A GUIDE TO THE BEST TECHNOLOGY-TRANSFER PRACTICES

Wm. E. Souder, Ahmed S. Nashar, and Venkatesh Padmanabhan

In analyzing the best technology-transfer practices of a broad cross-section of government agencies, research institutions, and national and industrial laboratories, it was found that different technology-transfer practices should be used at the prospecting, developing, trial, and adoption stages of technology transfer. These results are summarized in a benchmark model that indicates which best practices to use at each stage of the technology-transfer process, and what roles should be played by technology disseminators, developers, sponsors, and implementors during these stages. Rules are suggested for making cost-effectiveness trade-offs among alternative best practices and designing optimal transfer strategies when budgets are limited.

Technology transfer is the managed process of conveying a technology from one party to its adoption by another party, e.g., from a developer to a user, a seller to a buyer, one department to another, etc.(1-9) "Conveying" implies a systematic interpersonal process of passing the control of a technology from one party to another. "Adoption" implies strong emotional and financial commitments to routine use. Thus, transfer efforts that do not achieve adoption are failures.

High transfer failure rates persist throughout industry, government, and academia, and many managers are concerned about them.(10-19) In response to this state of affairs, numerous practices have been proposed for improving technology transfer, such as improving management of the process, overcoming organizational and human barriers to success, making the process more systematic, improving the conveying of technologies, and increasing the users' willingness to adopt new technologies.(20-35)

However, the proposed practices are many and varied, and it is difficult to determine when to use which ones. Thus, the purposes of this study were to identify the best state-of-the-art technology-transfer methods, and to document them in a guide that managers can consult in formulating transfer policies for their particular situations.

Wm. E. Souder, Ph.D., is the Alabama Eminent Scholar Endowed Professor of Management and director of the Center for the Management of Technology at the University of Alabama in Huntsville, AL 35899, where he also holds appointments as professor of management science and professor of engineering. He is the author of five books and over 200 papers on the management of technology, and the recipient of numerous awards, including one from the White House. Souder has 12 years of industrial research experience in the chemical industry, seven years of government-laboratory service, and was for many years the director of the Technology Management Studies Institute at the University of Pittsburgh.

Ahmed S. Nashar, Ph. D., is currently the development officer of the Saudi National Bank and an international consultant in technology transfer. He was for several years a senior research associate with the Technology Management Studies Institute.

Venkatesh Padmanabhan is currently project engineer, Advanced Engineering Staff at General Motors in Warren, MI, where he specializes in the development and implementation of expert systems for manufacturing automation. He was previously a project manager with the Technology Management Studies Institute.

TRANSFER MODEL

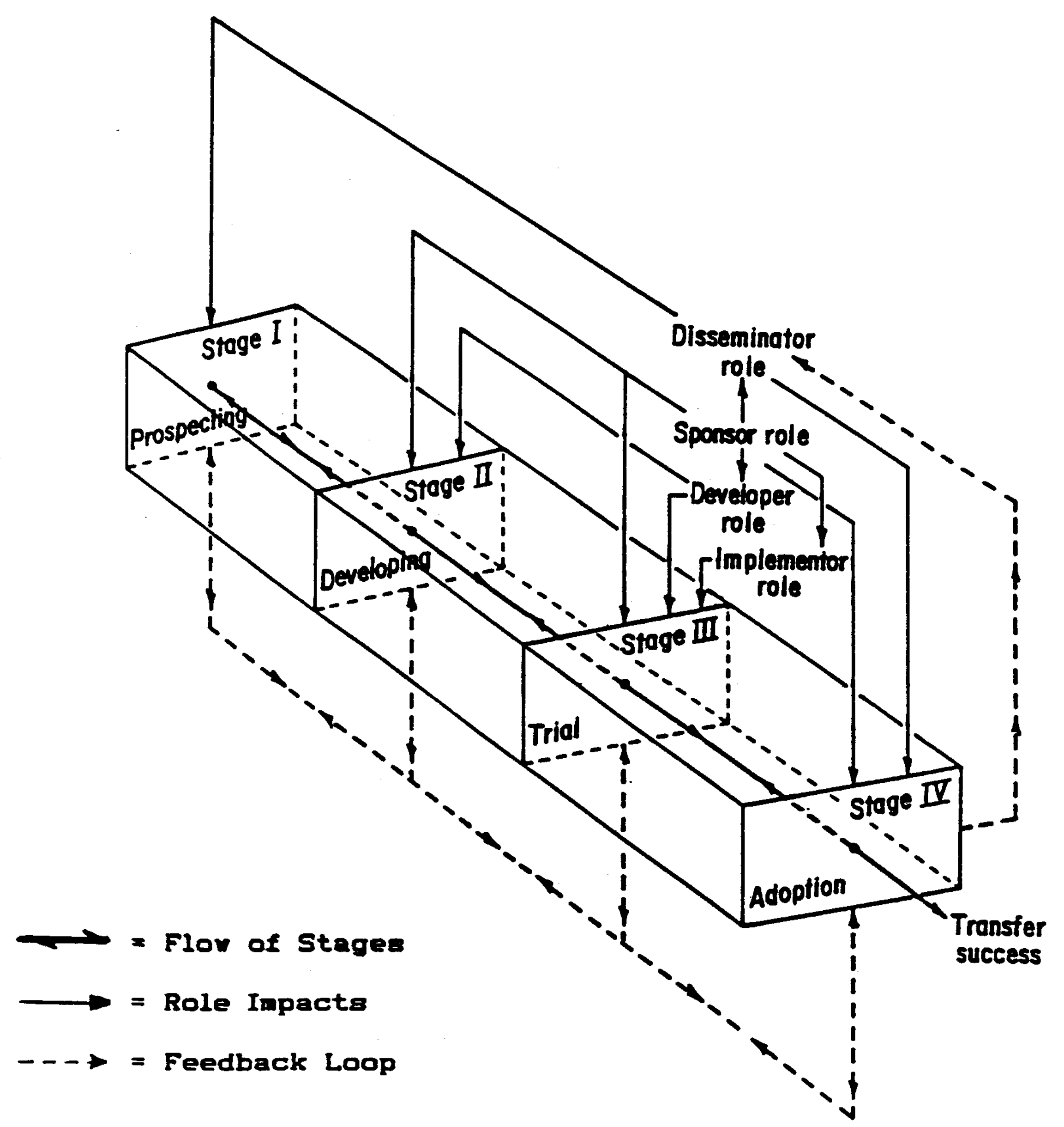
Several useful technology-transfer models have been developed.(36-43) Figure 1 was derived from these models, and was used as the framework for this study. In the figure, transfer success is viewed as resulting from management of a systematic process, consisting of interacting roles and stages of activities aimed at promoting the adoption of a technology.

