INFORMATION SYSTEMS FOR TRANSFER OF SIMULATION TECHNOLOGY

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I. Introduction

In principle an information system designed to encourage the diffusion or transfer of simulation technology would emphasize factors which tend to facilitate this transfer, suppress factors which inhibit transfer, and ignore factors which are neutral. A problem in designing such a system stems from limited knowledge of factors which affect technology transfer, either positively or negatively. A study by Downs and Mohr (1976) suggests that existing innovation process findings are often contradictory. Thus the system designer's task is made more difficult by uncertainty over just what factors really need to be considered.

To treat it as a case study in technology transfer, computer simulation must satisfy the definition of being a technology. Compared to many product and process technologies, such as photographic film and the modern oil refinery, simulation tends to be abstract, complex, and ambiguous. Nevertheless simulation is a tool by which human capability is extended, in the same way that the optical telescope extends such capability, and computer simulation clearly is realized through the use of a machine. Such intellectual or "soft" technologies which include Newtonian calculus and architechtural design techniques fill an obviously important technology category.

In the case of intellectual or "soft" technologies like simulation, the diffusion or technology transfer problem may be further complicated in at least two respects. First, it may be important to distinguish between the transfer of intellectual concepts, and the transfer of applications. Second, it may be important to differentiate between movement of simulation across distinctly different topics. This way of conceiving the technology transfer problem provides for a number of distinct combinations, each of which may define a unique design problem (Dutton and Starbuck, 1978):

- the transfer of simulation concepts across geographic space
- the transfer of simulation concepts across substantive topics
- the transfer of field applications across geographic space
- the transfer of field applications across substantive topics.

In the case of computer simulation an added problem dimension is the transfer of computing work across different central processors and peripheral devices, but this dimension is not dealt with here. Thus it can be seen that the problem of designing an information system to assist in transferring simulation technology may not be simple even at the conceptual level, aside from questions of creating a feasible means for physical implementation of any information system.

II. Factors relevant to transfer of computer simulation

Working within this conceptual scheme one can consider the impact of different factors on each of several technology transfer situations. Factors in simulation transfer perhaps more relevant to information system design considerations include:

- visibility of work results
- role of promotional agents
- means of communication regarding concepts and applications
- role of computing machine hardware and software.

A. Visibility of work results

Work results may be more or less visible to coworker, to workers on similar projects at other sites, to supervisors, to sponsors, and to client users. Ben-David (1962) and Gordon and Marquis (1967) both found visibility of results and research site productivity to be related. In the case of

simulation visibility of conceptual results seems to be of greater importance at early project stages when basic framework issues are being resolved.

Evidence from one study suggests that computer simulation as a working concept emerged independently and simultaneously in the late 1940's and early 1950's at several sites - sites which spanned international geographic distances, and different simulation concepts (Dutton and Starbuck, 1978). Within a short time, however, several of these separate work sites were in direct contact with one another by means of face to face contact, third party intervention, or correspondence. These contacts provided important mutual technical and social support to work groups struggling with simulation complexities at primitive stages of development. Many if not most of these contacts were of a direct and informal nature and took place on a peer level. Supervisory initiatives were not apparently prominent.

Transfer of applications seems considerably enhanced by visibility of work results. The more prominent and visible sites tended to have capable well organized workers, were more successful, and frequently transferred applications to other sites. Many if most of these transfers occurred as the result of the relocation of workers to new sites. These workers brought with them both knowledge of and the means to implement computer simulation models. Relocation of academic workers was one transfer method, but perhaps a more dominant tendency was relocation of workers from both government and private work groups to newly established sites.

B. The role of promotional agents

In the case of highway design simulation projects, two types of promotional agents are evident. One agent was typically an individual with considerable conceptual ability who visualized the potential role of computer simulation models both in extending the scope of the designer's territory and in pretesting design ideas. This individual was often academically related, an active traveler, and a vocal proponent of ideas. Such agents provided a first link between a number of sites who unbeknown to one another were attempting to use simulation methods to solve design problems.

A second type of promotional agent was also apparent in the case of American highway design projects. The U.S. Bureau of Public Roads actively sought to cross fertilize ideas among separate state and other major highway design groups. This policy considerably influenced the extent and speed of the transfer of highway simulation in the U.S. Sometimes the Bureau played a sponsorship role in projects, but most often simply acted as an active communication agent.

