADMINISTRATION OF
MANAGED HEALTH CARE, DEPARTMENT OF
MANDATES, COMMISSION ON STATE
MARITIME ACADEMY, CALIFORNIA
MEDICAL ASSISTANCE COMMISSION, CALIFORNIA
MEDICAL BOARD OF CALIFORNIA
MEDICAL INSURANCE BOARD, MANAGED RISK
MENTAL HEALTH, DEPARTMENT OF
MINING AND GEOLOGY BOARD, STATE
MOTOR VEHICLES, DEPARTMENT OF
NARCOTIC ADDICT EVALUATION AUTHORITY
NEW MOTOR VEHICLE BOARD
NURSING, BOARD OF REGISTERED
NURSING HOME ADMINISTRATOR PROGRAM
OCCUPATIONAL SAFETY AND HEALTH (CAL/OSHA), DIVISION OF
OCCUPATIONAL SAFETY AND HEALTH APPEALS BOARD
OCCUPATIONAL SAFETY AND HEALTH STANDARDS BOARD
OCCUPATIONAL THERAPY, BOARD OF
OPTICIAN PROGRAM, REGISTERED DISPENSING
OPTOMETRY, STATE BOARD OF
OSTEOPATHIC MEDICAL BOARD OF CALIFORNIA
PARKS AND RECREATION, DEPARTMENT OF
PEACE OFFICER STANDARDS AND TRAINING, COMMISSION ON
PERSONNEL ADMINISTRATION, DEPARTMENT OF
PERSONNEL BOARD, STATE
PEST CONTROL BOARD, STRUCTURAL
PESTICIDE REGULATION, DEPARTMENT OF
PHARMACY, CALIFORNIA STATE BOARD OF
PHYSICAL THERAPY BOARD OF CALIFORNIA
PHYSICIAN ASSISTANT COMMITTEE
PILOT COMMISSIONERS, BOARD OF
PLANNING AND RESEARCH, OFFICE OF
PODIATRIC MEDICINE, BOARD OF
POLLUTION CONTROL FINANCING AUTHORITY, CALIFORNIA
PRISON TERMS, BOARD OF
PRIVATE POSTSECONDARY AND VOCATIONAL EDUCATION, BUREAU FOR
PROCUREMENT, OFFICE OF
PROFESSIONAL ENGINEERS AND LAND SURVEYORS, BOARD FOR
PSYCHOLOGY, BOARD OF
PUBLIC EMPLOYEES' RETIREMENT SYSTEM
PUBLIC EMPLOYMENT RELATIONS BOARD
PUBLIC UTILITIES COMMISSION, STATE OF CALIFORNIA
REAL ESTATE, DEPARTMENT OF
REAL ESTATE APPRAISERS, OFFICE OF
RECLAMATION BOARD
REHABILITATION, DEPARTMENT OF
RESOURCES AGENCY
RESPIRATORY CARE BOARD
SAN FRANCISCO BAY CONSERVATION AND DEVELOPMENT COMMISSION
SAN GABRIEL AND LOWER LOS ANGELES RIVERS AND MOUNTAINS CONSERVANCY
SAN JOAQUIN RIVER CONSERVANCY
SANTA MONICA MOUNTAINS CONSERVANCY
SAVINGS AND LOAN, DEPARTMENT OF
SCHOLARSHARE INVESTMENT BOARD
SECRETARY OF STATE
SECURITY AND INVESTIGATIVE SERVICES, BUREAU OF
SEISMIC SAFETY COMMISSION, CALIFORNIA
SHORTHAND REPORTERS, BOARD OF CERTIFIED
SMALL AND MINORITY BUSINESS, OFFICE OF
SMALL BUSINESS, CALIFORNIA OFFICE OF
SMALL BUSINESS CERTIFICATION AND RESOURCES, OFFICE OF
SOCIAL SERVICES, DEPARTMENT OF
SPEECH-LANGUAGE PATHOLOGY AND AUDIOLOGY BOARD
SPILL PREVENTION AND RESPONSE, OFFICE OF
STRUCTURAL PEST CONTROL BOARD
STUDENT AID COMMISSION, CALIFORNIA
TAHOE CONSERVANCY, CALIFORNIA
TAX CREDIT ALLOCATION COMMITTEE, CALIFORNIA
TAX EDUCATION COUNCIL, CALIFORNIA
TEACHER CREDENTIALING, COMMISSION ON
TEACHERS' RETIREMENT SYSTEM, STATE
TECHNOLOGY, TRADE AND COMMERCE AGENCY, CALIFORNIA
TOXIC SUBSTANCES CONTROL, DEPARTMENT OF
TRANSPORTATION, DEPARTMENT OF
TRANSPORTATION COMMISSION, CALIFORNIA
TREASURER, STATE
UNEMPLOYMENT INSURANCE APPEALS BOARD, CALIFORNIA
UNIVERSITY, BOARD OF TRUSTEES OF THE CALIFORNIA STATE
VETERANS AFFAIRS, DEPARTMENT OF
VETERINARY MEDICAL BOARD
VICTIM'S COMPENSATION AND GOVERNMENT CLAIMS BOARD
VOCATIONAL NURSE AND PSYCHIATRIC TECHNICIANS, BOARD OF
WASTE MANAGEMENT BOARD, CALIFORNIA INTEGRATED
WATER RESOURCES, DEPARTMENT OF
WATER RESOURCES CONTROL BOARD, STATE
WORKERS' COMPENSATION, DIVISION OF
WORKERS' COMPENSATION APPEALS BOARD
YOUTH AND ADULT CORRECTIONAL AGENCY
YOUTH AUTHORITY, DEPARTMENT OF THE
YOUTHFUL OFFENDER PAROLE BOARD

Appendix G. California Universities Graduate Engineering Programs

Cal Poly Pomona

- Available majors information from Cal Poly Pomona Catalog 1999-2001, pages 492-493.
- Graduate Majors (M.S.):
    - Engineering
        - Minimum 45 quarter units required.
        - Emphasis areas available:
            - Aerospace Engineering
            - Chemical Engineering
            - Civil Engineering
            - Electrical Engineering
            - Engineering Management
            - Environmental Engineering
            - Industrial Engineering
            - Manufacturing Engineering
            - Materials Engineering
            - Mechanical Engineering
            - Structural Engineering
    - Electrical Engineering
        - Minimum 46 quarter units required.
        - Options available:
            - Communication and Microwave Engineering
            - Computer Systems Engineering
            - Control Systems and Robotics Engineering

Cal Poly San Luis Obispo

- Available majors information from 2001-2003 Cal Poly Catalog, pages 190, 197, 202, 210, 214, and 230.
- Minimum 45 quarter units required for each major.
- Graduate Majors (M.S.):
    - Engineering
        - Specializations available:
            - Biochemical Engineering
            - Bioengineering
            - Industrial Engineering
            - Integrated Technology Management
            - Materials Engineering
            - Water Engineering
    - Aerospace Engineering
    - Civil and Environmental Engineering
    - Computer Science
    - Electrical Engineering
    - Mechanical Engineering
- Joint Programs:
    - Engineering Management Specialization, MBA/M.S. Engineering
    - Transportation Planning Specialization, MCRP/M.S. Engineering

