Factors Affecting Adoption of Information Systems in State Departments of Transportation

Jeffrey S. Lane and David T. Hartgen

A recent survey of state departments of transportation purchasing practices for major management information systems is discussed in this paper. The study is based on responses from 26 states to a questionnaire covering four large information systems. State DOTs spent an average of $13.2 million on four systems (Computer Aided Drafting and Design (CADD), Geographic Information Systems (GIS), Roadway Data, and Capital Project Management); another $5.75 million is currently planned for spending in the next three years. Although total costs per access point range from $7,400 for Capital Project Management to $113,000 for CADD, they are expected to fall by 50 percent. System diffusion has been slow for some systems—more than 40 years—and fairly rapid for others—18 to 22 years—for CADD and GIS. The projected dates for complete system diffusion is similarly wide-ranging: 1995 for GIS, but 2005 for Roadway Data and 2010 for Capital Project Management systems. These differences result primarily from the large gap between leading and lagging states. Leading states, such as Texas, Pennsylvania, Wisconsin, and Washington, are installing information systems an average of 13 years ahead of lagging states. The gap between states is primarily because of the leading states' larger relative investment in hardware and software, and greater relative number of skilled computer personnel per employee. Several suggestions are made on how lagging states can catch up, including investing in computer infrastructure, setting clear priorities, networking with other states, and supporting professional organizations' efforts to modernize systems.

The 1970s and 1980s have witnessed a revolution in information processing technologies. Within the span of just a few years, the unit cost of information systems [cost per millions of instructions per second (MIPs)] have fallen dramatically. The last ten years have seen many advances, particularly in the availability of microcomputers, larger and faster mainframes, increasing functionality, relational data bases, graphical and fourth generation computer languages, geographical information systems, communications networks for local and wide areas, the advent of minicomputers and distributed processing, and the beginnings of data, voice, and image integration. The effect of this evolution is to decentralize computing power, and along with it responsibility and authority, while increasing analytical capability data access. Experts believe that these trends will continue: by the turn of the century, the average office worker's computing power is likely to be orders of magnitude larger than that possessed by entire companies in the 1960s, at a fraction of the cost.

Department of Geography and Earth Sciences, University of North Carolina at Charlotte, Charlotte, N.C. 28223.

State highway departments have participated in these trends. But limited budgets, lengthy recapitalization processes, periodic management changes, staff and skill shortages, small research and development budgets, and heavy prior investments in information processing technology have meant that these organizations often find it difficult to modernize quickly. Internal pressures for modernization, increasing knowledge of agency personnel, and fiscal opportunities have encouraged change.

Since 1970, the diffusion of computerized information systems in the field of transportation has been steady. But progress has been more rapid in some states than in others. Understanding the reasons behind these differences suggests that three items be examined: (a) "carriers"—those factors which encourage adoption of innovation, (b) "barriers"—those factors which impede adoption of innovation, and (c) "leaders"—the innovators in the field and the characteristics they possess which put them on the leading edge of innovation (*1*, *2*). This paper intends to provide some understanding of the diffusion of computerized transportation information systems in state-level DOTs, the processes of diffusion, and the traits that innovators in the transportation field possess. In this way, the diffusion process can be accelerated by providing information about pitfalls and suggesting positive ideas.

In recent years, many states and local governments have begun the process of developing integrated management information system (MIS) capabilities. In the transportation sector, efforts began in the late 1960s and focused primarily on highway locations for accident data reporting and public assistance (*3*). Storage and retrieval systems for highway data were well established by the mid-1970s (*4*), with two agencies (Texas and Illinois) planning the development of distributed systems using minicomputers, and 20 states using or developing integrated data base systems. This 1978 National Cooperative Highway Research Program (NCHRP) study recommended that "Maximum use should be made of user-controlled, interactive systems with on-line terminals which allow data input at the source, reduce errors, have information available when needed, and allow all data to be available to all users." A 1986 workshop on file linkages, sponsored by FHWA (*5*), found that all 10 participating states were developing integrated information systems, often driven by the need for better accident data. The workshop concluded that "file linkage" (integration), as a management tool, had far more comprehensive potential and that highway safety was a principal [driving factor], but that discussion could not be confined to safety only. A recent review of integrated information systems (*6*) found efforts to develop integrated information systems underway in Pennsylvania, Wisconsin, Idaho, Washington, Maine, Utah, Michigan, Kansas, Colorado, New York, and Kentucky, to name a few. Although each state adopted different approaches and focuses, all states were extensively involved in strategic planning for the end result: integrated information on a modern MIS. NCHRP recently advertised for new systems development in GIS and executive MISs.

ADOPTION PROCESS

Diffusion is the process by which a product, idea, or service moves through a potential market. The sequence of diffusion for many innovations begins slowly, then builds speed, but later slows and eventually ceases. This produces a normal bell-shaped curve (percent of adoptions versus time) showing which adoptions were first (leaders) and which were last (laggards) (*2*). If the number of adopters is cumulated, an S-shaped curve results. Figures 1a and b show typical curves.

Basic Elements of Diffusion Process

Rogers (*2*) and other diffusion researchers identify several basic elements of the diffusion process that are useful.

1. Carriers—factors which assist or encourage adoption to take place. Among the most commonly observed factors are
   - Money
   - Management directives
   - Service or product failures
   - Presence of champions
   - Actions of competitors
   - New market creation
   - New management approaches
   - Staff ideas
   - Literature searches
   - External assistance
   - New technology
   - Legal orders (laws, ordinances, etc.)

2. Barriers—Factors which slow or stop the process of innovation
   - Lack of communication
   - Turf battles
   - Lack of fiscal reserves
   - Outdated technology
   - Ignorance of one's field

3. Leaders—innovators in an area are called leaders, while those who tend to lag behind are called laggards. The differences between leaders and laggards has been related to
   - Education or experience
   - Professional expertise
   - Awareness of technology
   - Negotiating or managing skills
   - Views about innovation

The adoption process can also be thought of as a technology lifecycle (Figure 1). In this model, the adopter moves through stages of adoption, honeymoon, increasing dissatisfaction, review of alternatives, decision to adopt, and subsequent adoption of a new or revised product. Adopter satisfaction with the product is likely to peak just after the decision to adopt—before actual adoption or the honeymoon phase lets the adopter see the flaws—and lowest just before the review of alternatives. Figure 1 shows these stages.

Variables Affecting Diffusion Process

The literature concerning innovation and diffusion suggests many different variables which may affect a particular adoption process. Six categories of variables have been identified which might affect the adoption of computerized information systems in state DOTs.

1. *System characteristics (functionality)*—the functionality of a particular system is a measure of how that system serves the user's needs. Systems with a low measure of functionality are likely targets for replacement or updating.
2. *Agency characteristics*—the size (*7*) and spending capital (*8*) of an agency have been proposed as having positive effects on the rate of diffusion. The presence of internal mechanisms of change, such as development groups in the agency, has been used in the study of diffusion in retail operations (*9*).
3. *Management characteristics*—conference attendance (*10*, *11*) and knowledge of current literature in one's field of work (*10*) have been cited as characteristics of innovators. The length of time at a position within the same agency also has been proposed as having an effect on innovativeness.
4. *Geography*—the degree of interaction with nearby universities and communication with other groups similar to the one being examined (*10*, *12*) have been used as explanatory variables in several studies, including cultural diffusion.
5. *Vendor characteristics*—supplier aggressiveness may also play a part in the decision on when a system is chosen (*10*). Support, product price, and other similar features will often influence adoption.
6. *Governmental factors*—the introduction of a government mandate or the availability of government funding might prompt the adoption of a system that otherwise would be deemed too costly to produce.

The information in Table 1 suggests how these factors might be expected to affect innovation.

METHODOLOGY

For this research, state-level DOTs were questioned regarding different types of information systems. It was not possible to review all such systems, therefore four systems were chosen to represent a range of diffusion levels, function, and other concerns. These four systems are as follows:

1. CADD (Computer Aided Drafting and Design),
2. GIS (Geographic Information Systems),
3. Roadway Data Inventory Systems, and
4. Capital Project Management Systems.