Transfer Stages

Prospecting (Stage I, Figure 1) consists of research, analytical, and decisionmaking activities aimed at screening alternative concepts or technologies and selecting the ones that fit the users' requirements. Though such activities occurring in the prospecting stage may look much like those in other stages, prospecting is distinguished by its focus on preliminary analyses, searching, and screening. Developing (Stage II) consists of physical and laboratory R&D activities focused on enhancing, elaborating, embodying, and tailoring the selected technologies from Stage I to meet the users' requirements. In the trial stage (Stage III), the developed technologies are field tested. The adoption stage (Stage IV) consists of final development, technology modification, and user implementation activities.

In reality, the four stages depicted in Figure 1 are dynamic. For example, the scopes and durations of the stages (widths and lengths of the boxes) may vary with the nature of the technology. Some of the stages may be carried out in parallel, and the activities within each stage may overlap. The bold line connecting the stages is a two-way superhighway of activities and interfaces. Some technologies may be so desirable that the user adopts them during their prospecting or developing stages, thus by-passing the subsequent stages. In other

Figure 1. Technology Transfer Process



cases, the user may return to prospecting for better technologies after several acceptable ones have been identified, developed, and tested. The prospecting, developing, trial, and adoption activities may be repeated several times before the technology becomes appropriate for the user and/or the user is convinced to finally implement it.

Transfer Roles

Four important roles influence the flow of activities through the stages in Figure 1. The *disseminator* role involves making potential users aware of appropriate technologies, counselling the users about their needs, and generally serving as a marriage broker between technologies and users. As the arrows in the figure show, adoption may occur as a direct result of the disseminator's work if the technology is appropriate and the user is eager to adopt it. More often, the disseminator and the user will interact through several feedback loops and adjustments in the technology, as illustrated in the figure. Examples of disseminators are not difficult to find, e.g., libraries, librarians, and information specialists often play this role. The *sponsor* role covers political and financial support for various activities, as well as for disseminators, developers, and implementors. Government funding agencies are examples of sponsor role players. The *developer* role involves the conduct of laboratory, scale-up, and field trial R&D, and the *implementor* deals with selling, customer development, and trouble shooting.

Disseminators operate primarily within the prospecting and adoption stages; sponsors within the developing, trial, and adoption stages; developers within the developing and trial stages; and implementors within the trial and adoption stages. Sponsors also facilitate the work of the disseminators, developers, and implementors. In reality, these are dynamic and interacting roles. The same party may play different roles at different points in time, the roles may reinforce each other in various ways, and they may be combined. For example, the typical industrial R&D laboratory often plays combinations of the four roles at various times for various users.

The static model in Figure 1 may not capture all the dynamics of technology-transfer stage-role interactions, and it may not completely portray all the challenges in managing these complex processes. However, it was a very effective guide in understanding and documenting the complex processes encountered in the study.