San Jose State

- Available majors information from 2000-2001 SJSU Online Catalog.
    - http://info.sjsu.edu/home/catalog.html
- Information also drawn from College of Engineering website.
    - http://www.engr.sjsu.edu/
- 30 semester units required for each major.
- Graduate Majors (M.S.):
    - Aerospace Engineering
    - Chemical Engineering
        - Areas of Specialization:
            - Biotechnology
            - Environmental Engineering
            - Semiconductors and Polymer Processing
    - Civil Engineering
        - Areas of Specialization:
            - Construction Management
            - Environmental
            - Geotechnical
            - Structural
            - Transportation
            - Water Resources
    - Computer Engineering
        - Areas of Specialization:
            - Computer Design
            - Software Engineering
            - Microcomputers and Embedded Systems
            - Computer Vision and Robotics
            - Computer Networks
            - Computer Applications
    - Electrical Engineering
    - Engineering (Interdisciplinary Program)
        - Areas of Concentration:
            - Client Server Computing
            - Electronic Materials & Devices
            - Engineering Management
            - Environmental Systems
            - Manufacturing Systems
            - Software Systems
            - Special Concentration
    - Industrial and Systems Engineering
    - Materials Engineering
        - Areas of Concentration:
            - Electronic Materials and Devices
            - Microelectronic Packaging
    - Mechanical Engineering
        - Areas of Specialization:
            - Mechanical Engineering Design
            - Thermal/Fluids Engineering Systems
            - Controls and Manufacturing Systems Engineering

- Quality Assurance (Department of Technology)

<u>Stanford</u>

- Available majors information from Stanford Bulletin 2001-2002, pages 103-106; also from Stanford University School of Engineering website (http://soe.stanford.edu).
    - The Master of Science (M.S.) degree requires 45 units of coursework and has no thesis requirement.
    - The Engineer's (Engr.) degree requires 45 units of coursework and research combined, as well as a thesis, requiring three quarters of work beyond the M.S..
    - The Doctor of Philosophy (Ph.D.) requires a minimum of 72 units of coursework and research combined, passage of an oral examination, and submission of a dissertation.
- Graduate Majors (M.S., Engr., Ph.D.):
    - Aeronautics and Astronautics
    - Chemical Engineering
    - Civil and Environmental Engineering
        - M.S. degree offered in special field designations.
            - Construction Engineering and Management
            - Design/Construction Integration
            - Environmental Engineering and Science
            - Environmental Fluid Mechanics and Hydrology
            - Geomechanics
            - Structural Engineering
    - Computer Science
    - Electrical Engineering
    - Engineering
        - M.S. in Engineering offered as a broad interdisciplinary program.
        - M.S. degree offered also in two specialized areas.
            - Biomechanical Engineering
            - Product Design
    - Engineering in Biology and Medicine
    - Management Science and Engineering
        - M.S. degree offered in two areas.
            - Management Science and Engineering
            - Manufacturing Systems Engineering
    - Materials Science and Engineering
    - Mechanical Engineering
    - Scientific Computing and Computational Mathematics
    - Space Science

<u>UC Berkeley</u>

- Available majors information from the *2001-2002 Announcement of the College of Engineering, University of California, Berkeley*
    - http://www.coe.berkeley.edu/Students/announce/
- Required units information unavailable.
- Graduate Majors (M.S., M.Eng., Ph.D., D.Eng.):
    - Bioengineering (Ph.D.)
        - Joint degree program with the University of California, San Francisco.
    - Civil and Environmental Engineering (M.S., M.Eng., Ph.D., D.Eng.)

        - Areas of specialization:
            - Construction Engineering and Management
            - Environmental Engineering
            - Geoengineering
            - Structural Engineering, Mechanics, and Materials
            - Transportation Engineering
    - Electrical Engineering and Computer Sciences (M.S., M.Eng., Ph.D., D.Eng.)
        - Electrical Engineering program areas:
            - Computer-Aided Design for VLSI
            - Communications
            - Control, Robotics, and Biosystems
            - Solid-State Devices
            - Integrated Circuits
            - Networks
            - Optoelectronics and Electromagnetics
            - Power and Electronics Systems
            - Signal Processing
        - Computer Science program areas:
            - Artificial Intelligence
            - Database Management Systems
            - Human-Computer Interaction
            - Scientific Computing
            - Graphics
            - Operating Systems
            - Programming Systems
            - Computer Architecture and Engineering
            - Theory
    - Industrial Engineering and Operations Research (M.S., Ph.D.)
    - Materials Science and Materials Engineering (M.S., M.Eng., Ph.D., D.Eng.)
        - Areas of emphasis:
            - Materials Science, Ceramics, and Physical Metallurgy
            - Mineral Processing/Process Metallurgy
            - Hydrogeology
    - Mechanical Engineering (M.S., Ph.D.)
        - Areas of concentration:
            - Dynamics and Controls
            - Fluid and Solid Mechanics
            - Materials and Design
            - Microelectromechanical Systems (MEMS)
            - Thermosciences
            - Manufacturing Processes
            - Computer Mechanics
            - Bioengineering
            - Environmental Engineering
    - Nuclear Engineering (M.S., M.Eng., Ph.D., D.Eng.)
        - Program areas:
            - Applied Nuclear Reactions and Instrumentation
            - Bionuclear and Radiological Physics

            - Chemistry and Materials in Nuclear Technology
            - Energy and the Environment
            - Fission Reactor Analysis
            - Fission Reactor Engineering
            - Fusion Reactor Analysis and Engineering
            - Radioactive Waste and Materials Management
            - Risk Analysis
- Interdisciplinary Programs:
    - Applied Science and Technology (Ph.D.)
        - Areas of emphasis:
            - Applied Physics
            - Engineering Science
            - Mathematical Sciences
    - Biophysics (Ph.D.)
    - Ocean Engineering (M.S., M.Eng., Ph.D., D.Eng.)
        - Areas of emphasis:
            - Naval Architecture
            - Offshore Engineering
            - Ocean Engineering

<u>UCLA</u>

- Available majors information from the UCLA General Catalog 2001-2003, pages 90, 94-95.
    - The M.S. requires a total of nine courses (beyond the B.S.) for completion of the degree.
    - Engr. degree signifies a level equivalent to the completion of preliminaries in the Ph.D. program; it does not require a dissertation. It requires a minimum of 15 courses beyond the bachelor's degree.
    - Graduate Certificate of Specialization available in all areas except for Computer Science; each program consists of five courses.
- Graduate Majors:
    - Aerospace Engineering (M.S., Engr., Ph.D.)
    - Biomedical Engineering (M.S., Ph.D.)
        - Fields of study:
            - Bioacoustics, Speech, and Hearing
            - Biocybernetics
            - Biomechanics, Biomaterials, and Tissue Engineering
            - Biomedical Instrumentation
            - Biomedical Signal and Image Processing
            - Molecular and Cellular Bioengineering
            - Neuroengineering
    - Chemical Engineering (M.S., Engr., Ph.D.)
    - Civil Engineering (M.S., Engr., Ph.D.)
        - Fields of study:
            - Environmental Engineering
            - Geotechnical Engineering
            - Structures (Structural Mechanics and Earthquake Engineering)
            - Water Resource Systems Engineering
    - Computer Science (M.S., M.S./M.B.A., Engr., Ph.D.)

        - Fields of study:
            - Artificial Intelligence
            - Computer Networks
            - Computer Science Theory
            - Computer System Architecture
            - Scientific Computing (Biomedical Systems, Physical Systems)
            - Software Systems
    - Electrical Engineering (M.S., Engr., Ph.D.)
        - Fields of study:
            - Applied Mathematics (established minor field only)
            - Communications and Telecommunications
            - Control Systems
            - Electromagnetics
            - Engineering Optimization/Operations Research
            - Integrated Circuits and Systems
            - Photonics and Optoelectronics
            - Plasma Electronics
            - Signal Processing
            - Solid-State Electronics
    - Engineering (M.Engr., Engr.)
    - Engineering and Applied Science (Graduate Certificate of Specialization)
    - Integrated Manufacturing Engineering (M.Engr.)
    - Manufacturing Engineering (M.S.)
    - Materials Science and Engineering (M.S., Ph.D.)
        - Fields of study:
            - Ceramics and Ceramic Processing
            - Electronic Materials
            - Structural Materials
    - Mechanical Engineering (M.S., Engr., Ph.D.)
        - Fields of study:
            - Applied Mathematics (established minor field only)
            - Applied Plasma Physics and Fusion Engineering (minor field only)
            - Dynamics
            - Fluid Mechanics
            - Heat and Mass Transfer
            - Manufacturing and Design
            - Microelectromechanical Systems (MEMS)
            - Structural and Solid Mechanics
            - Systems and Control

<u>USC</u>

- Available majors information from USC Catalog 2001-2002, pages 458-539.
    - The M.S. can be completed either with or without a thesis, and requires a minimum of 27 semester units.
    - The Engr. degree requires a minimum of 30 semester units of graduate coursework beyond the M.S.
    - The Ph.D. requires a minimum of 60 semester units of graduate coursework, passage of qualifying exams, and a doctoral dissertation.