These four systems were chosen because each system was thought to be at a different stage of development, thus providing an opportunity to study information systems at various stages of diffusion. The survey instrument was designed to gather information in several areas that literature in the fields of both diffusion and transportation research has identified as being important to the adoption of innovation. A mail-out questionnaire was sent to each DOT, with one questionnaire going to each state. The questionnaire was broken into five two-page parts, one part for each of the four systems and a background sheet to be answered by the head of the computer division. A copy of the survey instrument (for the CADD system) is provided (Figure 2). A total of 26 states answered all or part of the questionnaire, which included a series of follow-up telephone calls. Table 2 summarizes the survey's findings, and Table 3 shows data on the responses. Figures 3–6 show the pattern of responding states; data was most complete for the CADD and background information sections of the survey.

The methods used in the study are simple statistics, mapping, and logistic curve analysis. Simple statistics, such as means comparison, are easy to create and can be converted into charts or diagrams that can be used to visually emphasize characteristics of an individual system or a group of systems. Mapping the spatial characteristics of a diffusion process has been used extensively in diffusion research (*1*, *13*). Logistic curve analysis is also a popular tool among many diffusion researchers (*12*, *14*, *15*).

Logistic curves, or S-shaped curves, are used to determine the level that an innovation has reached within its potential marketplace. The highest level that a particular innovation

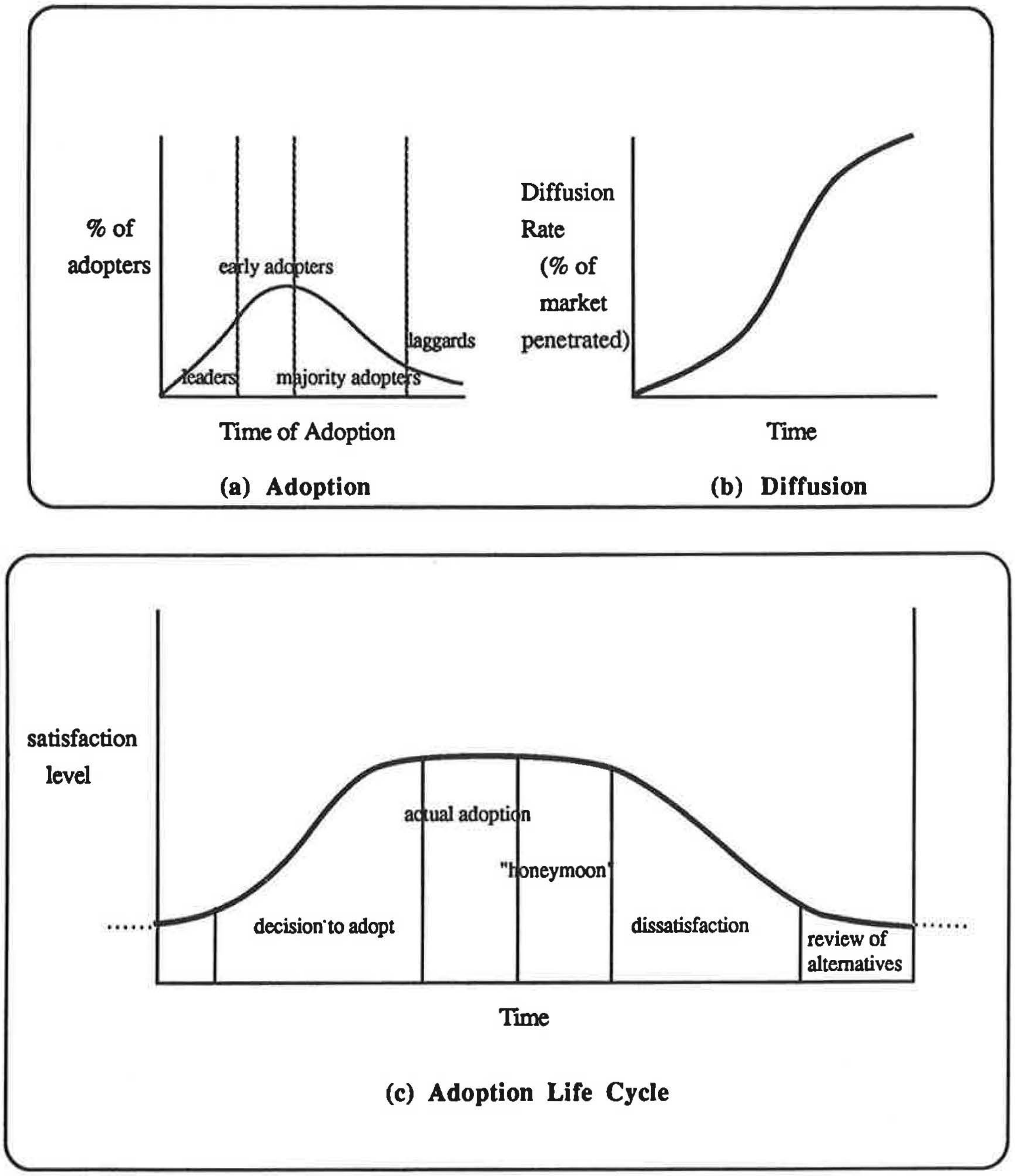

FIGURE 1 Adoption and diffusion curves.

TABLE 1 VARIABLE CATEGORIES AND DEFINITIONS

Category	Definitions: Conceptual	Definitions: Operational	Purpose/Level of Measurement
A. System Itself			
1.	Functionality	Desired Characteristics of a System	It is proposed that the degree of functionality is positively related to the speed of diffusion.
B. Agency Characteristics			
1.	Size	Employment	It is proposed that the size of an agency may be correlated to its willingness to adopt innovation.
2.	Wealth/Capital	Operating Budget	It is proposed that the amount of available capital in an agency is positively related to the willingness to adopt innovation.
3.	Internal Mechanisms for Change	Presence of Development Groups/Facilities	It is proposed that the presence of development groups which may adapt or modify systems will positively influence adoption.
C. People/Management			
1.	Awareness of progress in the field	Conference Attendance & Literature Read	It is proposed that an awareness of the transporttion field is positively related to the acceptance of innovation.
2.	Familiarity with position in agency	Length of Time at Current Position in Agency	It is proposed that the length of time a manager spends at the same position will be related to the willingness to adopt innovation.
D. Geography/Organization Interaction			
1.	Size of Community	Population of City/SMSA	It is proposed that the size of the metropolitan area around an agency has a positive effect upon the speed of diffusion.
2.	Distance/Interaction with Related Organizations	Presence/Interaction with a University	It is proposed that interaction with a university will aid the diffusion process.
		Interaction with the Same or Similar Agencies	It is proposed that the degree of interaction with similar agencies will increase the speed of diffusion.
E. Supplier Factors			
1.	Sales Aggressiveness	Number of Contacts with a Supplier/Distributor Prior to Adoption of System	It is proposed that the number of contacts with a a supplier or distributor of a system will increase the speed of adoption.
F. Governmental Factors			
1.	Government Impetus for Innovation	Government Mandate Calling for the Acquisition of a Computer System or Funding	It is proposed that the presence of government mandates or government funding will have a positive effect on the speed of diffusion.

Please Return To: David T. Hartgen
Department of Geography and Earth Sciences
University of North Carolina at Charlotte
Charlotte, N.C. 28223

Questionnaire number _____
State ___________________

Please answer, as accurately as possible, the questions below concerning characteristics of your DOT.

==

1) How many people were employed in your entire DOT in the previous fiscal year (1988)? ____________

2) How many operators, programmers, technicians, and supervisory personnel were employed in the CADD, GIS, roadway data inventory, and capital projects management system areas in your agency in the previous fiscal year (1988)?