METHODOLOGY

The following is a brief description of the method used in selecting organizations and best technology-transfer practices for the study:

Sample of Organizations and Successful Transfer

A sample of organizations was selected to represent each of the roles in Figure 1. A National Aeronautics and Space Administration dissemination center and a Department of Defense technical information analysis center were selected for their disseminator roles (44,45), and the National Science Foundation and US Departments of Transportation and Energy for their sponsor roles.

Finding organizations that specialized in playing only developer or implementor roles was more difficult. Thus, three federal laboratories, two private laboratories, and one research institute were chosen because they each play combined disseminator-developer roles, while emphasizing the developer part.(46,47). Also selected were three private laboratories and three university research centers that combined developer and implementor roles (48,49); the US Bureau of Mines and the US Departments of Agriculture and Education which also combined developer-implementor roles, but emphasized implementation.

Two successful technology-transfer programs were picked at each of these organizations, thus obtaining a sample of 40 programs for study. The major criterion for successful programs was those whose technologies were adopted by more than three-fourths of the targeted user population. Adoption was defined as occurring when the user made a significant financial and emotional commitment to the routine use of the technology for more than two years, and when the user expressed satisfaction with the technology. Because a significant commitment for one user may be a trivial commitment for another, judgments were required in applying these criteria. In every case, the details of the actual adoption were verified through audit reports and field interviews with key individuals within both the transfer and the user organizations (see below). The resulting sample thus reflected a cross-section of industrial, government, and university successes in transferring a diversity of technologies to a variety of users.

Data Collection and Analyses

Each of the 40 programs studied here had been documented in audits by members of the various transfer organizations. Content analyses (50) were done on these reports to generate a list of practices that appeared to account for the transfer success in each case. In order to verify and update the list, field interviews were conducted at all transfer and user organizations.

For each program an expert panel was assembled comprising three members from the adopting organization and two from the transfer organization. The panels provided a consensus rating on each practice relative to each stage in Figure 1 using the following scale: "O" for optional (a non-essential practice that facilitates success when used), "I" for important (a non-essential practice that, if not used, hinders transfer success), and "E" for essential (a practice required for success). Practices found unimportant in any stage were eliminated from further consideration and are not reported in Table 1.

Some practices received only unimportant ratings, some received only essential scores, and others received a mixture of scores. Some were rated 40 times because they were present in all programs, while others received fewer scores. Statistical discriminant, correlation, and path analyses were run on these data (51) to ascertain any statistical relationships between the practices, and to determine whether each practice was primarily scored as unimportant, optional, important, or essential. All statistical tests were run at the 95% confidence level, e.g., a practice that could not be placed in one of the four rating categories with 95% confidence through statistical discriminant analyses was eliminated from further consideration.

Table 1. Summary of Best Practices

Best Practices	Stage I Prospecting	Stage II Developing	Stage III Trial	Stage IV Adoption
ANALYTICAL				
Transfer Audits	I	I	I	E
Benefit Measurements	I	I	I	E
Operations Audits	I	I	E	E
Decision Checklist	I	E	E	E
Strategy Matching	E	E	E	E
FACILITIES				
Hand-on Laboratories	O	I	E	I
Society Sponsorship	O	I	I	I
Incubators	O	O	E	E
Joint Demonstrations	I	I	E	E
Joint Evaluations	I	E	E	E
Vendor Access	O	O	I	E
R&D at the User Site	I	I	E	E
PRO-ACTIONS				
Passive Outreach	I	E	E	E
Co-op Agreements	I	I	I	E
Joint Funding	I	I	I	I
Joint Transfer Team	I	E	E	E
Loans to Recipients	O	O	O	I
Personnel Transfers	O	I	E	E
Co-op Training	O	I	E	E
Consulting	I	E	E	E
Open Interactions	E	E	E	E
R&D Does Training	I	I	I	E
PEOPLE-ROLES				
Boundary Spanner	O	O	I	E
Gatekeepers	I	I	E	O
Champions	I	I	E	E
Angels	O	I	I	E
CONDITIONS				
Outside Authority	I	I	E	E
Research Ties	I	I	E	E
TECHNOLOGY QUALITY				
Tangible Value	I	I	E	E
Divisibility	I	I	E	E
Incrementality	I	I	E	E
Adaptiveness	O	O	I	E
ORGANIZATION				
Life-Cycle Teams	I	E	E	E
Leader Responsibility	I	E	E	E
Transfer as R&D Goal	E	E	E	E
R&D/User Partners	E	E	E	E
Early Involvement	E	E	E	E

*Key: O = Optional; I = Important; E = Essential

DISCUSSION OF BEST PRACTICES FOUND

As Table 1 shows, 37 practices were either optional, important, or essential to one or more transfer stages, and were designated as "best practices". With the aid of statistical cluster-analyses methods (52), these best practices were found to cluster into the seven types of practices (analytical, facilities, etc.) listed in Table 1, as described below:

Analytical

Analytical practices consist of various techniques for measuring and assessing transfer efforts. Five best-analytical practices were identified: transfer audits, benefit measurement, operations audits, decision checklists, and strategy matching. In *transfer audits*, the transfer organization conducts follow-up client interviews at the end of every project to measure the client's level of satisfaction. Most of the transfer audits involved some type of *benefit measurement*. For example, one transfer organization studied here used the dimensions in Table 2 to create a score card for self-evaluation and a database which they used to demonstrate their effectiveness. Assessments of the gateway quality, extent of adaptation, and value added (Table 2) were also used in a *decision checklist* to rate prospective technologies with an eye toward selecting the most promising ones for transfer. Several clients noted how these practices inspired greater confidence in the transfer organi-

Table 2. Dimensions For Measuring Transfer Benefits

1. **Number of Units of the Technology Adopted.** The most beneficial technologies will be adopted by the users at several plants, locations and departments.
2. **The Gateway Quality of the Technology.** The most beneficial technologies provide a "gateway" to others, e.g., the steam engine opened the gates for many other important technologies.
3. **The Extent of Adaptation in Use.** The most useful technologies are the ones that undergo the most modifications by various users, and therefore have the largest number of adaptations and variations in use.
4. **The Value Added from Adoption.** The value added from the adoption of the technology is measured by client perceptions about the reduced costs, improved profits, increased market shares and increased client know how that resulted from its adoption.
5. **Sustained Use.** The length of time the organization uses a technology is the ultimate measure of transfer success.

zations and led to closer working relationships.

In an *operations audit,* an ad hoc interdisciplinary team from the transfer agency performs a systematic audit of the client's total operations. Recommendations can range from minor adjustments to the adoption of highly sophisticated technologies. The audit insures that a systematic viewpoint has been taken and that the recommended technology or solution is the most appropriate one for the user.

In the *strategy-matching* analytical practice, the transfer organizations purposely fit their transfer strategies to the nature of the technologies and the users. For example, if the technology was unfamiliar to the user, a high degree of personal consulting and promotional activity was employed. For immature technologies, extensive development and proof testing was used. The transfer organizations also commonly used decision checklists like the one illustrated in Table 3 to confirm that they had carefully considered all the important segments of the transfer process.

Facilities

Many of the transfer agencies studied here provided testing facilities and related support for the potential adopters. As the data in Table 1 show, seven best practices were found: hands-on laboratories, society sponsorship, incubators, joint demonstrations and evaluations, vendor access, and R&D at the user site. *Hands-on laboratories* where prospective users could experiment with new technologies under close supervision, were especially valuable to prospective users who had neither the staff nor the expertise to perform their own in-house research. Several users noted that they would never have tried the technology if the laboratories had not been available. *Society sponsorship* (professional and trade societies and interest groups) provided a kind of laboratory where potential adopters could vicariously examine new technologies by hearing about the experiences of their peers. Society members included prospective users, sponsors, implementors, disseminators, and developers who traded ideas, learned from each other, and generally kept each other up to date.

Incubators, which are funded by the transfer organization to develop the advanced technologies and reduce them to practice in order to remove doubts about their utility, were also popular. The incubators studied here conducted public evaluations and demonstrations of their technologies for the world to witness. As Table 1 shows, the expert panels felt that incubators were essential for trial and adoption. The literature generally supports this notion, based on the idea that incubation reduces the risks to the adopter.(53-58) Note that *joint demonstrations and evaluations* were scored either

Table 3. Example of a Transfer-Decision Checklist

Considerations relevant to the nature of the technology

Does the technology perform reliably?
Will it perform reliably in the recipient's applications?
Is it a low risk venture for the recipient?
Is it a low cost venture for the recipient?
Is this technology important to the world?
Will this technology have a major positive impact?

Considerations relevant to the recipient

Is the recipient familar with the technology?
Is the technology appropriate for the recipient?
Does the recipient have a plan to receive the technology?
Does the recipient have adequate resources to receive it?
Does the recipient have an angel for this technology?
Does the recipient have adequate business acumen?
Will the recipient be able to maintain the technology, or is there a vendor who can?

Considerations relevant to us (the transfer agency)

Are we fully committed to the technology?
Do we have a long term partnership with the recipient?
Do we have the technical ability to transfer the technology?
Do we have the appropriate staff for this transfer?
Can we adequately train the recipient?

Considerations relevant to the transfer process

Has complete information been exchanegd?
Has useful information been exchanged?
Is there a proper hand-off point for this technology?
Does a sense of joint emotional commitment exist on the parts of both the recipient and us?

important or essential to all four stages. Carried out at selected high visibility user sites, these demonstrations emphasized the "neighborhood effect," where one innovative user commits to a new technology and others follow suit.(59-65)

To provide *vendor access,* transfer agencies introduced technology adopters to several appropriate vendors and helped them build relationships with the vendors. Studies show that when a prospective user does not have access to good vendors to maintain and update the technology over time, they either resist adoption or soon abandon the technology after initially using it.(66-68) In all the successes studied here, the transfer organization developed lists of recommended vendors and service firms, and assisted the adopters and the vendors in developing close working relationships.