Transfer via sponsors and clients of simulation projects presents a different picture from that of transfer via coworkers or promotional agents. Sponsors may also be clients of particular simulation projects, but not always by any means. For instance a considerable amount of simulation work with applied objectives has been sponsored by private and government foundations without a specific client application involved.

While independence of sponsorship and client may affect transfer of results, the most prominent influence of sponsors and clients in simulation seems to be in the transfer of specific and successful applications, where success means that the use of simulation produced implemented designs. In this case clients and sponsors via a separate network of their peer and other contacts influenced the movement of simulation. For instance the work of one independent highway design group with successful results in one major urban design project quickly spread nationally to a number of new locations. Some of this transfer seems due to the pull of new project opportunities and the desire of individual workers for more autonomy or a different work location. But a considerable amount seems due to reports of successful results by clients and sponsors.

The prominent role of sponsors and clients in transferring the results of successful applications contrasts sharply with their minor role in transferring simulation concepts or technical information. Perhaps not surprisingly neither clients nor sponsors in many cases seem to share enough motivation or common language with simulation workers to facilitate this latter type of transfer.

C. Means of communication regarding simulation concepts and applications

A primary medium for the transfer of both simulation concepts and applications seems to be face to face contact. Written material and telephone contacts play a supporting role, but most often when face to face contact has been already established. A time ordered sequence of the role of various media in transferring simulation seems to be:

- face-to-face meetings at applied sites
- formal conferences arranged for simulation project leaders and workers at simulation problems and results at different sites are discussed
- working papers and personal written correspondence
- conference proceedings

- academic and technical journals
- books, trade magazines, and news media reports.

This sequence, while not invariant for every simulation project, does suggest that conventional views regarding the transfer role of work published in traditional academic and professional madia may not hold in the case of intellectual technologies like computer simulation.

D. The role of computing machine hardware and software

The existence of the modern computer is an obvious stimulant to the development of working simulation models. Before 1950 virtually no working simulation models existed. Prior to that time a few researchers had laboriously constructed mechanical devices that produced interesting but limited results. But invention of the modern electronic computer (both digital and analogue) vastly expanded possibilities for realization of simulation ideas (Starbuck and Dutton, 1971).

While the role of the computer in fostering innovation in the field of simulation seems clear, its role in facilitating the transfer of results is less clear. One suspects that many results of high potential value are not transferred. Two frequent inhibiting factors are lack of machine compatibility and poor program documentation. But even where these problems are absent, good results are not transferred. Thus the existence of good simulation results and means for their replication elsewhere are not sufficient to bring about transfer of results. The major transfer problem therefore does not seem due to lack of hardware or software, but seems to originate elsewhere.

III. Designing information systems to enhance the transfer of simulation technology

Given the previous discussion of simulation transfer characteristics, one can begin to formulate design guide lines for an information system to enhance such transfer.

A. Major issues

Since system design may be contingent upon type of simulation work involved, this question might be a point of departure. For instance, a system aimed at informing local executives or project sponsors may make little sense when key contacts needed are those with coworkers or workers on similar projects at distant and independent sites.

Another issue computer simulation presents to the designer is that an information system may need different characteristics at one stage of a project than for another. That is, at an early stage a simulation project may offer only concepts for transfer, while at a later state it may offer finished applications. Since effective transfer of concepts and applications may need to involve different both parties and media, a system design for early stage conditions may not enhance later stage transfer requirements. Indeed there is some case evidence that uncontrolled communications between simulation project sponsors and workers can be detrimental to project results (Brewer, 1973).

Still another issue that confronts the information systems designer is managing the time demands of information exchange within a project coworker group and the time demands of information exchange between workers in different projects. Here a familiar trade off between making use of local information and seeking added global information asks to be considered.

B. Design guidelines

This set of issues while incomplete does serve to indicate the wide range of considerations to be dealt with by an information system designed to enhance diffusion of simulation technology. This range, plus limited knowledge of technology of innovation and diffusion processes, tends to make narrow and rigid prescriptions for systems design ineffective for many if not most cases. Currently more useful perhaps is a set of directed but broad questions that serve to guide the information designer toward and through the relevant issues in particular cases:

- In order to design an information system the parties involved need to be defined, who will be the parties to the system?
- Are the parties aware of their information needs, are they motivated to participate in the system? If not how can they be included to participate?
- The usefulness of simulation technology information is contingent upon the type of information available and the potential user's needs, have these been identified?
- While both are important processes, conditions for transfer of simulation concepts tend to differ from conditions for transfer of proven field applications, which type of transfer is more central to the system being designed?