____

3) What was your agency's operating budget for the CADD, GIS, roadway data inventory, and capital projects management systems in the previous fiscal year (1988)? __________

4) Please place a check mark (√) beside the functions this DOT normally performs:

design computer systems _____
build computer systems _____
modify computer systems _____

5) How many individual computerized workstations (terminals) does your DOT currently have? __________

6) Do you currently have a formal or structured planning process which allows you to assess computing needs in your DOT?

circle one: YES NO

TO THE PERSON WHO COMPLETES THIS FORM:

7) On the average, how many professional conferences do you attend a year? ________/year

8) On the average, how many technical periodicals (magazines, newsletters) do you see a month? ________/month

9) How long have you been employed in this agency? (years/months) ______/______

10) How long have you been employed in your current position? (years/months) ______/______

Please indicate with a check mark (√) if you would like a copy of our results: _____

Thank you for your cooperation.

FIGURE 2 Survey instrument.

FIGURE 2 *(continued)*

Please Return To: David T. Hartgen
Department of Geography and Earth Sciences
University of North Carolina at Charlotte
Charlotte, N.C. 28223

CADD
State ________________
Questionnaire No. _____

CADD system manager:

Please answer the following questions concerning the CADD system your agency currently has. The answers will be used in a nationwide study to determine how state transportation agencies make choices about the acquisition of computer equipment.

==

1) Please place a check mark (√) indicating the importance of the following reasons why your agency decided to focus on the area of computer-aided design.

	unimportant	somewhat important	very important	don't know/ not applicable
Federal regulation or requirement	_____	_____	_____	_____
High agency priority	_____	_____	_____	_____
Increase staff productivity	_____	_____	_____	_____
Easy to integrate with existing equipment	_____	_____	_____	_____
Availabilty of federal grant	_____	_____	_____	_____
Dissatisfied with previous system perfomance	_____	_____	_____	_____
Previous system was outdated	_____	_____	_____	_____
Other ____________________ *(please explain)*	_____	_____	_____	_____

2) Please name the CADD system and version you have:

system name ________________________

system version ________________________

3) Please place a check mark (√) indicating the importance of each factor below in the decision-making process of which particular CADD system version you chose.

	unimportant	somewhat important	very important	don't know/ not applicable
Review of professional literature	_____	_____	_____	_____
Communication with a college	_____	_____	_____	_____
Several agency persons "pushing" the system	_____	_____	_____	_____
Discussions with other state DOT's	_____	_____	_____	_____
Compatability with existing equipment	_____	_____	_____	_____
Result of a formal evaluation	_____	_____	_____	_____
Supplier or vendor salesmanship	_____	_____	_____	_____
Other ____________________ *(please explain)*	_____	_____	_____	_____

4) If you believe that another state DOT was important in the decision-making process, then please list in order of importance up to three state DOT's that most influenced the decision of which system you chose.

state DOT #1 ________________________

state DOT #2 ________________________

state DOT #3 ________________________

5) How long did this decision-making process (pre-installation) take? (years/months) _____/_____

6) When was your CADD system first installed? (month/year) _____/_____

7) How many people are presently able to use your CADD system simultaneously?
(how many access points)? ____________

FIGURE 2 (*continued*)

8) Was the acquisition of any new hardware or software required to operate your CADD system?

circle one: YES NO

9) What is the cost of each of the following elements of your CADD system to date (including capital, personnel, contracts, operation)?

Planning	$________
Equipment	$________
Consulting	$________
Training	$________
Development	$________
Operation (after installation)	$________
Other	$________
Total system cost	$________

10) Please indicate the percentage of funding the following source(s) used to develop (prior to operation) your CADD system:

	% of funding
Federal funds	____
State funds	____
User fees	____
Private sector financing	____
Other ________________ (*please explain*)	____

11) How well does your CADD system fit your present needs?

(*circle one*)

very poorly	poorly	adequately	well	very well
1	2	3	4	5

12) How many more access points to your CADD system are planned for in the future? ____________

13) By what date are these access points planned to be entered into your CADD system? (month/year) ____/____

14) How much more money is currently planned for your CADD system? $__________

15) In the forseeable future, is your DOT planning to keep a CADD system? *circle one*: YES NO

TO THE PERSON WHO COMPLETES THIS FORM:

16) On the average, how many professional conferences do you attend a year? ________/year

17) On the average, how many technical periodicals (magazines, newsletters) do you see a month? ______/month

18) How long have you been employed in this agency? (years/months) ____/____

19) How long have you been employed in your current position? (years/months) ____/____

Please return this questionnaire to the Computer Systems Director. Thank you for your cooperation.

TABLE 2 PAST AND FUTURE PLANNED STATE DOT INVESTMENTS IN FOUR INFORMATION SYSTEMS

	CADD	GIS	Roadway Data Inventory	Capital Project Management
Planning Process Length (yrs)	1.52	2.2	3.43	2.64
Installed (years ago)	4.43	3.43	13.53	8.19
Access Points	90.45	40.27	113.87	54.46
Total Costs	$10,282,614	$1,215,471	$1,395,888	$405,921
Federal Share of Funding	.05%	48.8	40.24	25.2
Satisfaction Level (1-5)	3.91	3.86	3.68	3.38
Future Access Points	41.20	190.8	197.33	52.80
Years to Installation of Planned Access Points	1.74	2.97	2.20	2.50
Planned Future Expenditures	$2,191,222	$2,360,000	$207,272	$992,250
Past Cost/Access Point	$113,682	$30,183	$12,258	$7,442
Future Cost/Access Point	$53,185	$12,368	$1,050	$18,797

can achieve is called its "ceiling." Typically, a logistic curve graph has time or some function of time represented on the x-axis and the accumulated percentage of adopters on the y-axis. (Refer to Figure 1.) The logistic curve's slope is usually gradual at first, followed by a sharper incline as the innovation "catches on" among potential adopters. The final phase ends with a leveling off as the market becomes saturated.

FINDINGS

In the analysis that follows, it is important to realize that diffusion rates are measured by the number of respondents reporting (26 states). If nonresponding states were considered, then the adoption rates would probably be lower.

Present Level of Diffusion

The results of the study reveal several interesting features of the innovation process in DOTs. The graph in Figure 7 shows the current level of diffusion for each of the information systems being studied. Perhaps not surprisingly, GISs are the least diffused information system among state DOTs at the present time, with 57 percent of respondents now in possession of a geographic information system. CADD systems are completely (100 percent) diffused among state DOTs with every respondent having such a system in place. Roadway Data Inventory systems and Capital Project Management systems fall in between these two extremes, being 87 and 61 percent diffused, respectively.

The average number of years since an information system was installed is shown in Figure 8. GISs are the most recent systems to be added, installed on an average of less than 2.7 years ago. Roadway Data Inventory systems are the oldest, having been installed, on average, more than 11.5 years ago. The need to handle the large amount of roadway data that is necessary for a state-level DOT to function effectively made such a system appear to be an invaluable asset. At the time Roadway Data Inventory systems were first being installed in DOTs, the remaining three systems were either not technologically feasible or were considered a less vital addition to the agencies. Another interesting feature of this graph is that although CADD systems came on-line an average of only 4.24 years ago, they are the only systems surveyed that were completely diffused throughout the DOTs that responded. This indicates the very high priority that DOTs attached to these systems.

Rates of diffusion can also be seen in the logistics curves shown in Figure 9. The first states having Roadway Data systems were installed in 1965, adoption climbed steadily to the early 1980s, then leveled off. Capital Project Management systems followed a similar course. CADD systems began in the early 1970s, but then "took off" in the early 1980s, reaching their ceiling at the present time. GIS systems appear to be following a similar track to CADD. At its present rate of diffusion, GISs could be totally diffused in just a few years (estimated at 1995). However, at present rates of diffusion, Capital Project Management systems and Roadway Data