In several cases, the transfer organizations provided turnkey operations by carrying out the *R&D at the user site.* One of the transfer agencies in this study noted how they had copied this idea from Japanese life-cycle developer-user partnerships.(69-71)

Pro-actions

Pro-actions consist of various initiatives that the transfer agencies took to foster successful adoption. *Passive outreach* consisted of newsletters, meetings, talks, reports, press releases, training courses, demonstrations, advertising, and testimonials from satisfied users. In *cooperative agreements,* transfer organizations and prospective users developed 50-50 partnerships to fund and carry out the work. *Joint-funding* actions, in which both parties shared the costs (though not the work), were popular. Consistent with other studies, the data in Table 1 show that *joint-transfer teams,* composed of members from transfer and user organizations, are effective.(72-81) *Loans* from the transfer agency to the user organization, permanent and temporary *personnel transfers* between the two organizations, and *cooperatively funded training* also worked well. Interestingly, the purpose of the loans was not to defray user costs, but rather to obtain commitments to the technology.

In most of the cases studied here, one-on-one personal *consulting* was critical to the successful transfer. The disseminators, developers, and implementors assisted the adopters in analyzing their needs, determining the suitability of various technologies, and deciding whether or not to adopt them. The transfer organization played the role of a neutral consultant rather than a salesperson for a particular technology. *Open interactions* characterized the successes, with the top management, middle management, scientist, and bench-level engineering personnel at both organizations freely interacting on all issues and problems. As the table data show, the expert panel felt that consulting and open interactions were essential for success in nearly all stages. The literature is consistent with this assessment.(82-84)

In several successful cases, the technology developers worked intimately with the adopters to train them in the use of the technology (*R&D does training*). These actions emulated Japanese technology-transfer practices, by which scientists are evaluated on how well they train their counterparts in the user organizations. It is significant that this training begins well before the technology is perfected, using prototypes, models, and mock-ups.(85-88)

People-Roles

Four people-roles were found to be important to success: boundary spanners, gatekeepers, champions, and angels.(89-96) *Boundary spanners* range freely throughout an organization and link resources across several departments. They derive their power informally, as a result of their alliances and informal power bases. By comparison, *gatekeepers* do not command any resources. Their talent lies in introducing the outsider to the power centers, i.e., they hold the key to unlocking the organization's gates. *Champions* are the organizational "guerrilla-warfare" agents who will ruthlessly grab a technology and carry through or around organizational obstructions. On the other hand *angels* are the high-level executives and patron saints of the organization who will carefully protect start-up projects and shield them from harm until they mature. In all the successful cases studied here, the transfer organizations carefully sought out these various players within the user organizations, cultivated them, and used them as a team to aid in the successful transfers.

Conditions

Also in all the successful cases, the technologies were highly recommended by competent and respected *authorities outside* the transfer organization. The technology had much greater credibility when a neutral party endorsed it. Most of these successes had *research ties,* in that there were connections with research-based universities. The rare technical question that could not be answered by the technically proficient transfer-organization personnel or the outside authorities could be researched at an affiliated university.

Technology Quality

The dimensions of quality found in the study to be important were tangible value, divisibility, incrementality, and adaptiveness. The values of all the successful technologies studied here had *tangible value* that was measurable. Thus, the potential users could see the improvements, side by side with their less-effective current practices. Note that the degree of risk associated with the technologies did not appear to be a barrier to their adoption; it was the uncertainty of the value of the new technologies vis-a-vis the current practices that mattered.

Moreover, all the successes studied here involved *divisible* technologies, which can be adopted piecemeal. Installment-plan adoption allows the users to sample without major commitments and risk-taking. The most successful transfers consisted of technologies that were modifications and *incremental extensions* of things already familiar to the users. The capability to perform *adaptive engineering* on the technologies to make them fit the users' needs or the ability to effectively contract out these functions characterized all the successful transfer agencies.

Note that these results do not indicate that radical technologies cannot be transferred. Rather, they emphasize that special efforts must be made to clarify the benefits and break the technologies into smaller pieces that are less imposing to users. (97)

Organization

Organizational best practices were life-cycle teams, leader responsibility, transfer as R&D goal, R&D/user partners, and early involvement. In *life-cycle teams,* interdisciplinary groups of researchers stay with the project throughout its research-to-transfer life cycle, crossing from one organization to another, moving to new locations as the project evolves. This practice, which is common in Japan (98-101), is seldom used in the US and was not frequently found in this study. However, statistical analyses determined that it was a "best practice" on the basis of its importance to success in every case where it was used. Similarly, the best practice of making the R&D team *leader directly responsible* for the transfer of the outputs from the project was seldom found in this survey. This routine Japanese practice is based on the premise that no R&D project is a success unless it is fully transferred.(102, 103) It contrasts with US practices, where some R&D projects that are commercial failures may be regarded as technical successes.(104) The best practices of emphasizing *transfer as an explicit goal* at the early stage of the R&D work and placing the responsibility for transfer on the R&D team leader were also seldom found in this study. However, *developer-user partnership* agreements and *early involvements* between developers and users were often found.