- Graduate Majors:
    - Aerospace Engineering (M.S., Engr., Ph.D.)
    - Aerospace Engineering (Astronautics) (M.S.)
    - Applied Mechanics (M.S.)
    - Biomedical Engineering (M.S., Ph.D.)
    - Biomedical Engineering (Biomedical Imaging and Telemedicine) (M.S.)
    - Chemical Engineering (M.S., Engr., Ph.D.)
    - Civil Engineering (M.S., Engr., Ph.D.)
    - Computer-Aided Engineering (Master of Engineering)
    - Computer Engineering (M.S., Ph.D.)
    - Computer Science (M.S., Ph.D.)
        - M.S. specializations:
            - Software Engineering
            - Computer Networks
            - Multimedia and Creative Technologies
            - Robotics and Automation
            - Computational Linguistics
    - Construction Management (Master of Construction Management)
    - Electrical Engineering (M.S., Engr., Ph.D.)
        - M.S. options:
            - Computer Networks
            - Multimedia and Creative Technologies
            - VLSI Design
    - Engineering Management (M.S.)
    - Environmental Engineering (M.S., Ph.D.)
    - Industrial and Systems Engineering (M.S., M.S./M.B.A., Engr., Ph.D.)
    - Integrated Media Systems (M.S.)
    - Manufacturing Engineering (M.S.)
    - Materials Engineering (M.S.)
    - Materials Science (M.S., Engr., Ph.D.)
    - Mechanical Engineering (M.S., Engr., Ph.D.)
        - M.S. areas of concentration:
            - Combustion and Propulsion
            - Continuum Mechanics
            - Controls and Guidance
            - Design Methodology
            - Dynamics and Vibrations
            - Fluid Dynamics
            - Heat Transfer
            - Intelligent Design Systems
            - Stress Analysis and Materials
    - Operations Research Engineering (M.S.)
    - Petroleum Engineering (M.S., Engr., Ph.D.)
    - Systems Architecture and Engineering (M.S.)

Civil Engineering Exam Topics

			Civil Reference #
1. Environmental	A. Wastewater Treatment	1) Wastewater flow rates	1A1
		2) Primary clarification	1A2
		3) Biological treatment	1A3
		4) Secondary clarification	1A4
		5) Chemical precipitation	1A5
		6) Sludge systems	1A6
		7) Digesters	1A7
		8) Disinfection	1A8
		9) Nitrification/denitrification	1A9
		10) Effluent limits	1A10
		11) Wetlands	1A11
		12) Unit processes	1A12
		13) Operations	1A13
	B. Biology (including micro & aquatic)	1) Toxicity	1B1
		2) Algae	1B2
		3) Food chain	1B3
		4) Stream degradation	1B4
		5) Organic load	1B5
		6) Oxygenation/deoxygenation/oxygen sag curve	1B6
		7) Eutrophication	1B7
		8) Temperature	1B8
		9) Indicator organisms	1B9
		10) Disinfection	1B10
		11) Water taste & odor	1B11
		12) Most probable number (MPN)	1B12
		13) BOD	1B13
		14) Quality control	1B14
	C. Solid/Hazardous Waste	1) Collection	1C1
		2) Storage/transfer	1C2
		3) Treatment	1C3
		4) Disposal	1C4
		5) Quantity estimates	1C5
		6) Site & haul economics	1C6
		7) Energy recovery	1C7
		8) Hazardous waste systems	1C8
		9) Applicable standards	1C9
	D. Ground Water and Well Fields	1) Dewatering	1D1
		2) Well analysis	1D2
		3) Water quality analysis	1D3
		4) Subdrain systems	1D4
		5) Groundwater flow	1D5
		6) Groundwater contamination	1D6
		7) Recharge	1D7
		8) Aquifers (e.g., characterization)	1D8

[1] This appendix includes copies of the material for comparing the NCEES exam outlines for chemical, control systems, electrical & computer, fire protection, industrial, mechanical, manufacturing and nuclear engineering with civil engineering. The format of this same information was modified slightly so that the same procedure could also be followed in comparing electrical & computer engineering and mechanical engineering to the other disciplines.

			Civil Reference #
2. Geotechnical	A. Subsurface Exploration and Sampling	1) Drilling & sampling procedures	2A1
		2) In-situ testing	2A2
		3) Soil classification	2A3
		4) Boring log interpretation	2A4
		5) Soil profile development	2A5
	B. Engineering Properties of Soils	1) Index properties	2B1
		2) Phase relationships	2B2
		3) Shear strength properties	2B3
		4) Permeability	2B4
	C. Soil Mechanics Analysis	1) Effective & total stresses	2C1
		2) Pore pressure	2C2
		3) Pressure distribution	2C3
		4) Lateral earth pressure	2C4
		5) Consolidation	2C5
		6) Compaction	2C6
		7) Slope stability	2C7
		8) Seepage	2C8
		9) Erosion	2C9
	D. Shallow Foundations	1) Bearing capacity	2D1
		2) Settlement	2D2
		3) Allowable bearing pressure	2D3
		4) Proportioning individual/combined footings	2D4
		5) Mat & raft foundations	2D5
		6) Pavement design	2D6
	E. Deep Foundations	1) Axial capacity (single pile/drilled shaft)	2E1
		2) Lateral capacity (single pile/drilled shaft)	2E2
		3) Settlement	2E3
		4) Lateral deflection	2E4
		5) Behavior of pile/drilled shaft groups	2E5
		6) Pile dynamics	2E6
		7) Pile load tests	2E7
	F. Earth Retaining Structures	1) Gravity walls	2F1
		2) Cantilever walls	2F2
		3) Mechanically stabilized earth wall	2F3
		4) Braced & anchored excavations	2F4
		5) Earth dams	2F5
		6) Earth pressure diagrams	2F6
		7) Stability analysis	2F7
		8) Serviceability requirements	2F8
	G. Seismic Engineering	1) Earthquake fundamentals	2G1
		2) Liquefaction potential evaluation	2G2

			Civil Reference #
3. Structural	A. Loadings	1) Dead & live loads	3A1
		2) Moving loads	3A2
		3) Wind loads	3A3
		4) Earthquake loads	3A4
		5) Repeated loads	3A5
	B. Analysis	1) Determinate	3B1
		2) Indeterminate	3B2
		3) Shear diagrams	3B3
		4) Moment diagrams	3B4
	C. Mechanics of Materials	1) Flexure	3C1
		2) Shear	3C2
		3) Torsion	3C3
		4) Tension & compression	3C4
		5) Combined stresses	3C5
		6) Flexure, shear, tension & compression	3C6
		7) Deflection	3C7
	D. Materials	1) Reinforced concrete	3D1
		2) Pre-stressed concrete	3D2
		3) Structural steel	3D3
		4) Timber	3D4
		5) Concrete mix design	3D5
		6) Masonry	3D6
		7) Composite construction	3D7
	E. Member Design	1) Beams	3E1
		2) Slabs	3E2
		3) Columns	3E3
		4) Reinforced concrete footings	3E4
		5) Pile foundations	3E5
		6) Retaining walls	3E6
		7) Trusses	3E7
		8) Braces & connections	3E8
		9) Shear and bearing walls	3E9
	F. Failure Analysis	1) Buckling	3F1
		2) Fatigue	3F2
		3) Failure modes	3F3
	G. Design Criteria	1) UBC, BOCA, SBC, ACI, PCI, AISC, NDS, AASHTO, ASCE-7	3G1