TABLE 3 STATES RESPONDING TO SURVEY OF INFORMATION SYSTEMS

	STATE	BACKGROUND	CADD	GIS	ROADWAY DATA	CAPITAL PROJECT
1	Alaska			✓	✓	
2	Arkansas	✓	✓	✓	✓	
3	California	✓	✓	✓	✓	✓
4	Colorado	✓	✓	✓	✓	✓
5	Georgia	✓	✓	✓	✓	
6	Idaho	✓	✓		✓	✓
7	Indiana	✓	✓	✓	✓	
8	Iowa	✓	✓	✓	✓	
9	Maine	✓	✓	✓	✓	✓
10	Maryland	✓	✓	✓	✓	✓
11	Mississippi	✓	✓		✓	✓
12	Montana	✓	✓			
13	Nebraska	✓	✓	✓	✓	
14	Nevada	✓	✓	✓	✓	✓
15	New York	✓	✓	✓	✓	✓
16	N. Carolina	✓	✓	✓	✓	✓
17	N. Dakota	✓	✓			
18	Oklahoma	✓	✓		✓	✓
19	Rhode Isl.	✓	✓	✓	✓	✓
20	S. Carolina		✓			
21	Tennessee	✓	✓		✓	✓
22	Texas	✓	✓	✓	✓	✓
23	Utah	✓	✓		✓	✓
24	Vermont	✓	✓		✓	
25	W. Virginia	✓	✓		✓	✓
26	Wyoming	✓	✓		✓	

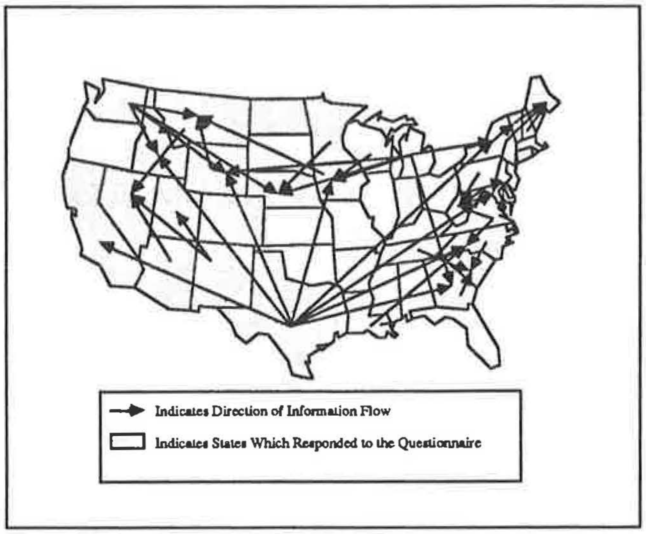

FIGURE 3 CADD communication between state DOTs.

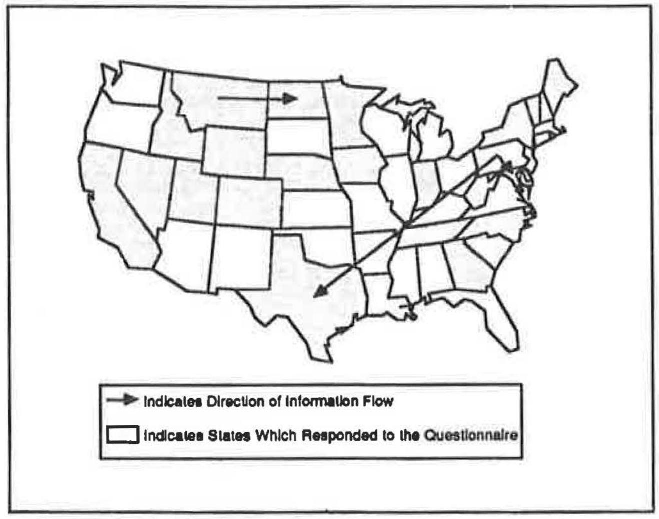

FIGURE 5 Roadway data inventory system communication flow between state DOTs.

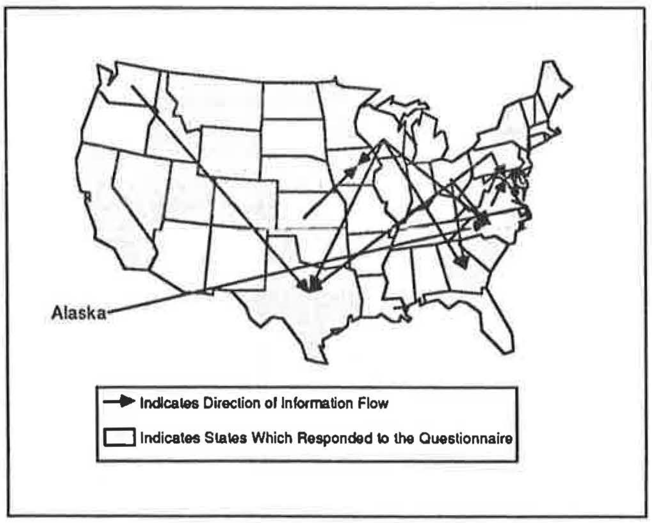

FIGURE 4 GIS communication between state DOTs.

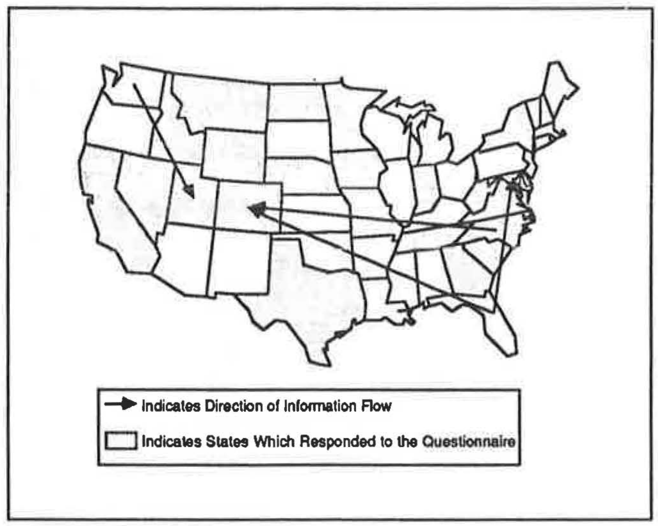

FIGURE 6 Capital project management system communication flow between state DOTs.

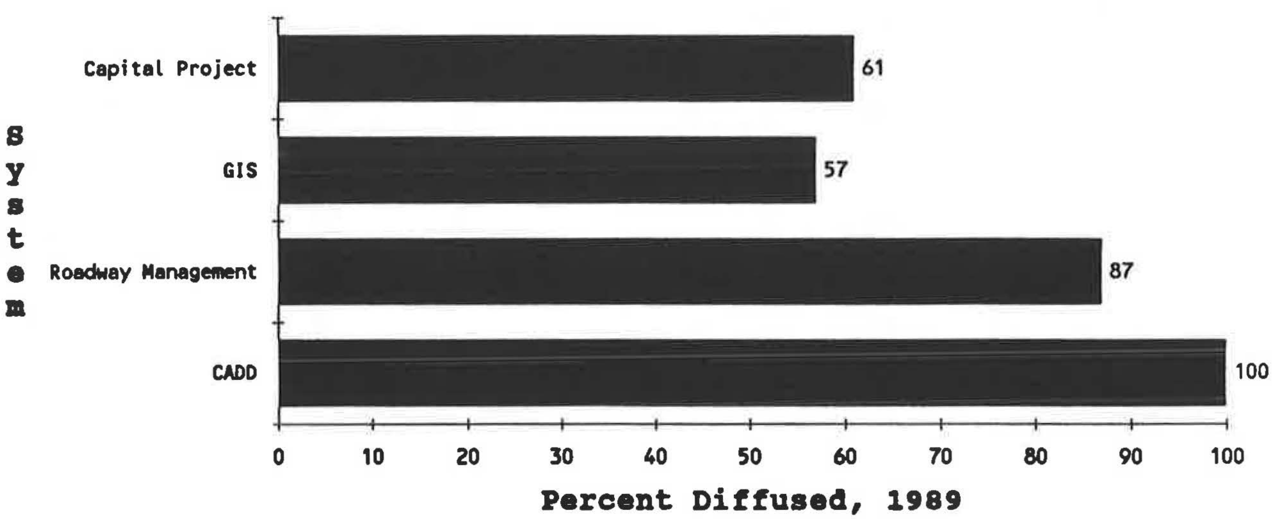

FIGURE 7 Information system diffusion among state DOTs.