- Conditions for transfer of simulation geographically differ from conditions for transfer across substantive topics, which of these types of transfer is more central to the system being designed?

- Visibility of results tend to enhance the transfer of both concepts and applications, but applications are perhaps especially sensitive to visibility, in the situation(s) being dealt with will results be highly visible?

- Transfer of simulation concepts across substantive topics and through geographic space may be sensitive to the work of promotional agents, are natural and credible promotional agents present that can be made parties to the information system?

- Traditional technological communications media can be useful, although often not the most central, avenue for passing information on simulation technology, what traditional media are most readily available to the system under design?

- Non traditional communications media such as exchange visits between work sites for project supervisors and workers can facilitate simulation technology transfer, is provision being made for identification of sites and exchange visits?

C. The use of funds

Funds are of course necessary in a contemporary project network and its supporting information system. Computer simulation typically produces little for barter or for immediate consumer monetary exchange. Hence most simulation projects are part of someone's expense budget. However, there is some evidence that transfer of simulation can depend not only on the pull of funds from new work sites but also on the push from lack of funds at existing sites. To use an analogy the westward migration of farmers from Northeastern America in the 1800s depended not only on the availability of new rich farmland in the Midwest but also on the depletion of farmland in the Northeast, at least at the margin for newer, younger farmers. Thus if one could extend an information system so as to provide data on the marginal effectiveness of funds at new versus existing simulation work sites, the leverage of an information system might be enhanced.

D. Newer information transfer technologies

As previously stated, the more existence of computer hardware and software at a work site does not in itself induce the transfer of simulation technology to a site. Other means are necessary to bring about such a transfer. One such means may be another technology, one that uses computers but for telecommunications rather than for simulation. Newer, emerging systems that provide electronic transfer of live video signals for conference purposes may provide an added basis for the transfer of intellectual technologies like computer simulation. These technologies may provide face to face meetings that enhance the transfer of simulation concepts and applications.

IV. Conclusions

Intellectual technologies like simulation can present transfer problems unlike those typical of product and process technologies, which are less abstract, less complex, less ambiguous and are not realized on an electronic computer. Transferring computer simulation concepts often requires adapters to change their way of conceiving of problems, or at least to add to their ways of thinking. The transfer of applications on the other hand often requires the support of sponsors and/or clients who understand neither the essential properties of modern computers nor the basic structural features of simulation models. These knowledge gaps are not easily filled, either for concepts or for applications. Thus in the case of diffusion of intellectual technologies distinctions often may be needed regarding the type of information to be transferred and matching differentiations made regarding channels of transfer that will be effective.

Transfer of simulation project findings does occur, however, and seems to be enhanced by a number of factors including: visibility of consequences, use of promotional agents, choice of communications media, hardware and software availability, and project funding policies. Each of these factors is at least somewhat amenable to manipulation, so that it can be treated as a control variable. Visibility of results for instance can be increased by the project group's location and by site visits. Natural promotional agents may already exist that can be incorporated into an information network. Nontraditional as well as traditional communication media can be employed, and current computer industry technology eases the task of simulation transfer.

Project funding policies and newer, emerging telecommunications technology offer further means to enhance the transfer of intellectual

technologies like computer simulation. Such technologies reside as much or more in the minds of users as they do embodied in any physical apparatus. One obvious means of transferring such information is to move those people who possess it to new locations. Project funding policies in a monetary world can help to initiate such movement, both by increasing the attractiveness of new locations (positive inducement) and reducing the attractiveness of present location (negative inducement).

Another means for transferring largely intellectual technologies is through education (or learning). Such education often occurs faster through face to face contact between experienced and inexperienced users of the technology. Just why this is so is a learning issue still not well understood. But since it seems to be so, one way to enhance transfer is to provide more personal such contacts. Newer computer based personal telecommunications developments, which include video as well as audio message transmission, may provide added avenues of diffusion of intellectual technologies. These avenues may be more effective than traditional ones with respect to spontaneity of timing and may reduce the marginal cost of such contacts.

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