08:44:48 OCA PAD INITIATION - PROJECT HEADER INFORMATION 08/19/88

Active

Project #: D-48-615 Cost share #: Rev #: 0
Center # : R6539-2A0 Center shr #: OCA file #: 119
Work type : RES
Contract#: DACA88-88-D-0020-0005 Mod #: Document : DO
Prime #: Contract entity: GTRC

Subprojects ? : N
Main project #:

Project unit: ARCH COLL Unit code: 02.010.164
Project director(s):
AYNSLEY R M ARCH COLL

Sponsor/division names: ARMY / CON ENG RES LAB, IL
Sponsor/division codes: 102 / 020

Award period: 880801 to 881130 (performance) 881130 (reports)

Sponsor amount	New this change	Total to date
Contract value	13,882.64	13,882.64
Funded	13,882.64	13,882.64
Cost sharing amount		0.00

Does subcontracting plan apply ?: N

Title: TECHNOLOGY ADOPTION INDEX

PROJECT ADMINISTRATION DATA

OCA contact: William F. Brown 894-4820

Sponsor technical contact

RICHARD LAMPO
(217)373-6765
US ARMY CONSTRUCT. ENGR. RES. LAB.
NEWMARK DR., P.O. BOX 4005
CHAMPAIGN, IL 61820-1305

Sponsor issuing office

MS. V. IVERSON/CONTRACTS BRANCH
(217)373-6798
US ARMY CONSTRUCT. ENGR RES. LAB.
2902 NEWMARK DR., P.O. BOX 4005
CHAMPAIGN, IL 61820-1305

Security class (U,C,S,TS) : U
ONR resident rep. is ACO (Y/N): N
Defense priority rating : DO-C2
NA supplemental sheet
Equipment title vests with: Sponsor X GIT
NONE PROPOSED

Administrative comments -
INITIATION OF D-48-615. THIS IS A FIXED PRICE D.O. SUBJECT TO THE TERMS OF BOA DACA88-88-D-0020.

GEORGIA INSTITUTE OF TECHNOLOGY
OFFICE OF CONTRACT ADMINISTRATION

NOTICE OF PROJECT CLOSEOUT

Closeout Notice Date 03/30/90

Project No. D-48-615 Center No. R6539-2A0

Project Director AYNSLEY R M School/Lab ARCH COLL

Sponsor ARMY/CON ENG RES LAB, IL

Contract/Grant No. DACA88-88-D-0020-0005 Contract Entity GTRC

Prime Contract No.

Title TECHNOLOGY ADOPTION INDEX

Effective Completion Date 890901 (Performance) 890901 (Reports)

Closeout Actions Required:	Y/N	Date Submitted
Final Invoice or Copy of Final Invoice	Y	
Final Report of Inventions and/or Subcontracts	Y	
Government Property Inventory & Related Certificate	Y	
Classified Material Certificate	N	
Release and Assignment	Y	
Other	N	

Comments

Subproject Under Main Project No.

Continues Project No.

Distribution Required:

Project Director	Y
Administrative Network Representative	Y
GTRI Accounting/Grants and Contracts	Y
Procurement/Supply Services	Y
Research Property Managment	Y
Research Security Services	N
Reports Coordinator (OCA)	Y
GTRC	Y
Project File	Y
Other	N
	N

NOTE: Final Questionnaire sent to PDPI.

Summary Report

on

DEVELOPMENT OF A TECHNOLOGY ADOPTION INDEX (TAI) TO MEASURE THE EFFECTIVENESS OF ADOPTING NEW BUILDING TECHNOLOGY

Performed under Indefinite Delivery Contract
No. DACA88-88-D-0020

By Georgia Tech Research Corporation,
College of Architecture's
CONSTRUCTION RESEARCH CENTER

OCA Project #: D-48-615

Principal Investigator: Dr. Richard Aynsley

Date: September 1, 1988

CONTENTS

INTRODUCTION

Background

In the 1960's the United States began to take a serious interest in technology assessment due to unacceptable side effects of new technologies such as supersonic transport aircraft and long-lived pesticides. This concern led to the establishment of the U.S. Office of Technology Assessment. While the world was increasingly looking to new technologies for economic development, it was also apparent that the margin for error in adopting new technologies without incurring a large penalty was decreasing rapidly (Stambler,1982). The National Science Foundation began to focus on development of technology assessment methods (Green,1983) and international interest grew, leading to the International Symposium on the Role of Technology Assessment in the Decision- making process, held in Bonn, Germany in October 1982,(Gibbons,1983).

Traditional diversity and fragmentation within construction industries around the industrialized world have retarded the transfer of newly developed technology onto construction sites. Most industrialized countries have publicly funded studies of the problems of technology transfer within their building construction industries but none contacted have attempted the development of an index to quantify technology adoption.

Problem

USACE and other military services are being scrutinized regarding their adoption of newly developed technologies into standard practice. Criticism comes from Government regulators (i.e. legislators) as well as building industry's proponents of new technologies.

USACE currently has no means to determine their responsiveness to newly adopted technologies, either in absolute terms or compared to other similar owners and users of built facilities.

There is a need to determine where USACE could and ought to respond to changes and innovation in technologies and adopt technologies into standard practice; to develop "reasonable expectations" for responding to innovation.

Goals

To develop a METHOD whereby USACE can establish "reasonable expectations" for adopting newly established technologies. To develop a SYSTEM to regularly assess USACE status in adopting new technologies relative to the "reasonable expectations".

Objective

To develop a numerical index to indicate USACE status in adopting newly established technologies - relative to the construction industry in absolute terms, and relative to past USACE status.

This objective is seen as meeting the requirements of tasks 1 and 2 of the statement of work.

Purpose

To enable HQUSACE levels to make an informed response to inquiries, criticisms, or other issues relative to the adoption of newly established construction technologies.

To evaluate USACE progress in adopting newly established technologies, both compared to the general construction industry, and within USACE over time.

To enable USACE to identify areas where responsiveness to new technologies ought to be enhanced and technology adoption can be accelerated.

Statement Of Work

Objective: To formulate and advance conceptual ideas for a Technology Adoption Index (TAI), to a point where it can be demonstrated that a workable index is feasible.

Task 1: Formulate a variety of possibilities for an index through several "brain storming" sessions. A multi-departmental approach is suggested, e.g., business and psychology, besides engineering and architecture. Seek the opinions/input of recognized business experts that can provide valuable insights on the subject.

Task 2: Document the most promising ideas for the TAI in a summary report.

SOURCES OF DATA

For any index to have credibility, the data on which it is based should come from reputable sources, be used in an appropriate manner and be free of bias that could influence the index. Another criteria for index data is that they be readily available at reasonable cost on a continuing basis in order to allow credible historical trends in the index to be evaluated.

One source which meets the above criteria is the U.S. Bureau of the Census, Statistical Abstract of the United States (Bureau of Census, 1988). This publication contains a section on Construction and Housing which contains data on value of new construction of various building types put in place (subdivided into private and public sectors (figure 1) - does not detail Corps of Engineers work; Construction contracts by dollar value and floor space (figure 2); regional distribution of new privately owned one family and apartment housing (figure 3); numbers and percentages of household cooking, heating equipment and fuel characteristics (figure 4); expenditures by property owners for improvements, maintenance or repairs (figure 5); floor space and type of commercial buildings (figure 6).

This data, although it is reputable and readily available, has several drawbacks as source data for developing a Technology Adoption Index (TAI). Firstly, this data is not broken down into sufficient detail to enable data on specific new technologies to be identified. Secondly it classifies construction in such broad terms that building characteristics that could influence choice of technologies are not evident. Thirdly, geographic classification of data is at such a large (regional) scale that significant differences in climate can be expected within a region. Such climatic differences could be sufficient to effect a decision either to use or not to use a particular technology. A further drawback is the delays that occur before the publishing of much of the Census Summary data.

The principal source of the above data is the U.S. Bureau of Census which issues a variety of current publications such as their monthly "Construction Reports" with quarterly and annual supplements. Other publications of interest to this study by the Bureau include "Housing Completions" (by type and region) and "Value of New Construction Put in Place" (public and private by building type). Censuses of the construction industry have been conducted periodically since 1929 and every five years since 1967 (years ending in "2" and "7").

International Trade Administration, U.S. Department of Commerce publishes "Construction Review" annually which contains Bureau of Census data as well as statistics from other Federal Government and private agencies. The Energy Information Administration provides data on commercial buildings through its periodic sample surveys.

Private sector sources of building construction data include R.S. Means Company, Inc. from Kingston, MA. and the F.W. Dodge Division of McGraw-Hill Information Systems Company, in New York. More specialized data on developments in materials, specifications, and techniques are published by a wide range of professional and construction industry associations. Lists of names and addresses of such organizations can be found in publications such as the National Trade and Professional Associations of the United States (1988), published annually by Columbia Books Inc., Washington, DC., or Instant Information (Makower & Green, 1987).

Changes in building codes and industry specifications can be due to the acceptance of new technology but there are many other reasons for changes in such documents. If such changes are used to identify the industry adoption of new technology a careful investigation of each code or specification change will be necessary to determine if adoption of new technology was involved. The typical review period for many of the industry specifications and codes such as the AIA's Masterspec and CSI's Masterformat is 5 years. This time span may be too long if more regular technology adoption appraisals are intended by the USACE. The National Conference of States on Building Codes & Standards monitors changes to state, county and city codes on a monthly basis but the data produced does not give details of the reasons for the changes. This information could be determined by contacting the code authorities concerned. Each of the model Building Code organizations indicates changes in their new editions typically on an annual basis and documents the reasons for these changes in the reports of the code committees.

Technology assessment studies in the 1960's suggested that because of the difficulties involved in defining "new technologies", using the "delphi" survey approach with a panel of experts can be useful. This approach provides a means of overcoming the difficulties of identifying what are new technological developments, particularly in cases where important developments are really only incremental developments of existing technology. It is envisaged that the bulk of data collection would be done by university students enrolled in construction related programs. This data would then be edited by the "delphi" group of industry specialists into a set agreed to by consensus to be "New Industry Adopted Technologies". At the same time the delphi group would select pairs of "matched" construction projects to be evaluated for adoption of the new technologies. If project records do not provide sufficient data on the cost of new technologies in a project to calculate the weighting factors proposed in the TAI, then a standard method of measurement would be used to estimate such costs on each pair of projects.

In order to ensure compatibility between industry data and USA CERL data for comparison purposes it will be necessary to consult extensively with statisticians responsible for the various sources of industry data before assembling USACE data. Influences such as regional suitability and scale of projects would need to be considered in selecting industry and USACE projects for direct comparison.

FIGURE 1

No. 1201. Value of New Construction Put in Place: 1970 to 1986

[In millions of dollars, except percent. Represents value of construction put in place during year; differs from building permit and construction contract data in timing and coverage. Includes installed cost of normal building service equipment and selected types of industrial production equipment (largely site fabricated). Excludes cost of shipbuilding, land, and most types of machinery and equipment. For methodology, see Appendix III. See also *Historical Statistics, Colonial Times to 1970*, series N 1-29 and N 66-69]

ITEM	1970	1975	1979	1980	1981	1982	1983	1984	1985	1986
Total	101,281	144,311	252,411	251,719	260,160	246,568	281,266	328,641	355,994	388,817
Average annual percent change [1]	5.2	7.3	11.7	-.3	3.4	-5.2	14.1	16.8	8.3	9.2
Private	73,374	102,810	200,720	193,251	203,611	192,855	227,494	270,977	291,665	316,589
Percent of total	72.4	71.1	79.5	76.8	78.3	78.2	80.9	82.5	81.9	81.4
Residential buildings [2]	35,863	51,581	116,444	100,381	99,241	84,676	125,521	153,849	158,474	187,148
New housing units	27,059	36,317	89,272	69,629	69,424	57,001	94,849	113,826	114,662	133,192
1 unit	17,541	29,639	72,257	52,921	51,965	41,462	72,203	85,605	86,123	102,154
2 or more units	9,518	6,679	17,015	16,708	17,460	15,538	22,447	26,221	28,539	31,038
Improvements	8,804	15,264	27,172	30,752	29,817	27,675	30,872	40,023	43,812	53,956
Nonresidential buildings [3]	22,770	27,545	49,505	55,431	64,695	69,355	65,675	81,147	95,317	91,171
Industrial	6,537	8,018	14,950	13,837	17,030	17,343	12,861	13,745	15,769	13,747
Office	(4)	4,973	9,461	13,318	17,473	23,049	20,768	25,940	31,580	28,591
Hotels, motels	1,307	1,072	2,150	2,930	3,716	4,101	5,185	6,751	7,301	7,451
Other commercial	[4] 9,753	7,833	15,463	16,627	18,775	14,235	15,025	22,167	28,048	28,170
Religious	929	867	1,548	1,637	1,665	1,543	1,780	2,132	2,409	2,702
Educational	915	634	863	1,243	1,331	1,475	1,593	1,660	1,696	2,343
Hospital and institutional	2,529	3,209	3,530	4,046	4,907	5,875	6,559	6,297	5,583	5,422
Miscellaneous	800	939	1,540	1,794	1,798	1,733	1,905	2,455	2,729	2,745
Farm nonresidential	1,875	3,731	5,588	5,274	4,612	3,692	3,255	3,161	2,197	2,049
Public utilities	11,920	18,684	27,732	30,915	33,795	33,864	31,579	30,915	32,952	33,946
Telephone and telegraph	2,968	3,683	6,343	6,733	7,074	7,110	6,471	7,174	7,484	8,427
Other public utilities	8,952	15,001	21,389	24,181	26,721	26,754	25,108	23,741	25,468	25,520
Railroads	561	949	2,195	2,319	2,260	2,595	2,951	3,513	4,046	3,088
Electric light, power [5]	5,807	9,888	14,621	16,048	17,774	18,313	17,936	15,654	15,968	16,955
Gas	2,299	2,220	3,982	5,006	5,945	5,489	3,764	4,303	5,182	5,191
Petroleum pipelines	284	1,944	591	809	742	377	457	271	272	286
All other private	946	1,068	1,452	1,250	1,268	1,269	1,464	1,905	2,726	2,275
Public	27,908	41,702	51,690	58,468	56,549	53,713	53,772	57,664	64,328	72,228
Percent of total	27.6	28.9	20.5	23.2	21.7	21.8	19.1	17.5	18.1	18.6
Buildings	10,473	15,243	15,558	18,517	17,792	18,997	17,276	17,883	20,172	23,494
Housing, redevelopment	1,106	754	1,211	1,648	1,722	1,658	1,700	1,636	1,511	1,456
Industrial	318	687	1,112	1,441	1,655	1,632	1,809	1,828	1,968	1,657
Educational	5,619	7,780	6,903	8,050	6,737	5,927	5,374	5,557	6,708	8,440
Hospital	838	1,745	1,648	1,785	2,083	1,991	2,098	2,039	2,017	1,998
Other	2,594	4,296	4,684	5,593	5,595	5,789	6,295	6,822	7,967	9,943
Highways and streets	9,982	11,902	14,895	17,225	16,799	16,164	17,199	18,771	21,756	23,359
Military facilities	717	1,389	1,647	1,880	1,964	2,205	2,544	2,839	3,283	3,919
Conservation, redevelopment	1,907	3,257	4,587	5,090	5,300	5,027	4,820	4,654	4,744	4,668
Sewer systems	1,543	4,801	7,298	7,171	5,935	5,529	5,260	6,241	7,196	8,105
Water supply facilities	1,093	1,765	2,490	3,266	3,004	2,902	2,063	2,621	2,664	3,370
Miscellaneous	2,192	3,345	5,215	5,318	5,754	4,889	4,590	4,654	4,512	5,313
Public ownership:										
State and local government	24,798	35,614	43,126	48,827	46,136	43,705	43,214	46,423	52,282	59,706
Buildings	9,753	13,580	13,215	15,699	14,641	14,012	13,886	14,088	15,900	19,299
Highways and streets	9,728	11,595	14,367	16,769	16,048	15,646	16,731	18,255	21,287	22,957
Conservation, development	540	818	673	821	896	908	820	727	935	971
Other	4,777	9,821	14,872	15,538	14,550	13,139	11,777	13,354	14,160	16,478
Federal government	3,110	8,068	8,564	9,641	10,413	10,008	10,557	11,240	12,046	12,522
Conservation, development	1,367	2,638	3,915	4,270	4,404	4,119	4,000	3,927	3,810	3,697
Buildings	720	1,663	2,343	2,818	3,151	2,988	3,390	3,796	4,272	4,195
Military facilities	717	1,389	1,647	1,880	1,964	2,205	2,544	2,839	3,283	3,919
Misc. (incl. highways and streets)	305	397	659	673	694	699	624	678	681	712

[1] Change from immediate year, except 1970, change from 1965. Minus sign (-) indicates decrease. For explanation of average annual percent change, see Guide to Tabular Presentation. [2] Includes farm residential. [3] Excludes building by privately owned public utilities. [4] Office buildings included in "other commercial." [5] Includes construction with Rural Electrification Administration (REA) funds.

Source: U.S. Bureau of the Census, *Construction Reports*, series C30.

FIGURE 2

NO. 1202. VALUE OF NEW CONSTRUCTION PUT IN PLACE IN CONSTANT (1982) DOLLARS: 1970 TO 1986

[In millions of dollars, except percent. For details on derivation of constant values and description of revised series, see source. For description of nature of revisions and deflators used, see *Construction Reports*, series C30-80S]

ITEM	1970	1975	1979	1980	1981	1982	1983	1984	1985	1986
Total	277,618	255,670	311,973	280,741	268,055	246,821	274,108	308,770	324,817	347,831
Average annual percent change [1]	.1	-1.6	5.1	-10.0	-4.5	-8.0	11.1	12.6	5.2	7.1
Private	202,969	186,284	250,349	218,813	211,039	192,812	220,731	253,483	266,642	283,565
Percent of total	73.1	72.9	80.2	77.9	78.7	78.2	80.5	82.1	82.1	81.5
Residential buildings [2]	102,285	98,542	144,450	112,972	102,140	84,663	122,099	144,398	145,787	168,592
New housing units	77,218	69,378	110,743	78,379	71,496	56,990	92,062	106,873	105,505	120,000
1 unit	50,047	58,571	89,658	59,537	53,511	41,454	70,211	80,362	79,237	92,034
2 or more units	27,172	12,807	21,085	18,842	17,985	15,536	21,851	26,510	26,268	27,966
Improvements	25,067	29,164	33,707	34,594	30,643	27,673	30,037	37,525	40,282	48,591
Nonresidential buildings [3]	60,951	49,037	62,877	63,633	67,758	69,325	63,234	74,767	85,497	79,823
Industrial	17,493	14,272	19,028	15,946	17,823	17,341	12,395	12,685	14,145	12,038
Office	(4)	8,857	12,006	15,323	18,291	23,035	20,000	23,898	28,331	25,037
Hotels, motels	3,502	1,909	2,724	3,373	3,891	4,099	4,990	6,226	6,550	6,522
Other commercial	[4] 28,104	13,943	19,607	19,153	17,581	14,232	14,452	20,409	25,153	24,660
Religious	2,488	1,543	1,966	1,884	1,746	1,541	1,712	1,965	2,159	2,365
Educational	2,450	1,129	1,095	1,428	1,397	1,474	1,534	1,530	1,700	2,050
Hospital, institutional	6,771	5,714	4,498	4,656	5,141	5,871	6,318	5,811	5,011	4,747
Miscellaneous	2,142	1,671	1,954	2,068	1,888	1,732	1,833	2,263	2,448	2,403
Farm nonresidential	5,020	8,640	7,110	6,067	4,830	3,691	3,131	2,915	1,973	1,793
Public utilities	32,193	30,361	34,233	34,668	35,054	33,863	30,796	29,545	30,884	31,301
Telephone, telegraph	7,324	6,064	7,862	7,604	7,419	7,113	6,257	6,818	7,025	7,715
Other public utilities	24,869	24,297	26,350	27,064	27,635	26,750	24,539	22,727	23,859	23,586
Railroads	1,499	1,513	2,538	2,350	2,241	2,598	2,963	3,431	3,708	2,792
Electric light, power [5]	16,323	16,242	18,240	18,321	16,629	18,306	17,393	14,848	14,943	15,691
Gas	6,273	3,516	4,853	5,505	8,013	5,469	3,731	4,185	4,950	4,837
Petroleum pipelines	774	3,027	720	688	753	377	452	263	260	266
All other private	2,519	1,704	1,680	1,273	1,257	1,270	1,471	1,858	2,500	2,057
Public	74,650	69,387	61,624	61,928	57,016	53,809	53,377	55,287	58,175	64,266
Percent of total	26.9	27.1	19.8	22.1	21.3	21.8	19.5	17.9	17.9	18.5
Buildings	28,230	27,228	19,761	21,259	18,627	16,989	16,657	16,513	16,128	20,597
Housing, redevelopment	3,153	1,441	1,503	1,854	1,774	1,658	1,657	1,537	1,392	1,313
Industrial	845	1,224	1,418	1,660	1,738	1,631	1,743	1,686	1,767	1,451
Educational	15,043	13,810	8,778	9,255	7,067	5,924	5,176	5,122	6,014	7,382
Hospital	2,247	3,107	2,100	2,053	2,184	1,991	2,020	1,881	1,810	1,750
Other	6,943	7,643	5,962	6,438	5,863	5,785	6,061	6,287	7,145	8,702
Highways and streets	26,356	18,219	15,890	15,792	15,909	16,267	17,533	18,353	16,990	20,188
Military facilities	1,906	2,281	1,921	1,924	1,953	2,206	2,518	2,696	2,915	3,408
Conservation, development	5,153	5,429	5,771	5,771	5,536	5,026	4,780	4,541	4,554	4,424
Sewer systems	4,167	8,024	9,164	8,129	6,192	5,524	5,212	6,086	6,902	7,681
Water supply facilities	2,973	2,872	3,079	3,652	3,092	2,902	2,065	2,550	2,551	3,166
Miscellaneous	5,864	5,335	6,039	5,400	5,706	4,893	4,612	4,548	4,136	4,802

[1] Change from immediate prior year; except 1970, change from 1965. Minus sign (-) indicates decrease. For explanation of average annual percent change, see Guide to Tabular Presentation. [2] Includes farm residential. [3] Excludes building by privately owned public utilities. [4] Office buildings included in "Other Commercial." [5] Includes construction with Rural Electrification Administration (REA) funds.