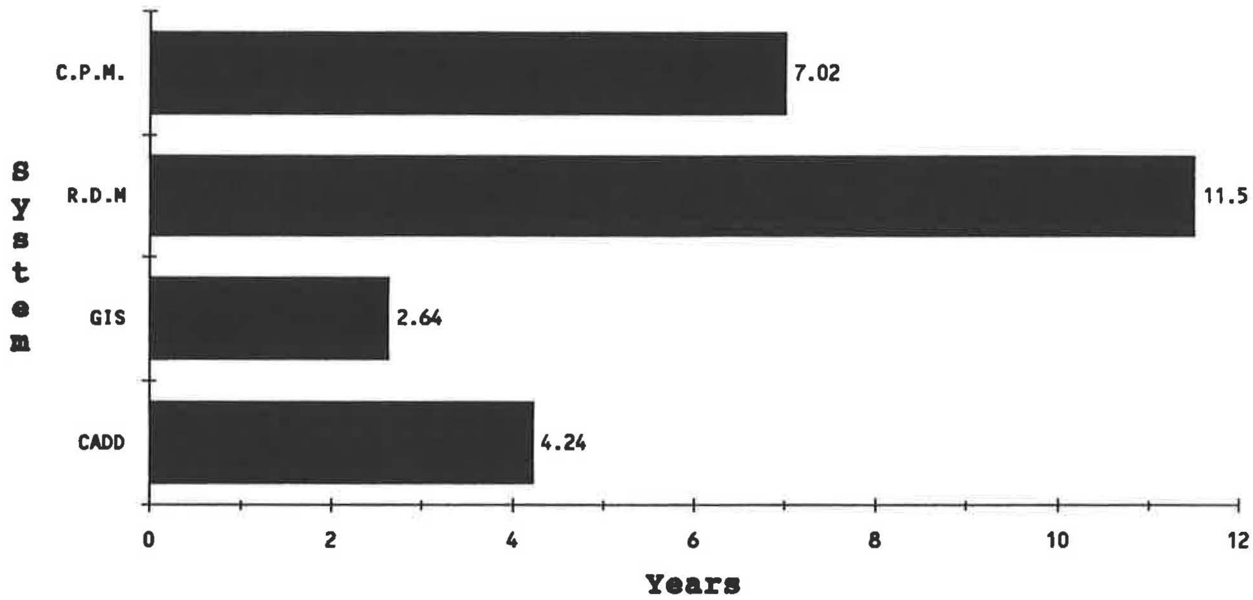

FIGURE 8 Average number of years since system installation occurred.

Inventory systems are unlikely to reach total diffusion before 2010 or 2005, respectively. This would imply diffusion times for these four systems as follows:

System	*Diffusion Time*
CADD	18 years (1971 to 1989)
GIS	22 years (1973 to 1995)
Roadway Data Inventory	40 years (1965 to 2005)
Capital Project Management	42 years (1968 to 2010)

The states have invested heavily in these systems. On average, DOTs have spent \$10.2 million on CADD, \$1.4 million on Roadway Data Inventory systems, \$1.2 million on GIS, and \$405,000 on Capital Project Management systems (Table 2). The total installation cost per access point (workstation or terminal) was highest for CADD (\$113,682) and lowest for Capital Project Management (\$7,442). State DOTs also plan future expenses for each system: GIS and Capital Projects future dollars are projected at twice present expenses. However, the projected cost per new access point will be lower, except for Capital Project Management systems, where a second round of basic development efforts is still taking place.

Factors Influencing Adoption of MIS Products

This discussion suggests that certain factors have propelled the diffusion process of CADD and GIS beyond those of Roadway Data and Capital Project Management systems. What are these factors?

To investigate these issues, Figure 10 shows responses to perceived importance of six variables in selecting a system to focus on. Clearly, the most critical variables are (a) perceived gains in productivity and performance, (b) perceived high agency priority, and (c) a presently outdated system. In other words, a squeaking wheel, with a need to fix it, gets the attention. In the present case, the "need" is the pressure to reduce operating costs by improving agency productivity. It is not enough for an outdated computer system to have problems; the system must serve a high priority function, and the agency must perceive that improvements in the old system will yield productivity gains.

Data in Figure 10 also suggest that several factors are less critical in focusing an agency's attention on certain systems. Grant money alone does not increase attention, nor will federal mandates (alone). Surprisingly, even the long-term goal of data system integration is not as critical. The message of these charts is clear: do not wave financial carrots or regulatory sticks. Instead show how improvements will accomplish high priority objectives, save money, and improve system performance.

Does it follow from Figure 10 that CADD and GIS systems are perceived as more critical than Roadway Data or Capital Project Management systems? Figure 11 shows a comparison of views on each system. Surprisingly, all systems rated high on "agency priority." Data in Figure 11 suggest that at the time they were implemented, all systems were a high priority; after implementation, priority naturally shifted to other systems. The image produced is one of a careful agency, selecting its targets sequentially, and implementing them in sequence. If adoption of Roadway Data and Capital Project Management systems has slowed—and apparently it has—then it would seem to be that these systems are not making the case that they are necessary, productivity will be gained, and that they are presently outdated.

A key element arising from our explanation is the idea of an agency's power structure—that is, which agency division holds the greatest sway. It is our experience that in the majority of state DOTs, it is the design and engineering division. One might view Figure 9 as an indicator of the shift in power over the past 15 years away from planning and financial functions, and toward engineering and design functions. Remembering that these agencies were originally engineering oriented in the 1950s, Figure 9 suggests a resurgence of traditional functions after an interim period of relatively greater attention to planning and fiscal matters. Further investigation of this

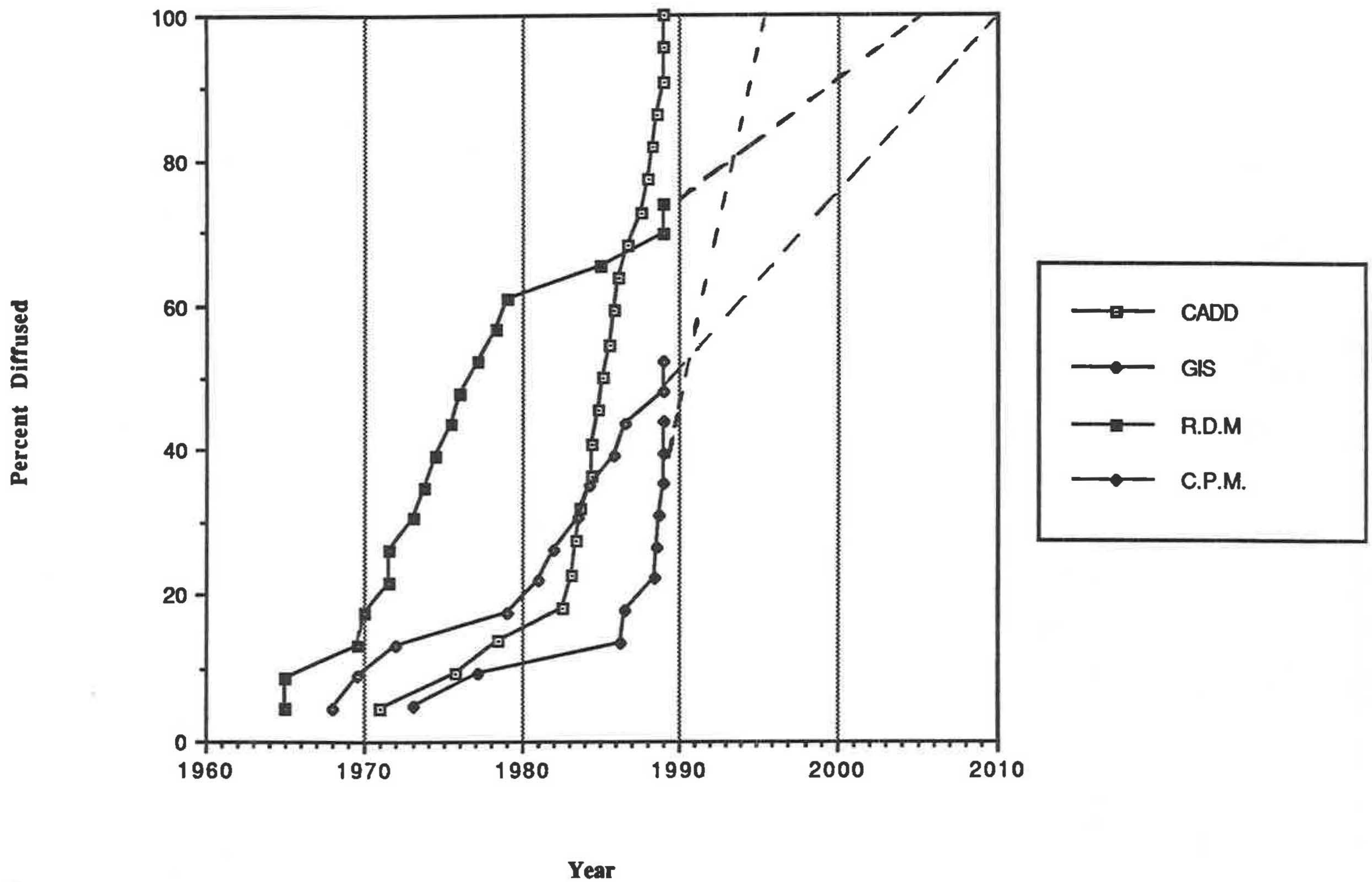

FIGURE 9 Diffusion of information systems in state DOTs.

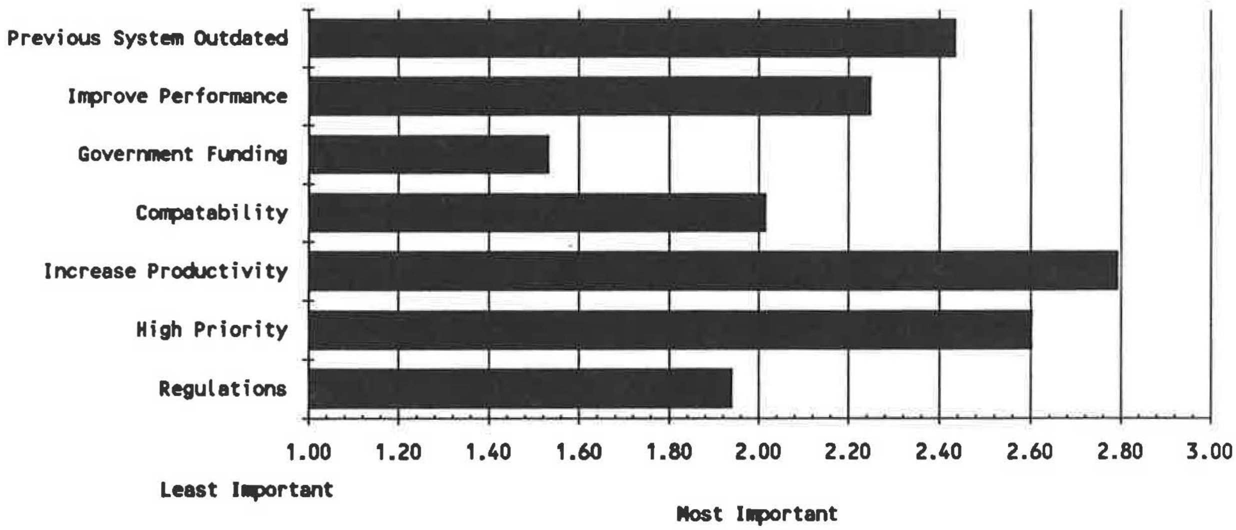

FIGURE 10 Importance of six variables to the selection of an information system.

would require a broad study of the evolution of power bases inside these organizations.

How Do Agencies Select MIS Products?

The process of product selection appears to be a deliberate one, based largely on comparisons. As Figure 12 shows, the state DOTs appear to be careful consumers of information systems, relying mostly on comparative evaluation of alternative systems and on the experiences of other state DOTs. System compatibility (with existing systems) and the presence of product "champions" inside the agency also seem to be important. Of much less importance were literature reviews, salespersons' pitches, and university expertise. The high showing of champions (within an agency) is disturbing because it is not clear why such persons deserve such influence or whether they may have conflicts of interest in making recommendations. The image suggested here is of a conservative yet vulnerable agency, asking advice of peers, doing its own evaluation, and resisting the input of others, yet relying heavily on inside champions' views.

Do these images vary for different systems? No. Figure 13 shows the same pattern of reliance for each of the four systems studied.

Who Are the Leaders?

Two approaches to this question are possible. First, one can simply list the adopters by date. This approach shows which respondents reported early development times. Because a complete survey is not available, however, this list would likely be inaccurate.

To enhance the first approach, another method would be to identify which states were contacted, as each developed its system, and trace these contact networks to their sources. Our survey yielded only sketchy information on these networks, but enough was found to describe.

Our most complete description was for CADD (Figure 3). Here respondents mentioned most frequently direct contacts with Texas (8), Washington (4), and New York and New Mexico, (2 each). Against this national picture, there are several regional distinctions: in the Southeast, Georgia, South Carolina, North Carolina, and Virginia all helped each other; in the Northeast, Maine obtained information from New Hampshire, Vermont, and New York; and in the West, Nevada, Idaho, Montana, Arizona, and New Mexico all interacted. Texas is of particular interest. It influenced eight states directly and four indirectly (South Carolina, through Georgia; Maine through New York; West Virginia through Maryland; and Montana through Iowa).

For GIS (Figure 4), the leaders appear to be Wisconsin (4 contacts) and Pennsylvania (2). No clear leader emerged, but Wisconsin seemed to be held in the highest regard. Regional clustering of information flows has not yet evolved.

The data was very sparse for both Roadway Data and Capital Project Management systems. It may be that because these systems were installed quite some time ago and were largely developed in-house, the amount of communication has not been recorded or was lower at the outset.

Leaders versus Laggards

To sharpen understanding of the adoption process, the characteristics of leaders (the first 25 percent of adopters) and laggards (the last 25 percent of adopters) were reviewed. Because the sample is incomplete and diffusion is ongoing, some laggards may be early adopters. If this is the case, the differences between these groups are likely to be smaller than if a complete sample was available.

Figure 14 compares the characteristics of information system managers of leading and lagging systems. The figure suggests leaders are more experienced, but they do not have as much exposure to professional input. In all cases, the differences are not large.

However, leading and lagging states do differ on other traits. System innovation is, on the average, *13 years ahead* in the

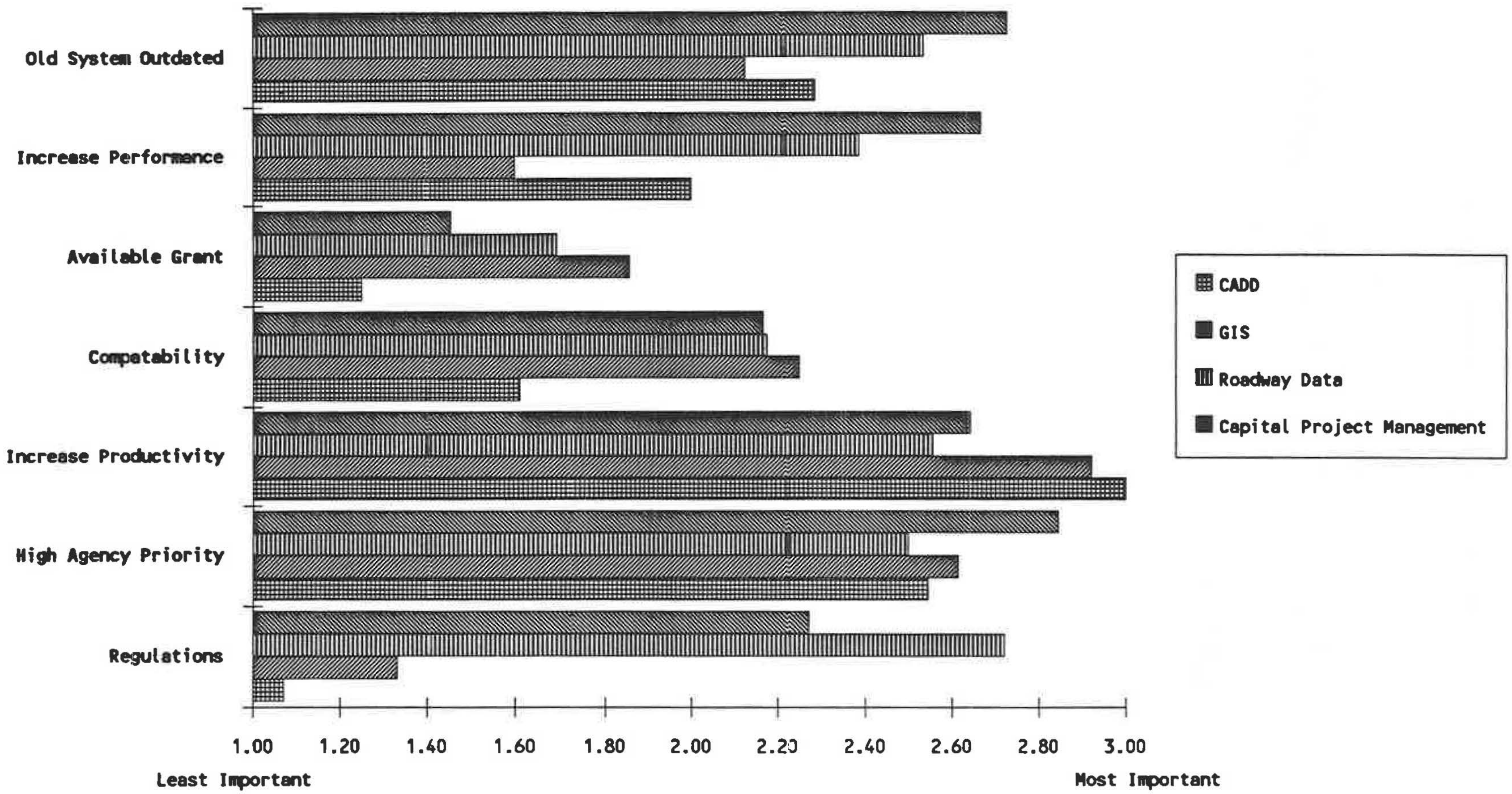

FIGURE 11 Importance of six factors to the development of an information system, by system.

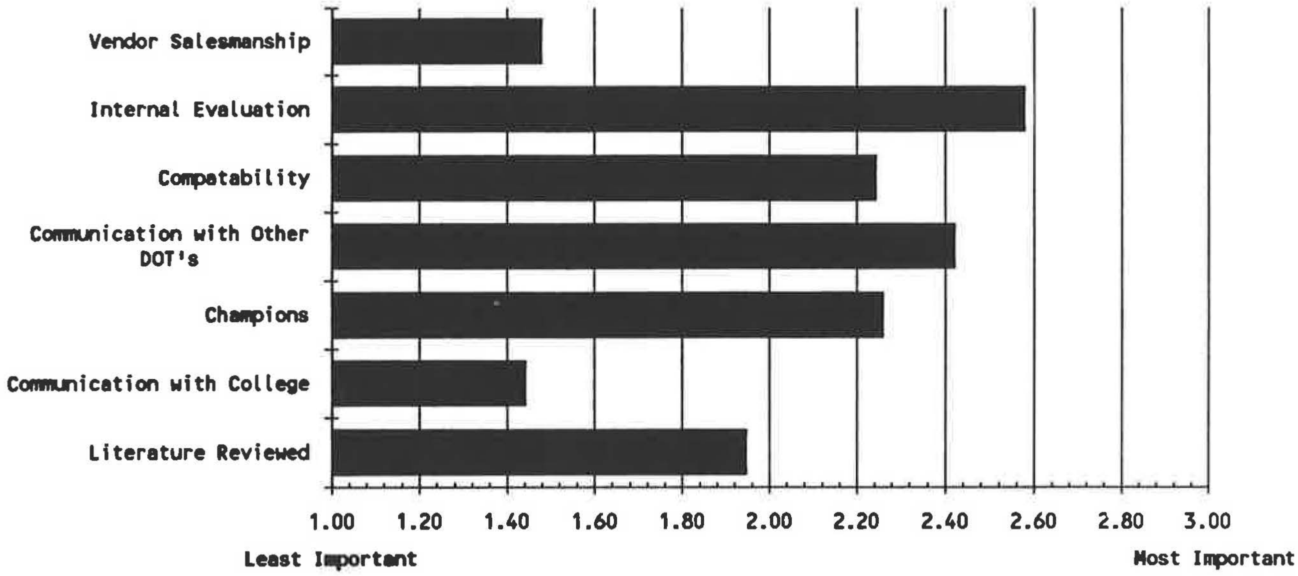

FIGURE 12 Importance of six variables to the selection of system version.

leading states. Table 4 suggests that leader agencies are bigger, more computer literate, and better staffed with computer expertise. On average, leaders have 46 percent more workstations per employee, spend 71 percent more money per employee on systems, and have 257 percent more computer experts per employee.

Ironically, laggards rated the factors cited as being most critical to system adoption consistently higher than did leaders. The pressures are greater on the smaller agency, but the tools are not present to do the job. The image is that of a tired horse being exhorted by his master to catch up, but not being given the sustenance to do so.

POLICY IMPLICATIONS AND CONCLUSIONS

Large differences exist in the status of state DOT information systems. Some systems are completely diffused, others are diffusing very rapidly, and still others are not diffusing at all. CADD and GISs are moving very rapidly, but Roadway Data and Capital Project Management systems are moving very slowly. Future plans for these systems are likewise skewed. State DOTs plan to more than double investment in both GIS and Capital Project Management systems, but will increase funding for Roadway Data and CADD by only 20 percent.

System priority depends on (a) perceived gains in productivity, (b) how outdated the current system is, and (c) the priority an agency places on a system's functions.

The amount of time it takes to reach a system's ceiling is quite long, even for the most rapidly diffusing systems. CADD diffusion took 18 years. Capital Project Management systems are estimated to take 42 years to achieve complete adoption (in the year 2010).

The perceived leaders in CADD are Texas and Washington. For GIS Wisconsin and Pennsylvania are the perceived leaders. For other systems, no clear picture emerges. Texas has influenced more than 50 percent of the state DOT's CADD systems through direct or indirect contact. With the exception of a few national leaders, most states tend to network with neighboring states, with regional networks apparent in the Southeast, Northeast, West, and central United States.

The speed of adoption appears to be a function of organization size, computer investment, and priority. Large states that have invested in computer infrastructure are leading in innovation, with adoption times averaging 13 years ahead of lagging states. System managers in both leading and lagging states are similar in the amount of experience they have. Lagging states are in high-pressure situations: management expects improvements in productivity and performance, but funds and manpower are inadequate to meet these demands.

Agency's system selection processes are generally conservative and methodical, relying primarily on internal evaluations and advice from other DOTs. However, states appear to be vulnerable to the views of agency champions (people who push a particular system for whatever reason) in their selection processes.

How can the pace of adoption for information systems be accelerated? The results of this survey indicate a number of approaches:

1. *Provide the money*. Lagging states are unlikely to catch up to the leaders unless they are able to invest in the computer infrastructure needed to permit adoption. Larger budgets for basic computer access (terminals, skilled people, mainframe computing power, and up-to-date software) must be made available.

2. *Set clear priorities*. In lagging states especially, everything seems to have a high priority! Most managers know that kind of pace can not be sustained. Agencies need to sort out, decide on, then move forward with systems that are key to their operations.