			Civil Reference #
4. Transportation	A. Traffic Analysis	1) Traffic signal	4A1
		2) Speed studies	4A2
		3) Capacity analysis	4A3
		4) Intersection analysis	4A4
		5) Parking operations	4A5
		6) Traffic volume studies	4A6
		7) Mass transit studies	4A7
		8) Sight distance	4A8
		9) Traffic control devices	4A9
		10) Pedestrian facilities	4A10
		11) Bicycle facilities	4A11
		12) Driver behavior/performance	4A12
	B. Transportation Planning	1) Origin-destination studies	4B1
		2) Site impact analysis	4B2
		3) Capacity analysis	4B3
		4) Optimization/cost analysis	4B4
		5) Trip generation/distribution/assignment	4B5
	C. Construction	1) Excavation/embankment	4C1
		2) Material handling	4C2
		3) Optimization	4C3
		4) Scheduling	4C4
		5) Mass diagrams	4C5
		6) Pavement design	4C6
	D. Geometric Design	1) Horizontal curves	4D1
		2) Vertical curves	4D2
		3) Sight distance	4D3
		4) Superelevation	4D4
		5) Vertical/horizontal clearances	4D5
		6) Acceleration & deceleration	4D6
		7) Intersections/interchanges	4D7
	E. Traffic Safety	1) Accident analysis	4E1
		2) Roadside clearance analysis	4E2
		3) Counter-measurement development	4E3
		4) Economic analysis	4E4
		5) Conflict analysis	4E5

			Civil Reference #
5. Water Resources	A. Hydraulics	1) Spillway capacity	5A1
		2) Energy dissipation	5A2
		3) Energy/continuity equation	5A3
		4) Pressure conduit	5A4
		5) Open channel flow	5A5
		6) Detention/retention ponds	5A6
		7) Pump application and analysis	5A7
		8) Pipe network analysis	5A8
		9) Flow rates	5A9
		10) Stormwater collection	5A10
		11) Flow rates (domestic, irrigation, fire)	5A11
		12) Surface water profile	5A12
		13) Cavitation	5A13
		14) Friction/minor losses	5A14
		15) Sub- & supercritical flow	5A15
		16) Hydraulic jump	5A16
		17) Flow measurement devices	5A17
		18) Flow equations	5A18
		19) Culvert design	5A19
		20) Velocity control	5A20
	B. Hydrology	1) Storm characterization	5B1
		2) Storm frequency	5B2
		3) Hydrograph (unit & others)	5B3
		4) Transpiration	5B4
		5) Evaporation	5B5
		6) Permeation	5B6
		7) Rainfall intensity & duration	5B7
		8) Runoff analysis	5B8
		9) Gauging stations	5B9
		10) Flood plain/floodway	5B10
		11) Sedimentation	5B11
	C. Water Treatment	1) Demands	5C1
		2) Hydraulic loading	5C2
		3) Storages (raw & treated water)	5C3
		4) Rapid mixing	5C4
		5) Flocculation	5C5
		6) Sedimentation	5C6
		7) Filtration	5C7
		8) Disinfection	5C8
		9) Applicable standards	5C9

Chemical Engineering Exam Topics for Comparison with Civil Engineering Exam Topics

Topic		Item	Chemical Reference #	Equivalent Civil Reference #*
1. Mass and Energy Balances	A.	Process stoichiometry and material balances	1A	
	B.	Process energy balances	1B	
	C.	Conservation laws	1C	
2. Heat Transfer Industrial heat transfer including but not limited to the following:	A.	Heat exchanger design and performance	2A	
	B.	Energy conservation	2B	
	C.	Conduction, especially insulation problems	2C	
	D.	Convection	2D	
	E.	Radiation, especially furnace design	2E	
	F.	Evaporation	2F	
3. Fluids	A.	Piping network problems	3A	
	B.	Pump sizing or pump performance	3B	
	C.	Compressor sizing or compressor performance	3C	
	D.	Control valve selection problems	3D	
	E.	Fluid flow through beds	3E	
	F.	Two-phase flow	3F	
	G.	Bernoulli equation applications	3G	
4. Thermodynamics	A.	Estimation and correlation of physical properties	4A	
	B.	Chemical equilibrium	4B	
	C.	Heats of reaction	4C	
	D.	Application of first and second laws	4D	
	E.	Vapor-liquid equilibrium	4E	
	F.	Combustion	4F	
	G.	Refrigeration	4G	
5. Mass Transfer Typical applications including but not limited to the following:	A.	Gas absorption and stripping	5A	
	B.	Distillation	5B	
	C.	Liquid-liquid extraction and leaching	5C	
	D.	Humidification and dehumidification	5D	
	E.	Drying	5E	
6. Kinetics	A.	Interpretation of experimental data and reaction rate modeling	6A	
	B.	Commercial reactor design from rate model and/or product distribution	6B	
	C.	Comparison of reactor types	6C	
	D.	Reaction control	6D	
7. Plant Design Process and equipment design including but not limited to the following	A.	Optimization of design	7A	
	B.	General safety considerations	7B	
	C.	Environmental and waste treating	7C	
	D.	Solids separation	7D	
	E.	Vapor-liquid separations	7E	
	F.	Flow sheets	7F	
	G.	HAZOP (hazard and operational) analysis	7G	
	H.	Fault tree analysis	7H	
	I.	Scheduling techniques	7I	
	J.	Sizing and fabrication of equipment	7J	
	K.	Material selection	7K	
	L.	Life cycle cost	7L	
	M.	Process control such as sensors, transmitters and controllers, control loops, and simulation	7M	
	N.	Material science as concerned with physical and chemical properties of matter, strength of materials, crystallographic structure, phase diagrams, latent heat, PVT data and relationships, and molecular structure	7N	

* Leave blank if no equivalent

Control Systems Engineering Exam Topics for Comparison with Civil Engineering Exam Topics

		Control Systems Reference #	Equivalent Civil Reference #*
1. Sensors	A. Fundamentals of Measurement	1A	______
	B. Sensor Principles	1B	______
	C. Selection and Installation Practices	1C	______
2. Analog and Digital Data Transmission	A. Conductor Pairs	2A	______
	B. Coaxial Cable	2B	______
	C. Fiber Optics	2C	______
	D. Shielding and Grounding	2D	______
	E. Protocols	2E	______
3. Valves and Final Elements	A. Fluid Mechanics	3A	______
	B. Valve Characteristics	3B	______
	C. Selection	3C	______
	D. Sizing and Installation Practices	3D	______
	E. Relief Valves	3E	______
4. Process Dynamics	A. Mass and Energy Balances	4A	______
	B. Fluid Flow and Heat Transfer for Typical Processes	4B	______
	C. Transfer Functions	4C	______
	D. Responses to Standard Inputs	4D	______
	E. Process Identification by Plant Tests	4E	______
5. Control System Analysis	A. Block Diagrams	5A	______
	B. Stability	5B	______
	C. Accuracy and Response-Time Considerations	5C	______
6. Controllers/ Modes/Tuning	A. Controller and Mode Selection	6A	______
	B. Tuning Procedures	6B	______
7. Digital Control Systems	A. Hardware And Software Fundamentals	7A	______
8. Discrete Logic, Interlocks, Alarms and Sequencing	A. Logic Elements	8A	______
	B. Timers/Counters	8B	______
	C. Design Tools	8C	______
	D. Recommended Practices	8D	______
9. Codes and Standards	A. Wiring	9A	______
	B. Burner/Boiler/Pressure Vessel Safety	9B	______
10. Documentation	A. Standard Symbols for Process And Instrument Drawings	10A	______
	B. Logic Diagrams	10B	______
	C. Displays	10C	______
11. Economics of Control	A. Costs	11A	______
	B. Benefits	11B	______
	C. Payout Criteria	11C	______