SELECTING THE BEST PRACTICES AND MAKING TRADE-OFFS

Figure 1 and Table 1 can be used to help select the contingent set of best practices within each stage of the technology-transfer process, as follows: First, consult Figure 1 to determine the stage of the transfer process at which activities are to occur. Then implement all the essential-rated practices from Table 1 for that stage. For example, for Stage I activities the following practices should all be implemented: strategy matching, open interactions, transfer is R&D goal, R&D/user partners, and early involvement.

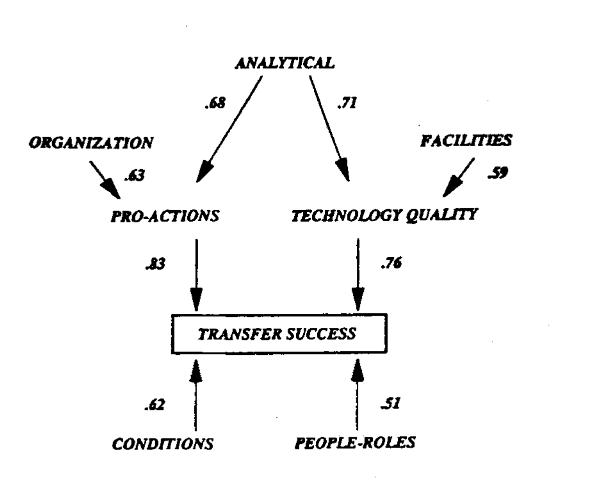
No situations were found in this study where either optional or important-rated practices were redundant when they were combined with essential-rated practices. And there were no indications that the use of multiple practices interfered with each other. In fact, the data supported the notion that transfer success rates increase as more best practices are employed.(105-107) When budgets and resources are adequate, funding all the optional and important practices in addition to the essential practices increases the odds of transfer success. Because several best practices exist within each type in Table 1, the above rule of thumb may be flexibly applied. For example, the transfer agency may not have the ability to implement the pro-action loans to recipients, but it may be able to implement several other optional or important pro-actions.

When budgets or resources constrain the choices, optional practices are the ones to sacrifice. Though there were indications that the deployment of optional practices (along with the essential practices) facilitated some transfer, there were no indications that the absence of an optional practice severely inhibited success. By comparison, the data showed that the absence of an important-rated practice could either reduce the degree of success or cause the transferring organization to exert extra efforts and costs to avoid failures. To reduce the risks of failure and to economize on the resources applied to the transfer effort, important practices should be employed. By contrast, the data demonstrated that essential-rated practices need to be employed, since they consistently correlated with transfer success in the cases examined here. Thus, depending on the tolerable risk of transfer failure and the available budget, the data in Table 1 may be used as a guide to the determination of various trade-offs in selecting cost-effective combinations of best practices to be employed.

Selecting the Most Important Types

Using statistical correlation and path-analysis methods (108), relationships between the seven

Figure 2. Relations Between Types of Practices



types of practices were determined as presented in Figure 2. To carry out these analyses, the expert panel ratings in Table 1 for the best practices within each of the seven types were pooled and considered to be ratings for the respective type. For example, an essential rating for transfer audits and for benefit measurements were treated as essential ratings for analytical practices and pooled together for the analyses. In Figure 2, the numbers along the arrows are the path coefficients (109), showing the strength of the causal relationships found between the types of practices on a scale from 0 to 1 (with 1 representing perfect correlation). All the relationships shown are statistically significant at the 95% confidence level. Any statistically non-significant relationships found were not included in Figure 2.

As evidenced by the magnitudes of the correlation coefficients in Figure 2, pro-actions and technology quality emerged as the two most important types of practices. Both were found to directly promote successful transfers. Conditions and people-roles also were found to promote successful transfers, but to a lesser degree of correlation. Analytical practices were identified as a significant facilitator of both pro-actions and technology quality. In contrast, organization practices were a significant facilitator of only pro-actions, and facilities practices only affected technology quality.

Figure 2 can be used to help determine which types of practices to sacrifice when transfer budgets are limited. For example, pro-action and technology-quality practices should always be employed. The path coefficients are statistically significant and these practices directly affect transfer success. In order to maximize their impacts, organization, analytical, and facilities practices should also be employed. Because conditions and people-roles are less strongly correlated with successful transfers, they are of lower importance and can be sacrificed under limited resources or budgets. Note that the same logic leads to sacrificing organization and facilities practices. Thus, under extreme budget constraints, the technology-transfer agent may be able to achieve a satisfactory transfer by deploying all the essential analytical, pro-action, organization, and technology-quality practices and ignoring all the other types of practices. However, the risk of a transfer failure is much higher than it would be if all the essential practices within all seven types were deployed.