3. *Network with other DOTs*. It was surprising to find the lack of communication among states and the degree of isolation in many systems. On a handful of states are perceived as leaders. The others need to get out and interact with their peers. Leading states could set up "buddy systems" to help nearby lagging states. Additionally, communication with nearby universities was rated the lowest of all factors on which system

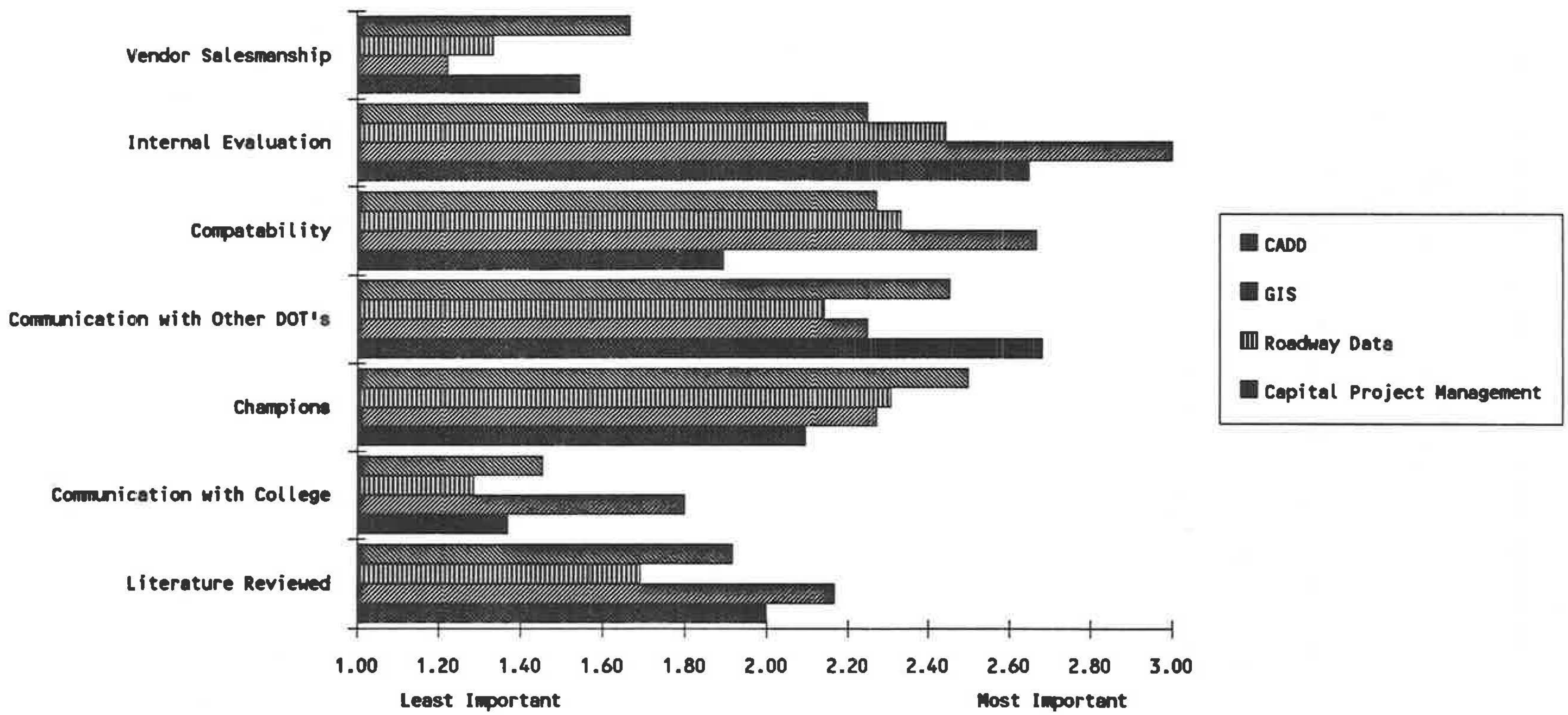

FIGURE 13 Importance of six variables to the selection of four system's version.

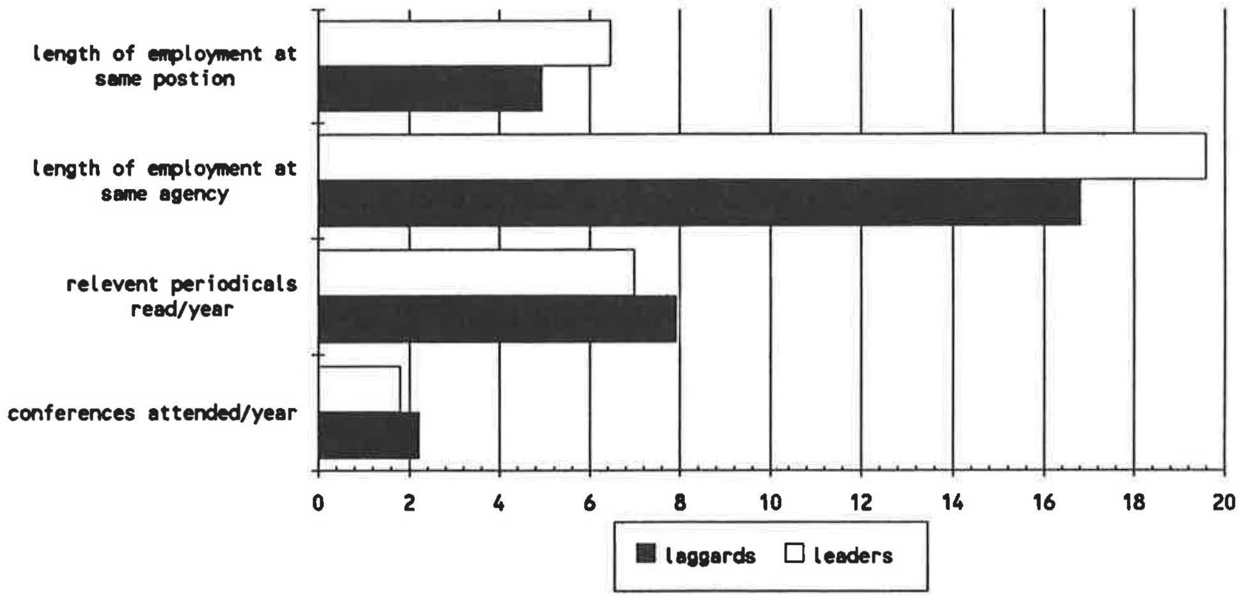

FIGURE 14 Selected characteristics of information system managers.

TABLE 4 CHARACTERISTICS OF LEADING AND LAGGING AGENCIES

	Leading	Lagging	Difference
Years since installation	14.79	1.73	13.06 yrs
Agency Size (Employees)	5,812	3,299	76%
Number of I.S. Employees	147	23	539%
Number of I.S. Employees/ Number of all Employees	.0253	.007	257%
Number of Workstations	1,086	444	144%
Workstations per Employee	.19	.13	46%
Budget for CADD, GIS, Roadway Data, and Capital Project Management	$2,341,667	775,000	202%
Computer Budget per Employee	$403	$235	71%
Perceived Importance to System Priority (scale of 1 to 3)			
productivity	2.69	2.88	-.21
agency priority	2.50	2.65	-.15
integration with other systems	2.20	1.87	+.37
performance	2.10	2.36	-.26
federal regulation	2.07	1.79	+.28
grant funds available	1.50	1.33	+.17
outdated systems	2.36	2.60	-.24

was chosen. Increasing interaction with these institutions could create a valuable source of information.

4. *Management responsibility*. Ultimately, managers decide on the pace of change. In lagging states, managers need to shoulder their responsibilities and increase the pace.

5. *Federal role*. The federal government's role in system innovation is multifaceted. Its most important role is to encourage and support modernization. It can also offer assistance by facilitating networking through conferences, publications, and workshops.

6. *AASHTO, TRB, and PTN Role*. Associations such as TRB and AASHTO can be very important to technology diffusion. The PTN (Public Transportation Network) was specifically designed to assist in the diffusion of technological innovation in DOTs. Since its establishment in February 1983, PTN has provided technical assistance to DOTs, conducted workshops, and encouraged networking (*16*). CADD diffusion has been supported by AASHTO Committee works and software development. Although GISs are diffusing rapidly without a considerable external support effort, AASHTO and TRB have recently instituted research for GIS design. Although the impacts of these organizations are not specifically addressed in this paper, continued involvement in these systems through committees and research activities and expanded involvement in other systems is appropriate.

This paper ends on a high note: the state of diffusion is advanced in the systems reviewed and progress is rapid. Although gaps between leading and lagging states are large, they can be reduced by positive, coordinated efforts. it is hoped that deficiencies in state-level DOT technical development have been identified in this paper, and some contribution made toward eliminating those deficiencies.

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