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Electrical & Computer Engineering Exam Topics for Comparison with Civil Engineering Exam Topics

				Electrical & Computer Reference #	Equivalent Civil Reference #*
Breadth Module	1. Basic Electrical Engineering	A. Professionalism and Engineering Economics	1) Engineering Economics	1A1	
			2) Ethics	1A2	
			3) Professional Practice	1A3	
		B. Safety and Reliability	1) Reliability	1B1	
			2) Electric Shock and Burns	1B2	
			3) General Public Safety	1B3	
		C. Electric Circuits	1) Ohm's Law	1C1	
			2) Coulomb's Law	1C2	
			3) Faraday's Law	1C3	
			4) Kirchhoff's Laws	1C4	
			5) Thevenin's Theorem	1C5	
			6) Norton's Theorem	1C6	
			7) Superposition	1C7	
			8) Source Transformation	1C8	
			9) Sinusoidal Steady State Analysis	1C9	
			10) Power and Energy Calculations	1C10	
			11) Transient Analysis	1C11	
			12) Fourier Analysis	1C12	
			13) Transfer Functions	1C13	
			14) Complex Impedance	1C14	
			15) Laplace Transforms	1C15	
			16) Mutual Inductance	1C16	
		D. Electric and Magnetic Field Theory and Applications	1) Electrostatic Effects	1D1	
			2) Magnetostatic Fields	1D2	
		E. Digital Logic	1) Digital Logic	1E1	
	2. Electronics, Electronic Circuits and Components	A. Components	1) Solid State Device Characteristics and Ratings	2A1	
			2) Operational Amplifiers	2A2	
			3) Transistors	2A3	
			4) Signal Grounding	2A4	
			5) Transducers/Sensors	2A5	
		B. Electrical and Electronic Materials	1) Conductivity/Resistivity	2B1	
			2) Thermal Characteristics	2B2	
			3) Semiconductors	2B3	
	3. Controls and Communications Systems	A. Controls and Communications Systems	1) System Stability	3A1	
			2) Frequency Response	3A2	
			3) Analog Modulation	3A3	
			4) Frequency Selective Filters	3A4	
	4. Power	A. Transmission and Distribution	1) Voltage Regulation	4A1	
			2) Power Factor Correction	4A2	
			3) Grounding	4A3	
		B. Rotating Machines and Electromagnetic Devices	1) AC and DC Machines	4B1	
			2) Transformers	4B2	

* Leave blank if no equivalent

Electrical & Computer Engineering Exam Topics for Comparison with Civil Engineering Exam Topics (Continued)

					Electrical & Computer Reference #	Equivalent Civil Reference #*
Computers Depth Module	5. General Computer Systems	A. Interpretation of Codes and Standards	1) IEEE Standards		5A1	____________
			2) ISO Standards		5A2	____________
		B. Microprocessor Systems	1) Number Systems and Codes		5B1	____________
			2) Microprocessor Systems	a) Components	5B2a	____________
				b) Control Applications	5B3b	____________
				c) Math Applications	5B4c	____________
				d) Programmable Logic Controllers	5B5d	____________
				e) Real-time Operations	5B6e	____________
	6. Hardware	A. Digital Electronics	1) Memory Devices		6A1	____________
			2) Medium Scale Integration Devices		6A2	____________
			3) Programmable Logic Devices and Gate Arrays		6A3	____________
			4) Tristate Logic		6A4	____________
			5) Digital Electronic Devices		6A5	____________
			6) Logic Components	a) Properties	6A6a	____________
				b) Fan-In, Fan-Out	6A6b	____________
				c) Propagation Delay	6A6c	____________
			7) Large Scale Integration		6A7	____________
			8) Analog to Digital and Digital to Analog Conversion		6A8	____________
		B. Design and Analysis	1) Clock Generation/Distribution		6B1	____________
			2) Memory Interface		6B2	____________
			3) Processor Interfacing		6B3	____________
			4) Asynchronous Communication		6B4	____________
			5) Metastability		6B5	____________
			6) Races and Hazards		6B6	____________
			7) State Transition Tables		6B7	____________
			8) State Transition Diagrams		6B8	____________
			9) Algorithmic State Machine Charts		6B9	____________
			10) Timing Diagrams		6B10	____________
			11) Synchronous State Machines		6B11	____________
			12) Asynchronous State Machines		6B12	____________
			13) Pipelining and Parallel Processing		6B13	____________
			14) Fault Tolerance		6B14	____________
			15) Sampling Theory		6B15	____________
		C. Systems	1) Digital Signal Processor Architecture		6C1	____________
			2) Design for Testability		6C2	____________
			3) Computer Architecture		6C3	____________
			4) Mass Storage Devices		6C4	____________
			5) Input/Output Devices		6C5	____________
			6) Central Processing Unit Architecture		6C6	____________

* Leave blank if no equivalent

Electrical & Computer Engineering Exam Topics for Comparison with Civil Engineering Exam Topics (Continued)

					Electrical & Computer Reference #	Equivalent Civil Reference #*
Computers Depth Module (Continued)	7. Software	A. System Software	1) Computer Security		7A1	____________
			2) Real-Time Operating Systems		7A2	____________
			3) Error Detection and Control		7A3	____________
			4) Drivers		7A4	____________
			5) Time Critical Scheduling		7A5	____________
		B. Development/ Applications	1) Computer Control and Monitoring		7B1	____________
			2) Software Lifecycle	a) Requirements Definition	7B2a	____________
				b) Specification	7B2b	____________
				c) Design	7B2c	____________
				d) Implementation and Debugging	7B2d	____________
				e) Testing	7B2e	____________
				f) Maintenance and Upgrade	7B2f	____________
			3) Fault Tolerance		7B3	____________
			4) Modeling and Simulation		7B4	____________
			5) Software Pipelining		7B5	____________
			6) Human Interface Requirements		7B6	____________
			7) Software Design Methods and Documentation	a) Structured Programming	7B7a	____________
				b) Top Down or Bottom Up Programming	7B7b	____________
				c) Successive Refinement	7B7c	____________
				d) Programming Specifications	7B7d	____________
				e) Program Testing	7B7e	____________
				f) Structure Diagrams	7B7f	____________
				g) Recursion	7B7g	____________
			8) Object Oriented Design		7B8	____________
			9) Data Structures	a) Internal	7B9a	____________
				b) External	7B9b	____________
	8. Networks	A. Networks	1) Protocols	a) TCP/IP	8A1a	____________
				b) Ethernet	8A1b	____________
			2) Computer Networks	a) OSI Model	8A2a	____________
				b) Network Topology	8A2b	____________
				c) Network Technology	8A2c	____________
				d) Network Security	8A2d	____________

* Leave blank if no equivalent

Electrical & Computer Engineering Exam Topics for Comparison with Civil Engineering Exam Topics (Continued)

				Electrical & Computer Reference #	Equivalent Civil Reference #*
Electronics, Controls, and Communication Depth Module	9. General Electrical Engineering Knowledge	A. Measurement and Instrumentation	1) Transducer Characteristics	9A1	
			2) Frequency Response	9A2	
			3) Quantization	9A3	
			4) Data Evaluation	9A4	
			5) Sampling Theory	9A5	
		B. Interpretation of Codes and Standards	1) ANSI Standards	9B1	
			2) NEC (code)	9B2	
			3) IEEE Standards	9B3	
			4) FCC Standards	9B4	
			5) EIA Standards	9B5	
			6) ISA Standards	9B6	
			7) ISO Standards	9B7	
		C. Computer Systems	1) Programmable Logic Devices	9C1	
			2) Computer Networks	9C2	
			3) Number Systems and Codes	9C3	
			4) Digital Electronic Devices	9C4	
	10. Electronics	A. Electric Circuit Theory	1) Small Signal and Large Signal	10A1	
			2) Active Networks and Filters	10A2	
			3) Delay	10A3	
			4) Distributed Parameter Circuits	10A4	
			5) Nonlinear Circuits	10A5	
			6) Two Port Theory	10A6	
			7) Phase Delay	10A7	
		B. Electric and Magnetic Field Theory and Applications	1) Microwave Systems	10B1	
			2) Transmission Line Models	10B2	
			3) Electromagnetic Fields and Interference	10B3	
			4) Antennas	10B4	
			5) Free Space Propagation	10B5	
			6) Guided Wave Propagation	10B6	
		C. Electronic Components and Circuits	1) Programmable Logic Devices	10C1	
			2) Programmable Gate Arrays	10C2	
			3) Solid State Power Devices and Applications	10C3	
			4) Battery Characteristics and Ratings	10C4	
			5) Power Supplies	10C5	
			6) Phase Locked Loops	10C6	
			7) Oscillators	10C7	
			8) Amplifiers	10C8	
			9) Modulators and Demodulators	10C9	
			10) Discrete Components	10C10	
			11) Diodes	10C11	
			12) Circuit Protection	10C12	
			13) Relays and Switches	10C13	
			14) Logic Components a) Properties	10C14a	
			b) Fan In, Fan Out	10C14b	
			c) Propagation Delay	10C14c	
			15) Transistors and Applications	10C15	

* Leave blank if no equivalent

Electrical & Computer Engineering Exam Topics for Comparison with Civil Engineering Exam Topics (Continued)

				Electrical & Computer Reference #	Equivalent Civil Reference #*
Electronics, Controls, and Communications Depth Module (Continued)	11. Controls	A. Control System Fundamentals	1) Difference Equations	11A1	
			2) z – Transform	11A2	
			3) Frequency Response	11A3	
			4) Characteristic Equations	11A4	
			5) Block Diagrams	11A5	
			6) State Variable Analysis	11A6	
		B. Control System Design/ Implementation	1) Compensators	11B1	
			2) Feed Forward	11B2	
			3) Feedback	11B3	
			4) Optimal Control Systems	11B4	
			5) Adaptive Control	11B5	
			6) Computer Control and Monitoring	11B6	
			7) Error Actuated Control	11B7	
			8) Proportional-Integral-Derivative Control	11B8	
		C. Stability	1) Stability Analysis and Design — a) Nyquist Stability	11C1a	
			b) Root Locus	11C1b	
			c) Bode Diagrams	11C1c	
			2) Poles and Zeros	11C2	
			3) Phase and Gain Margin	11C3	
			4) Transport Delay	11C4	
	12. Communications	A. Communications and Signal Processing	1) Modulation Theory — a) Linear Modulation	12A1a	
			b) Angle Modulation	12A1b	
			c) Pulse Modulation	12A1c	
			2) Correlation and Convolution	12A2	
			3) Fourier Transformers	12A3	
			4) Spectral Properties	12A4	
			5) Signal Processing	12A5	
			6) Digital Transmission	12A6	
			7) Quadrature Amplitude Modulation	12A7	
			8) Personal Communication System	12A8	
			9) Spread Spectrum Modulation	12A9	
			10) Adaptive Filtering	12A10	
			11) Nyquist Sampling Theorem	12A11	
		B. Noise and Interface	1) Signal to Noise Ratio	12B1	
			2) Quantization Noise	12B2	
			3) Noise Figure and Temperature	12B3	
			4) Aliasing	12B4	
			5) Random Variables	12B5	
			6) Error Detection and Correction	12B6	
		C. Telecommunications	1) Wireless Communications	12C1	
			2) Compression	12C2	
			3) Cellular Communications	12C3	
			4) Optical Communications	12C4	
			5) Circuit and Packet Switching	12C5	
			6) Network Distribution Systems	12C6	
			7) Wireline Communications	12C7	

* Leave blank if no equivalent

				Electrical & Computer Reference #	Equivalent Civil Reference #*
Power Depth Module	13. General Power Engineering	A. Measurement, Instrumentation and Statistics	1) Power Metering	13A1	
			2) Instrument Transformers	13A2	
			3) Transducers	13A3	
			4) Frequency Response of Measurement Devices	13A4	
			5) Data Evaluation	13A5	
			6) Reliability	13A6	
		B. Special Applications	1) Illumination Design	13B1	
			2) Lightning and Surge Protection	13B2	
		C. Codes and Standards	1) ANSI Standards	13C1	
			2) NEC (code)	13C2	
			3) IEEE Standards	13C3	
			4) NEMA Standards	13C4	
			5) NESC (code)	13C5	
	14. Circuit Analysis	A. Analysis	1) Short Circuit Analysis	14A1	
			2) Wye-Delta Transformation	14A2	
			3) Three-Phase Circuit Analysis	14A3	
			4) Symmetrical Components	14A4	
			5) Balanced and Unbalanced Systems	14A5	
			6) Per Unit Analysis	14A6	
		B. Devices and Power Electronic Circuits	1) Solid State Power Device Characteristics and Ratings	14B1	
			2) Battery Characteristics and Ratings	14B2	
			3) Power Supplies	14B3	
			4) Relays and Switches	14B4	
			5) Power Electronics	14B5	
		C. Electric and Magnetic Fields and Applications	1) Transmission Line Models	14C1	
			2) Mechanical Forces Between Conductors	14C2	
			3) Electromagnetic Fields, Coupling, and Interference	14C3	
			4) Electrostatics	14C4	
			5) Ferroresonance	14C5	
	15. Rotating Machines and Electromagnetic Devices	A. Rotating Machines	1) Synchronous Machines	15A1	
			2) Induction Machines	15A2	
			3) DC Machines	15A3	
			4) Machine Constants and Nameplate Data	15A4	
			5) Equivalent Circuits	15A5	
			6) Response Times	15A6	
			7) Speed-Torque Characteristics	15A7	
			8) Speed Control	15A8	
			9) Motor Starting	15A9	
			10) Variable Speed Drives	15A10	
			11) Testing	15A11	
		B. Electro-magnetic Devices	1) Transformers	15B1	
			2) Reactors	15B2	
			3) Magnetic Circuit Theory	15B3	
			4) Testing	15B4	

* Leave blank if no equivalent

Electrical & Computer Engineering Exam Topics for Comparison with Civil Engineering Exam Topics (Continued)

				Electrical & Computer Reference #	Equivalent Civil Reference #*
Power Depth Module (Continued)	16. Transmission and Distribution	A. System Analysis	1) Voltage Drop and Voltage Regulation	16A1	____
			2) Power Factor Correction	16A2	____
			3) Parallel Three-Phase Systems	16A3	____
			4) Surge Protection	16A4	____
			5) Power Quality	16A5	____
			6) Fault Current Analysis	16A6	____
			7) Grounding	16A7	____
			8) Resistance Grounding	16A8	____
			9) Transformer Connections	16A9	____
			10) Models	16A10	____
		B. Power System Performance	1) Load Flow	16B1	____
			2) Models	16B2	____
			3) Power System Stability	16B3	____
			4) Voltage Profile	16B4	____
			5) Computer Control and Monitoring	16B5	____
		C. Protection	1) Overcurrent Protection	16C1	____
			2) Protective Relaying	16C2	____
			3) Protective Devices	16C3	____
			4) Coordination	16C4	____