Source: U.S. Bureau of the Census, *Construction Reports*, series C30.

FIGURE 3

No. 1209. New Privately-Owned Housing Units Started—Selected Characteristics: 1970 to 1986

[In thousands. For composition of regions, see fig. I, inside front cover. See also *Historical Statistics, Colonial Times to 1970,* series N 156-163 and 170]

Year	Total units [1]	Structures with—			Region				Condominium units [2]			Type of assistance [3]	
		One unit	2-4 units	5 or more units	Northeast	Midwest	South	West	Total	Single-family	Multifamily	FHA	VA
1970	1,434	813	85	536	218	294	612	311	(NA)	(NA)	(NA)	421	61
1971	2,052	1,151	120	781	264	434	869	486	(NA)	(NA)	(NA)	528	94
1972	2,357	1,309	141	906	330	443	1,057	527	(NA)	(NA)	(NA)	371	104
1973	2,045	1,132	118	795	277	440	899	429	241	69	172	163	86
1974	1,338	888	68	382	183	317	553	285	175	46	130	95	73
1975	1,160	892	64	204	149	294	442	275	65	20	45	98	77
1976	1,538	1,162	86	289	169	400	569	400	95	30	64	144	100
1977	1,987	1,451	122	414	202	465	783	538	118	41	77	178	131
1978	2,020	1,433	125	462	200	451	824	545	156	42	114	178	127
1979	1,745	1,194	122	429	178	349	748	471	198	43	156	178	122
1980	1,292	852	110	331	125	218	643	306	186	35	150	177	95
1981	1,084	705	91	288	117	165	562	240	181	36	145	145	75
1982	1,062	663	80	320	117	149	591	205	170	40	130	152	73
1983	1,703	1,068	113	522	168	216	935	382	276	77	199	121	107
1984	1,750	1,084	121	544	204	243	866	436	291	96	194	63	97
1985	1,742	1,072	93	576	252	240	782	468	225	79	146	(NA)	(NA)
1986	1,805	1,179	84	542	294	296	733	483	214	80	134	(NA)	(NA)

NA Not available. [1] For 1970-1976, characteristics such as type of structure, and region, include data for publicly owned units. [2] Type of ownership under which the owners of the individual housing units are also joint owners of the common areas of the building or community, includes a small number of cooperatively-owned units. [3] Source: U.S. Department of Housing and Urban Development, 1970-1979, *HUD Statistical Yearbook;* thereafter unpublished data.

Source: Except as noted, U.S. Bureau of the Census, *Construction Reports,* series C20.

FIGURE 4

NO. 1211. CHARACTERISTICS OF NEW PRIVATELY OWNED ONE-FAMILY HOUSES COMPLETED: 1970 TO 1986

[Percent distribution, except as indicated. Data beginning 1980 show percent distribution of characteristics for all houses completed (includes new houses completed, houses built for sale completed, contractor-built and owner-built houses completed, and houses completed for rent). Data for 1970 cover contractor-built, owner-built, and houses for rent for year construction started and houses sold for year of sale. Percents exclude houses for which characteristics specified were not reported]

CHARACTERISTIC	1970	1980	1984	1985	1986
Total houses (1,000)	793	957	1,025	1,072	1,120
Financing	100	100	100	100	100
Mortgage	84	81	81	81	83
FHA-insured	30	16	13	15	20
VA-guaranteed	7	8	6	7	8
Conventional	47 (Conventional and Farmers Home Administration combined)	55	61	57	54
Farmers Home Administration		3	2	3	2
Cash or equivalent	16	18	19	19	16
Floor area	100	100	100	100	100
Under 1,200 sq. ft	36	21	19	20	17
1,200-1,599 sq. ft	28	29	30	30	30
1,600-1,999 sq. ft	16	22	21	21	21
2,000-2,399 sq. ft	21 (2,000 sq. ft. and over combined)	13	12	12	14
2,400 sq. ft. and over		15	17	17	18
Average (sq. ft.)	1,500	1,740	1,700	1,785	1,825
Median (sq. ft.)	1,385	1,595	1,605	1,605	1,660
Number of stories	100	100	100	100	100
1	74	60	54	52	51
2 or more	17	31	40	42	44
Split level	10	8	6	6	5
Foundation	100	100	100	100	100
Full or partial basement	37	36	32	35	37
Slab	36	45	50	48	45
Crawl space	27	19	18	18	18

CHARACTERISTIC	1970	1980	1984	1985	1986
Bedrooms	100	100	100	100	100
2 or less	13	17	24	25	21
3	63	63	58	57	59
4 or more	24	20	18	18	20
Bathrooms	100	100	100	100	100
1 or less	32	18	14	13	10
1½	20	10	10	11	9
2	32	48	48	48	47
2½ or more	16	25	28	29	33
Heating fuel	100	100	100	100	100
Electricity	28	50	48	44	44
Gas	62	41	45	49	47
Oil	8	3	2	3	5
Other	1	5	5	4	4
Heating system	100	100	100	100	100
Warm air furnace	71	57	55	54	54
Electric heat pump	(NA)	24	30	30	29
Other	29	19	15	15	17
Central air-conditioning	100	100	100	100	100
With	34	63	71	70	69
Without	66	37	29	30	31
Fireplaces	100	100	100	100	100
No fireplace	65	43	41	41	38
1 or more	35	56	59	59	62
Parking facilities	100	100	100	100	100
Garage	58	69	69	70	74
Carport	17	7	5	5	4
No garage or carport	25	24	25	25	21

NA Not available.

Source: U.S. Bureau of the Census and U.S. Dept. of Housing and Urban Development, *Construction Reports*, series C25, *Characteristics of New Housing* (a joint publication).

FIGURE 5

No. 1229. Expenditures by Residential Property Owners for Improvements and Maintenance and Repairs by Type of Property and Activity: 1970 to 1986

[In millions of dollars]

Year and type of expenditure	Total	1-unit properties with owner occupant	Other properties	Additions and alterations: Total	To structures: Additions	To structures: Alterations	To property outside of structures	Major replacements	Maintenance and repairs
1970	14,770	9,469	5,301	6,246	1,411	3,539	1,296	2,629	5,895
1975	25,239	15,684	9,556	10,997	1,971	8,844	2,182	4,484	9,758
1976	29,034	16,854	10,180	12,314	3,493	6,367	2,454	5,341	11,379
1977	31,280	21,761	9,519	14,237	2,655	8,505	3,077	5,699	11,344
1978	37,461	24,189	13,272	16,458	3,713	8,443	4,302	8,094	12,909
1979	42,231	28,280	13,951	18,285	3,280	9,642	5,363	8,996	14,950
1980	46,338	31,481	14,857	21,336	4,183	11,193	5,960	9,816	15,187
1981	46,351	30,201	16,150	20,414	3,164	11,947	5,303	9,915	16,022
1982	45,291	29,779	15,512	16,774	2,641	10,711	5,423	9,707	18,610
1983	49,295	32,524	16,771	20,271	4,739	11,673	3,859	10,895	18,128
1984, total [1]	69,784	43,781	26,003	27,822	6,007	14,486	7,329	13,067	28,894
Heating and air-conditioning [2]	5,071	2,768	2,303	959	(NA)	959	(NA)	2,391	1,721
Plumbing	6,919	3,346	3,573	1,201	(NA)	1,201	(NA)	2,408	3,310
Roofing	5,140	2,573	2,568	(NA)	(NA)	(NA)	(NA)	3,128	2,014
Painting	8,817	4,998	3,819	(NA)	(NA)	(NA)	(NA)	(NA)	8,817
1985, total [1]	80,267	47,742	32,525	28,775	3,966	17,599	7,211	16,134	35,358
Heating and air-conditioning [2]	5,096	3,287	1,809	1,121	(NA)	1,121	(NA)	2,322	1,653
Plumbing	8,120	4,029	4,091	1,502	(NA)	1,502	(NA)	3,115	3,503
Roofing	7,497	4,428	3,069	(NA)	(NA)	(NA)	(NA)	5,086	2,411
Painting	11,267	5,810	5,457	(NA)	(NA)	(NA)	(NA)	(NA)	11,267
1986, total [1]	91,274	54,298	36,976	38,608	7,377	21,192	10,040	16,695	35,971
Heating and air-conditioning [2]	6,232	3,993	2,239	974	(NA)	974	(NA)	3,399	1,860
Plumbing	8,461	3,791	4,670	1,484	(NA)	1,484	(NA)	3,408	3,569
Roofing	7,685	3,834	3,851	(NA)	(NA)	(NA)	(NA)	4,552	3,133
Painting	11,170	5,673	5,497	(NA)	(NA)	(NA)	(NA)	(NA)	11,170

NA Not available. [1] Includes types of expenditures not separately specified. [2] Central air-conditioning.

Source: U.S. Bureau of the Census, *Construction Reports*, series C50.

FIGURE 6

NO. 1237. COMMERCIAL BUILDINGS—SELECTED CHARACTERISTICS, BY SQUARE FOOTAGE OF FLOORSPACE: 1983

[Excludes Alaska and Hawaii. Building type based on predominant activity in which the occupants were engaged. Excludes industrial buildings. Based on a sample survey of building representatives conducted between March and August 1983; therefore, subject to sampling variability. For data on energy consumption and expenditures in commercial buildings, see tables 916 and 917. For composition of regions, see fig. I, inside front cover]

CHARACTERISTIC	Number of buildings (1,000)	FLOORSPACE (mil. sq. ft.) Total	Within all buildings having square footage of— 5,000 or less	5,001 to 10,000	10,001 to 25,000	25,001 to 50,000	50,001 to 100,000	100,001 and over	Average sq. ft. per building (1,000)	Median sq. ft. per building (1,000)
All buildings	3,948	52,325	4,908	5,246	8,912	7,692	7,168	18,399	13.3	4.0
Region:										
Northeast	670	11,615	784	939	1,960	1,915	1,754	4,264	17.3	5.7
Midwest	1,211	16,059	1,526	1,685	2,616	2,334	2,146	5,750	13.3	4.0
South	1,493	17,049	1,971	1,685	2,923	2,176	2,199	6,094	11.4	3.3
West	574	7,602	627	937	1,412	1,267	1,068	(S)	13.2	4.7
Year constructed:										
1980 to 1983	140	5,675	127	163	523	479	794	3,590	40.5	9.9
1974 to 1979	530	6,616	668	635	1,208	1,029	848	2,118	12.5	4.1
1971 to 1973	209	3,442	249	320	496	654	556	1,168	16.4	5.1
1961 to 1970	721	9,947	881	860	1,417	1,371	1,533	3,885	13.8	3.4
1946 to 1960	946	9,612	1,187	1,279	1,699	964	1,265	3,219	10.2	3.1
1921 to 1945	726	8,639	855	950	1,663	1,656	949	2,566	11.9	3.8
1901 to 1920	388	5,453	514	600	1,049	1,010	942	1,337	14.1	5.1
1900 or before	288	2,940	406	440	767	530	281	(S)	10.2	4.8
Principal activity within building:										
Assembly	457	5,483	485	901	1,390	912	621	(S)	12.0	5.9
Educational	177	6,044	113	182	560	1,322	1,619	2,248	34.2	18.1
Food sales/service	380	2,051	636	343	568	209	179	(S)	5.4	2.8
Health care	61	2,277	80	(S)	(S)	(S)	(S)	1,761	37.6	4.7
Lodging	106	2,241	95	166	310	495	318	856	21.1	6.8
Mercantile/services	1,071	10,427	1,433	1,562	2,013	1,065	1,089	(S)	9.7	3.5
Office	575	8,454	749	803	1,236	978	933	3,757	14.7	4.1
Residential	236	2,454	325	265	748	432	(S)	(S)	10.4	4.4
Warehouse	425	6,791	448	448	1,202	1,203	1,198	2,293	16.0	4.8
Other	179	2,760	176	186	405	350	214	1,429	15.4	3.4
Vacant	281	3,342	368	314	410	562	614	1,054	11.9	3.3
Number of establishments in building:										
None	142	1,475	218	(S)	137	187	342	300	10.4	3.1
Single establishment	3,160	35,227	4,077	3,870	6,563	5,710	5,031	9,975	11.1	3.6
Multi-establishment	645	15,623	613	1,202	2,212	1,795	1,794	8,007	24.2	7.5
Government occupancy:										
Government occupied	346	10,099	327	376	959	1,356	1,551	5,529	29.2	7.2
Not Government occupied	3,602	42,225	4,580	4,868	7,953	6,336	5,618	12,871	11.7	3.9
Fuels used alone or in combination:										
Electricity	3,783	51,359	4,701	5,079	8,810	7,491	6,973	18,305	13.8	4.1
Natural gas	2,314	37,090	2,732	3,522	8,081	5,484	4,930	14,342	16.0	5.0
Fuel oil	633	13,313	743	886	1,656	1,425	1,509	7,093	21.0	5.1
Propane	260	3,007	380	285	515	328	209	1,290	11.6	3.5
Purchased steam	60	4,594	(S)	(S)	235	448	645	3,173	76.2	29.2
Other	245	3,997	345	260	497	337	535	2,024	16.3	3.6

S Figure does not meet publication standards.

Source: U.S. Energy Information Administration, *Characteristics of Commercial Buildings, 1983.*

APPROACH

In accordance with Task 1 of the Statement of Work, investigators were recruited from Civil Engineering, Mechanical Engineering, Construction Research Center and Management faculty at Georgia Tech. Two other research consultants familiar with CERL operations were used in the final comment stage.

Part way through the study the principal investigator visited Richard G. Lampo and Thomas R. Napier at CERL in Champaign to discuss progress, inspect facilities and be briefed on the progress of the Corps of Engineers Technology Adoption Process (CETAP) study which is closely related to the TAI project.

Brainstorming sessions were held on Aug. 22, Aug. 29, and Sept. 19, 1988. These sessions culminated in presentations by each of the investigators on their individual concept for a Technology Adoption Index on Sept. 26, 1988. Each of these proposals is described on the following pages.

As required by Task 2 of the statement of work, elements were selected from these independent studies to formulate the recommended procedure for evaluating technology as an index. Other suggestions were incorporated as diagnostic tools for examining those technologies which generate an index significantly greater than or less than 1. Such cases would indicate when the USACE significantly leads or trails other construction industry sectors in technology adoption.

With the recommended procedure described, two consultants Carolyn Dry of Natural Process Design, Champaign, Illinois and Charles Lozar of Architects Equities Inc., Champaign, Illinois, both familiar with USACE operations were engaged to critically review the draft report proposal. Their reports are included in the appendixes of this report.

Both reviewers, while generally supportive of the concept, independently identified similar potential problems with the recommended procedures. These potential problems are discussed in the conclusions of this report. Both supported the recommendation that a pilot study be performed in order to better measure the order of difficulties likely to be encountered during data collection and appraisal.

PROPOSAL 1:

Leland S. Riggs
Associate Professor
School of Civil Engineering
(Specialist in Construction Management)

I(a). "ANSWER THE MAIL APPROACH"

This proposal suggests a direct response to inquiries regarding the adoption of new technologies by the USACE relative to the construction industry. That is, compile a list of new technologies adopted by industry in the last five or ten years and analyze (explain) why the technology was or was not appropriate for use by the Corps. Presumably, there are well-founded reasons why a given technology was not adopted.

In those cases where technology could have been used by the Corps, but was not used a compelling rationale would have to be prepared arguing the reasons for non-adoption. This approach can also be used to cast a spotlight on those new technologies adopted by the Corps but not by industry.

The type list proposed here could serve as recent history as well as lending itself to updating. The disadvantage to this approach is that it is not necessarily linked to an index. On the other hand, this approach lends itself well to economic or other analysis of individual technologies.

I(b). "INDEX APPROACH"

This approach includes developing an index on which to compare the adoption rate of new technology of the Corps and industry. It is suggested that the basis of this index be the facility life cycle shown below.

PLANNING, PROGRAMMING, DESIGN, CONSTRUCTION, O&M, UTILIZATION

Within the construction and operations and maintenance area, the CSI or Uniform Building Code may be appropriate for organizing candidate technologies. It is further suggested that different contracting systems such as Reimbursable with a Guaranteed Maximum Cost and sharing of savings be addressed under the construction category.

The general form of the index would be as shown below:

$$TAI = SUM_i K_i (PLAN_i) + \ldots + SUM_i K_n (UTILIZ_n)$$

$$\text{where each } K_i = \frac{\text{Applications}_i}{\text{Opportunities}_i} \text{ in units, SF, \$, etc.}$$

In order to establish a valid basis for assessment for adoption of a particular technology adoption, a reference project must be identified incorporating significant utilization of the technology under study. This reference project should be similar in age, scale, function and regional location to the USACE subject project. With a reference project identified "opportunities" and "applications" for the technology can be determined.

DEFINITIONS

Opportunities:

are defined as the dollar cost of the technology under study in the reference project divided by the total project cost of the reference project.

Applications:

are defined as the dollar cost of the technology under study in the subject USACE project divided by the total project cost of the subject USACE project.

In comparing indexes or individual technology ratios of the Corps activities with those of the construction industry as a whole, it would be the responsibility of an expert panel of independent advisors to ensure that subject and reference projects and cost elements used were truly comparable, i.e., "apples to apples".

PROPOSAL 2:

Sheldon M. Jeter
Associate Professor
School of Mechanical Engineering
(Specialist in HVAC Systems)

The goal of the Technology Adoption Index Project is to develop a quantitative measure of the effectiveness of the Corps of Engineers in adopting and implementing appropriate innovative construction and property development industries. Particular emphasis is on materials, equipment, and on-site methods.

To address the question proposed by CERL, it is my view that the project needs to identify at least three increasingly detailed bodies of information. These aspects are as follows:

1. The introductory technologies that are actually innovative. New products may not necessarily involve innovative technology.

2. The innovative technologies that are actually appropriate to the mission of the Corps of Engineers and the mission of the units and activities that the Corps supports.

3. When these technologies were adopted and implemented by the corresponding civilian sectors and when by the Corps.

Since I am hardly familiar with the existing data bases on construction technology and the capabilities and extent of these sources of information, design and execution of a successful research plan based on existing and readily accessible information seems highly problematical to me. Acknowledging my lack of experience with such data bases, I would defer to any knowledgeable person the judgment as to the likelihood of success if the project proceeds along these lines. I would submit, however, that a preliminary exercise should be conducted to educate the research team on the extent, quality, and pertinence of these data bases and the capability of manipulating them. I am concerned about three critical issues, one for each level of information listed above:

1. How can one determine from a standard data base if a new product incorporates an innovative technology. Every product that is introduced is touted as being innovative, but most incorporate only incremental improvements if any. A new listing in, for example, the Sweets Catalog File does not necessarily indicate a new technology.

2. It seems even more difficult to determine if an innovative technology is appropriate. The Corps should not be criticized for avoiding a product or technology for valid reasons.

3. A final difficulty is determining when and where products are being used. I suppose that this information exists in commercial records, but how can it be extracted and analyzed?

As an alternative to dealing with data bases that may be poorly defined and thereby introducing an element of uncertainty into the project, I propose a case study approach. The proposed study is composed of well defined tasks, all of which can surely be completed. The overall project, then, is likely to be successful, although its goals may be limited.

The case study would involve the identification of innovative technologies and an investigation of the relative success of these technologies in the civilian and military sections. Because my professional experience is limited to the HVAC, energy conservation, and energy management areas, I will use energy in buildings as my example.

The sub-tasks are itemized in Table 1. Innovative technologies would be identified by a literature search complemented with a review by a panel of experts. A subset of the technologies that pass the review would be selected randomly for further investigation. The literature search could focus on feature articles in the ASHRAE Journal and a trade paper such as Heating/Piping/Air Conditioning (Penton Publishers, Cleveland, OH). A proposed list of technologies would be assembled from the last two or three decades of these publications. The expert panel should then review the list and confirm whether the proposed technologies are substantially innovative. Candidates that survive this review would then comprise the subject population for a random drawing to select technologies for further study. This procedure has the advantage of being broad, as all significant developments are likely to be reported in the source publications. The expert panel can eliminate trivial or useless technologies, but since the work of the panel is in review, rather than in construction of the list, there is less chance of introducing bias. If bias does corrupt the selection, at least it will be overt as we should publish both the preliminary and final list. The sample obtained by random selection will be small enough to work with and also be free of additional bias. The sample should include selections and alternatives in case sufficient data is not available on the prime selections.

Table 1

Schedule of Sub-tasks

1.1	Identify preliminary Candidate Technologies
1.2	Screen Preliminary List of Technologies
1.3	Select Sample of Technologies for Further Analysis
2.1	Identify Private Sector Introduction Date
2.2	Identify Private Sector Demonstration Date
2.3	Identify Private Sector Adoption Date
2.4	Allow Private Sector Review of Data
3.1	Date of Consideration by Corps
3.2	Date of Adoption by Corps
4.0	Compute TAI

We can return to the literature to determine the dates of introduction, consideration/demonstration, and commercial adoption of the innovative technologies. I would count the first advertisement in an appropriate trade paper as the date of commercial introduction. The date of consideration/demonstration could be represented by a substantive report in an independent publication of a completed demonstration project. If the technology has progressed this far, it could be considered as at least as demonstrated to be feasible and worthy of broad consideration. Commercial adoption could be represented by the technology being included in publications that represent broad specification guidelines such as the ASHRAE Systems and Equipment volumes or if the technology appears in a broad pricing guideline such as Means Mechanical and Electrical Cost Data. It would then be desirable to inquire of manufacturers and vendors about the accuracy of our estimates. General adoption in this sense could be defined as a capture of a few percent of the market. We could also contact selected users such as general contractors, subcontractors, AE firms, and utility companies about these dates. The utility companies should be very helpful in this regard as they periodically review their customer's use of various energy technologies.