It should be noted that Figure 2 was developed using only Stage III and IV data. Because there are fewer essential-rated practices in Stages I and II, the transfer organizations studied here did not experience any budgetary problems in funding all of the essential practices within these stages. Questions about which essential practices to sacrifice within these stages never arose. However, a model like the one in Figure 2, could be developed for any stage around essential practices, important practices, etc., depending on the user's needs.

Designing Systematic Transfer Strategies

The results in Table I and Figure 2 reinforce the lesson that successful technology transfer is a multi-faceted matter, involving the careful manipulation of a complex system of factors.(110-115) Independently deploying only one or a few of the factors may not achieve transfer success because it does not take full advantage of the potential synergism within the system. Limited budgets that force the transfer agency to sacrifice some essential practices or to eliminate some types of practices may severely depress the odds of transfer success. Does the use of Table 1 and Figure 1 as a benchmark prescriptive model of the best strategies facilitate a comprehension of these lessons and lead to more systematic transfer strategies?

In an attempt to answer this question, the authors have been working with three transfer agencies (different from the ones studied here) to evaluate their programs against the above prescriptions. Where variances were found between their programs and these benchmarks, the managers in each agency met as a group to discuss, justify, and rationalize the differences. As a result of the interventions, one agency has significantly increased its transfer budget, and all three have altered their strategies by funding more essential practices, deleting several optional practices, and trading off some less important types of practices for more important types. The three agencies have increased their transfer success rates as a result of these changes.

These pilot experiences reinforce the notion that useful models of technology-transfer processes can be developed, and that these models can be applied to help discover various ways to increase the effectiveness of transfer strategies. This strengthens the hope that, through additional research, models can be developed that can aid managers in optimizing their transfer efforts.(116-120)

SUMMARY AND CONCLUSIONS

The best technology-transfer practices of a broad cross-section of organizations were studied. Best practices were defined as those characterized by successful transfers of technologies adopted by a significant percentage of the target users, who made long-term commitments to the routine use of those technologies. The best practices were studied within the framework of a technology-transfer process-stage model. It was expected that a set of contingent relationships would be found, i.e., that some practices would be essential to the success of some stages while other practices would not.

Seven types of best practices were found: analytical, facilities, pro-actions, people-roles, conditions, technology quality, and organization. The contingent relationships that were found showed that some practices were essential for transfer success, some were less important, and some were optional. The seven types of best practices were found to interrelate in cause-effect chains. Collectively, these results were shown to comprise a benchmark model that managers can consult to assist them in developing more effective technology-transfer strategies.

This research has made a start towards a model that technology-transfer managers can use to aid them in selecting optimal strategies for particular situations. Future research should focus on the in-depth study of matched success and failure transfer cases in order to further clarify the causal relationships between the best practices, the degree to which each is important to transfer success, and the cost-effectiveness of trade-offs between them.

ACKNOWLEDGEMENTS

The authors wish to acknowledge funding from the Alcoa Foundation and the General Motors Corporation for portions of this research, and to thank two anonymous referees for some helpful comments on an earlier version of this paper. The opinions and conclusions are the authors, and do not necessarily reflect any policies of any of organizations who cooperated in this study nor of the organizations that funded this study.

REFERENCES

1. Devine, M.D., E.J. Adams, Jr. and T.I. Adams (Winter 1987). *Government Supported Industry-University Research Centers: Issues for Successful Technology Transfer.* Journal of Technology Transfer, Volume 12, Number 1, pp. 27-37.

2. Doctors, S. (1969). *The Role of Federal Agencies in Technology Transfer.* Cambridge, MA: MIT Press.

3. Ettlie, J.E. (June 1973). *Technology Transfer from Innovators to Users.* Industrial Engineering, Volume 5, Number 6, pp. 16-23.

4. Sagal, M.W. (April 1978). *Effective Technology Transfer—From Laboratory to Production Line.* Mechanical Engineering, Volume 100, Number 4, pp. 32-35.

5. Schoenecker, T.S., et.al. (Spring 1989). *Technology Transfer at Land-Grant Universities.* Journal of Technology Transfer, Volume 14, Number 2, pp. 28-32.

6. Souder, W.E. and V. Padmanabhan (September-October 1989). *Transferring New Technologies from R&D to Manufacturing.* Research-Technology Management, Volume 32, Number 5, pp. 38-43.

7. Souder, W.E. and V. Padmanabhan (1990). *A Role*

Interaction Model for Implementing CIMS. In *Justification Methods for Computer Integrated Manufacturing Systems,* edited by Parsaei, Ward, and Karwowski. Amsterdam: Elsevier.

8. Souder, W.E. (1989). *Managing New Product Innovations.* Lexington, MA: Lexington Books, pp. 23-81, 101-238.

9. Souder, W.E. (March-April 1989). *Improving Productivity Through Technology Push.* Research-Technology Management, Volume 32, Number 2, pp. 19-24.

10. Baron, S. (January-February 1990). *Overcoming Barriers to Technology Transfer.* Research-Technology Management, Volume 32, Number 2, pp. 19-24.

11. Cutler, R.S. (February 1989). *A Comparison of Japanese and U.S. High-Technology Transfer Practices.* IEEE Transactions on Engineering Management, Volume 36, Number 1, pp. 17-24.

12. Cutler, R.S. (Fall 1988). *Survey of High-Technology-Transfer Mechanisms in Japan and the USA.* Journal of Technology Transfer, Volume 13, Number 1, pp. 42-48.

13. Ibid., Souder (1989).

14. Ibid., Souder (March-April 1989).

15. Souder, W.E. and A.S. Nashar. *A Zero-One Model for Optimizing Technology Transfer.* Submitted to Management Science.

16. Suh, N.P. (January-February 1987). *NSF Engineering Research Centers: Lessons Learned.* Research Management, Volume 30, Number 1, pp. 33-34.

17. Swyt, D.A. (Fall 1988). *Transferring NBS Technology to Small Manufacturers Through State and Local Centers.* Journal of Technology Transfer, Volume 13, Number 1, pp. 7-13.

18. Vozikis, G., B. Schroer and T.S. Mescon (January 13-15, 1988). *New Product Development and Technology Transfer: A Feasibility Study for the U.S. Missile Command (MICOM).* Proceedings of Managing the High Technology Firm Conference, University of Colorado at Boulder.

19. Weijo, R.O. (Spring 1987). *Strategies for Promoting Technology Transfer to the Private Sector.* Journal of Technology Transfer, Volume 11, Number 2, pp. 43-65.

20. Blanchard, P.A. and F.B. McDonald (January 1986). *Reviving the Spirit of Enterprise: Role of the Federal Labs.* Physics Today, Volume 39, Number 1, pp. 42-50.

21. Ibid., Devine.

22. Heaton, G.R. (Fall 1988). *The Truth About Japan's Cooperative R&D.* Issues in Science and Technology, Volume 5, Number 1, pp. 32-40.

23. Monden, Y., et.al. (1985). *Innovations in Management: The Japanese Corporation.* Atlanta: Industrial Engineering and Management Press.

24. Morone, J. and R. Ivins (May 1982). *Problems and Opportunities in Technology Transfer from the National Laboratories to Industry.* Research Management, Volume 25, Number 3, pp. 35-44.

25. Ibid., Sagal.

26. Ibid., Schoenecker.

27. Ibid., Souder (Sept.-Oct. 1989).

28. Ibid., Souder (1990).

29. Ibid., Souder (1989).

30. Ibid., Souder (March-April 1989).

31. Ibid., Souder (submitted).

32. Ibid., Suh.

33. Ibid., Swyt.

34. Ibid., Vozikis.

35. Ibid., Weijo.

36. Ibid., Ettlie.

37. Ibid., Sagal.

38. Ibid., Souder (Sept.-Oct. 1989).

39. Ibid., Souder (1990).

40. Ibid., Souder (1989).

41. Ibid., Souder (March-April 1989).

42. Ibid., Souder (submitted).

43. Ibid., Weijo.

44. Department of Defense (March 1988). *Information Analysis Centers Directory.* Alexandria, VA: Defense Logistics Agency.

45. Ibid., Doctors.

46. Ibid., Baron.

47. Ibid., Morone.

48. Ibid., Devine.

49. Ibid., Suh.

50. Samuels, A.C. (1968). *Handbook of Social and Economic Measurement Methods.* Pittman: London.

51. Ibid.

52. Ibid.

53. Ibid., Sagal.

54. Ibid., Schoenecker.

55. Ibid., Souder (Sept.-Oct. 1989).

56. Ibid., Souder (1990).

57. Ibid., Souder (1989).

58. Ibid., Souder (March-April 1989).

59. Ibid., Ettlie.

60. Ibid., Heaton.

61. Ibid., Monden.

62. Ibid., Morone.

63. Ibid., Sagal.

64. Ibid., Schoenecker.

65. Ibid., Souder (1989).

66. Ibid., Souder (Sept.-Oct. 1989).

67. Ibid., Souder (1990).

68. Ibid., Souder (1989).

69. Ibid., Cutler (Feb. 1989).

70. Ibid., Cutler (Fall 1988).

71. Ibid., Monden.

72. Ibid., Cutler (Fall 1988).

73. Ibid., Ettlie.

74. Ibid., Heaton.

75. Ibid., Sagal.

76. Ibid., Samuels.

77. Ibid., Souder (Sept.-Oct. 1989).

78. Ibid., Souder (1990).

79. Ibid., Souder (1989).

80. Ibid., Souder (March-April 1989).

81. Ibid., Souder (submitted).

82. Ibid., