Enhancing the Future Pool of Civil Engineers

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Recent demographic trends and employment facts indicate that the traditional major source for the supply of civil engineers will decline. In the civil engineering profession, ethnic minorities and women are significantly underrepresented. Additionally, although overall college enrollments held steady during the 1980s, the number of students graduating from high school has declined from its peak in the mid-1970s. To confound the situation, it is a national expectation that the fastest-growing sectors of the work force will be the areas requiring the highest skill levels. It is anticipated that the civil engineering profession will find itself competing for high-quality, competent individuals who will simultaneously be considering the appeal of other careers. To meet the changing needs of the civil engineering work force, an NCHRP study was undertaken in which a conceptual model (herein referred to as "ARC") was developed. The ARC model contains three comprehensive and interrelated strategies: (a) to heighten the awareness of the civil engineering profession, (b) to improve the retention rate of the existing pool of potential civil engineering candidates, and (c) to enhance the curriculum of pre-college and college programs. The findings of the initial research to identify existing programs and practices to promote the civil engineering profession and the results of 17 diverse focus group sessions are also presented.

The concept of supply and demand applies to human resources as well as to traditional consumer goods. ASCE reports that the supply of civil engineers graduating with bachelor's degrees each year decreased from 10,547 in 1981 to 7,688 in 1989 (*1*). At the same time, the demand for civil engineering professionals is seen to be on the rise. Several of the predicted growth rates for engineering and civil engineering are as follows:

- The Hudson Institute predicts a rate of growth of 41 percent between the years 1985 and 2000 for engineering, architecture, and surveying (*2*).
- TRB estimates that future demand for civil engineers will increase at an annual rate of 5 percent, with 60 percent of the increase exclusively a result of growth and the remaining 40 percent a result of death and retirement (*3*).
- The Bureau of Labor Statistics (BLS) projects that the employment of civil engineers will increase 17.9 percent between 1988 and the year 2000 (*4*).

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If the supply of civil engineers continues to decrease, the required demand will need to be met in an even more highly competitive market.

Some argue that the shortage issue is really one of providing adequate and commensurate compensation. Success to overcome the financial arguments requires long-term, continuous efforts. The broad-based employment of civil engineers (private versus public sector), however, does not lend itself to very timely or convenient solutions. Nonetheless, near-term strategies for recruitment and retention must consider the emerging demographic changes in the future work force, which will severely curtail the size of the traditional pool of entering students. Additionally, students currently enrolling in civil engineering score lower on SAT/ACT examinations than students pursuing other engineering fields, which introduces a student quality dimension into the shortage situation (*5*).

Immigration currently adds approximately 750 to 800 civil engineers to the pool annually (*3*). This population influx is relatively stable but is always subject to modifications in U.S. immigration policy. The largest supply to this pool, approximately 90 percent, is from the university system. Currently, regarding the outflow, approximately 20 percent of graduate civil engineers elect to pursue a career path other than civil engineering (*5*).

The makeup of the U.S. work force is changing with respect to an aging population, low birth rate, population shifts, and increased educational and per-capita income levels (*6*). The ramification of all these changes is that the size of the traditional college-age population (18- to 24-year-olds) will decrease approximately 25 percent from current levels by the year 1996. This drop is predicted to reduce college enrollments by 12 to 16 percent (*7*). Additionally, approximately 75 percent of the undergraduate degrees conferred annually are obtained by white males. However, data indicate that this group, although currently the clear majority, may be a minority in the 21st century (*8*).

Table 1 presents a comparison of the number of civil engineering degrees conferred for 1980 and 1989 in total for women and for ethnic minority groups (*1*). The percentage of women conferred civil engineering degrees has increased during this period from 9 percent of all civil engineering degrees to 14 percent. The percentage of African-Americans has remained constant, and those for Hispanic-Americans and Asian-Americans have shown modest increases. However, women and minorities remain underrepresented relative to their numbers in the population.

Although the need for civil engineers will continue in the future, the reduced levels of college-age individuals in the

TABLE 1 Summary of Civil Engineering Degrees Conferred—1980 and 1989 (*1*)

Group	1980	1989	Percent Change
All	10,346	7,688	-25.7
Women	931	1,036	11.3
African-Americans	158	170	7.6
Hispanic-Americans	257	274	6.6
Asian-Americans	290	353	21.7
Native-Americans	9	28	211.0
Foreign	1,309	864	-34.0

population combined with the changes in the demographic makeup of this group will make it difficult to maintain an adequate number of quality civil engineers to satisfy reported demands. Efforts to encourage more students, particularly women and minorities, to pursue civil engineering as a profession may be categorized as either supply side or demand side. The supply side involves increasing the number of students interested in civil engineering and prepared to enter the profession. The demand side involves the improvement of the "product," in which the product includes both enhancing engineering employment conditions and a responsive engineering curricula.

This paper is based on the findings of the initial efforts of NCHRP Project 20-24(3), entitled "Expanding the Civil Engineering Pool."

NCHRP STUDY

Project Objective

The overall scope of the NCHRP study includes the identification, development, and testing of specific actions that will increase the quality and diversity of civil engineers available to the transportation profession. Particular attention and emphasis have been placed on the implications of changing demographics on the future work force.

Research Approach

The research approach comprises three phases; a brief description of the primary research activities follows.

Survey of Practices and Programs To Increase Pool of Civil Engineers

Many professional associations and resource organizations were contacted for relevant information and sample documents and programs. Letters of request for samples and descriptions of pertinent materials were sent to 224 civil engineering departments and 114 civil engineering technology departments on record with the ASCE and 50 state highway agencies/departments of transportation (DOTs) in the United States. The final survey response is shown in Table 2. The findings are summarized in the following sections of this paper; specific details are documented in the NCHRP project reports.

Market Research Study

The principal means of field data collection in this study was a market research study designed to determine how people make career choice decisions and what underlying attitudes and perceptions they have about civil engineering and other professions. A method of qualitative research known as the "depth group" or "focus group" was used. The study was conducted by the Brand Consulting Group, Southfield, Michigan, coordinated by the Pennsylvania State University study team and with the assistance of the study consultants located at the field data collection sites.

Seventeen focus group sessions were conducted in five locations (Table 3). Selected groups consisted entirely of African-American or Hispanic-American subjects, whereas the balance were ethnically mixed (although predominantly Caucasian). All groups contained a mix of male and female participants. All sessions were viewed by at least one study team principal, and all were recorded on both audio- and videotape.

Documentation of Phase I and Phase II Efforts

A comprehensive research report was prepared that contained the detailed findings of the Phase I and Phase II efforts. The report fully documents the results and products of the overall project. The research report is divided into two parts: Part 1 summarizes the overall research activities, and Part 2 presents a synthesis of current practices to increase specific labor supplies and contains seven detailed appendixes related to state

TABLE 2 Summary of Survey Response

	Number of Departments/Agencies Contacted	Number of Departments/Agencies Responding
Civil Engineering Departments	224	83
Civil Engineering Technology Departments	114	30
State Transportation/ Highway Agencies	50	44
Resource Organizations	9	5
Professional Associations	16	10

TABLE 3 Focus Group Design

	State College, PA	Pittsburgh, PA	Lafayette, IN	Austin, TX	Los Angeles, CA
Junior High School Students			▓▓	▓▓	
High School Students		▓▓*		▓▓	▓▓
Parents			▓▓	▓▓**	▓▓*
Junior High School/High School Teachers	▓▓				
Junior High School/High School Counselors					▓▓
College Students	▓▓		▓▓*	▓▓	▓▓**
College Faculty			▓▓		▓▓
Civil Engineers		▓▓			

*AA--African-American

**HA--Hispanic-American

agency, academic institution, and professional practices to increase interest in civil engineering and closely aligned technical areas. A full copy of the market research study and recommended action plans are also provided in a set of appendixes.

A second executive summary style report cites the activities of the overall project, concisely presents the results of the Phase I and Phase II efforts, discusses the strategies for enhancing the civil engineering pipeline, and presents a list of recommended action plans to be considered for further development and eventual implementation.

Phase III Activities

Phase III of this research is under way as of this writing. The goal of the overall project is to produce a user's manual of selected techniques to be used by transportation agencies, educational institutions, national organizations, and others interested in increasing the pool of civil engineers. Phase III includes the development, testing, and refinement of selected action plans identified at the conclusion of the Phase II efforts. A specific set of recommended, highly selective strategies has been assembled on the basis of the recorded findings of Phase I, the results of the Phase II evaluation procedures described above, and the articulation of the concerns, issues, and suggestions of the project team, consultants, and the NCHRP panel.

CHANGING DEMOGRAPHICS

General Trends

The predicted changes in the composition of the work force into the next century are documented in several research studies and papers. In 1987 the Hudson Institute published *Workforce 2000* (*2*). This study examined the changes occurring in the economy and the work force and projected the jobs that this work force will perform between the years 1985 and 2000. Five demographic trends were reported by the study:

1. The population and work force will grow more slowly than at any time since the 1930s.
2. The average age of the population and work force will rise, and the pool of young workers entering the labor market will shrink.
3. More women will enter the work force. The report predicts that approximately two-thirds of the new entrants into the labor force between the years 1985 and 2000 will be women.
4. Minorities will represent a larger share of new entrants into the labor force. The report predicts that nonwhites will make up 29 percent of the new entrants into the labor force between the years 1985 and 2000. This percentage is twice the current minority share of the work force.
5. Immigration will account for the largest share of the increase in the population and the work force since World War I. The report predicts that the majority of the new workers entering the labor pool from immigration will be located in the South and West.

The combined effect of these demographic trends is an expected shift in the makeup of the work force between the years 1985 and 2000. Women, nonwhites, and immigrants are expected to contribute 85 percent of the net additions to the work force. Currently, these groups constitute approximately one-half of the work force.

The Office of Technology Assessment has reported on two additional demographic trends and their impact on the scientific and engineering work force (*7*). These demographic trends are (a) the decline in the number of 18- to 24-year-olds (the traditional college-age population) from a peak of

30 million in 1982 to approximately 24 million in 1995, after which this number is expected to rise; and (b) the increased representation of ethnic minorities in the 18- to 24-year-old group, from 20 percent to 27 percent in 1998.

The Hudson Institute study predicts not only a change in the supply of new entrants to the work force but also a change in the demand for skills. Specifically, the new jobs to be created will demand far greater skill levels. More than one-half of new jobs will require education beyond high school, and approximately one-third of these new jobs will be filled by college graduates. Furthermore, the Hudson Institute reports that if occupations are rated and categorized according to skill level (comprising mathematics, language, and reasoning skills), 27 percent of the current (1985) jobs are within the three highest categories. However, the study predicts that 41 percent of the new jobs created by the year 2000 will require a skill level within these three highest skill categories. [Engineering had a skill rating of 5.1. Only the natural sciences (skill rating, 5.7) and law (skill rating, 5.2) were rated higher.]

Effects of Changing Demographics on Engineering and Civil Engineering

Historically, white males have been the principal recipient of the engineering degrees awarded, representing 90 percent of all practicing engineers (*9*). Currently, excluding degrees awarded to foreign nationals, white males obtain 70 to 75 percent of the degrees awarded annually (*10,11*). Women, African-Americans, and Hispanic-Americans are underrepresented groups; that is, their representation in the engineering profession is less than their representation in the general population. Women constitute 47 percent of the population; however, the proportion of undergraduate degrees in engineering awarded to women grew from 1 to only 15 percent during the years between 1970 and 1985 (*10*). This percentage has remained relatively constant over the past several years and is well below the representation of women in the working population. Women earned 15.3 percent of the B.S. engineering degrees awarded in 1989 (*12*).

Over the past 10 to 15 years, third-year (junior-year) civil engineering enrollments have been characterized by the following:

- Enrollments peaking between 1977 and 1981;
- A long downward trend until 1989, when enrollments were 27 percent lower than their peak years;
- White males composing about 70 percent of civil engineering enrollments;
- Female enrollments peaking in the beginning of the 1980s, similar to the general trend, with women currently representing 16.6 percent of total enrollments;
- Ethnic groups representing a very small percentage of undergraduate enrollments;
- Hispanic-Americans representing the highest enrollment among ethnic groups, with increasing representation;
- African-American enrollments peaking in the beginning of the 1980s and then starting to decline;
- Increasing Asian-American enrollment; and
- Already very small and still decreasing Native-American enrollment.

Regarding retention characteristics, the following can be stated:

- In general, retention rates are promising at the junior undergraduate level.
- 94 percent of junior-year civil engineering students graduate.
- 85 percent of female junior-year civil engineering students graduate.
- Retention rates among the ethnic minority civil engineering students are lower and stand at about 65 percent.

The general belief that foreign nationals are accounting for an ever-increasing share of civil engineering students is not completely true. The research found that

- Foreign national representation is very high at graduate levels only. At the undergraduate level, representation has dropped to below 10 percent.
- In 1988 foreign nationals constituted 43 percent of all master's-level enrollments in civil engineering and 65.7 percent of all doctorate enrollments.
- Retention rates among foreign nationals are high.

Studies by the Hudson Institute, the U.S. Office of Technology Assessment, and the Western Interstate Commission for Higher Education indicate the following by the end of the century:

- The number of high school graduates will continue to decline until about 1995 and then begin to rise.
- The western and south/south-central regions of the country will experience an increase in the number of high school graduates, whereas the northeastern and north-central regions will experience a decrease.
- Women and ethnic minority groups, who have a history of underrepresentation in the engineering profession, are expected to represent 62 percent of the net additions to the work force.
- White males, who have traditionally filled the civil engineering ranks, will represent only 15 percent of the net new workers entering the work force.
- The fastest growing sectors of the work force are those sectors requiring the highest skill level. These sectors include lawyers, natural scientists, and engineers.

A decrease in the number of civil engineering graduates is likely based on the preceding discussion. However, shortages are difficult to predict. Alexander (*13*) has examined previous impending shortages in civil engineering during the 1950s, 1960s, and 1970s. He determined that in each of the periods following the shortage prediction, the average salary for civil engineers decreased relative to the average worker, demonstrating an oversupply, not a shortage. For 1990 the College Placement Council's September *Salary Survey* reports that the average starting salary for civil engineering graduates, both males and females, was the lowest of all engineering specialties (*14*, p. 1). Another study analyzed the BLS predictions made for several engineering occupations in 1960 and 1965 for the years 1975 and 1980 (*15*). The analysis determined that the BLS overestimated, by 20 to 55 percent, the requirements for aeronautical, civil, and mechanical engineers.

In summary, current knowledge reveals that

- The fastest growing sectors of the work force are those sectors requiring the highest skill levels. These sectors include lawyers, natural scientists, and engineers.
- White males, who have traditionally filled the engineering and civil engineering ranks, will represent only 15 percent of the net new workers entering the work force through the year 2000.
- Women and ethnic minority groups, who have continued to be underrepresented in the engineering profession, are expected to represent 62 percent of the net additions to the work force between 1985 and 2000.
- Long-term engineering work force predictions are debatable.
- Occupational mobility has served to balance short-term labor shortages.

SUMMARY OF DATA GATHERING—PHASE I

The first phase of the project concentrated on collecting and documenting information on current practices, perceptions, and attitudes in the overall career choice decision-making process. Significant efforts were placed on identifying, synthesizing, and evaluating related literature, products, and programs related to civil engineering, engineering in general, and the mathematics and science disciplines.

Three specific activities were conducted in the Phase I research efforts:

1. Documentation of practices used by undergraduate civil engineering/engineering technology programs and state transportation agencies to increase interest in civil engineering and civil engineering–related careers.
2. Documentation of practices used by other professional disciplines to address their labor shortages.
3. Identification of the attitudes and expectations of various constituencies affecting civil engineering career choice decisions (via intensive "focus" group interviews).

A complete presentation of the documentation of selective and related practices and programs is beyond the scope of this paper. Particular attention and emphasis of the research were placed on the implications of the changing demographics in the U.S. work force throughout the data-gathering phase. Each inquiry attempted to identify specific considerations being given to underrepresented groups. A common assessment among the many sources was a fundamental need to heighten the awareness of the public to the attributes of the civil engineering profession. Efforts to better inform prospective students and their parents, teachers, and counselors are seen as having the broader benefit of educating the public regarding the role of the civil engineer in society.

Practices To Increase Interest in Civil Engineering

Federal and State Transportation Agencies

Several initiatives by federal and state transportation agencies were identified to increase interest in civil engineering with an emphasis on the participation of minorities and women. On-the-job training, minority engineering scholarships, and summer intern programs are representative of transportation agency programs. Several state transportation agencies reported the use of "adopt-a-school" programs to encourage employees to volunteer their services for mentoring, speaking, guidance, and judging at science fair activities. The Transportation and Civil Engineering (TRAC) careers center concept would strengthen the existing initiatives used by the various states (*16*). The TRAC program would provide quality information that could be readily implemented through the programs already identified. Such a national outreach program would permit the state agencies to use their time disseminating consistent, reliable, and effective materials rather than using their resources to produce new material.

The survey of civil engineering/engineering technology departments revealed that few schools are very active in recruiting students in civil engineering. The responses indicated that the college of engineering or the entire educational institution, or both, generally provides precollege career information and undergraduate information.

Professional and Industrial Organizations

ASCE In 1990 ASCE had a marketing plan prepared for career guidance. The marketing plan provides information about the development and implementation of an educational career guidance campaign. The plan includes specific strategies for attracting young people to civil engineering, with an emphasis on women and minority students. The recommended action plan for ASCE includes

- Development of programs at the branch and section levels of ASCE to promote science and mathematics at all grade levels;
- Promotion of interest in civil engineering by involving the ASCE membership in in-class presentations and demonstrations;
- Encouragement and education of high school science and mathematics teachers through involvement in science fairs and mathematics competitions and with information about the benefits and rewards of a civil engineering career;
- Provision of tours of construction sites and related civil engineering facilities;
- Continuation and expansion of advertising initiatives at the national level to increase the awareness of civil engineering;
- Coordination of ASCE activities with other efforts to promote and expand science and mathematics awareness;
- Increased participation and encouragement of underrepresented groups to pursue the civil engineering career; and
- Encouragement of undergraduate degrees holders to pursue graduate study and consider faculty careers.

ITE ITE also has been active in recruiting and retaining civil engineering students in the traffic and transportation engineering discipline. Its activities include fellowship programs, support of student chapter activities, committee activities, investigation of professional career opportunities in

transportation engineering, and preparation of informational materials in the form of printed material and videotape.

Career Choice Decisions

Another task in the data-gathering process was the conduct of focus group sessions to determine

- Attitudes and expectations of students, teachers, and guidance counselors;
- Degree of awareness of civil engineering as a discipline and career alternative; and
- Perception of what a civil engineer does.

A summary of the key findings of a selective literature review and the major results of the focus group sessions follow. The final NCHRP reports contain a complete copy of the Brand Consulting Group findings on the focus group sessions.

The focus group activities proved to be a highly effective means of data collection, in that they produced observations that are very difficult to capture through questionnaires or other quantitative methods. The information provided in this report is based on the results of 17 intensive group sessions.

Attitudes Toward Math and Science

- Teaches most directly affect subject preferences.
- Teachers' enthusiasm and qualifications motivate the student.
- Math classes, at all levels, pay very little attention to practical applications.
- Teachers would use materials featuring technical applications if they were prepackaged and integrated into the existing curriculum.
- Parents want their children to do well in all classes. Many parents do not feel qualified to help their children in math and science.
- Secondary school guidance counselors do not appear to greatly influence student attitudes toward math and science.

Attitudes Toward Career Planning

- Elementary school students are stimulated more by outside influences than by what specifically happens at school.
- Students and parents both indicate that junior high school is too early for specific career planning but definitely appropriate for career awareness.
- In high school there is increased recognition that career options must be seriously considered. Students and parents seek specific career information; students, however, respond with mixed enthusiasm regarding programs specifically oriented toward career awareness.
- Summer programs and other types of enrichment experiences (exposing target groups to technical careers), however, are received enthusiastically and are considered highly successful.
- There is little or no exposure to career-related material in the classroom.
- Teachers are interested in using career-related materials, but these materials can potentially overcrowd a curriculum, so using them effectively requires great motivation and dedication on the part of the teacher.
- Students who do well in math and science are attracted or directed toward careers in engineering.

Attitudes Toward Careers

- Students (and virtually everyone else) have very little information about specific careers. This is especially true of engineering and particularly true of civil engineering. The term "civil engineering" means almost nothing to those who are uninformed.
- Individuals relate better to career terms such as transportation engineering, structural engineering, construction, and environmental engineering.
- Individuals indicated that the civil engineering field would not be challenging because most techniques for building roads and bridges are well known. (Similar misconceptions were noted for other civil engineering specialty areas.)
- Professional licensing tended to confer distinction on the civil engineering field as a career choice.

Attitudes of Women and Minorities

- Women and minority reactions to the civil engineering profession were not markedly different from those of the other groups already identified.
- Minority students reported favorable reactions to math/science/engineering enrichment programs.
- College-bound minority students recognize the need for financial aid and are highly motivated to seek and qualify for such aid. The remuneration potential among engineering careers was of relatively greater concern to minority students, although this seems to be related more to economic status than to ethnicity.
- Parents appeared somewhat troubled by recruiting efforts directed toward their children; several cautioned against painting a false picture of the relative desirability of engineering or civil engineering careers.
- Students as role models were mentioned often, and with greater emphasis by the minority group members.
- College students were mentioned as good role models for communicating with secondary school students.
- Women and minority engineering students are concerned about the continuing "chilly climate" for women and minorities in the workplace.
- Many women and minority group members felt that they would have to start their own firms to get around a "glass ceiling" that blocks their advancement in larger organizations.
- Civil engineering was noted as a field in which entrepreneurship is highly possible, but few students are aware of this.

RECOMMENDED PLAN OF IMPLEMENTABLE ACTIONS—PHASE II

Phase I resulted in the identification of several fundamental obstacles facing the civil engineering profession in general and the future pipeline of entrants:

1. An image problem exists for the civil engineering profession.
2. Institutional barriers exist that contribute to the increasing attrition rates among high school and college students.
3. Changes are necessary in precollege and college curricula if enhancements are to be made in mitigating the previous two items.

ARC Model

To address these obstacles effectively, the research effort developed a conceptual framework consisting of three interrelated long-range market strategies:

1. Heighten the *awareness* of technology, engineering, and civil engineering.
2. Increase the *retention* of the existing pool of future civil engineers.
3. Modify the existing *curriculum* from kindergarten through college.

These key strategies serve as a focus such that future efforts will recognize the developmental stages of the pool of potential engineers. Table 4 gives the primary components of the recommended conceptual framework, which is referred to as the "ARC" (awareness, retention, curriculum) model. The target audiences for the candidate action plans include students and their adult influencers (teachers, counselors, parents, and practicing professionals).

The ARC model has the following characteristics:

- It is a continuum model that builds on previous experiences.
- The action plans, although not independent of each other, are implemented differently at each developmental stage.
- To achieve a long-term effectiveness, the model as a whole must be implemented.
- The action plans for the three strategies are broad at the early developmental stages and narrow to more specific actions as higher developmental stages are reached.
- Overlap and crossover benefits occur among the three strategies.

Recommended Action Plans

The ARC model argues that to successfully enhance the civil engineering pipeline, future marketing strategies must consider awareness, retention, and curriculum issues in the development of individual action plans. Specific objectives must likewise be defined at each developmental stage of the model for the pipeline constituents.

As one proceeds through the developmental stages, a selected objective becomes more narrowly defined (from global engineering to civil engineering to the specialties of civil engineering). Similarly, as one proceeds from the awareness strategy to the retention strategy to the curriculum strategy, the target audience also narrows.

Awareness strategies target both the potential pool and the influencers (parents, teachers, counselors, and practicing professionals). The retention strategies tend to be more personalized. Curriculum strategies intimately affect the students (and teachers).

Fifteen candidate action plans were developed to essentially address specific issues at each defined developmental stage. The goal of each recommended action plan is cited in Table 5. If the ARC model is fully implemented, the awareness, retention, and curriculum strategies applied at the precollege developmental stages should reduce the need for the college actions.

The NCHRP reports contain the detailed individual action plans recommended for further development in Phase III of this NCHRP project.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The research completed in this project leads to eight principal conclusions:

1. The poorly defined image of civil engineering is a serious impediment to recruiting new entrants to the profession.
2. Additional efforts to enhance the civil engineering pool are warranted.

TABLE 4 ARC Model

Market Strategies	DEVELOPMENTAL STAGES				
	Pre-College (grade level)			College (year of study)	
	K-6	7-8-9	10-11-12	1-2	3-4
AWARENESS	The Environment ⇒	The Engineer ⇒	The Civil Engineer	Introduction to Civil Engineering Disciplines ⇒	Summer/ Co-op Employment
RETENTION	Field Trips ⇒	Role Models ⇒	Peer Mentors	Clustering ⇒	Professional Mentors
CURRICULUM	Technology Applications ⇒	Mathematics and Science Emphasis		Introduction to Design ⇒	Project Design

TABLE 5 Goals of Candidate Action Plans

Market Strategies	Pre-College			University	
	Elementary (Grades K-6)	Junior High (Grades 7-8-9)	Senior High (Grades 10-11-12)	Engineering/Non-Engineering Students (Freshman/Sophomore)	Civil Engineering Students (Junior/Senior)
AWARENESS	**ARC-1** Discuss technology and global engineering.	**ARC-4** Present engineering as a career alternative with an introduction to civil engineering.	**ARC-7** Provide civil engineering career information.	**ARC-10** Provide engineering career information to: • Civil engineering students • Students in other majors • Students at other institutions	**ARC-13** Provide information regarding the disciplines within civil engineering.
RETENTION	**ARC-2** Build confidence in mathematics and science.	**ARC-5** Maintain confidence in mathematics and science.	**ARC-8** Promote and retain technical interest.	**ARC-11** Retain and graduate civil engineering students.	**ARC-14** Retain and graduate engineering students.
CURRICULUM	**ARC-3** Integrate early relevancy of mathematics and science.	**ARC-6** Encourage further pursuit of mathematics and science.	**ARC-9** Complete mathematics and science requirements.	**ARC-12** Integrate early exposure to engineering/civil engineering disciplines.	**ARC-15** Integrate design projects (collaborative learning) into the curriculum.

3. Enhancement efforts should go forward as a coordinated program with the themes of awareness, retention, and curriculum.
4. Enhancement efforts should address all of the educational development stages of the civil engineer, from preschool through college.
5. Enhancement efforts should target the adults who influence career choice decisions as well as students.
6. Enhancement efforts should effectively use existing programs.
7. Personal involvement of civil and transportation engineers is crucial to the success of efforts to enhance the civil engineering pool.
8. Additional market research is needed.

Recommendations

The basic recommendation resulting from the research is to adopt the ARC model and further develop and implement the candidate action plans. Table 6 shows the ARC matrix of candidate action plans and highlights those that are recommended for testing in Phase III of the research:

1. Develop and test a coordinated set of awareness actions, across all student developmental levels.
2. Develop and test a coordinated set of awareness, retention, and curriculum actions at the high school level.
3. Develop and test retention actions for civil engineering students.

TABLE 6 Actions Recommended for Phase III

Market Strategies	Pre-College			University	
	Elementary (Grades K-6)	Junior High (Grades 7-8-9)	Senior High (Grades 10-11-12)	Civil Engineering Students	Freshman/Sophomore Engineering Students
AWARENESS	Discuss technology and global engineering.	Present engineering as a career alternative with an introduction to civil engineering.	Provide civil engineering career information.	Provide civil engineering career information to: • Other engineering majors • Other institutions	Provide engineering career information to: • Other majors • Other institutions
RETENTION	Build confidence in mathematics and science.	Maintain confidence in mathematics and science.	Promote and retain technical interest.	Retain and graduate civil engineering students.	Retain and graduate engineering students.
CURRICULUM	Integrate early relevancy of mathematics and science.	Encourage further pursuit of mathematics and science.	Complete mathematics and science requirements.	Integrate early exposure to civil engineering disciplines.	Integrate early exposure to engineering disciplines.

4. Formulate a complete marketing strategy for civil engineering careers.
5. Disseminate the findings of this research to a broad audience of civil engineering, engineering, and education decision makers.
6. Encourage AASHTO to spearhead the recommended national implementation effort.

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