At this point the data which consists of several identified technologies and the corresponding introduction, consideration/demonstration, and adoption dates should be referred to the Corps. There ought to be dates corresponding to consideration and/or demonstration as well as adoption for each technology. Consideration that results in a negative opinion and does not lead to demonstration is a perfectly valid result. Demonstration may not be possible because of budget or program constraints. Of course, demonstrations may be executed, and the technologies found to be faulty, risky, or inappropriate. The summary results would be organized as illustrated in Table 2.

Table 2

Summary of Intermediate Results

Private Sector		Corps of Engineers
Introduction date, d_0	or	Introduction date, d_{c0}
Consideration/ Demonstration date, d_1		Consideration/ Demonstration date, d_{c1}
Adoption date, d_2		Adoption date, d_{c2}

For technologies that are ultimately adopted in the civilian sector, we can compute the TAI as follows:

$$TAI = ((d_1 - d_0)/(d_{c1} - d_0) + (d_2 - d_1)/(d_{c2} - d_{c1}))/2$$

For technologies that only receive some initial interest in the private sector but are never, or not yet, adopted, we can compute the TAI as follows:

$$TAI = (d_1 - d_0)/(d_{c1} - d_0)$$

No doubt we will encounter some special cases that require modification of the proposed formulas.

The project plan presented above has been designed to make use of readily available and widely accepted sources of information. The sub-tasks appear to be well defined and within the span of available abilities and capacities. The result will be a quantitative measure in terms that are commensurate across a wide range of technologies.

PROPOSAL 3:

Louis J. Circeo
Director
Construction Research Center
College of Architecture
(Specialist in USA CERL Construction Research Activities)

STEPS IN THE DEVELOPMENT OF A TECHNOLOGY ADOPTION INDEX

1. Develop a definition of a "newly adopted technology".

   a. Use a very simple index that can be readily monitored; e.g.,

      (1) Changes in the Uniform Building Code

      (2) Changes in Association Codes/Specifications; e.g., ASTM, ACI, etc.

   b. Establish a baseline zero time to determine how long it takes to introduce new technologies; e.g., when a code change takes place.

2. Establish a threshold of "worthiness" factor to determine whether a newly adopted technology is worthwhile to implement; e.g.,

   a. A cost-benefit comparison of old vs. the new technology

   b. Life Cycle cost comparisons

   c. Subjective evaluations

   d. Combinations of the above

3. Determine the extent to which the above "worthy" newly adopted technologies are being implemented in civilian and Corps projects.

   a. Compare times for first and "standard" use

   b. Compare actual use to the opportunities for use

   c. Regional factors may have to be considered

   d. A model may be required to normalize the data for valid comparisons

4. Based on the above paragraph 3 comparisons, develop a single "implementation factor" for each newly adopted technology for both industry and the Corps.

5. Collate the implementation factors under construction categories (e.g., Structural, Mechanical, Management, etc.) separately for industry and the Corps.

6. Combine the results within and between each broad category to get an overall Technology Adoption Index for both the industry and the Corps (see figures 7 and 8).

7. A simple comparison of these two indexes should indicate the relative degree of technology adoption between industry and the Corps.

DEFINITIONS

"Newly Adopted Technology" could be technology associated with any addition to a recognized construction code or standard within the period of one calendar year.

"Available Technology" is the full spectrum of construction technology available within a given calendar year and would include those in their early development and demonstration stages.

FIGURE 7

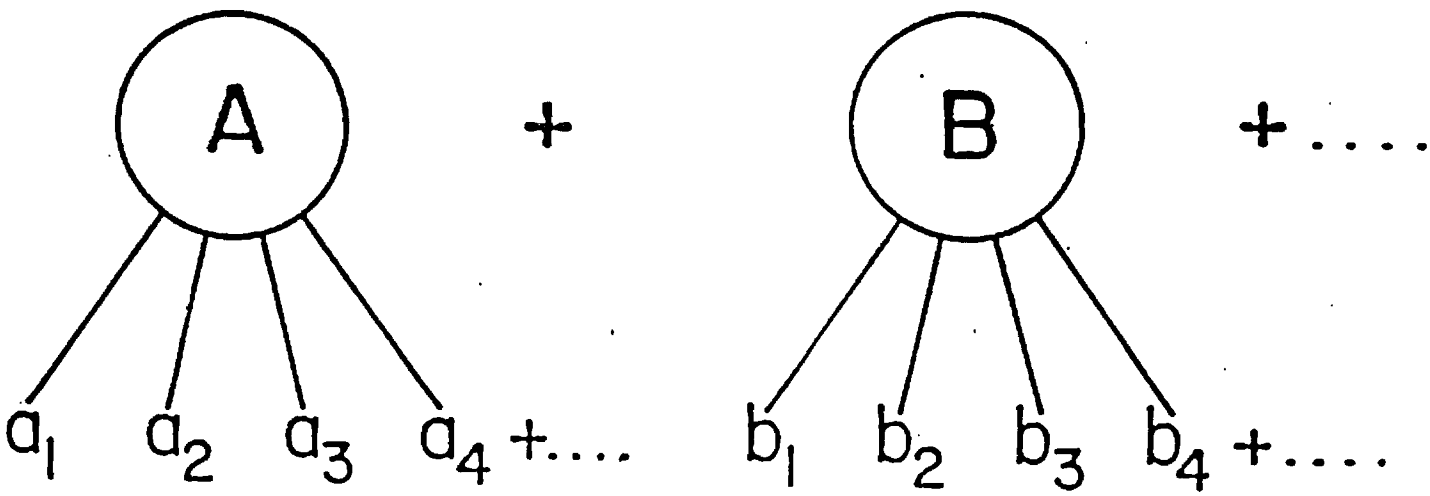

FIGURE 8

$$A_C + B_C + C_C + D_C + \ldots = I_{CORPS}$$

$$A_P + B_P + C_P + D_P + \ldots = I_{PRIVATE\ INDUSTRY}$$

PROPOSAL 4:

Richard Aynsley
Professor
College of Architecture
(Specialist in Building Science)

1. Identify newly adopted technologies through:

   a. Changes in model building codes
      (via the CodeWORKS database, see appendix):

   Basic Building code
   Southern Standard Building code
   Uniform Building code
   National Plumbing code
   Uniform Plumbing, Heating & Comfort Cooling Codes
   National Electrical Code

Note: differences between these codes often reflect regional and geographic influences.

   b. Changes in industry association specifications and cost indexes:

   ANSI's standards (updated about every 5 years)
   AIA's Masterspec (updated quarterly)
   ASTM's materials specs (updated quarterly)
   McGraw-Hill's SweetSpec and SweetSearch
   ACI's concrete specifications
   Underwriters Laboratories
   (Product Index, 6 monthly update)
   Mean's Cost Data
   American Concrete Institute
      (Industry Developments noted in monthly journal "Concrete International ")
   Construction Specification Institute's Master format
      (updated every 5 years)
   Information Handling Services' SPEC-DATA microfilm data
      VEND and TECH DATA electronic databases
   ICBO Evaluation Service Inc.'s Building Standards journal

2. With new technologies identified, a three step evaluation would be made of each technology:

   a. The number of applications of each technology would be divided by the number of opportunities for application, for USACE and each of the other industry sectors surveyed to yield an implementation index for each new technology.

b. A lead/lag index would be calculated for each new technology for both the USACE and Industry based on the number of months, positive or negative, between the USACE's adoption and the industry's adoption. Adoption by the USACE would be determined by a technology's appearance in a standard specification. Industry adoption would be based on a technologies appearance in an industry standard specification.

Technology adoption indexes for the USACE and industry would be based on comparable sample projects executed by the USACE and industry and determined by summing the products of implementation indexes and lead/lag indexes for each technology. Comparisons of technology adoption indexes for the USACE and industry could be qualified by consideration of a significance ratio and a risk index when appropriate. These are described below.

3. SIGNIFICANCE RATIO - This would be the ratio of the dollar value of a technology in all Corps or private sector projects, divided by the total dollar value of those corps or private sector projects. This ratio could be used to establish a "threshold" for significant technologies.

4. RISK INDEX - This would be the product of the estimated probability of failure of the technology and the estimated dollar value of repairing the consequences of such a failure divided by the total dollar value of the project. The risk index is not envisaged as an integral part of the technology adoption index but more as an ancillary tool for assessing technologies.

PROPOSAL 5:

Peter G. Sassone
Associate Professor
College of Management
(Specialist in Economic Indexes)

This proposal suggests implementation of a "relative" index approach as opposed to an "absolute" index approach. The idea is not to compare Corps construction activity to some absolute "norm", in terms of what technology ought to be used, rather simply to use a "benchmark" approach by comparing the Corps' activity to the industry as a whole. The rationale for recommending a "benchmark" approach is that such an approach minimizes the problems arising from differences between industry and Corps operational philosophies. Private industry generally operates by trading off risks against rewards, while the Corps operates under a wide range of different government and policy constraints. This approach would develop three levels of indexes.

1. CONSTRUCTION/TECHNOLOGY INDEX - An index of use of a certain technology within a specified building sector, for example, multi-family residential construction might be one sector. Such sectors initially could reflect those adopted by the US Bureau of Census and Statistics. More suitable sector divisions may become evident after extensive application of the proposed TAI.

   There is likely to be a number of different technologies requiring assessment in each sector. From the assessment of all technologies within a sector an index I(j,k) would be developed for that sector. Each index would be a ratio with the numerator being the money spent by the Corps in that technology divided by the total amount of money spent by the Corps in that sector. The denominator is a similar ratio for private sector activity for a comparable to that used for the Corps' sample.

2. CONSTRUCTION SECTOR INDEXES - Aggregating the individual indexes for a particular construction sector into an overall index for that sector. For example, multi-family residential construction. The trick to combining them is to have a reasonable weighting scheme. The W(j,k) are the weights suggested to be applied. They are the relative value of that technology among all of the technologies being considered. The sum of all weightings then adds up to one.

3. SUMMARY OVERALL INDEX - An overall index for the Corps or the private sector can be calculated by using a weighted aggregation of indexes across all industry sectors. If there are ten construction sectors, these would need to be weighted by their relative importance.

A mathematical description of these procedures is provided in Figure 9 later in this report. The procedure is well suited to computerization using a spreadsheet such as Lotus 123. The example provided on the disk takes 3 technologies and two construction sectors to indicate the nature of the data required. These data are the amount of money spent in each technology and the total amount of money spent in the sector.

INTERPRETING INDEXES

If the Corps' performance was relatively IDENTICAL to that of the private sector, (i.e. the Corps adopts new technology at a similar rate to the private sector), the index will be equal to 1. This holds true for individual indexes, sector indexes as well as the summary index.

If the Corps is adopting new technology at a GREATER rate than the private sector the indexes will be greater than 1.

If the Corps is adopting new technology at a LESSER rate than the private sector, the indexes will be less than 1.

It is to be expected in any "real world" application that indexes for individual technologies and construction sectors are likely to range from less than 1, through equal to 1, to greater than 1, indicating the Corps' in various activities. The summary index will indicate the Corps' overall performance in such complex comparisons.

DETERMINING THE TIME OF AVAILABILITY

This would seem to be straight forward. The first appearance of a technology in advertising, or the first use in a project would be events that ought to be identifiable, and data acquirable. The time at which a technology captures X% of a market might also be identifiable, although acquisition of this information would be considerably more complicated. It is important to distinguish between a technology in the generic sense, and any specific example of "exterior insulation systems", and its share in the "exterior wall market", not necessarily the introduction of DRYVIT, or DRYVIT's share of the "exterior insulation market".

"Availability" to the construction market can be defined as the general time frame at which marketing the first example of the generic technology type is initiated (i.e. advertised or otherwise) and can be applied to a "common" construction project. Precision in time is not required. It is doubtful that any existing data would contain the Contact with the technology's developers and proponents should identify availability time with a reasonable degree of accuracy. Supporting documents/evidence can be requested.

DETERMINING THE TIME OF ADOPTION

"Adoption" can be defined as the point when an item becomes acceptable or accepted practice; when it can be applied without any extraordinary consideration (i.e. product research, criteria waivers, code approval, etc.) and given equal credibility as the traditional or status-quo practice. This would occur when 1) the regulatory/ approval environment allows, and 2) when the item attains a degree of acceptability and is used routinely with confidence.

The times at which code approval or the issuance of the implementing engineering guidance or criteria ought to be readily identifiable. Data may be obtained from the regulatory entity and/or form the proponent of the technology.

Determining whether or not a technology has actually been adopted as accepted practice becomes much more imprecise. By necessity, this feature would be determined essentially on a subjective basis. It should indicate TRENDS rather than a precise date or duration of time. An expert opinion/case-study approach can be taken. Expert opinion can be solicited to assess the adoption of a given technology. Design professionals and the proponents of the technology would be the major contributors, and ought to reflect the acceptance and use of a technology in practice (i.e. the "state-of-the-market") with an acceptable level of accuracy. Supporting evidence should be required from the experts. This would include a description of the code/regulatory/ guidance environment and presentation of case studies on the subject technologies.

The appropriate rigor or precision needed for this expert adoption assessment would have to be determined. There would seem to be a point of diminishing return, beyond which additional effort will result in little appreciable improvement in results.

DETERMINING OPPORTUNITIES

An opportunity to use a technology exists when the use of the technology is both possible and feasible. "Feasibility" also seems to imply that the technology is adopted (i.e. can be used without extraordinary consideration) and that its use would result at least in equivalent performance and economy compared to the traditional or status-quo practice.

Determining the instances where a technology could legitimately have been used throughout an owner/builder's construction program can be determined through a "parametric" approach, or through a case-specific investigation. The preferable approach may vary with the specific technology.

The occurrence (existence, magnitude, cost) of any building system/component/item within a particular building type can be identified through commonly available data. Systems- and component- specific data is available through such sources as Dodge and Means estimating manuals. The occurrence of sub-components and materials may have to be interpolated or calculated, based on the component data. This should be an achievable operation.

In some cases, legitimate applicability could be judged only by project-specific conditions (i.e. environmental conditions or design requirements). The technology would be applicable to the specific item, but only under given conditions. Project-specific studies would be necessary to determine these cases. The occurrence of the particular item would have to be identified (same as above). The conditions which would permit application of the technology would have to be identified, and compared to the specific conditions surrounding the project being examined. An assessment would be made indicating whether or not there was a legitimate opportunity to use the technology.

In either case, an "opportunity" factor should be able to be assessed or calculated for any type of building technology. A sample approach may be more realistic to accomplish than an examination of several hundred projects per year. A sample must be developed to be representative of the general construction program for both the Corps and private owner/builders.

The success of either of these approaches depends on the availability of construction program data; line-item descriptions of individual projects indicating building type, size or scope, location, and maybe cost. These are available for Corps projects and ought to be available from most major corporate owner/builders as well.

DETERMINING APPLICATION

Actual applications of a given technology will probably have to be accomplished on a case-specific basis. Project documents or completed facilities would have to be examined. A sample approach may be more realistic to accomplish than an examination of several hundred projects per year. This sample must be comprehensive enough to represent "Corps" or "private" design and construction trends, while at the same time be compact enough to be achievable. Perhaps 20 or 30 projects per year would be appropriate.

The success of this approach depends on the availability of project documentation. Project documents should be available for all Corps projects, although retrieval of older project documents may be extremely inconvenient. Private owner/builders may or may not have this information at hand, although most should.

INDEX COMPOSITION

Perhaps a simple "number of occurrences" would provide an equally valid ratio, without necessitating extensive cost research (i.e. "four out of a possible twenty"). Alternatively, a comparison of the magnitudes may be preferable (i.e. 400,000 SF out of a possible 20,000,000 SF).

An "adoption factor" can be calculated for each technology area, for each of the Corps and private sectors (i.e. appl's/oppr's; in number of occurrences, units used, etc.). An index for any particular technology area could be a ratio of the "adoption factors", i.e. a ratio of ratios.

<u>appl's/oppr's -- Corps</u>
appl's/oppr's -- private

which is:

<u>adoption factor -- Corps</u>
adoption factor -- private

If the ratio is 1, the Corps is doing "better" than private owner/builders; if 1, the Corps is doing "worse". If the sub-indices for each technical area were to be weighted according to its relative economic contribution (I'm not sure that's necessary anyway) a simple proportional factor might be used rather than a direct cost comparison.

COMPARATIVE EVALUATION OF PROPOSALS

Proposal 1a does not offer an index but suggests continuation of the existing practice of responding to each criticism as they occur.

Proposal 1b suggests the creation of an index based on cumulative ratios of applications/opportunities of selected new technologies. The proposal does not address the problem of identifying relevant new technologies or methods. Gathering applications may be relatively straightforward, but identifying valid opportunities for application is likely to be more problematic.

Proposal 2 identifies some of the problems associated with defining what are new technologies and whether or not a particular technology is appropriate to the USACE's mission. A suggestion is also made that a panel of experts may be needed to make a final selection of the new technologies to be used in calculating a Technology Adoption Index. It also discusses the concept of a time line approach to adoption by the USACE and industry. It is made clear in this proposal that a case study application is needed to determine the usefulness or otherwise of suggested data sources and as a check on the validity of comparisons to be made in calculating the index.

Proposal 3 suggests changes in codes and specifications as the definition of new technology adoption. This is problematic as many changes are not technology related and those that are may not be obvious from the changes made. Also significant but incremental developments in an established technology may not appear in a code at all. This situation may be overcome by including an expert panel of review to advise on the final selection of technologies to be included in any technology adoption index calculations. Another difficulty with using code and specification changes is their frequency, often only each 5 years. It is likely that the USACE will want to calculate technology adoption indexes more frequently than at 5 year intervals. This proposal expands the screening process for new technologies on the basis of "worthiness" using cost benefit, life cycle cost comparison of old and new technologies. An implementation factor is described but it would suffer from the same difficulties in determining valid opportunities as described in proposal 1. While the method for combining indexes from each technology studied is relatively simple, the result has no particular meaning in itself and is only meaningful in terms of comparison with the corresponding index for the civilian or other sector of the construction industry.

Proposal 4 is similar to proposal 3 but it does identify additional sources of data to aid identification of new technologies. A significance ratio and a risk index are suggested as ways of qualifying a technology adoption index. While the significance index will indicate the level of investment associated with a technology it may work against the adoption of inexpensive but effective technology. The risk index is probably more valuable as a qualifier of a technology index as there have been numerous cases of costly failures of new technologies.

Proposal 5 illustrates the benefits of including a non-engineering, non-architectural person in the study group. This proposal stresses methodology and clearly outlines a number of quantities leading to a single meaningful index. It does not address the problems of identifying new technologies for such a study but does stress the need for care in sampling USACE and civilian projects to ensure validity of comparisons.

DISCUSSION

After careful consideration of all five proposals it was felt that the simple but strong methodology described in proposal 5 deserved recommendation. At the same time the emphasis on the need for careful sampling of projects from the Corps and elsewhere to ensure they were comparable projects in scale, application, building type and region. A case study seems to be the only way to identify the extent of the problems associated with choosing comparable sample projects on which to assess technology adoption. More study is needed also to refine techniques for identifying appropriate new technologies to survey and how to determine what could have been valid applications (opportunities) for each technology. In itself, the identification of all relevant new technologies on a periodic basis should be beneficial to the Corps. The risk index seems a useful and valid concept for qualifying a calculated TAI in view of the limited track record of many new technologies.

Both consultant critics identified potential difficulties in identifying the "new technologies" and finding appropriate projects for comparative evaluation. Neither critic suggested that the proposed TAI would not work. This suggests that the ongoing thrust of the project should be to tackle the potential problems associated with identifying new technologies and assembling valid cost data for calculating weighting factors for the TAI indexes.

One critic suggested that money spent on a technology may reflect the degree of consideration given to the adoption of that technology. One viable alternative is to substitute the number of times a technology was used versus the number of opportunities to use the technology. The formulation of the index overcomes any such problem by insisting that cost data be drawn from compatible projects selected with care by experienced professionals.

The way the USACE does business has been raised as a reason why comparisons of construction projects may be invalid. TAI is directed at quantifying new technology adoption which may show how "the way the Corps does business" affects its adoption of new technologies. This would lead to a judgement call as to which is of greater importance, the way the Corps does business or more effective adoption of new technologies. It was suggested that a factor be included in the TAI to account for variation in risk/reward situations between the private sector of the construction industry and the Corps operations. Such a factor would be extremely difficult to enumerate and would compromise the classic simplicity of the TAI as it is proposed. If such a factor was included it could be interpreted by other industry sectors as a fudge factor to achieve a desired result for the Corps. Other reviewers reject such a "factor" in favor of a well argued explanation of the differences between USACE and private sector projects under evaluation. Where the proposed TAI indicates significant differences between the Corps and another sector of the construction industry, then it may be possible in some cases to show that the differences result from differing risk/reward management policies between industry sectors.

Despite the general feeling by industry experts both nationally and internationally that development of a technology adoption index would be an extremely challenging task, the ideas suggested in the various proposals by the study group indicated such an index is feasible. The next step is clearly to mount a pilot study to investigate further the concepts and difficulties outlined in this preliminary study. Letters indicating interest in such a project are included in the appendices from NIBS and Heery International.

APPLICATIONS FOR TAI

If data collection for the TAI can be organized as a routine activity in construction projects, the calculation of indexes is so simple that construction industry management could use TAI's on a routine basis as a tool to compare technology adoption performance within their organization or with competitors. Many economists predict a downturn would increase competition and encourage more effective management including new technology adoption, particularly where it can be shown to be cost effective.

AS A MANAGEMENT TOOL

Within public and private sector construction organizations, TAI can be used as a management tool to review historical performances in new technology adoption and help to identify relative performance in all aspects of projects, planning, programming, design, construction, operation and maintenance, and utilization. These relative performance studies can be used as a management tool to identify areas of effective technology adoption as well as areas that may require more attention. Over a longer period, review of projects could indicate the historical rates of progress or regression in new technology adoption.

IN CASE STUDIES

In the short term, until it can be demonstrated that a TAI can and will be developed, a "case studies" approach may be justified. This could be an "Answer the Mail" approach as suggested by Professor Riggs or the "Case Study" approach suggested by Professor Jeter.

Much could be learned from some case studies of past adoption mechanisms used by the Corps. What technologies were adopted sooner than the private sector, later than the private sector or never adopted. In each case, the question must be answered as to why such happened and what were the consequences. For example: what were the costs of delaying the use of a new beneficial technology (e.g., decreased initial costs or life-cycle costs or enhanced system performance)? Did a new technology turn out to be less than originally expected? What was the cost of failure? Valuable insights into the Corps ad-hoc technology adoption mechanisms may be identified and a better process established to maximize the adoption of beneficial new technologies while reducing the risk of failure. Case studies can also show us how we compare to the private sector. They just do not lend themselves to a numerical/periodically updated comparison, however.

Should the cost of industry-wide data collection for routine calculation of TAI prove to be excessively costly, the same TAI procedures can be applied in case studies performed on USACE projects to reply to specific inquiries from congress. The inclusion of TAI's in such reports would quickly establish TAI as a general relative index of Corps performance and provide a means of historical comparison between case studies. In case studies the particular technologies would normally be identified which would eliminate the need for a survey to identify newly adopted technologies. Reference projects for comparison with USACE subject projects would still need to be identified but again these would be limited by the scope of each particular case study.

COST ESTIMATES FOR DEVELOPMENT AND MAINTENANCE OF A TAI

Ongoing TAI Team

To operate the TAI as an ongoing activity, the "delphi" group of experts would need to be selected and serviced by an in-house CERL group of data collectors and processors. An annual estimate for this approach is given below:

Delphi Group:

Say 5 members independently reviewing material supplied by the clerical support team at CERL.

5 members @ 14 days per year @ $500/day	= $ 35,000

Clerical data support team:

Say 1 man/yr at USA CERL + clerical overheads	= $ 90,000
	= $125,000

Individual Case Study:

1/2 man/yr + clerical overheads	= $45,000/study

RECOMMENDED PROCEDURE

The recommendation is for implementation of a "relative" index approach as opposed to an "absolute" index approach. The idea is not to compare Corps construction activity to some absolute norm, in terms of what technology ought to be used, rather simply to compare the Corps' activity to the industry as a whole. This approach would develop three levels of indexes.

1. CONSTRUCTION/TECHNOLOGY INDEX I(j,k)
   (as described in proposal # 5)

Each index would be a ratio with the numerator being the money spent by the Corps in that technology divided by the total amount of money spent by the Corps in that sector. To ensure that this gives a reasonable number, initial trials may experiment with division by a suitable subtotal. The denominator is a similar ratio for private sector activity for a comparable sample to that used for the Corps' sample.

"New technologies" would be defined as those associated with changes in industry accepted building codes, industry association specifications and materials and products indexes. Lists from these and other sources would be identified and edited by a panel of industry/Corps experts under the cognizance of a neutral third party such as a university organization. These experts would also supervise the selection of comparable sample projects executed by the USACE and others to be provide the data for analysis.

2. CONSTRUCTION SECTOR INDEXES W(j,k)

Each W(j,k) is a weighting factor being the relative value of that technology among all of the technologies being considered. The sum of all weightings then adds up to one.

3. SUMMARY OVERALL INDEX I

An overall index for the Corps or the private sector I, can be calculated by using a weighted aggregation of indexes across all industry sectors. If there are ten construction sectors, these would need to be weighted by their relative importance.

The procedure is well suited to computerization using a spreadsheet such as Lotus 123.

The example provided later in this report takes three technologies and two construction sectors to indicate the nature of the data required. These data are the amount of money spent in each technology and the total amount of money spent in the sector.

INTERPRETING INDEXES

If the Corps' performance was relatively IDENTICAL to that of the private sector, (i.e. the Corps adopts new technology at a similar rate to the private sector), the index will be equal to 1. This holds true for individual indexes, sector indexes as well as the summary index.

If the Corps is adopting new technology at a GREATER rate than the private sector the indexes will be greater than 1.

If the Corps is adopting new technology at a LESSER rate than the private sector, the indexes will be less than 1.

It is to be expected in any "real world" application that indexes for individual technologies and construction sectors are likely to range from less than 1, equal to 1 and greater than 1, indicating the Corps' in various activities. The summary index will indicate the Corps' overall performance in such complex comparisons.

EXAMPLE ILLUSTRATING RECOMMENDED PROCEDURE

Definitions

j	Index of types of construction (e.g. multi-unit residential) j = 1 ... j
k	Index of technologies (e.g. heat pumps), k = 1 ... k
s	Index of sectors (e.g. Corps or Private), s = c or p
$T(j,k,s)	Dollars spent in construction type j on technology k by sector s, (note: $T(j,k,p) must be positive).
$C(j,s)	Total dollars spent on construction type j by sector s.
I(j,k)	Index of Corps' use of technology k in construction type j.
I(j)	Index of Corps' use of all k technologies in construction type j.
I	Index of Corps' use of all k technologies in all j types of construction.
W(j,k)	Weighting factor applied to I(j,k) in calculation of I(j).
W(j)	Weighting factor applied to I(j) in calculation of I.

Formulae

$$W(j,k) = \frac{\$T(j,k,c) + \$T(j,k,p)}{SUM(k)[\$T(j,k,c)] + SUM(k)[\$T(j,k,p)]}$$

$$W(j) = \frac{\$C(j,c)}{SUM(j)[\$C(j,c)]}$$

$$I(j,k) = \frac{\$T(j,k,c)/\$C(j,c)}{\$T(j,k,p)/\$C(j,p)}$$

$$I(j) = SUM(k)[I(j,k)*W(j,k)]$$

$$I = SUM(j)[I(j)*W(j)]$$

<u>Data</u>

To demonstrate the procedure the following data will be used:

Corps Data:

Type of Construction	Dollars spent in const. j on technologies k (1,2,3)			Total dollars const.j, sect c
j	$T(j,1,c)	$T(j,2,c)	$T(j,3,c)	$C(j,c)
1	$50.00	$10.00	$100.00	$20,000
2	$ 5.00	$50.00	$ 0.50	$ 2,500

Private Sector Data:

Type of Construction	Dollars spent in const. j on technologies k (1,2,3)			Total dollars const.j, sect c
j	$T(j,1,c)	$T(j,2,c)	$T(j,3,c)	$C(j,c)
1	$100.00	$20.00	$400.00	$40,000
2	$ 5.00	$25.00	$ 1.00	$ 2,500

Weighting Factors for Construction Sector Indexes

Using the above data Weighting Factors for calculation of I(j)'s are:

$$W(j,k) = \frac{\$T(j,k,c) + \$T(j,k,p)}{SUM(k)[\$T(j,k,c)] + SUM(k)[\$T(j,k,p)]}$$

$$W(1,1) = \frac{(50) + (100)}{(50 + 10 + 100) + (100 + 20 + 400)}$$

$$= \frac{150}{680}$$

$$= 0.2206$$

$$W(1,2) = \frac{(10) + (20)}{(50 + 10 + 100) + (100 + 20 + 400)}$$

$$= \frac{30}{680}$$

$$= 0.0441$$

$$W(1,3) = \frac{(100) + (400)}{(50 + 10 + 100) + (100 + 20 + 400)}$$

$$= \frac{500}{680}$$

$$= 0.7353$$

$$W(2,1) = \frac{(5) + (5)}{(5 + 50 + 0.5) + (5 + 25 + 1)}$$

$$= \frac{10}{86.5}$$

$$= 0.1156$$

$$W(2,2) = \frac{(50) + (25)}{(5 + 50 + 0.5) + (5 + 25 + 1)}$$

$$= \frac{75}{86.5}$$

$$= 0.8671$$

$$W(2,3) = \frac{(0.5) + (1)}{(5 + 50 + 0.5) + (5 + 25 + 1)}$$

$$= \frac{1.5}{0.0173}$$

Weighting Factors applied to I(j) in calculation of Summary Overall Index I are:

$$W(j) = \frac{\$c(j,c)}{SUM(j)[\$c(j,c)]}$$

$$W(1) = \frac{20,000}{22,500}$$

$$= 0.8889$$

$$W(2) = \frac{2{,}500}{22{,}500}$$

$$= 0.1111$$

Indexes

Corps' Construction/Technology indexes for use of all k technologies in construction type j are:

$$I(j,k) = \frac{\$T(j,k,c)/\$C(j,c)}{\$T(j,k,p)/\$C(j,p)}$$

$$I(1,1) = \frac{50 / 20{,}000}{100 / 40{,}000}$$

$$= \frac{0.0025}{0.0025}$$

$$= 1.0000$$

$$I(1,2) = \frac{10 / 20{,}000}{20 / 40{,}000}$$

$$= \frac{0.0005}{0.0005}$$

$$= 1.0000$$

$$I(1,3) = \frac{100 / 20{,}000}{400 / 40{,}000}$$

$$= \frac{0.005}{0.010}$$

$$= 0.5000$$

$$I(2,1) = \frac{5 / 2{,}500}{5 / 2{,}500}$$

$$= 1.0000$$

$$I(2,2) = \frac{50 / 2{,}500}{25 / 2{,}500}$$

$$= 2{,}0000$$

$$I(2,3) = \frac{0.5 / 2{,}500}{1.0 / 2{,}500}$$

$$= 0.5000$$

Corps' Construction Sector indexes for use of all k technologies in construction types j are:

I(j) = SUM(k)[I(j,k)*W(j,k)]

I(1) = [(1*0.2206) + (1*0.0441) + (0.5*0.7353)]

= 0.6324 (i.e. less than private sector)

I(2) = [(1*0.1156) + (2*0.8671) + (0.5*0.173)]

= 1.8584 (i.e. greater than private sector)

Corps' Summary Overall index for adopting all k technologies in all j types of construction is:

$$I = SUM(j)[I(j)*W(j)]$$

$$= [(0.6324*0.8889) + (1.8584*0.1111)]$$

$$= 0.7686 \text{ (i.e. less than the private sector)}$$

It can be seen from the comments on interpreting this index that in this hypothetical example the value of the index, being less than 1, would indicate that the Corps is adopting the chosen technologies LESS than the private sector.

RECOMMENDATIONS

That a pilot study be undertaken to enable the concepts outlined in the previously described procedure to be evaluated using real world data on a small "expert" panel. Emphasis should be placed on investigating the difficulties associated with defining and identifying "new technologies"; and ensuring comparability between USACE projects and those by others. The usefulness or otherwise of significance factors, lead or lag time indexes and risk indexes in qualifying TAI's should also be evaluated.

Case studies of various technologies should be performed as an interim to further development of TAI. Case studies will allow a comparison between USA CERL and private sector activities and help the Corps better understand and improve its own adoption mechanisms. Execution of several case studies may also help in the establishment of the "delphi panel".

CONCLUSIONS

1. Consensus among investigators and commentators that a workable index of Technology Adoption is feasible along the lines proposed in this report.

2. While the use of dollars as a unit of measurement is simple, obtaining accurate itemized costs on projects could be a sensitive and difficult task. It has been pointed out in the report that the TAI index proposed would work equally well using numbers of applications of a technology versus the opportunities available for applications. Measurement could be simply as numbers of applications or square feet/cubic feet of applications etc., which ever was appropriate to each particular technology.

3. Much could be learned from some case studies of past technology adoption practices used by the Corps and private sector organizations during a common time frame. Relative speed of adoption by each could also reveal the reasons behind differing adoption rates as well as the consequences of adopting technologies at the observed rates. Some consequences of delaying the adoption of new beneficial technologies could be decreased initial costs or life cycle costs and/or enhanced system performance. Alternately where a technology did not live up to initial expectations, some estimate of the cost of premature failure or poor performance could be evaluated. Case studies of this type by the Corps may identify procedures that would increase the success rate of newly adopted technologies and decrease the risk of costs associated with new technologies with a limited track record.

4. While case studies of technology adoption of particular technologies could provide interesting insights into the relative performance of the Corps versus private sector organizations, they could not provide any general comparative measure or index of the Corps' relative performance in technology adoption. Compilation of an index of technology adoption for various sectors involved in construction over a period of years could provide an interesting insight into the historical trends of technology adoption by each industry sector. Such trends could be used as a management tool to identify periods of relative success or failure as well as potential fruitful areas of new technology for adoption.

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National Institute of Building Sciences, The Construction Criteria Base (CD-ROM Federal Construction Specification, Standard, and Manual Guide Subscription Service for Personal Computers), Washington, D.C., pp. 50,000+.

SOURCES & RESOURCES FOR NEW TECHNOLOGIES

American Hardboard Association, Park Ridge, IL.

American Institute of Architects, Washington, D,C.

American Institute of Steel Construction, Chicago, IL.

American Institute of Timber Construction, Englewood, CO.

American National Standards Institute (ANSI), New York, NY.

American Plywood Association, Tacoma, WA.

American Society of Civil Engineers, New York, NY.

American Society of Mechanical Engineers, New York, NY.

American Society of Plumbing Engineers, Sherman Oaks, CA.

American Wood Preservers Institute, McLean, VA.

American Society for Testing and Materials, Philadelphia, PA.

Asphalt Institute, College Park, MD.

Asphalt Roofing Manufacturers Association, Washington, D.C.

Association of Wall and Ceiling Industries, Washington, D.C.

Brick Institute of America, McLean, VA.

Builders Hardware Manufacturers Association, New York, NY.

Building Officials and Code Administrators International, Inc., Homewood, IL.

Carpet and Rug Institute, Dalton, GA.

Cellulose Insulation Association, Salt Lake City, UT.

Center for Building Technology - National Bureau of Standards, Washington, D.C.

Ceramic Tile Institute, Los Angeles, CA.

Department of Commerce, Product Standards, Washington, D.C.

Dept. of Housing & Urban Development (HUD) Minimum Property Standards, Washington, D.C.

FHA Housing Programs, Material Releases for Specific Proprietary Products, Washington, D.C.

The Fiberglass Fabrication Association, Fabrication News, Monthly Journal, Washington, D.C.

General Services Administration, Federal Specifications, Washington, D.C.

Gypsum Association, Evanston, IL.

Illuminating Engineering Society of North America, New York, NY.

International Conference of Building Officials, Whittier, CA.

Metal Building Manufacturers Association, Cleveland, Ohio, MBMA Fact Book, 1988.

Military specifications

NAHB Research Foundation, Inc. (National Association of Home Builders), Rockville, MD.

National Association of Architectural Metal Manufacturers, Chicago, IL.

National Building Code, New York, NY.

National Fire Protection Association, Washington, D.C.

National Particleboard Association, Silver Spring, MD.

National Precast Concrete Association, Indianapolis, IN.

Plastics in Construction Council, New York, NY.

Prestressed Concrete Institute, Chicago, IL.

Resilient Floor Covering Institute, Washington, D.C.

Sealed Insulating Glass Manufacturers Association, Chicago, IL.

Southern Building Code Congress International, Birmingham, AL.

Steel Deck Institute, St. Louis, MO.

Underwriters Laboratories Inc., Building Materials Directory, Jan. 1988.

Urethane Institute, New York, NY.

U.S. Forest Products Laboratory, Madison, WI.

Zinc Institute, Inc., New York, NY.

CONTACTS USED IN STUDY

Dr. Don Gibson. C.S.I.R.O. Division of Construction & Energy, Highett, VIC. Australia.

Dr. Gy Sebestyen, Secretary, International Council for Building Research Studies & Documentation, Rotterdam, Netherlands.

Dr. J.B. Menzies, Assistant Director, Building Research Establishment, Garston, Watford, Herts, United Kingdom.

Dr. Phil Schneider, National Institute of Building Sciences, Washington, DC.

Chuck McGinnis, Construction Industry Institute, University of Texas at Austin.

Bob Gold, National Association of Home Builders, Research Foundation, 627 Southlawn Ln., Rockville, MD 20852.

Andrew Nemmer, Building Research Board, 202-334-4319

Ed Beardsworth, Electric Power Research Center, 415-855-2740

Bob Gasperow, Construction Labor Research Council, 202-223-8045

Portland Cement Association, 312-966-6200.

American Society for Testing and Materials, 215-299-5400.

Mike King, American Institute of Architects, Research and Planning, 1735 New York Ave. N.W., Washington, D.C. 20006, (202) 626-7300.

American Concrete Institute, (313) 532-2600.

National Bureau of Standards, Center for Building Technology, Gaithersburg, Maryland 20899, (301) 975-5905.

APPENDIX

APPENDIX 1

CodeWORKS has released its proposed schedule for adding metropolitan jurisdictions to its CodeCONTROL database. The CodeCONTROL database will cover the entire United States by the end of 1989.

The CodeCONTROL database contains technical summaries of model, state, and local building regulations. You can search more than 750 code subjects -- as they apply to a specific project in a specific jurisdiction -- from the locally adopted versions of each of these seven codes:

Building Code

Life Safety Code

Handicapped Accessibility Code

Fire Prevention Code

Plumbing Code

Mechanical Code

Energy code

There are four kinds of CodeCONTROL reports:

1. Global Reports contain technical summaries of all applicable code requirements for a given project. There are three types of Global Reports: Comprehensive, Architectural, and Mechanical/ Electrical. The Global Report should be ordered when the most basic decision about a building project -- such as occupancy, construction type, structural systems, major materials, and approximate height and area -- have been made.

2. Administrative Reports identify (by name and edition) the codes adopted by any jurisdiction in the CodeCONTROL database. They also include the titles, addresses, and phone number of each code enforcing authority within the jurisdiction. The Administrative Report should be requested at the onset of a building project and again before ordering a Global Report.

3. Comparative Reports allow the user to perform "what if" queries by comparing a changed set of building conditions against an existing Global Report. The Comparative Report should be ordered when the original design has been modified and information is needed on what effects the modifications will have on code requirements.

4. Specific Reports identify code requirements that apply to a particular design issue or question.

To request a CodeCONTROL search, the user can fill out a short questionnaire, which can be sent to CodeWORKS either electronically through our PC or by mail.

The tentative schedule for adding jurisdictions is as follows:

Third Quarter 1988

Maryland -- Baltimore

New York -- Albany, Buffalo, New York City, Rochester, Syracuse

North Carolina -- Charlotte, Durham, Greensboro, Raleigh, Winston-Salem

Tennessee -- Chattanooga, Knoxville

Virginia -- Newport News, Norfolk, Richmond, Roanoke

Washington, D.C.

Fourth Quarter 1988

Kentucky -- Frankfurt, Lexington, Louisville

Ohio -- Akron, Dayton, Cincinnati, Cleveland, Columbus, Toledo

Pennsylvania -- Harrisburg, Philadelphia, Pittsburgh

First Quarter 1989

California -- Anaheim, Bakersfield, Fresno, Long Beach, Los Angeles, Modesto, Oakland, Sacramento, San Bernadino, San Francisco, San Jose, Stockton

Oregon -- Portland

Washington -- Spokane

Second Quarter 1989

Arizona -- Phoenix, Tucson

Colorado -- Colorado Springs, Denver, Pueblo

Illinois -- Chicago, Peoria, Rockford, Springfield

Indiana -- Evansville, Fort Wayne, Indianapolis, South Bend

Iowa -- Cedar Rapids, Davenport, Des Moines

Kansas -- Kansas City, Topeka, Wichita

Michigan -- Detroit, Flint, Grand Rapids, Lansing, Madison, Milwaukee

Missouri -- Kansas City, St. Louis

Nebraska -- Lincoln, Omaha

New Mexico -- Albuquerque

Nevada -- Las Vegas, Reno

Texas -- Amarillo, Austin, Beaumont, Corpus Cristi, Dallas, El Paso, Fort Worth, Houston, Lubblock, Oklahoma City, San Antonio, Tulsa, Waco

Metropolitan areas already covered by CodeCONTROL include:

Alabama -- Birmingham, Montgomery

Connecticut -- Hartford, New Haven, Stamford

Florida -- Fort Lauderdale/Hollywood, Jacksonville, Miami, Orlando, Tampa/St. Petersburg, West Palm Beach

Georgia -- Atlanta, Columbus, Macon, Savannah

Massachusetts -- Boston

New Jersey -- Newark, Trenton

Rhode Island -- Providence

South Carolina -- Columbia

Tennessee -- Memphis, Nashville

Prices:

Administrative Reports are $25 plus the cost of delivery other than first class mail. If you need administrative information immediately, call CODEWORKS Professional Services at 1-800-634- CODE and specify the jurisdiction. They will answer questions over the telephone and will mail you a copy of the administrative report the same day.

The prices for other reports are:

Global Comprehensive Report $350

Global Architectural Report $200

Global Mechanical/Electrical Report........$200

Comparative Report $100

Specific Report ....$ 25

APPENDIX 2

Letters

Proposal

National Institute of
BUILDING SCIENCES
1201 L Street, N.W., Suite 400
Washington, D.C. 20005
(202) 289-7800
FAX (202) 289-1092

June 5, 1989

Dr. Richard Aynsley
Old Architecture Building
Room 119
Campus Drive
College of Architecture
Georgia Institute of technology
Atlanta, Georgia 30332

Dear Dick:

Attached is a proposal, work plan and a budget for convening an expert panel to identify new building technologies for the development of the Technology Adoption Index.

Please let me know the name of the person in the Army Corps of Engineers to whom this proposal will be forwarded.

If you have any questions concerning this material please do not hesitate to call me.

Respectfully,

Philip J. Schneider
Director of Technical Programs

Enclosures

PROPOSAL TO ESTABLISH
A PANEL OF EXPERTS TO IDENTIFY NEW BUILDING TECHNOLOGIES
FOR THE U.S. ARMY CORPS OF ENGINEERS

June 5, 1989

The U.S. Army Corps of Engineers (The Corps) currently has no means to determine the timeliness of their use of new building construction technologies, including building systems and materials, either in absolute terms or compared to other similar owners and users of built facilities. A method called a technology adaption index (TAI) has been developed by Georgia Institute of Technology (GIT) whereby the Corps can determine where it could and ought to respond to the changes and innovations in technologies and adapt these new technologies into their building program.

As part of the development of the TAI, new construction technologies must be identified. For this effort, GIT has asked the National Institute of Building Sciences (NIBS) to submit a proposal to convene a panel of building community experts to develop lists of new construction technologies. From the lists the panel will select sample technologies for the Corps to use in testing and developing the TAI.

The panel will consist of twenty or more volunteers to be chosen from associations, government, academic and research institutions, A-E firms, contractors, and product manufacturers. Representatives from the Corps will also be asked to participate on the panel. Travel expenses will be provided for a number of out-of-town volunteers. Gathering of data on new technologies, development of a technology list and writing a report will be performed by NIBS staff in cooperation with the panel. The panel will be responsible for defining the scope of technologies to be gathered, reviewing the list of technologies developed, and reviewing drafts of the report. NIBS will also provide an oversight management function. The project is estimated to last ten months and cost $125,000.

After identification of the new technologies by NIBS and subsequent implementation of the TAI by the Corps, the entire system would provide a means for the Corps to regularly assess its performance in adopting new construction technologies relative to the Corps headquarters' established projections. The development of such a system offers two main benefits. First, it would provide the Corps headquarters a means to make an informed response to inquiries relative to the Corps' adaption of newly developed market-ready construction technologies. Such inquires typically come from government regulators, i.e., legislators, as well as building industries proponents of new technologies. Second, by having the system as a composite of indicators, the Corps could evaluate its progress in adopting new technologies (both compared to the general construction industry and within the Corps over time) in order to identify areas where responsiveness to new technologies ought to be enhanced, and technology adoption ought to be accelerated.

WORK PLAN TO ESTABLISH A PANEL OF EXPERTS
TO IDENTIFY NEW BUILDING TECHNOLOGIES
FOR THE US ARMY CORPS OF ENGINEERS

June 5, 1989

Phase I - Project Development

Four weeks

1. Staff assembles a panel of building experts.

   a. Develop a list of panel applicants according to the following eight disciplines:

      Civil engineering
      Architecture
         Construction
         Construction materials
      Fire engineering
      Energy
      Structural engineering
      Mechanical engineering
      Electrical engineering

   b. Select panel participants for each discipline.

   c. Develop and send a project information package.

Subtotal for Phase I =
Four weeks

Phase II - New Technology Identification

Four weeks

1. First meeting of the panel.

   a. Identify scope of new technologies.

   b. Identify sources of newly adopted building technologies from changes in building codes, changes in industry standards and specifications, and periodical literature.

   c. Develop guidelines for identification of new technologies from sources.

Subtotal for Phase II =
Four weeks

Phase III - Document Acquisition

Note: the following are partial lists to be further developed as part of Phase III.

<u>One week</u> 1. Planning

<u>Six weeks</u> 2. Document Acquisition

a. Staff acquires the following building codes and standards.

National Building Code
Standard Building Code
Uniform Building Code
National Plumbing Code
Life Safety Code
National Gas Code
National Electrical Code

b. Staff acquires the following industry and association standards and specifications.

ANSI standards
ASTM standards
AIA MASTERSPEC
McGraw-Hill's SweetSpec and SweetSearch
ACI's concrete specifications
Underwriters Laboratories
Mean's Cost Data

c. Staff acquires the following federal government standards and specifications.

Department of Energy criteria
NAVFAC criteria
Veterans Administration criteria
NASA criteria

d. Staff acquires the following publications.

Automated Builder
Architectural Record
Architecture
Home Energy
Builder

<u>Subtotal for Phase III =</u>
<u>Seven weeks</u>

Phase IV - Development of Lists of New Technologies

<u>Eight weeks</u> 1. Staff documents new technologies according to guidelines developed by the panels.

a. Documentation is mailed to panel members.

<u>Four weeks</u> 2. Panel members receive and review new technology documentation.

<u>One week</u> 3. Second meeting of the panel.

a. Develop lists of new technologies.

b. Select sample projects for development by USACE.

<u>Subtotal for Phase IV = Thirteen weeks</u>

Phase V - Report Preparation and Review

<u>Four weeks</u> 1. Staff develops a first draft of a report listing new technologies and sample projects.

a. First draft is mailed to panel members.

<u>Two weeks</u> 2. First draft received and reviewed by panel members.

<u>One week</u> 3. Third meeting of the panel.

a. Develop guidelines for development of a second draft.

<u>Two weeks</u> 4. Comments incorporated into the first draft by staff to produce a second draft which is sent out to panel members for final comment.

<u>Two weeks</u> 5. Final comments received.

<u>Two weeks</u> 6. Final editing of the report.

<u>Two weeks</u> 7. Report approved by the NIBS Board of Directors.

8. Report delivered to USACE.

<u>Subtotal for Phase V = Fifteen weeks</u>

Summary Schedule

Four weeks	Phase I - Project Development
Four weeks	Phase II - New Technology Identification
Seven weeks	Phase III - Document Acquisition
Thirteen weeks	Phase IV - Development of List of New Technologies
Fifteen weeks	Phase V - Report Preparation and Review

Grand total for all phases =
Forty-three weeks or ten months

BUDGET FOR PROJECT MANAGEMENT
FOR ESTABLISHMENT OF A PANEL OF EXPERTS
TO IDENTIFY NEW BUILDING TECHNOLOGIES
FOR THE US ARMY CORPS OF ENGINEERS

June 5, 1989

Phase I - Project Development

1. Assemble a panel of building experts.

Project manager	40 hrs.
Clerical	8 hrs.

2. Develop and send project information package.

Project manager	8 hrs.
Clerical	
Repro	4 hrs.
Mailing	4 hrs.

<u>Subtotals for Phase I</u>

Project manager.....................................48 hrs.
Clerical..16 hrs.

Phase II - New Technology Identification

1. First meeting of the panel.

Project manager	
Meeting preparation	4 hrs.
Meeting	8 hrs.
Meeting follow-up	4 hrs.
Travel requisitions	4 hrs.
Clerical staff	
Repro	4 hrs.
Notice mailings	4 hrs.
Room preparation	2 hrs.

<u>Subtotal for Phase II</u>

Project manager.....................................20 hrs.
Clerical..10 hrs.

Phase III - Document Acquisition

1. Project planning.

Project Manager	24 hrs.

2. Document acquisition.

Project Manager	100 hrs.
Staff researcher	100 hrs.

<u>Subtotal for Phase III</u>

Project manager....................................	124 hrs.
Staff researcher....................................	100 hrs.

Phase IV - Development of Lists of New Technologies

1. New technology documentation.

Project Manager	160 hrs.
Staff researcher	160 hrs.

2. Documentation dissemination.

Project Manager	8 hrs.
Staff researcher	8 hrs.
Clerical	
Repro	16 hrs.
Mailing	8 hrs.

3. Second meeting of the panel.

Project manager	
Meeting preparation	4 hrs.
Meeting	8 hrs.
Meeting follow-up	4 hrs.
Travel requisitions	4 hrs.

Clerical staff	
Mailing list	2 hrs.
Repro	4 hrs.
Notice mailings	4 hrs.
Room preparation	2 hrs.

Subtotal for Phase IV

Project manager	188 hrs.
Staff researcher	168 hrs.
Clerical staff	36 hrs.

Phase V - Report Preparation and Review

1. Prepare a first draft report.

Project manager	80 hrs.
Staff researcher	80 hrs.
Clerical staff	
Repro	8 hrs.
Report mailing	4 hrs.

2. Third meeting of the panel.

Project manager	
Meeting preparation	4 hrs.
Meeting	8 hrs.
Meeting follow-up	4 hrs.
Travel requisitions	4 hrs.
Clerical staff	
Mailing list	2 hrs.
Repro	4 hrs.
Notice mailings	4 hrs.
Room preparation	2 hrs.

3. Prepare a second draft report.

Project manager	40 hrs.
Staff researcher	40 hrs.
Clerical	
Repro	8 hrs.
Report mailing	4 hrs.

4. Final editing.

Project manager	20 hrs.
Staff researcher	20 hrs.

5. Report approved by the NIBS Board of Directors.

Project manager	8 hrs.
Clerical staff	
Repro	8 hrs.
Report mailing	4 hrs.

6. Report delivered to EPA and project close-out.

Project manager	24 hrs.

Subtotal for Phase V

Project manager......................................192 hrs.
Staff researcher.....................................140 hrs.
Clerical staff..48 hrs.

Budget Summary

Direct Costs

Personnel

Director: 40 hrs. @ 25.97 per hr............................$1,039
Project manager: 572 hrs. @ $21.64 per hr...................$12,378
Staff researcher: 408 hrs. @ $13.47 per hr..................$5,496
Clerical staff: 110 hrs. @ $11.54 per hr....................$2,479

Subtotal..$21,392

Fringes and Inflation

Fringes: 44% of personnel costs.............................$9,883
Inflation: 5% of personnel costs............................$1,070

Subtotal..$10,953

Expenses

Travel: 15 members x 3 trips x $1000 per trip...............$45,000
Telephone: $80 per mo. for 6 mos..............................$480
Postage: $70 per mo. for 6 mos................................$420
Printing/Reproduction...$2,000
Meetings..$300

Subtotal..$48,200

Total direct costs...$80,545

Indirect Costs

Overhead and G & A

Overhead: 1130 hrs. @ $23.00 per hr.........................$25,990
G & A: 19% of direct costs + overhead.......................$20,242

Total indirect costs...$46,232

Grand total...$126,777

Rob Dean, Vice President
Technical Services Group
Heery International
999 Peachtree St.
Atlanta, GA 30367

April 4, 1989

RE COST ESTIMATE FOR INFORMATION ON ANNUAL
LISTING OF NEW TECHNOLOGY ENTRIES IN SWEETSPEC DATABASE

Dear Mr Dean,

Further to our telephone conversation on April 3, I am writing to you to obtain an estimate of the cost for an annual listing of new technology entries in the Sweetspec database.

As I explained the purpose for this information is to to provide one of a number of raw sources of data from which significant newly adopted technologies can be selected by an expert panel as part of the calculation of a proposed Technology Adpotion Index (TAI) for the US Army Corps of Engineers. I have enclosed a copy of a draft report as further background on this project.

If possible I would appreciate this cost estimate within 2 weeks of the date of this letter in order to meet my report delivery schedule to CERL.

Yours sincerely,

Dr Richard Aynsley
Professor of Architecture
Principal Investigator

HEERY

April 7, 1989

Dr. Richard Aynsley
Professor of Architecture
Principal Investigator
College of Architecture
Georgia Institute of Technology
Atlanta, Georgia 30332-0155

Dear Dr. Aynsley:

In response to your request of April 4, I am pleased to provide this estimate of the cost for an annual listing of new technology entries in the SweetSpec database. As I told you yesterday, the additional effort required for us to code new technology information as it goes into our database should be quite minimal. However, the initial effort required to identify and code new technologies already in the database would be considerably greater. I have provided estimates for initial coding on an ongoing basis, and for identifying and coding existing entries.

	Time	Cost
Computer Programmer Time to Enable Coding of New Technology Entries and to Develop Simple Report of Printed Information.	16 hrs	$ 640
Specification Section Programmer Time Required to Code New Technology Entries for Initial Entry into the Database.	10 hrs	$ 800
Specification Section Programmer Time Required to Identify and Code New Technology Entries Already in the Database.	40 hrs	$3,200
Total for First Year		$4,640

An annual fee of approximately $800 would be charged for each additional year.

The time estimates are based on the assumption that the listing of new technologies provided will be a simple listing, including at most, the names of the new technologies entered during the year, the dates the entries were made, and the name of one manufacturer which could be contacted for further information.

Please call if you have any questions.

Sincerely yours,

Robert Paul Dean, AIA, CCS
Vice President

Heery International, Inc.
A group of design and professional service practices

999 Peachtree Street, N.E., Atlanta, Georgia 30367-5401, Telephone (404) 881-9880 Telex 54-2165

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Summary Report

on

DEVELOPMENT OF A TECHNOLOGY ADOPTION INDEX (TAI)

TO MEASURE THE EFFECTIVENESS

OF ADOPTING NEW BUILDING TECHNOLOGY

Performed under Indefinite Contract

No. DACA88-88-D-0020

By Georgia Tech Research Corporation,

College of Architecture's

CONSTRUCTION RESEARCH CENTER.

OCA Project #: D-48-615

Principal Investigator: Dr. Richard Aynsley

Date: October 23, 1988..

Summary Report

on

DEVELOPMENT OF A TECHNOLOGY ADOPTION INDEX (TAI)

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Principal Investigator: Dr. Richard Aynsley

Date: October 23, 1988..

CHECKED BOXES	[X] ORDER FOR SUPPLIES OR SERVICES	[ ] REQUEST FOR QUOTATIONS NO. RETURN COPY(IES) OF THIS QUOTE BY	PAGE 1 OF 3

1. CONTRACT/PURCH ORDER NO.	2. DELIVERY ORDER NO.	3. DATE OF ORDER	4. REQUISITION PURCH REQUEST NO.	5. CERTIFIED FOR NATIONAL DEFENSE UNDER DMS REG 1
DACA88-88-D-0020	0005	88 AUG 01	CERL-EN-87-055D, #5	DO C-2

6. ISSUED BY CODE A52AXN

US Army Construction Engineering Research Laboratory, 2902 Newmark Drive
P.O. Box 4005, ATTN: Contracts Branch
Champaign, IL 61820-1305

7. ADMINISTERED BY *(If other than 6)* CODE

POINT OF CONTACT: Ms. V. IVERSON 217/373-6798
OR: Ms. J. PERCIVAL 217/373-7297

8. DELIVERY FOB [X] DEST [ ] OTHER *(See Schedule if other)*

9. CONTRACTOR/QUOTER CODE FACILITY CODE

NAME AND ADDRESS

Georgia Tech Research Corporation
ATTN: Mr. R. D. Simpkins, Contracting Ofcr
Centennial Research Building
Atlanta, Georgia 30332-0420

10. DELIVER TO FOB POINT BY SEE SCHEDULE

11. CHECK IF BUSINESS IS [ ] SMALL [ ] SMALL DISADVANTAGED [ ] WOMEN-OWNED

12. DISCOUNT TERMS SEE CONTRACT

13. MAIL INVOICES TO SAME AS BLOCK 14

14. SHIP TO CODE

US Army Construction Engineering Research Laboratory, Interstate Research Park, Newmark Drive, P.O. Box 4005
Champaign, IL 61820-1305, ATTN: Rec. Clk.

15. PAYMENT WILL BE MADE BY CODE

DISBURSING OFFICER
US Army Engineers Waterways Exper. Sta.
PO Box 631
Vicksburg, Mississippi 39180-0631

MARK ALL PACKAGES AND PAPERS WITH CONTRACT OR ORDER NUMBER.

16. TYPE OF ORDER

DELIVERY [X] This delivery order is subject to instructions contained on this side of form only and is issued on another Government agency or in accordance with and subject to terms and conditions of above numbered contract.

PURCHASE: Reference your quote dated 07/26/88* furnish the following on terms specified herein, including, for U.S. purchases General Provisions of Purchase Order on DD Form 1155r (EXCEPT CLAUSE NO 12 APPLIES ONLY IF THIS BOX [ ] IS CHECKED AND NO 14 IF THIS BOX [ ] IS CHECKED), special provisions and delivery as indicated. This purchase is negotiated under authority of 2304(a)(3) or as specified in the schedule if within the U.S., its possessions or Puerto Rico; if otherwise under 2304(a)(5).

[ ] If checked, Additional General Provisions apply. Supplier shall sign Acceptance on DD Form 1155r and return copies.

17. ACCOUNTING AND APPROPRIATION DATA/LOCAL USE

2182050 08-9644 P6300.1-2572 S22079 LAEMCAMV6871001, 0285
*Georgia Tech Ref No: RDS/02.102.020.89.002
R1088N055 RFQ: DACA88-88-Q-0514

18. ITEM NO	19. SCHEDULE OF SUPPLIES/SERVICES	20. QUANTITY ORDERED/ ACCEPTED*	21. UNIT	22. UNIT PRICE	23. AMOUNT
1	Services inclusive of all supervision, labor, materials, facilities, equpment, travel and per diem necessary to Develop the Technology Adoption Index to measure the Effectiveness of Adopting New Building Technologies, per the attached Statement of Work.	1	job	XXXX	$13,882.64
2	Partial Payments are authorized.				
3	The above services are to be performed under Indefinite Delivery Contract No. DACA88-88-D-0020 with Georgia Tech Research Corporation, College of Architecture, Construction Research Ctr. ATTN: L.Circeo				

*If quantity accepted by the Government is same as quantity ordered, indicate by ✓ mark. If different, enter actual quantity accepted below quantity ordered and encircle.

24. UNITED STATES OF AMERICA 88 AUG 01
BY: ... M. IVERSON CONTRACTING OFFICER

25. TOTAL See Page 3
29. DIFFERENCES

28. QUANTITY IN COLUMN 20 HAS BEEN [ ] INSPECTED [ ] RECEIVED [ ] ACCEPTED, AND CONFORMS TO THE CONTRACT EXCEPT AS NOTED

DATE SIGNATURE OF AUTHORIZED GOVERNMENT REPRESENTATIVE

27. SHIP. NO. [ ] PARTIAL [ ] FINAL
28. D.O. VOUCHER NO
30. INITIALS
32. PAID BY
33. AMOUNT VERIFIED CORRECT FOR
31. PAYMENT [ ] COMPLETE [ ] PARTIAL [ ] FINAL
34. CHECK NUMBER
35. BILL OF LADING NO

36. I certify this account is correct and proper for payment

DATE SIGNATURE AND TITLE OF CERTIFYING OFFICER

37. RECEIVED AT	38. RECEIVED BY	39. DATE RECEIVED	40. TOTAL CONTAINERS	41. S/R ACCOUNT NUMBER	42. S/R VOUCHER NO

CONTINUATION SHEET	REFERENCE NO. OF DOCUMENT BEING CONTINUED RFQ DACA88-88-Q-0514 DACA88-88-D-0020	PAGE 2 OF 3 PAGES

NAME OF OFFEROR OR CONTRACTOR
GEORGIA TECH RESEARCH CORPORATION Delivery Order No. 0005

ITEM NO.	SUPPLIES/SERVICES	QUANTITY	UNIT	UNIT PRICE	AMOUNT

STATEMENT OF WORK

TECHNOLOGY ADOPTION INDEX (TAI) TO MEASURE THE EFFECTIVENESS OF ADOPTING NEW BUILDING TECHNOLOGIES

1. INTRODUCTION: The U.S. Army Corps of Engineers (USACE) currently has no means to determine their responsiveness to new technologies, either in absolute terms or compared to other similar owners and users of built facilities. A method/system is, therefore, needed whereby USACE can determine where it could and ought to respond to the changes and innovations in technologies and adopt these new technologies into standard practice. The system would provide a means to regularly assess USACE status in adopting new technologies relative to Headquarters USACE established "reasonable expectations".

The development of such a system offers two main benefits: First, it would provide HQ USACE levels a means to make an informed response to inquiries relative to USACE s adoption of newly developed, market-ready construction technologies. (These inquiries typically come from Government regulators, i.e., legislators, as well as the building industries proponents of new technologies.) Second, by designing the system as a composite of indicators, USACE could evaluate its progress in adopting new technologies (both compared to the general construction industry and within USACE over time) in order to identify areas where responsiveness to new technologies ought to be enhanced and technology adoption ought to be accelerated.

2. OBJECTIVE: The objective of this delivery order is to formulate an advance conceptual ideas for the TAI, to the point where it can be demonstrated that a workable index is feasible.

3. Major Requirements: In order for the TAI to be of greatest utility, it is conceived that it should be a composite of several factors (indicators) much like the Cost of Living Index. Consideration shall be given to the accessibility of input information, the different ways in which the TAI might be used, and the resources necessary to establish and maintain any such TAI. In order to accomplish the work under this delivery order, it shall be necessary for the Contractor to complete the following Tasks:

a. Task 1: Formulate a variety of possibilities for an index through several "brain storming" sessions. A multi-departmental approach is suggested, e.g., business and psychology, besides engineering and architecture. Seek the opinions/input of recognized business experts that can provide valuable insights on the subject.

b. Task 2: Document the most promising ideas for the TAI in a summary report, which shall be used for the oral briefing referenced in Task 3. (See Paragraph 7 - Reports/Deliverables).

CONTINUATION SHEET

REFERENCE NO. OF DOCUMENT BEING CONTINUED: RFQ DACA88-88-Q-0514 / DACA88-88-D-0020

NAME OF OFFEROR OR CONTRACTOR: GEORGIA TECH RESEARCH CORPORATION Delivery Order No. 0005

ITEM NO.	SUPPLIES/SERVICES	QUANTITY	UNIT	UNIT PRICE	AMOUNT

c. Task 3: Present an oral briefing of the study findings to HQ USACE, Washington D.C. (See Paragraph 7 - Reports/Deliverables).

4. POINT OF CONTACT (POC): The USA-CERL technical POC is Mr. Richard Lampo, telephone 217/373-6765

5. MEETINGS/REVIEWS: Upon award of the delivery order, the USA-CERL technical (POC) shall meet with the Contractor, at the Contractor s location, in order to provide guidance, and answer any questions, relative to the completion of this effort.

6. TRAVEL REQUIREMENTS: Anticipated travel under this delivery order shall consist of:

a. one trip, two-days, two persons to HQ USACE, Washington, D. C. to present an oral briefing of the study findings.

b. Any additional travel, USA-CERL will provide U. S. Government travel orders and direct reimbursement to Contractor employees required to travel under this delivery order.