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Fire Protection Engineering Exam Topics for Comparison with Civil Engineering Exam Topics

		Fire Protection Reference #	Equivalent Civil Reference #*
1. Planning and Design of Water Supplies	A. Water supplies dedicated to fire protection	1A	____________
	B. Public water supplies	1B	____________
2. Planning and Design of Building Systems	A. Structural fire resistance	2A	____________
	B. Fire barriers	2B	____________
	C. Opening protection	2C	____________
	D. Means of egress	2D	____________
	E. Construction materials	2E	____________
	F. Smoke management systems	2F	____________
	G. Building use and occupancy	2G	____________
3. Planning and Design of Water-Based Suppression Systems	A. Specifying, evaluating, testing, and maintaining sprinkler and waterspray systems	3A	____________
	B. Fire and explosion suppression systems	3B	____________
4. Planning and Design of Non Water-Based Suppression Systems	A. Specifying, evaluating, testing, and maintaining CO2, dry chemical, foam, and alternate agent systems	4A	____________
	B. Fire and explosion suppression systems	4B	____________
5. Planning and Design of Detection and Alarm Systems	A. Specifying, evaluating, testing and maintaining heat, smoke, and flame detectors	5A	____________
	B. Alarm and supervisory systems	5B	____________
6. Planning and Design of Fire Prevention	A. Control of combustible materials, ignition sources, and oxidizing agents	6A	____________
7. Implementation and Monitoring of Fire Prevention	A. Inspection, testing and preventive maintenance	7A	____________
	B. Process safety	7B	____________
	C. Hazard abatement	7C	____________
8. Research and Development of Hazard and Risk Analysis	A. Quantification of frequency and severity of fire events	8A	____________
	B. Estimation of time available for occupant egress from rooms	8B	____________
	C. Analysis of damage potential to exposed objects from fire or explosion	8C	____________

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Industrial Engineering Exam Topics for Comparison with Civil Engineering Exam Topics

			Industrial Reference #	Equivalent Civil Reference #*
1. Facilities	A.	Site selection	1A	
	B.	Plant layout	1B	
	C.	Equipment	1C	
	D.	Material handling and waste management systems	1D	
	E.	Packaging equipment	1E	
	F.	Capacity analysis	1F	
	G.	Power service and other utility requirements	1G	
2. Manufacturing	A.	Products	2A	
	B.	Manufacturing processes	2B	
	C.	Maintenance procedures	2C	
	D.	Operations sequencing	2D	
	E.	Machine grouping	2E	
	F.	Robotics	2F	
	G.	Automation	2G	
	H.	Value engineering	2H	
3. Production and Inventory Systems	A.	Forecasting	3A	
	B.	Production scheduling	3B	
	C.	Project scheduling	3C	
	D.	Production control	3D	
	E.	Resource planning	3E	
	F.	Logistics	3F	
	G.	Distribution	3G	
4. Work Systems and Ergonomics	A.	Measuring work	4A	
	B.	Methods analysis	4B	
	C.	Incentive and other payment plans	4C	
	D.	Workplace design	4D	
	E.	Human-machine interfacing	4E	
	F.	Industrial hygiene and safety	4F	
5. Quality Assurance	A.	Quality assurance plans	5A	
	B.	Reliability analysis	5B	
	C.	Control procedures	5C	
	D.	Capability analysis	5D	
	E.	Quality aspects of design	5E	
6. Management and Computer/ Information Systems	A.	Organization design	6A	
	B.	Staffing plans	6B	
	C.	Productivity	6C	
	D.	Human resources	6D	
	E.	Computer systems analysis and design	6E	
	F.	Specification of computer equipment	6F	
	G.	Computer communication protocols	6G	

* Leave blank if no equivalent

Mechanical Engineering Exam Topics for Comparison with Civil Engineering Exam Topics

		Mechanical Reference #	Equivalent Civil Reference #*
1. General Principles and Practices	A. Relevant Engineering Terminology	1A	
	B. Materials Properties	1B	
	C. Materials Selection	1C	
	D. Control Systems Components	1D	
	E. Fluid Mechanics	1E	
	F. Heat Transfer	1F	
	G. Mass Transfer	1G	
	H. Economic Analyses	1H	
	I. Project Management	1I	
	J. Ethics	1J	
	K. Regulations and Laws	1K	
	L. Industry and Company Design Standards	1L	
	M. Interpretation of Technical Drawings	1M	
	N. Electrical Principles	1N	
2. Machine Design and Materials	A. Strength of Materials	2A	
	B. Fatigue Theory	2B	
	C. Vibration Analysis	2C	
	D. Statics and Dynamics	2D	
	E. Bearings	2E	
	F. Gears	2F	
	G. Springs	2G	
	H. Shafts	2H	
	I. Fasteners	2I	
	J. Welding	2J	
	K. Kinematics	2K	
	L. Pressure Vessels	2L	
	M. Structural Analysis	2M	
	N. Mechanism Analysis	2N	
	O. Fits & Tolerances	2O	
	P. Manufacturing Processes	2P	
	Q. Quality Control	2Q	
3. Hydraulics and Fluids	A. Compressor Processes	3A	
	B. Compression Processes	3B	
	C. Compressible Flow	3C	
	D. Incompressible Flow	3D	
	E. Stress Analysis	3E	
	F. Hydraulic Pumps	3F	
	G. Hydraulic and Pneumatic Lines, Fittings, and Control Components	3G	

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Mechanical Engineering Exam Topics for Comparison with Civil Engineering Exam Topics (Continued)

		Mechanical Reference #	Equivalent Civil Reference #*
4. Energy Conversion/ Power Systems	A. Combustion Processes	4A	
	B. Thermodynamic Cycles	4B	
	C. Thermodynamic Properties	4C	
	D. Energy Balances	4D	
	E. Heat Exchangers	4E	
	F. Feedwater Heaters	4F	
	G. Cooling Towers	4G	
	H.Steam Generators	4H	
	I. Turbines	4I	
	J. Condensers	4J	
	K. Pumps/Compressors/Fans	4K	
	L. Power Systems	4L	
	M. Steam	4M	
	N. Gas	4N	
	O. Combined Cycles	4O	
	P. Internal Combustion	4P	
5. HVAC and Refrigeration	A. Psychrometrics	5A	
	B. Refrigerants	5B	
	C. Refrigeration Components	5C	
	D. Thermodynamics	5D	
	E. Vibration Control	5E	
	F. Acoustics	5F	
	G. Evaporators/Chillers	5G	
	H. Condensers	5H	
	I. Boilers & Furnaces	5I	
	J. Cooling Towers	5J	
	K. Cooling/heating Cycles	5K	
	L. Refrigeration Systems	5L	
	M. Air Quality Requirement	5M	
	N. Air Distribution Systems	5N	
	O. Water Distribution Systems	5O	
	P. Energy Recovery	5P	
	Q. Cooling/Heating Coils	5Q	
	R. Humidification/Dehumidification	5R	
6. Codes and Standards	A. ASTM, ANSI, ASME	6A	
	B. FM, NFPA, ASHRAE, BOCA, UBC, SBCC	6B	

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Manufacturing Engineering Exam Topics for Comparison with Civil Engineering Exam Topics