7. REPORTS/DELIVERABLES: The Contractor shall submit the following to USA-CERL:

a. Two (2) copies of a draft written summary report, referenced in Task 2, within three (3) months after award of the delivery order. This summary report will be the basis for the oral presentation of the information at HQ USACE. USA-CERL will review and provide comments, if any, within ten (10) calendar days after receipt of the summary report and approval of the findings of this study, prior to the presentation to HQ USACE, for their consideration to have the TAI further developed.

b. Two (2) copies of the final written summary report, incorporating USA-CERL comments shall be provided within ten (10) calendar prior to the presentation to HQ USACE.

8. PERIOD OF SERVICE: All work to be performed under this delivery order shall be completed within four (4) months after award of the delivery order.

$13,882.64

CONTENTS Page

INTRODUCTION

Background

In the 1960's the United States began to take a serious interest in technology assessment due to unacceptable side effects of new technologies such as supersonic transport aircraft and long lived pesticides. This concern led to the establishment of the U.S. Office of Technology Assessment. While the world was increasingly looking to new technologies for economic development, it was also apparent that the margin for error in adopting new technologies without incurring a large penalty was decreasing rapidly (Stambler,1982). The National Science Foundation began to focus on development of technology assessment methods (Green,1983) and international interest grew, leading to the International Symposium on the Role of Technology Assessment in the Decision- making Process, held in Bonn, Germany in October 1982,(Gibbons,1983).

Traditional diversity and fragmentation within construction industries around the industrialized world have retarded the transfer of newly developed technology onto construction sites. Most industrialized countries have publicly funded studies of the problems of technology transfer within their building construction industries but none contacted have attempted the development of an index to quantify technology adoption.

Problem

USACE and other military services are being scrutinized regarding their adoption of newly developed technologies into standard practice. Criticism comes from Government regulators (i.e. legislators) as well as building industry's proponents of new technologies.

USACE currently has no means to determine their responsiveness to new technologies, either in absolute terms or compared to other similar owners and users of built facilities.

There is a need to determine where USCAE could and ought to respond to changes and innovation in technologies and adopt new technologies into standard practice; to develop "reasonable expectations" for responding to innovation.

Goals

To develop a METHOD whereby USACE can establish "reasonable expectations" for adopting new technologies. To develop a SYSTEM to regularly assess USACE status in adopting new technologies relative to the "reasonable expectations".

Objective

To develop a numerical index to indicate USACE status in adopting new technologies - relative to the construction industry in absolute terms, and relative to past USACE status.

Purpose

To enable HQUSACE levels to make an informed response to inquiries, criticisms, or other issues relative to the adoption of new construction technologies.

To evaluate USACE progress in adopting new technologies, both compared to the general construction industry, and within USACE over time; To enable USACE to identify areas where responsiveness to new technologies ought to be enhanced and technology adoption can be accelerated.

SOURCES OF DATA

For any index to have credibility, the data on which it is based should come from reputable sources, be used in an appropriate manner and be free of bias that could influence the index. Another criteria for index data is that they be readily available at reasonable cost on a continuing basis in order to allow credible historical trends in the index to be evaluated.

One source which meets the above criteria is the U.S. Bureau of the Census' Statistical Abstract of the United States (Bureau of Census, 1988). This publication contains a section on Construction and Housing which contains data on value of new construction of various building types put in place (subdivided into private and public sectors (figure 1); Construction contracts by dollar value and floor space (figure 2); regional distribution of new privately owned one family and apartment housing (figure 3); numbers and percentages of household cooking,heating equipment and fuel characteristics (figure 4); expenditures by property owners for improvements, maintenance or repairs (figure 5); floorspace and type of commercial buildings (figure 6).

The principal source of the above data is the U.S. Bureau of Census which issues a variety of current publications such as their monthly "Construction Reports" with quarterly and annual supplements. Other publications of interest to this study by the Bureau include "Housing Completions" (by type and region) and "Value of New Construction Put in Place" (public and private by building type). Censuses of the construction industry have been conducted periodically since 1929 and every five years since 1967 (years ending in "2" and "7").

International Trade Administration, U.S. Department of Commerce publishes "Construction Review" annually which contains Bureau of Census data as well as statistics from other Federal Government and private agencies. The Energy Information Administration provides data on commercial buildings through its periodic sample surveys.

Private sector sources of building construction data include R.S. Means Company, Inc. from Kingston, MA. and the F.W. Dodge Division of McGraw-Hill Information Systems Company, in New York.

More specialized data on developments in materials, specifications, and techniques are published by a wide range of professional and construction industry associations. Lists of names and addresses of such organizations can be found in publications such as the National Trade and Professional Associations of the United States (1988), published annually by Columbia Books Inc., Washington, DC., or Instant Information (Makower & Green, 1987).

Changes in building codes and industry specifications can be due to the acceptance of new technology but there are many other reasons for changes in such documents.

If such changes are used to identify the industry adoption of new technology a careful investigation of each code or specification change will be necessary to determine if adoption of new technology was involved. The typical review period for many of the industry specifications and codes such as the AIA's Masterspec and CSI's Masterformat is 5 years. This time span may be too long if more regular technology adoption appraisals are intended by the USACE.

Technology assessment studies in the 1960's suggested that because of the difficulties involved in defining "new technologies", using the "delphi" survey approach with a panel of experts can be useful. This approach provides a means of overcoming the difficulties of identifying what are new technological developments, particularly in cases where important developments are really only incremental developments of existing technology.

In order to ensure compatibility between industry data and US CERL data for comparison purposes it will be necessary to consult extensively with statisticians responsible for the various sources of industry data before assembling USACE data. Influences such as regional suitability and scale of projects would need to be considered in selecting industry and USACE projects for direct comparison.

FIGURE 1.

No. 1201. Value of New Construction Put in Place: 1970 to 1986

[**In millions of dollars, except percent.** Represents value of construction put in place during year; differs from building permit and construction contract data in timing and coverage. Includes installed cost of normal building service equipment and selected types of industrial production equipment (largely site fabricated). Excludes cost of shipbuilding, land, and most types of machinery and equipment. For methodology, see Appendix III. See also *Historical Statistics, Colonial Times to 1970*, series N 1-29 and N 66-69]

ITEM	1970	1975	1979	1980	1981	1982	1983	1984	1985	1986
Total	101,281	144,311	252,411	251,719	260,160	246,568	281,266	328,641	355,994	388,817
Average annual percent change [1]	5.2	7.3	11.7	-.3	3.4	-5.2	14.1	16.8	8.3	9.2
Private	73,374	102,610	200,720	193,251	203,611	192,855	227,494	270,977	291,665	316,589
Percent of total	72.4	71.1	79.5	76.8	78.3	78.2	80.9	82.5	81.9	81.4
Residential buildings [2]	35,863	51,581	116,444	100,381	99,241	64,676	125,521	153,649	158,474	167,148
New housing units	27,059	36,317	89,272	69,629	69,424	57,001	94,649	113,626	114,662	133,192
1 unit	17,541	29,639	72,257	52,921	51,965	41,462	72,203	85,605	86,123	102,154
2 or more units	9,518	6,679	17,015	16,708	17,460	15,538	22,447	28,221	28,539	31,038
Improvements	8,804	15,264	27,172	30,752	29,817	27,675	30,872	40,023	43,812	53,956
Nonresidential buildings [3]	22,770	27,545	49,505	55,431	64,695	69,355	65,675	81,147	95,317	91,171
Industrial	6,537	8,018	14,950	13,837	17,030	17,343	12,861	13,745	15,769	13,747
Office	([4])	4,973	9,461	13,318	17,473	23,049	20,768	25,940	31,580	28,591
Hotels, motels	1,307	1,072	2,150	2,930	3,716	4,101	5,185	6,751	7,301	7,451
Other commercial	[4] 9,753	7,833	15,463	16,627	16,775	14,235	15,025	22,167	28,048	28,170
Religious	929	867	1,548	1,637	1,665	1,543	1,780	2,132	2,409	2,702
Educational	915	634	863	1,243	1,331	1,475	1,593	1,660	1,896	2,343
Hospital and institutional	2,529	3,209	3,530	4,046	4,907	5,875	6,559	6,297	5,583	5,422
Miscellaneous	800	939	1,540	1,794	1,798	1,733	1,905	2,455	2,729	2,745
Farm nonresidential	1,875	3,731	5,588	5,274	4,612	3,692	3,255	3,181	2,197	2,049
Public utilities	11,920	18,684	27,732	30,915	33,795	33,864	31,579	30,915	32,952	33,946
Telephone and telegraph	2,968	3,683	6,343	6,733	7,074	7,110	6,471	7,174	7,464	8,427
Other public utilities	8,952	15,001	21,389	24,181	26,721	26,754	25,108	23,741	25,468	25,520
Railroads	561	949	2,195	2,319	2,260	2,595	2,951	3,513	4,046	3,086
Electric light, power [5]	5,807	9,888	14,621	16,048	17,774	18,313	17,936	15,654	15,968	16,955
Gas	2,299	2,220	3,982	5,006	5,945	5,469	3,764	4,303	5,182	5,191
Petroleum pipelines	264	1,944	591	809	742	377	457	271	272	286
All other private	946	1,068	1,452	1,250	1,268	1,269	1,464	1,905	2,726	2,275
Public	27,908	41,702	51,690	58,468	56,549	53,713	53,772	57,664	64,328	72,228
Percent of total	27.6	28.9	20.5	23.2	21.7	21.8	19.1	17.5	18.1	18.6
Buildings	10,473	15,243	15,558	18,517	17,792	16,997	17,276	17,883	20,172	23,494
Housing, redevelopment	1,106	754	1,211	1,648	1,722	1,658	1,700	1,636	1,511	1,456
Industrial	316	687	1,112	1,441	1,655	1,632	1,809	1,828	1,968	1,657
Educational	5,619	7,780	6,903	8,050	6,737	5,927	5,374	5,557	6,708	8,440
Hospital	838	1,745	1,648	1,785	2,083	1,991	2,098	2,039	2,017	1,998
Other	2,594	4,296	4,684	5,593	5,595	5,789	6,295	6,822	7,967	9,943
Highways and streets	9,982	11,902	14,895	17,225	16,799	16,164	17,199	18,771	21,756	23,359
Military facilities	717	1,389	1,647	1,880	1,964	2,205	2,544	2,839	3,283	3,919
Conservation, redevelopment	1,907	3,257	4,587	5,090	5,300	5,027	4,820	4,654	4,744	4,668
Sewer systems	1,543	4,801	7,298	7,171	5,935	5,529	5,260	6,241	7,196	8,105
Water supply facilities	1,093	1,765	2,490	3,266	3,004	2,902	2,083	2,621	2,664	3,370
Miscellaneous	2,192	3,345	5,215	5,318	5,754	4,889	4,590	4,654	4,512	5,313
Public ownership:										
State and local government	24,798	35,614	43,126	48,827	46,136	43,705	43,214	46,423	52,282	59,706
Buildings	9,753	13,580	13,215	15,699	14,641	14,012	13,886	14,088	15,900	19,299
Highways and streets	9,728	11,595	14,367	16,769	16,048	15,646	16,731	18,255	21,287	22,957
Conservation, development	540	618	673	821	896	908	820	727	935	971
Other	4,777	9,821	14,872	15,538	14,550	13,139	11,777	13,354	14,160	16,478
Federal government	3,110	6,088	6,564	9,641	10,413	10,008	10,557	11,240	12,046	12,522
Conservation, development	1,367	2,638	3,915	4,270	4,404	4,119	4,000	3,927	3,810	3,697
Buildings	720	1,663	2,343	2,818	3,151	2,986	3,390	3,796	4,272	4,195
Military facilities	717	1,389	1,647	1,880	1,964	2,205	2,544	2,839	3,283	3,919
Misc. (incl. highways and streets)	305	397	659	673	894	699	624	678	681	712

[1] Change from immediate year, except 1970, change from 1965. Minus sign (-) indicates decrease. For explanation of average annual percent change, see Guide to Tabular Presentation. [2] Includes farm residential. [3] Excludes building by privately owned public utilities. [4] Office buildings included in "other commercial." [5] Includes construction with Rural Electrification Administration (REA) funds.

Source: U.S. Bureau of the Census, *Construction Reports*, series C30.

FIGURE 2.

No. 1202. Value of New Construction Put in Place in Constant (1982) Dollars: 1970 to 1986

[In millions of dollars, except percent. For details on derivation of constant values and description of revised series, see source. For description of natura of revisions and daflators used, see *Construction Reports*, series C30-80S]

ITEM	1970	1975	1979	1980	1981	1982	1983	1984	1985	1986
Total	**277,618**	**255,670**	**311,973**	**280,741**	**268,055**	**246,621**	**274,108**	**308,770**	**324,817**	**347,831**
Average annual percent change [1]	.1	−1.6	5.1	−10.0	−4.5	−8.0	11.1	12.6	5.2	7.1
Private	**202,969**	**186,284**	**250,349**	**218,813**	**211,039**	**192,812**	**220,731**	**253,483**	**266,642**	**283,565**
Percent of total	73.1	72.9	80.2	77.9	78.7	78.2	80.5	82.1	82.1	81.5
Residential buildings [2]	102,285	98,542	144,450	112,972	102,140	84,663	122,099	144,398	145,787	168,592
New housing units	77,218	69,378	110,743	78,379	71,496	56,990	92,062	106,873	105,505	120,000
1 unit	50,047	56,571	89,658	59,537	53,511	41,454	70,211	80,362	79,237	92,034
2 or more units	27,172	12,807	21,085	18,842	17,985	15,536	21,851	26,510	26,268	27,966
Improvements	25,067	29,164	33,707	34,594	30,643	27,673	30,037	37,525	40,282	48,591
Nonresidential buildings [3]	60,951	49,037	62,877	63,833	67,758	69,325	63,234	74,767	85,497	79,823
Industrial	17,493	14,272	19,026	15,948	17,823	17,341	12,395	12,665	14,145	12,038
Office	(4)	8,857	12,006	15,323	18,291	23,035	20,000	23,898	28,331	25,037
Hotels, motels	3,502	1,909	2,724	3,373	3,891	4,099	4,990	6,226	6,550	6,522
Other commercial	[4] 26,104	13,943	19,607	19,153	17,581	14,232	14,452	20,409	25,153	24,660
Religious	2,488	1,543	1,966	1,884	1,746	1,541	1,712	1,965	2,159	2,365
Educational	2,450	1,128	1,095	1,428	1,397	1,474	1,534	1,530	1,700	2,050
Hospital, institutional	6,771	5,714	4,498	4,656	5,141	5,871	6,318	5,811	5,011	4,747
Miscellaneous	2,142	1,671	1,954	2,068	1,888	1,732	1,833	2,263	2,448	2,403
Farm nonresidential	5,020	6,640	7,110	6,067	4,830	3,691	3,131	2,915	1,973	1,793
Public utilities	32,193	30,361	34,233	34,668	35,054	33,863	30,796	29,545	30,884	31,301
Telephone, telegraph	7,324	6,064	7,882	7,604	7,419	7,113	6,257	6,818	7,025	7,715
Other public utilities	24,869	24,297	26,350	27,064	27,635	26,750	24,539	22,727	23,859	23,586
Railroads	1,499	1,513	2,538	2,350	2,241	2,598	2,963	3,431	3,706	2,792
Electric light, power [5]	16,323	16,242	18,240	18,321	18,628	18,306	17,393	14,848	14,943	15,691
Gas	6,273	3,516	4,853	5,505	6,013	5,469	3,731	4,185	4,950	4,837
Petroleum pipelines	774	3,027	720	888	753	377	452	263	260	266
All other private	2,519	1,704	1,680	1,273	1,257	1,270	1,471	1,858	2,500	2,057
Public	**74,650**	**69,387**	**61,624**	**61,928**	**57,016**	**53,809**	**53,377**	**55,287**	**58,175**	**64,266**
Percent of total	26.9	27.1	19.8	22.1	21.3	21.8	19.5	17.9	17.9	18.5
Buildings	28,230	27,226	19,761	21,259	18,627	16,989	16,657	16,513	18,128	20,597
Housing, redevelopment	3,153	1,441	1,503	1,854	1,774	1,658	1,657	1,537	1,392	1,313
Industrial	845	1,224	1,418	1,660	1,738	1,631	1,743	1,686	1,767	1,451
Educational	15,043	13,810	8,778	9,255	7,067	5,924	5,176	5,122	6,014	7,382
Hospital	2,247	3,107	2,100	2,053	2,184	1,991	2,020	1,881	1,810	1,750
Other	6,943	7,643	5,962	6,438	5,863	5,785	6,061	6,287	7,145	8,702
Highways and streets	26,356	18,219	15,890	15,792	15,909	16,267	17,533	18,353	18,990	20,188
Military facilities	1,906	2,281	1,921	1,924	1,953	2,206	2,518	2,696	2,915	3,408
Conservation, development	5,153	5,429	5,771	5,771	5,536	5,026	4,780	4,541	4,554	4,424
Sewer systems	4,167	8,024	9,164	8,129	6,192	5,524	5,212	6,086	6,902	7,681
Water supply facilities	2,973	2,872	3,079	3,652	3,092	2,902	2,065	2,550	2,551	3,166
Miscellaneous	5,864	5,335	6,039	5,400	5,706	4,893	4,612	4,548	4,136	4,802

[1] Change from immediate prior year; except 1970, change from 1965. Minus sign (−) indicates decrease. For explanation of average annual percent change, see Guide to Tabular Presentation. [2] Includes farm residential. [3] Excludes building by privately owned public utilities. [4] Office buildings included in "Other Commercial." [5] Includes construction with Rural Electrification Administration (REA) funds.

Source: U.S. Bureau of the Census, *Construction Reports*, series C30.

FIGURE 3.

No. 1209. New Privately-Owned Housing Units Started—Selected Characteristics: 1970 to 1986

[**In thousands.** For composition of regions, see fig. I, inside front cover. See also *Historical Statistics, Colonial Times to 1970*, series N 156–163 and 170]

Year	Total units [1]	Structures with— One unit	Structures with— 2–4 units	Structures with— 5 or more units	Region: Northeast	Region: Midwest	Region: South	Region: West	Condominium units [2]: Total	Condominium units [2]: Single-family	Condominium units [2]: Multifamily	Type of assistance [3]: FHA	Type of assistance [3]: VA
1970	1,434	813	85	536	218	294	612	311	(NA)	(NA)	(NA)	421	61
1971	2,052	1,151	120	781	264	434	869	486	(NA)	(NA)	(NA)	528	94
1972	2,357	1,309	141	906	330	443	1,057	527	(NA)	(NA)	(NA)	371	104
1973	2,045	1,132	118	795	277	440	899	429	241	69	172	163	86
1974	1,338	888	68	382	183	317	553	285	175	46	130	95	73
1975	1,160	892	64	204	149	294	442	275	65	20	45	98	77
1976	1,538	1,162	86	289	169	400	569	400	95	30	64	144	100
1977	1,987	1,451	122	414	202	465	783	538	118	41	77	178	131
1978	2,020	1,433	125	462	200	451	824	545	156	42	114	178	127
1979	1,745	1,194	122	429	178	349	748	471	198	43	156	178	122
1980	1,292	852	110	331	125	218	643	306	186	35	150	177	95
1981	1,084	705	91	288	117	165	562	240	181	36	145	145	75
1982	1,062	663	80	320	117	149	591	205	170	40	130	152	73
1983	1,703	1,068	113	522	168	218	935	382	276	77	199	121	107
1984	1,750	1,084	121	544	204	243	866	436	291	96	194	63	97
1985	1,742	1,072	93	576	252	240	782	468	225	79	146	(NA)	(NA)
1986	1,805	1,179	84	542	294	296	733	483	214	80	134	(NA)	(NA)

NA Not available. [1] For 1970–1976, characteristics such as type of structure, and region, include data for publicly owned units. [2] Type of ownership under which the owners of the individual housing units are also joint owners of the common areas of the building or community, includes a small number of cooperatively-owned units. [3] Source: U.S. Department of Housing and Urban Development, 1970–1979, *HUD Statistical Yearbook;* thereafter unpublished data.

Source: Except as noted, U.S. Bureau of the Census, *Construction Reports*, series C20.

FIGURE 4.

No. 1211. Characteristics of New Privately Owned One-Family Houses Completed: 1970 to 1986

[**Percent distribution, except as indicated.** Data beginning 1980 show percent distribution of characteristics for all houses completed (includes new houses completed, houses built for sale completed, contractor-built and owner-built houses completed, and houses completed for rent). Data for 1970 cover contractor-built, owner-built, and houses for rent for year construction started and houses sold for year of sale. Percents exclude houses for which characteristics specified were not reported]

CHARACTERISTIC	1970	1980	1984	1985	1986
Total houses (1,000)	793	957	1,025	1,072	1,120
Financing	100	100	100	100	100
Mortgage	84	81	81	81	83
FHA-insured	30	16	13	15	20
VA-guaranteed	7	8	6	7	8
Conventional	47	55	61	57	54
Farmers Home Administration		3	2	3	2
Cash or equivalent	16	18	19	19	16
Floor area	100	100	100	100	100
Under 1,200 sq. ft	36	21	19	20	17
1,200–1,599 sq. ft	28	29	30	30	30
1,600–1,999 sq. ft	16	22	21	21	21
2,000–2,399 sq. ft	21	13	12	12	14
2,400 sq. ft. and over		15	17	17	18
Average (sq. ft.)	1,500	1,740	1,700	1,785	1,825
Median (sq. ft.)	1,385	1,595	1,605	1,605	1,660
Number of stories	100	100	100	100	100
1	74	60	54	52	51
2 or more	17	31	40	42	44
Split level	10	8	6	6	5
Foundation	100	100	100	100	100
Full or partial basement	37	36	32	35	37
Slab	36	45	50	48	45
Crawl space	27	19	18	18	18

CHARACTERISTIC	1970	1980	1984	1985	1986
Bedrooms	100	100	100	100	100
2 or less	13	17	24	25	21
3	63	63	58	57	59
4 or more	24	20	18	18	20
Bathrooms	100	100	100	100	100
1 or less	32	18	14	13	10
1½	20	10	10	11	9
2	32	48	48	48	47
2½ or more	16	25	28	29	33
Heating fuel	100	100	100	100	100
Electricity	28	50	48	44	44
Gas	62	41	45	49	47
Oil	8	3	2	3	5
Other	1	5	5	4	4
Heating system	100	100	100	100	100
Warm air furnace	71	57	55	54	54
Electric heat pump	(NA)	24	30	30	29
Other	29	19	15	15	17
Central air-conditioning	100	100	100	100	100
With	34	63	71	70	69
Without	66	37	29	30	31
Fireplaces	100	100	100	100	100
No fireplace	65	43	41	41	38
1 or more	35	56	59	59	62
Parking facilities	100	100	100	100	100
Garage	58	69	69	70	74
Carport	17	7	5	5	4
No garage or carport	25	24	25	25	21

NA Not available.

Source: U.S. Bureau of the Census and U.S. Dept. of Housing and Urban Development, *Construction Reports*, series C25, *Characteristics of New Housing* (a joint publication).

FIGURE 5.

No. 1229. Expenditures by Residential Property Owners for Improvements and Maintenance and Repairs by Type of Property and Activity: 1970 to 1986

[In millions of dollars]

YEAR AND TYPE OF EXPENDITURE	Total	1-unit properties with owner occupant	Other properties	ADDITIONS AND ALTERATIONS				Major replacements	Maintenance and repairs
				Total	To structures		To property outside of structures		
					Additions	Alterations			
1970	14,770	9,469	5,301	6,246	1,411	3,539	1,296	2,629	5,895
1975	25,239	15,684	9,556	10,997	1,971	6,844	2,182	4,484	9,758
1976	29,034	18,854	10,180	12,314	3,493	6,367	2,454	5,341	11,379
1977	31,280	21,761	9,519	14,237	2,655	8,505	3,077	5,699	11,344
1978	37,461	24,189	13,272	16,458	3,713	8,443	4,302	8,094	12,909
1979	42,231	28,280	13,951	18,285	3,280	9,642	5,363	8,996	14,950
1980	46,338	31,481	14,857	21,336	4,183	11,193	5,960	9,816	15,187
1981	46,351	30,201	16,150	20,414	3,164	11,947	5,303	9,915	18,022
1982	45,291	29,779	15,512	18,774	2,641	10,711	5,423	9,707	16,810
1983	49,295	32,524	16,771	20,271	4,739	11,673	3,859	10,895	18,128
1984, total [1]	**69,784**	**43,781**	**26,003**	**27,822**	**6,007**	**14,486**	**7,329**	**13,067**	**28,894**
Heating and air-conditioning [2]	5,071	2,768	2,303	959	(NA)	959	(NA)	2,391	1,721
Plumbing	8,919	3,346	3,573	1,201	(NA)	1,201	(NA)	2,408	3,310
Roofing	5,140	2,573	2,568	(NA)	(NA)	(NA)	(NA)	3,126	2,014
Painting	8,817	4,998	3,819	(NA)	(NA)	(NA)	(NA)	(NA)	8,817
1985, total [1]	**80,267**	**47,742**	**32,525**	**28,775**	**3,966**	**17,599**	**7,211**	**16,134**	**35,358**
Heating and air-conditioning [2]	5,096	3,287	1,809	1,121	(NA)	1,121	(NA)	2,322	1,653
Plumbing	8,120	4,029	4,091	1,502	(NA)	1,502	(NA)	3,115	3,503
Roofing	7,497	4,428	3,069	(NA)	(NA)	(NA)	(NA)	5,086	2,411
Painting	11,267	5,810	5,457	(NA)	(NA)	(NA)	(NA)	(NA)	11,287
1986, total [1]	**91,274**	**54,298**	**36,976**	**38,608**	**7,377**	**21,192**	**10,040**	**16,695**	**35,971**
Heating and air-conditioning [2]	6,232	3,993	2,239	974	(NA)	974	(NA)	3,399	1,860
Plumbing	8,461	3,791	4,670	1,484	(NA)	1,484	(NA)	3,408	3,569
Roofing	7,685	3,834	3,851	(NA)	(NA)	(NA)	(NA)	4,552	3,133
Painting	11,170	5,673	5,497	(NA)	(NA)	(NA)	(NA)	(NA)	11,170

NA Not available. [1] Includes types of expenditures not separately specified. [2] Central air-conditioning.

Source: U.S. Bureau of the Census, *Construction Reports*, series C50.

FIGURE 6.

No. 1237. Commercial Buildings—Selected Characteristics, by Square Footage of Floorspace: 1983

[Excludes Alaska and Hawaii. Building type based on predominant activity in which the occupants were engaged. Excludes industrial buildings. Based on a sample survey building representatives conducted between March and August 1983, therefore, subject to sampling variability. For data on energy consumption and expenditures in commercial buildings, see tables 916 and 917. For composition of regions, see fig. I, inside front cover]

CHARACTERISTIC	Number of buildings (1,000)	FLOORSPACE (mil. sq. ft.) Total	Within all buildings having square footage of— 5,000 or less	5,001 to 10,000	10,001 to 25,000	25,001 to 50,000	50,001 to 100,000	100,001 and over	Average sq. ft. per building (1,000)	Median sq. ft. per building (1,000)
All buildings	**3,948**	**52,325**	**4,908**	**5,246**	**8,912**	**7,692**	**7,166**	**18,399**	**13.3**	**4.0**
Region:										
Northeast	670	11,615	784	939	1,960	1,915	1,754	4,264	17.3	5.7
Midwest	1,211	16,059	1,526	1,685	2,616	2,334	2,146	5,750	13.3	4.0
South	1,493	17,049	1,971	1,685	2,923	2,176	2,199	6,094	11.4	3.3
West	574	7,602	627	937	1,412	1,267	1,068	(S)	13.2	4.7
Year constructed:										
1980 to 1983	140	5,675	127	163	523	479	794	3,590	40.5	9.9
1974 to 1979	530	6,616	688	635	1,298	1,029	848	2,118	12.5	4.1
1971 to 1973	209	3,442	249	320	496	654	556	1,168	16.4	5.1
1961 to 1970	721	9,947	881	860	1,417	1,371	1,533	3,885	13.8	3.4
1946 to 1960	946	9,612	1,187	1,279	1,699	964	1,265	3,219	10.2	3.1
1921 to 1945	726	8,639	855	950	1,663	1,656	949	2,566	11.9	3.8
1901 to 1920	388	5,453	514	600	1,049	1,010	942	1,337	14.1	5.1
1900 or before	288	2,940	406	440	767	530	281	(S)	10.2	4.8
Principal activity within building:										
Assembly	457	5,483	485	901	1,390	912	621	(S)	12.0	5.9
Educational	177	6,044	113	182	560	1,322	1,619	2,248	34.2	16.1
Food sales/service	380	2,051	636	343	568	209	179	(S)	5.4	2.8
Health care	61	2,277	80	(S)	(S)	(S)	(S)	1,761	37.6	4.7
Lodging	106	2,241	95	166	310	495	318	856	21.1	6.8
Mercantile/services	1,071	10,427	1,433	1,562	2,013	1,065	1,089	(S)	9.7	3.5
Office	575	8,454	749	803	1,236	976	933	3,757	14.7	4.1
Residential	236	2,454	325	265	748	432	(S)	(S)	10.4	4.4
Warehouse	425	6,791	448	446	1,202	1,203	1,198	2,293	16.0	4.8
Other	179	2,760	176	186	405	350	214	1,429	15.4	3.4
Vacant	281	3,342	368	314	410	582	614	1,054	11.9	3.3
Number of establishments in building:										
None	142	1,475	218	(S)	137	187	342	300	10.4	3.1
Single establishment	3,160	35,227	4,077	3,870	6,563	5,710	5,031	9,975	11.1	3.6
Multi-establishment	645	15,623	613	1,202	2,212	1,795	1,794	8,007	24.2	7.5
Government occupancy:										
Government occupied	348	10,099	327	378	959	1,356	1,551	5,529	29.2	7.2
Not Government occupied	3,602	42,225	4,580	4,868	7,953	6,336	5,616	12,871	11.7	3.9
Fuels used alone or in combination:										
Electricity	3,783	51,359	4,701	5,079	8,810	7,491	6,973	18,305	13.6	4.1
Natural gas	2,314	37,090	2,732	3,522	6,081	5,484	4,930	14,342	16.0	5.0
Fuel oil	633	13,313	743	886	1,656	1,425	1,509	7,093	21.0	5.1
Propane	260	3,007	360	285	515	328	209	1,290	11.6	3.5
Purchased steam	60	4,594	(S)	(S)	235	446	645	3,173	76.2	29.2
Other	245	3,997	345	260	497	337	535	2,024	16.3	3.6

S Figure does not meet publication standards.

Source: U.S. Energy Information Administration, *Characteristics of Commercial Buildings, 1983.*

APPROACH

In accordance with task 1 of the Statement of Work, investigators were recruited from Civil Engineering, Mechanical Engineering, Construction Research Center and Management faculty at Georgia Tech. Two other research consultants familiar with CERL operations were used in the final comment stage.

Part way through the study the principal investigator visited Richard Lampo and Tom Napier at CERL in Champaign to discuss progress inspect facilities and be briefed on progress on the CETAP project which could be closely related to the TAI project.

Brainstorming sessions were held on Aug.22, Aug.29, and Sept. 19, 1988. These sessions culminated in presentations by each of the investigators on their individual concept for a Technology Adoption Index on Sept. 26, 1988. Each of these proposals is described on the following pages.

PROPOSAL 1.

Leland S. Riggs

Associate Professor

School of Civil Engineering

(Specialist in Construction Management)

1(a). "Answer the Mail Approach"

This proposal suggests a direct response to inquiries regarding the adoption of new technologies by the USACE relative to the construction industry. That is, compile a list of new technologies adopted by industry in the last five or ten years and analyze (explain) why the technology was or was not appropriate for use by the Corps. Presumably, there are well-founded reasons why a given technology was not adopted.

In those cases where technology could have been used by the Corps, but was not used, a compelling rationale would have to be prepared arguing the reasons for non-adoption. This approach can also be used to cast a spotlight on those new technologies adopted by the Corps but not by industry.

The type list proposed here could serve as recent history as well as lending itself to updating. The disadvantage to this approach is that it is not necessarily linked to an index. On the other hand, this approach lends itself well to economic or other analysis of individual technologies.

1(b). "Index Approach"

This approach includes developing an index on which to compare the adoption rate of new technology of the Corps and industry. It is suggested that the basis of this index be the facility life cycle shown below.

PLANNING	PROGRAMMING	DESIGN	CONSTRUCTION	O&M	UTILIZATION

Within the construction and operations and maintenance area, the CSI or Uniform Building Code may be appropriate for organizing candidate technologies. It is further suggested that different contracting systems such as Reimbursable with a Guaranteed Maximum Cost and sharing of savings be addressed under the construction category.

The general form of the index would be as shown below:

$$TAI = SUM_i\, K_i(PLAN_i) + \ldots + SUM_i\, K_n(UTILIZ_n)$$

where each K_i = Applications $_i$ / Opportunities $_i$ in units, SF, \$, etc.

In comparing indexes or individual technology ratios of the Corps activities with those of the construction industry as a whole, care would be needed to ensure that elements used were truly comparable, i.e., "apples to apples".

PROPOSAL 2.

Sheldon M. Jeter

Associate Professor

School of Mechanical Engineering

(Specialist in HVAC Systems)

The goal of the Technology Adoption Index Project is to develop a quantitative measure of the effectiveness of the Corps of Engineers in adopting and implementing appropriate innovative construction and property development industries. Particular emphasis is on materials, equipment, and on-site methods.

To address the question proposed by CERL, it is my view that the project needs to identify at least three increasingly detailed bodies of information. These aspects are as follows:

1. The introductory technologies that are actually innovative. New products may not neccessarily involve innovative technology.

2. The innovative technologies that are actually appropriate to the mission of the Corps of Engineers and the mission of the units and activities that the Corps supports.

3. When these technologies were adopted and implemented by the corresponding civilian sectors and when by the Corps.

Since I am hardly familiar with the existing data bases on construction technology and the capabilities and extent of these sources of information, design and execution of a successful research plan based on existing and readily accessible information seems highly problematical to me. Acknowledging my lack of experience with such data bases, I would defer to any knowledgeable person the judgment as to the likelihood of success if the project proceeds along these lines. I would submit, however, that a preliminary exercise should be conducted to educate the research team on the extent, quality, and pertinence of these data bases and the capability of manipulating them. I am concerned about three critical issues, one for each level of information listed above:

1. How can one determine from a standard data base if a new product incorporates an innovative technology. Every product that is introduced it touted as being innovative, but most incorporate only incremental improvements if any. A new listing in, for example, the Sweets Catalog File does not necessarily indicate a new technology.

2. It seems even more difficult to determine if an innovative technology is appropriate. The Corps should not be criticized for avoiding a product or technology for valid reasons.

3. A final difficulty is determining when and where products are being used. I suppose that this information exists in commercial records, but how can it be extracted and analyzed?

As an alternative to dealing with data bases that may be poorly defined and thereby introducing an element of uncertainty into the project, I propose a case study approach. The proposed study is composed of well defined tasks, all of which can surely be completed. The overall project, then, is likely to be successful, although its goals may be limited.

The case study would involve the identification of innovative technologies and an investigation of the relative success of these technologies in the civilian and military sections. Because my professional experience is limited to the HVAC, energy conservation, and energy management areas, I will use energy in buildings as my example.

The subtasks are itemized in Table 1. Innovative technologies would be identified by a literature search complemented with a review by a panel of experts. A subset of the technologies that pass the review would be selected randomly for further investigation. The literature search could focus on feature articles in the ASHRAE Journal and a trade paper such as Heating/Piping/Air Conditioning (Penton Publishers, Cleveland, OH). A proposed list of technologies would be assembled from the last two or three decades of these publications. The expert panel should then review the list and confirm whether the proposed technologies are substantially innovative. Candidates that survive this review would then comprise the subject population for a random drawing to select technologies for further study. This procedure has the advantage of being broad as all significant developments are likely to be reported in the source publications. The expert panel can eliminate trivial or useless technologies, but since the work of the panel is in review, rather than in construction of the list, there is less chance of introducing bias. If bias does corrupt the selection, at least it will be overt as we should publish both the preliminary and final list. The sample obtained by random selection will be small enough to work with and also be free of additional bias. The sample should include selections and alternatives in case sufficient data is not available on the prime selections.

Table 1.

Schedule of Subtasks

1.1 Identify Preliminary Candidate Technologies

1.2 Screen Preliminary List of Technologies

1.3 Select Sample of Technologies for Further Analysis

2.1 Identify Private Sector Introduction Date

2.2 Identify Private Sector Demonstration Date

2.3 Identify Private Sector Adoption Date

2.4 Allow Private Sector Review of Data

3.1 Date of Consideration by Corps

3.2 Date of Adoption by Corps

4.0 Compute TAI

We can return to the literature to determine the dates of introduction, consideration / demonstration, and commercial adoption of the innovative technologies. I would count the first advertisement in an appropriate trade paper as the date of commercial introduction. The date of consideration/demonstration could be represented by a substantive report in an independent publication of a completed demonstration project. If the technology has progressed this far, it could be considered as at least as demonstrated to be feasible and worthy of broad consideration. Commercial adoption could be represented by the technology being included in publications that represent broad specification guidelines such as the ASHRAE Systems and Equipment volumes or if the technology appears in a broad pricing guideline such as Means Mechanical and Electrical Cost Data. It would then be desirable to inquire of manufacturers and vendors about the accuracy of our estimates. General adoption in this sense could be defined as a capture of a few percent of the market. We could also contact selected users such as general contractors, sub- contractors, AE firms, and utility companies about these dates. Since at least some confirming information, possibly even a consensus. The utility companies should be very helpful in this regard as they periodically review their customer's use of various energy technologies.

At this point the data which consists of several identified technologies and the corresponding introduction, consideration/demonstration, and adoption dates should be referred to the Corps. There ought to be dates corresponding to consideration and/or demonstration as well as adoption for each technology. Consideration that results in a negative opinion and does not lead to demonstration is a perfectly valid result. It may be true, for example, that the Corps mandate to consider future costs precludes the use of a low first cost but less efficient component. If a technology is not successfully demonstrated, the Corps would not be expected to pursue it further. Demonstration may not be possible because of budget or program constraints. Of course, demonstrations may be executed, and the technologies found to be faulty, risky, or inappropriate. The summary results would be organized as illustrated in Table 2.

Table 2.

Summary of Intermediate Results

Private Sector		Corps of Engineers
Introduction date, d_0	or	Introduction date, d_{c0}
Consideration/		Consideration/
Demonstration date, d_1		Demonstrationdate, d_{c1}
Adoption date, d_2		Adoption date, d_{c2}

For technologies that are ultimately adopted in the civilian sector, we can compute the TAI as follows:

$$TAI = ((d_1-d_0)/(d_{c1} - d_0) + (d_2-d_1)/(d_{c2}-d_{c1}))/2$$

For technologies that only receive some initial interest in the private sector but are never, or not yet, adopted, we can compute the TAI as follows:

$$TAI = (d_1-d_0)/(d_{c1}-d_0)$$

No doubt we will encounter some special cases that require modification of the proposed formulas.

The project plan presented above has been designed to make use of readily available and widely accepted sources of information. The subtasks appear to be well defined and within the span of available abilities and capacities. The result will be a quantitative measure in terms that are commensurate across a wide range of technologies.

PROPOSAL 3.

Louis J. Circeo

Director

Construction Research Center

College of Architecture

(Specialist in US.CERL Construction Research Activities)

STEPS IN THE DEVELOPMENT OF A TECHNOLOGY ADOPTION INDEX

1. Develop a definition of a "new technology".

a. Use a very simple index that can be readily monitored e.g.;

(1) Changes in the Uniform Building Code

(2) Changes in Association Codes/Specifications; e.g., ASTM, ACI, etc.

b. Establish a baseline zero time to determine how long it takes to introduce new technologies; e.g., when a code change takes place.

2. Establish a threshold of "worthiness" factor to determine whether a new technology is worthwhile to implement; e.g.,

a. A cost-benefit comparison of old vs. the new technology

b. Life Cycle cost comparisons.

c. Subjective evaluations.

d. Combinations of the above.

3. Determine the extent to which the above "worthy" new technologies are being implemented in civilian and Corps projects.

a. Compare times for first and "standard" use.

b. Compare actual use to the opportunities for use.

c. Regional factors may have to be considered.

d. A model may be required to normalize the data for valid

comparisons.

4. Based on the above paragraph 3 comparisons, develop a single "implementation factor" for each new technology for both industry and the Corps.

5. Collate the implementation factors under construction categories (e.g., Structural, Mechanical, Management, etc.) separately for industry and the Corps

6. Combine the results within and between each broad category to get an overall Technology Adoption Index for both the industry and the Corps (see figures 7 and 8).

7. A simple comparison of these two indexes should indicate the relative degree of technology adoption between industry and the Corps.

FIGURE 7.

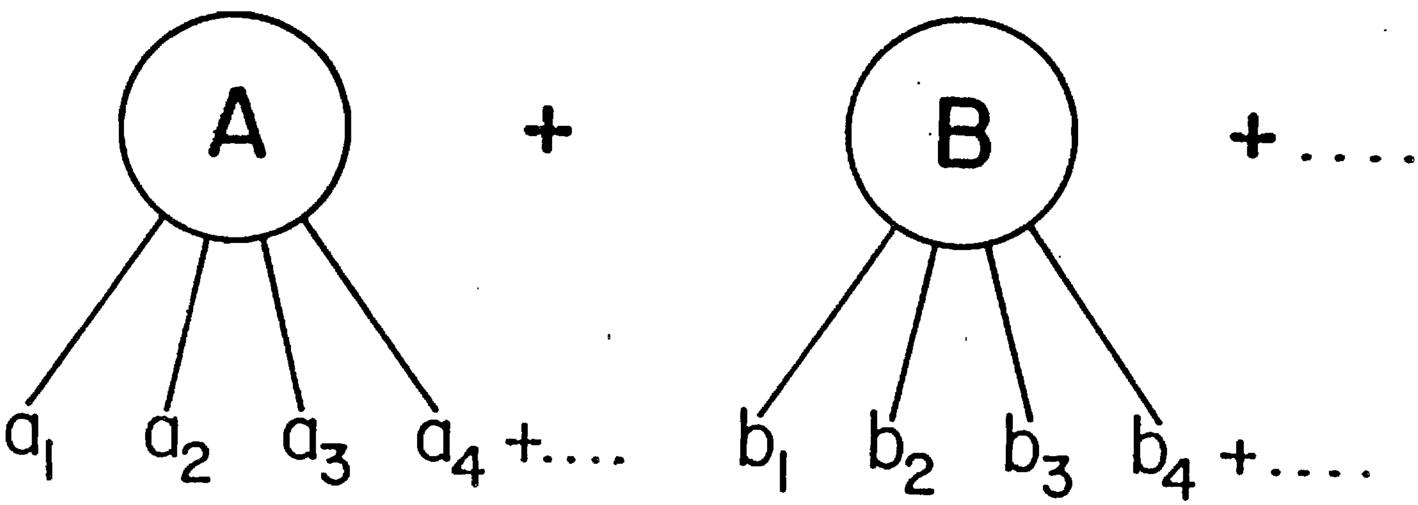

FIGURE 8.

$$A_C + B_C + C_C + D_C + \ldots = I_{CORPS}$$

$$A_P + B_P + C_P + D_P + \ldots = I_{\substack{PRIVATE \\ INDUSTRY}}$$

PROPOSAL 4.