				Manufacturing Reference #	Equivalent Civil Reference #*
1. Product Process Design, Materials Application	A. Materials Engineering & Applications	1) Metals		1A1	
		2) Plastics		1A2	
		3) Fluids		1A3	
	B. Product/ Process Design	1) R&D, prototyping, testing		1B1	
		2) Concurrent engineering		1B2	
		3) Design for X	a) Manufacturing	1B3a	
			b) Assembly	1B3b	
			c) Maintenance	1B3c	
			d) System constraints	1B3d	
			e) Environment/recycling	1B3e	
		4) Engineering graphics/CAD		1B4	
		5) Engineering design analysis	a) Modeling of products	1B5a	
			b) Simulation of processes	1B5b	
			c) Finite element analysis	1B5c	
			d) Risk analysis	1B5d	
			e) Probability of success	1B5e	
			f) Independence of requirements	1B5f	
			g) Other aspects of engineering design analysis	1B5g	
		6) Cost engineering analysis	a) Make vs. buy	1B6a	
			b) Variable vs. fixed costs	1B6b	
			c) Capital budgeting/cost justification of production systems or equipment	1B6c	
			d) Value engineering	1B6d	
		7) Tolerance analysis/GD&T		1B7	
		8) Process design and development		1B8	
2. Manufacturing Processes	A. Material Removal			2A	
	B. Fabrication, Joining and Assembly	1) Fabrication processes		2B1	
		2) Joining and assembly processes		2B2	
	C. Forming	1) Casting and molding processes		2C1	
		2) Hot and cold forming processes		2C2	
		3) Powders processing		2C3	
	D. Finishing	1) Surface modification		2D1	
		2) Coatings		2D2	
		3) Surface performance (e.g., friction, corrosion, etc.)		2D3	

* Leave blank if no equivalent

Manufacturing Engineering Exam Topics for Comparison with Civil Engineering Exam Topics (Continued)

				Manu-facturing Reference #	Equivalent **Civil** Reference #*
3. Production Systems, Controls & Equipment Design	A. Production Systems & Control	1) Tool and equipment selection		3A1	____________
		2) Production system design		3A2	____________
		3) Safety, health and OSHA	a) Environmental impact	3A3a	____________
			b) Ergonomics	3A3b	____________
		4) Facility design/plant layout		3A4	____________
		5) Process planning		3A5	____________
		6) Capacity planning		3A6	____________
		7) Cost justification		3A7	____________
		8) CAM/CIM systems		3A8	____________
	B. Equipment Design	1) Machine design		3B1	____________
		2) Jig and fixture design		3B2	____________
		3) Tool design		3B3	____________
4. Quality		1) Probability and statistics	a) Frequency analysis	41a	____________
			b) Reliability	41b	____________
			c) Analysis of variance	41c	____________
		2) Statistical control methods (sampling/charting/etc.)		42	____________
		3) Process and equipment capability analysis		43	____________
		4) Inspection and testing		44	____________
		5) Systems analysis and problem solving		45	____________
5. Manufacturing Management		1) Project management		51	____________
		2) Business/engineering ethics		52	____________
		3) Production planning and inventory control	a) Line balancing	53a	____________
			b) Quantitative methods	53b	____________
			c) Theory of constraints	53c	____________
			d) Queuing theory	53d	____________
			e) Learning curves	53e	____________

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Nuclear Engineering Exam Topics for Comparison with Civil Engineering Exam Topics

			Nuclear Reference #	Equivalent Civil Reference #*
1. Nuclear Power Systems	A.	NSSS	1A	
	B.	BOP (e.g. Heat exchangers)	1B	
	C.	Thermal hydraulics applications	1C	
	D.	PRA	1D	
	E.	Energy generation	1E	
2. Nuclear Fuel and Waste Management	A.	Material balance	2A	
	B.	Fuel composition design	2B	
	C.	Economic analysis	2C	
	D.	Depletion and burn up	2D	
	E.	Radioactive materials handling	2E	
	F.	Radioactive material storage (including spent fuel)	2F	
	G.	Radioactive material transportation	2G	
	H.	High and low level waste disposal	2H	
	I.	High and low level waste treatment	2I	
3. Nuclear Radiation Protection/Radiation Shielding	A.	Radioactive material control and monitoring	3A	
	B.	Dose assessment	3B	
	C.	Environmental surveillance	3C	
	D.	Regulatory compliance	3D	
	E.	Decontamination	3E	
4. Nuclear Criticality/ Kinetics/Neutronics	A.	Analysis of critical and subcritical systems	4A	
	B.	Single and multi group calculations	4B	
	C.	Point kinetics	4C	
	D.	Bare and reflected systems	4D	
	E.	Effects of strong absorbers	4E	
	F.	Reactivity calculations	4F	
5. Nuclear Measurements and Instruments	A.	Radiation detection	5A	
	B.	Sensors	5B	
	C.	Instrumentation and control	5C	
	D.	Counting statistics	5D	
	E.	Electronics of instruments	5E	

* Leave blank if no equivalent.

As background, I have been a registered professional chemical engineer in California since 1980. I now live and primarily practice engineering in Arizona, where I have been registered since 1991, and have operated a small consulting firm since 1995. I also have been registered to practice in New Mexico since 2001. The Arizona and New Mexico registrations were obtained through reciprocity/comity based on the California registration. I earned my BS degree (1973) in chemical engineering from the University of California at Davis, and my MS degree (1975) in chemical engineering from U. C. Berkeley.

I have recently experienced a direct loss in consulting engineering income as a result of California's Title Act. I am a team member of a design group working on a new science building for a San Jose area high school. The specific design area I was contracted to perform was for potable water distribution and wastewater drains from new science labs, and piping of low pressure natural gas to lab stations. These systems were designed per applicable Code requirements. I contacted the California Board for Professional Engineers and Land Surveyors after reviewing their web site for specific requirements for use of engineering seals in California. I was told that the City reviewers would reject plans submitted sealed by a chemical engineer, but the seal of a mechanical engineer would be needed....

Arizona also registers engineers by discipline (branch), but broadly defines the typical work performed by different disciplines. The standard applied is as a professional, one is expected to operate within their area of competence. For example, a civil engineer specializing in bridges may want to get help before working on wastewater treatment facilities. Arizona recognizes a number of engineering branches, including agricultural, chemical, civil, control systems, electrical, environmental, fire protection, geological, industrial, mechanical, metallurgical, mining, nuclear, petroleum, sanitary, and structural. The definitions (as provided in Arizona Administrative Code Title 4, Chapter 30, Rules of the Arizona State Board of Technical Registration, R4-30-221. Engineering Branches Recognized) are broad in nature, with considerable overlap potential between branches. The regulations also explicitly state "the branches do not limit the areas of a registrants practice of engineering". There are a number of specific instances cited in Arizona to protect the public such as requiring that a licensed electrical engineer seal drawings and specifications where voltage or amperage limits exceed specified values (R4-30-302). Public safety is protected by these specific exclusions.

As a registered chemical engineer in Arizona I have designed and sealed plans for industrial ventilation from microelectronics facilities (Motorola, Intel); managed design and installation of: chemical fume scrubbers (Chem Research Co); particulate scrubbers (TRW); hot (1200F) compressed air (300 psig) distribution systems (Honeywell); industrial wastewater treatment from metal finishing operations (CRC); wastewater effluent from semiconductor processing facilities (Motorola, ATMI, Intel). I have also sealed drawings for potable water distribution in commercial buildings (retail and restaurants), and natural gas supply lines in a restaurant. My qualifications and competency to successfully and safely perform these services has never been questioned; all projects have been successfully completed....

I carry errors and omissions (E&O) insurance for my engineering practice. It is not priced based on state of registration, or even where the majority of the work is performed. If the insurers do not feel it necessary to charge different premiums for coverage in different geographic locations (as is the case for automobile insurance), it seems very reasonable to conclude the public is protected at comparable loss rates in all US jurisdictions. The part that seems very unreasonable to me is the arbitrary narrow discipline definitions in California's current laws unnecessarily restrict my ability to provide competent services there. The only rationale for continuing the current rules is to cater to the special interests of the three practice act disciplines. This does not promote public safety, and quite likely leads to higher consumer prices because it restricts reasonable competition.