Richard Aynsley

Professor

College of Architecture

(Specialist in Building Science)

1. Identify newly adopted building technologies through:

a. Changes in model building codes (via the CodeWORKS database, see appendix):

Basic Building Code

Southern Standard Building Code

Uniform Building Code

National Plumbing Code

Uniform Plumbing, Heating &ComfortCooling Codes

National Electric Code

Note: differences between these codes often reflect regional and geographic influences.

b. Changes in industry association specifications and cost indexes:

ANSI's standards (updated about every 5 years)

AIA's Masterspec (updated quarterly)

ASTM's materials specs (updated quarterly)

McGraw-Hill's SweetSpec and SweetSearch

ACI's concrete specifications

Underwriters Laboratories (Product Index, 6 monthly update)

Mean's Cost Data

American Concrete Institute (Industry Developments noted in monthly journal "Concrete International")

Construction Specification Institute's Masterformat (updated every 5 years)

Information Handling Services' SPEC-DATA microfilm data. VEND and TECH DATA electronic databases

ICBO Evaluation Service Inc.'s Building Standards journal.

2. With new technologies identified, a three step evaluation would be made of each technology:

a. The number of applications of each technology would be divided by the number of opportunities for application, for USACE and each of the other industry sectors surveyed to yield an implementation index for each new technology.

b. A lead/lag index would be calculated for each new technology for both the USACE and Industry based on the number of months, positive or negative, between the USACE's adoption and the industry's adoption. Adoption by the USACE would be determined by a technology's appearance in a standard specification. Industry adoption would be based on a technology's appearance in an industry standard specification.

c. Technology adoption indexes for the USACE and industry would be based on comparable sample projects executed by the USACE and industry and determined by summing the products of implementation indexes and lead/lag indexes for each technology. Comparisons of technology adoption indexes for the USACE and industry could be qualified by consideration of a significance ratio and a risk index when appropriate. These are described below.

3) SIGNIFICANCE RATIO - This would be the ratio of the dollar value of a technology in all Corps or private sector projects, divided by the total dollar value of those Corps or private sector projects. This ratio could be used to establish a "threshold" for significant technologies.

4) RISK INDEX - This would be the product of the estimated probability of failure of the technology and the estimated dollar value of repairing the consequences of such a failure divided by the total dollar value of the project. The risk index is not envisaged as an integral part of the technology adoption index but more as an ancillary tool for assessing technologies.

PROPOSAL 5.

Peter G. Sassone

Associate Professor

College of Management

(Specialist in Economic Indexes)

This proposal suggests implementation of a "relative" index approach as opposed to an "absolute" index approach. The idea is not to compare Corps construction activity to some absolute "norm", in terms of what technology ought to be used, rather simply to use a "benchmark" approach by comparing the Corps' activity to the industry as a whole. The rationale for recommending a "benchmark" approach is that such an approach minimizes the problems arising from differences between industry and Corps operational philosophies. Private industry generally operates by trading off risks against rewards, while the Corps operates under a wide range of different government and policy constraints. This approach would develop three levels of indexes.

1) CONSTRUCTION/TECHNOLOGY INDEX - An index of use of a certain technology within a specified building sector, for example, multi-family residential construction might be one sector. Such sectors could reflect those adopted by the US Bureau of Census and Statistics.

There is likely to be a number of different technologies requiring assessment in each sector. From the assessment of all technologies within a sector an index I(j,k) would be developed for that sector. Each index would be a ratio with the numerator being the money spent by the Corps in that technology divided by the total amount of money spent by the the Corps in that sector. The denominator is a similar ratio for private sector activity for a comparable to that used for the Corps' sample.

2) CONSTRUCTION SECTOR INDEXES - Aggregating the individual indexes for a particular construction sector into an overall index for that sector. For example, multi-family residential construction. The trick to combining them is to have a reasonable weighting scheme. The W(j,k) are the weights suggested to be applied. They are the relative value of that technology among all of the technologies being considered. The sum of all weightings then adds up to one.

3) SUMMARY OVERALL INDEX - An overall index for the Corps or the private sector can be calculated by using a weighted aggregation of indexes across all industry sectors. If there are ten construction sectors, these would need to be weighted by their relative importance.

A mathematical description of these procedures is provided later in this report. The procedure is well suited to computerization using a spreadsheet such as Lotus 123.

The example provided later in this report takes 3 technologies and two construction sectors to indicate the nature of the data required. These data are the amount of money spent in each technology and the total amount of money spent in the sector.

Interpreting Indexes

If the Corps' performance was relatively IDENTICAL to that of the private sector, (i.e. the Corps adopts new technology at a similar rate to the private sector), the index will be equal to 1. This holds true for individual indexes, sector indexes as well as the summary index.

If the Corps is adopting new technology at a GREATER rate than the private sector the indexes will be greater than 1.

If the Corps is adopting new technology at a LESSER rate than the private sector, the indexes will be less than 1.

It is to be expected in any "real world" application that indexes for individual technologies and construction sectors are likely to range from from less than 1, equal to 1 and greater than 1, indicating the Corps' performance in various activities. The summary index will indicate the Corps' overall performance in such complex comparisons.

COMPARATIVE EVALUATION OF PROPOSALS

Proposal 1a does not offer an index but suggests continuation of the existing practice of responding to each criticism as they occur.

Proposal 1b suggests the creation of an index based on cumulative ratios of applications/opportunities of selected new technologies. The proposal does not address the problem of identifying relevant new technologies or methods. Gathering applications may be relatively straightforward, but identifying valid opportunities for application is likely to be more problematic.

Proposal 2 identifies some of the problems associated with defining what are new technologies and whether or not a particular technology is appropriate to the USACE's mission. A suggestion is also made that a panel of experts may be needed to make a final selection of the new technologies to be used in calculating a Technology Adoption Index. It also discusses the concept of a time line approach to adoption by the USACE and industry. It is made clear in this proposal that a case study application is needed to determine the usefulness or otherwise of suggested data sources and as a check on the validity of comparisons to be made in calculating the index.

Proposal 3 suggests changes in codes and specifications as the definition of new technology adoption. This is problematic as many changes are not technology related and those that are may not be obvious from the changes made. Also significant but incremental developments in an established technology may not appear in a code at all. This situation may be overcome by including an expert panel of review to advise on the final selection of technologies to be included in any technology adoption index calculations. Another difficulty with using code and specification changes is their frequency, often only each 5 years. It is likely that the USACE will want to calculate technology adoption indexes more frequently than at 5 year intervals. This proposal expands the screening process for new technologies on the basis of "worthiness" using cost benefit, life cycle cost comparison of old and new technologies. A implementation factor is described but it would suffer from the same difficulties in determining valid opportunities as described in proposal 1. While the method for combining indexes from each technology studied is relatively simple, the result has no particular meaning in itself and is only meaningful in terms of comparison with the corresponding index for the civilian or other sector of the construction industry.

Proposal 4 is similar to proposal 3 but it does identify additional sources of data to aid identification of new technologies. A significance ratio and a risk index are suggested as ways of qualifying a technology adoption index. While the significance index will indicate the level of investment associated with a technology it may work against the adoption of inexpensive but effective technology. The risk index is probably more valuable as a qualifier of a technology index as there have been numerous cases of costly failures of new technologies.

Proposal 5 Illustrates the benefits of including a non- engineering, non-architectural person in the study group. This proposal stresses methodology and clearly outlines a number of quantities leading to a single meaningful index. It does not address the problems of identifying new technologies for such a study but does stress the need for care in sampling USACE and civilian projects to ensure validity of comparisons.

CONCLUSIONS

After careful consideration of all five proposals it was felt that the simple but strong methodology described in proposal 5 deserved recommendation. At the same time the emphasis on the need for careful sampling of projects from the Corps and elsewhere to ensure they were comparable projects in scale, application, building type and regionally. A case study seems to be the only way to identify the extent of the problems associated with choosing comparable sample projects on which to assess technology adoption. More study is needed also to refine techniques for identifying appropriate new technologies to survey and how to determine what could have been valid applications (opportunities) for each technology. In itself, the identification of all relevant new technologies on a periodic basis should be beneficial to the Corps. The risk index seems a useful and valid concept for qualifying a calculated TAI in view of the limited track record of many new technologies.

Despite the general feeling by industry experts both nationally and internationally that development of a technology adoption index would be an extremely challenging task, the ideas suggested in the various proposals by the study group indicated such an index may be feasible. The next step is clearly to mount a pilot study to investigate further the concepts and difficulties outlined in this preliminary study.

RECOMMENDED PROCEDURE

The recommendation is for implementation of a "relative" index approach as opposed to an "absolute" index approach. The idea is not to compare Corps construction activity to some absolute norm, in terms of what technology ought to be used, rather simply to compare the Corps' activity to the industry as a whole. This approach would develop three levels of indexes.

1) CONSTRUCTION/TECHNOLOGY INDEX I(j,k)

(as described in proposal # 5)

Each index would be a ratio with the numerator being the money spent by the Corps in that technology divided by the total amount of money spent by the the Corps in that sector. To ensure that this gives a reasonable number, initial trials may experiment with division by a suitable subtotal. The denominator is a similar ratio for private sector activity for a comparable sample to that used for the Corps' sample.

"New technologies" would be defined as those associated with changes in industry accepted building codes, industry association specifications and materials and products indexes. Lists from these and other sources would be identified and edited by a panel of industry/Corps experts under the cognizance of a neutral third party such as a university organization. These experts would also supervise the selection of comparable sample projects executed by the USACE and others to be provide the data for analysis.

2) CONSTRUCTION SECTOR INDEXES W(j,k)

Each W(j,k) is a weighting factor being the relative value of that technology among all of the technologies being considered. The sum of all weightings then adds up to one.

3) SUMMARY OVERALL INDEX I

An overall index for the Corps or the private sector I, can be calculated by using a weighted aggregation of indexes across all industry sectors. If there are ten construction sectors, these would need to be weighted by their relative importance.

The procedure is well suited to computerization using a spreadsheet such as Lotus 123. The example provided later in this report takes 3 technologies and two construction sectors to indicate the nature of the data required. These data are the amount of money spent in each technology and the total amount of money spent in the sector.

Interpreting Indexes

If the Corps' performance was relatively IDENTICAL to that of the private sector, (i.e. the Corps adopts new technology at a similar rate to the private sector), the index will be equal to 1. This holds true for individual indexes, sector indexes as well as the summary index.

If the Corps is adopting new technology at a GREATER rate than the private sector the indexes will be greater than 1.

If the Corps is adopting new technology at a LESSER rate than the private sector, the indexes will be less than 1.

It is to be expected in any "real world" application that indexes for individual technologies and construction sectors are likely to range from from less than 1, equal to 1 and greater than 1, indicating the Corps' performance in various activities. The summary index will indicate the Corps' overall performance in such complex comparisons.

EXAMPLE ILLUSTRATING RECOMMENDED PROCEDURE

Definitions

j Index of types of construction (e.g. multi-unit residential)

j = 1 ... j

k Index of technologies (e.g. heat pumps),

k = 1 ... k

s Index of sectors (e.g. Corp or private),

s = c or p

$T(j,k,s) Dollars spent in construction type j on technology k by sector s, (note: $T(j,k,p) must be positive).

$C(j,s) Total dollars spent on construction type j by sector s.

I(j,k) Index of Corps' use of technology k in construction type j.

I(j) Index of Corps' use of all k technologies in construction type j.

I Index of Corps' use of all k technologies in all j types of construction.

W(j,k) Weighting factor applied to I(j,k) in calculation of I(j).

W(j) Weighting factor applied to I(j) in calculation of I.

Formulae

$$W(j,k) = \frac{\$T(j,k,c) + \$T(j,k,p)}{SUM(k)[\$T(j,k,c)] + SUM(k)[\$T(j,k,p)]}$$

$$W(j) = \frac{\$C(j,c)}{SUM(j)[\$C(j,c)]}$$

$$I(j,k) = \frac{\$T(j,k,c)/\$C(j,c)}{\$T(j,k,p)/\$C(j,p)}$$

$$I(j) = SUM(k)[I(j,k)*W(j,k)]$$

$$I = SUM(j)[I(j)*W(j)]$$

Data

To demonstrate the procedure the following data will be used:

Corps Data

Type of Dollars spent in const. j Total dollars

Construction on technologies k (1,2,3) const.j, sect c

j	$T(j,1,c)	$T(j,2,c)	$T(j,3,c)	$C(j,c)
1	$50.00	$10.00	$100.00	$20,000
2	$5.00	$50.00	$0.50	$2,500

Private Sector Data

Type of Dollars spent in const. j Total dollars

Construction on technologies k (1,2,3) const.j, sect c

j	$T(j,1,c)	$T(j,2,c)	$T(j,3,c)	$C(j,c)
1	$100.00	$20.00	$400.00	$40,000
2	$5.00	$25.00	$1.00	$2,500

Weighting Factors for Construction Sector Indexes

Using the above data Weighting Factors for calculation of I(j)'s are:

$$W(j,k) = \frac{\$T(j,k,c) + \$T(j,k,p)}{SUM(k)[\$T(j,k,c)] + SUM(k)[\$T(j,k,p)]}$$

$$W(1,1) = \frac{(50) + (100)}{(50 + 10 + 100) + (100 + 20 + 400)}$$

$$= 150 / 680$$

$$= 0.2206$$

$$W(1,2) = \frac{(10) + (20)}{(50 + 10 + 100) + (100 + 20 + 400)}$$

$$= 30 / 680$$

$$= 0.0441$$

$$W(1,3) = \frac{(100) + (400)}{(50 + 10 + 100) + (100 + 20 + 400)}$$

$$= 500 / 680$$

$$= 0.7353$$

$$W(2,1) = \frac{(5) + (5)}{(5 + 50 + 0.5) + (5 + 25 + 1)}$$

$= 10 / 86.5$

$= 0.1156$

$$W(2,2) = \frac{(50) + (25)}{(5 + 50 + 0.5) + (5 + 25 + 1)}$$

$= 75 / 86.5$

$= 0.8671$

$$W(2,3) = \frac{(0.5) + (1)}{(5 + 50 + 0.5) + (5 + 25 + 1)}$$

$= 1.5 / 86.5$

$= 0.0173$

Weighting Factors applied to I(j) in calculation of Summary Overall Index I are:

$$W(j) = \frac{\$C(j,c)}{SUM(j)[\$C(j,c)]}$$

W(1) = 20,000 / 22,500

= 0.8889

W(2) = 2,500 / 22,500

= 0.1111

Corps' Construction/Technology indexes for use of all k technologies in construction type j are:

$$I(j,k) = \frac{\$T(j,k,c)/\$C(j,c)}{\$T(j,k,p)/\$C(j,p)}$$

I(1,1) = (50 / 20,000) / (100 / 40,000)

= 0.0025 / 0.0025

= 1.0000

I(1,2) = (10 / 20,000) / (20 / 40,0000)

= 0.0005 / 0.0005

= 1.0000

$$I(1,3) = (100 / 20{,}000) / (400 / 40{,}000)$$
$$= 0.005 / 0.010$$
$$= 0.5000$$

$$I(2,1) = (5 / 2{,}500) / (5 / 2{,}500)$$
$$= 1.0000$$

$$I(2,2) = (50 / 2{,}500) / (25 / 2{,}500)$$
$$= 2.0000$$

$$I(2,3) = (0.5 / 2{,}500) / (10 / 2{,}500)$$
$$= 0.5000$$

Corps' Construction Sector indexes for use of all k technologies in construction types j are:

$$I(j) = SUM(k)[I(j,k)*W(j,k)]$$

$$I(1) = [\ (1*0.2206) + (1*0.0441) + (0.5*0.7353)\ ]$$
$$= 0.6324 \text{ (i.e. less than private sector)}$$

$$I(2) = [\ (1*0.1156) + (2*0.8671) + (0.5*0.173)\ ]$$
$$= 1.8584 \text{ (i.e. greater than private sector)}$$

Corps' Summary Overall index for adopting all k technologies in all j types of construction is:

I = SUM(j)[I(j)*W(j)]

= [(0.6324*0.8889) + (1.8584*0.1111)]

= 0.7686 (i.e. less than the private sector)

It can be seen from the comments on interpreting this index that in this hypothetical example the value of the index, being less than 1, would indicate that the Corps is adopting the chosen technologies LESS than the private sector.

RECOMMENDATIONS

That a pilot study be undertaken to enable the concepts outlined in the previously described procedure to be evaluated using real world data on a small "expert" panel. Emphasis should be placed on investigating the difficulties associated with defining and identifying "new technologies"; and ensuring comparability between USACE projects and those by others. The usefulness or otherwise of significance factors, lead or lag time indexes and risk indexes in qualifying TAI's should also be evaluated.

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Dr. Don Gibson. C.S.I.R.O. Division of Construction & Energy, Highett, VIC. Australia.

Dr. Gy Sebestyen, Secretary, International Council for Building Research Studies & Documentation, Rotterdam, Netherlands.

Dr. J.B. Menzies, Assistant Director, Building Research Establishment, Garston, Watford, Herts, United Kingdom.

Dr. Phil Schneider, National Institute of Building Sciences, Washington , DC.

Chuck McGinnis, Construction Industry Institute, University of Texas at Austin.

Bob Gold, National Association of Home Builders,Research Foundation, 627 Southlawn Ln. Rockville, MD. 20852.

Andrew Nemmer, Building Research Board, 202-334-4319

Ed Beardsworth, Electric Power Research Center, 415-855-2740

Bob Gasperow, Construction Labor Research Council, 202-223-8045

Portland Cement Association, 312-966-6200.

American Society for Testing Materials, 215-299-5400.

Mike King, American Institute of Architects, Research and Planning,1735 New York Ave. NW, Washington, D.C. 20006.(202) 626- 7300.

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APPENDIX

CODEWORKS ANNOUNCES ADDITIONS TO DATABASE

CODEWORKS has released its proposed schedule for adding metropolitan jurisdictions to its CodeCONTROL database. The CodeCONTROL database will cover the entire United States by the end of 1989.

The CodeCONTROL database contains technical summaries of model, state, and local building regulations. You can search more than 750 code subjects -- as they apply to a specific project in a specific jurisdiction -- from the locally adopted versions of each of these seven codes:

Building code

LIfe Safety code

Handicapped accessibility code

Fire prevention code

Plumbing code

Mechanical code

Energy code

There are four kinds of CodeCONTROL reports:

1. Global Reports contain technical summaries of all applicable code requirements for a given project. There are three types of Global Reports: Comprehensive, Architectural, and Mechanical/Electrical. The Global Report should be ordered when the most basic decision about a building project -- such as occupancy, construction type, structural systems, major materials, and approximate height and area -- have been made.

2. Administrative Reports identify (by name and edition) the codes adopted by any jurisdiction in the CodeCONTROL database. They also include the titles, addresses, and phone number of each code enforcing authority within the jurisdiction. The administrative report should be requested at the onset of a building project and again before ordering a Global Report.

3. Comparitive reports allow the user to perform " what if " queries by comparing a changed set of building conditions against an existing Global Report. The comparitive report should be ordered when the original design has been modified and information is needed on what effects the modifications will have on code requirements.

4. Specific Reports identify code requirements that apply to a particular design issue or question.

To request a Code CONTROL search, the user can fill out a short questionnaire, which can be sent to CODEWORKS either electronically through our PC or by mail.

The tentative schedule for adding jurisdictions is as follows:

Third Quarter 1988

Maryland -- Baltimore

New York -- Albany, Buffalo, New York City, Rochester, Syracuse

North Carolina -- Charlotte, Durham, Greensboro,

Raleigh, Winston-Salem

Tennessee -- Chatanooga, Knoxville

Virginia -- Newport News, Norfolk, Richmond, Roanoke

Washington DC

Fourth Quarter 1988

Kentucky -- Frankfurt, Lexington, Louisville

Ohio -- Akron, Dayton, Cincinnati, Cleveland, Columbus,

Toledo

Pennsylvania -Harrisburg, Philadelphia, Pittsburgh

First Quarter 1989

California -- Anaheim, Bakersfield, Fresno, Long Beach, Los Angeles,

Modesto, Oakland, Sacramento, San Bernadino, San Francisco,

San Jose, Stockton

Oregon -- Portland

Washington -- Spokane

Second Quarter 1989

Arizona -- Pheonix, Tucson

Colorado -- Colorado Springs, Denver, Pueblo

Illinois -- Chicago, Peoria, Rockford, Springfield

Indiana -- Evansville, Fort Wayne, Indianapolis, South Bend

Iowa -- Cedar Rapids, Davenport, Des Moines

Kansas -- Kansas City, Topeka, Wichita

Michigan -- Detroit, Flint, Grand Rapids, Lansing, Madison, Milwaukee

Missouri -- Kansas City, St. Louis

Nebraska -- Lincoln, Omaha

New Mexico -- Albuquerque

Nevada -- Las Vegas, Reno

Texas -- Amarillo, Austin, Beaumont, Corpus Cristi, Dallas, El Paso, Fort Worth, Houston, Lubblock, Oklahoma City, San Antonio, Tulsa, Waco

Metropolitan areas already covered by CodeCONTROL include:

Alabama -- Birmingham, Montgomery

Conneticut -- Hartford, New Haven, Stamford

Florida -- Fort Lauderdale/Hollywood, Jacksonville, Miami, Orlando, Tampa/St. Petersburg, West Palm Beach

Georgia -- Atlanta, Columbus, Macon, Savannah

Massachusettes -- Boston

New Jersey -- Newark, Trenton

Rhode Island -- Providence

South Carolina -- Columbia

Tennessee -- Memphis, Nashville

Prices:

Adminstrative Reports are $25 plus the cost of delivery other than first class mail. If you need administrative information immediately, call CODEWORKS Professional Services at 1-800-634- CODE and specify the jurisdiction. They will answer questions over the telephone and will mail you a copy of the administrative report the same day.

The prices for other reports are:

Global Comprehensive Report..................$350

Global Architectural Report.......................$200

Global Mechanical/Electrical Report..........$200

Comparative Report..................................$100

Specific Report...$25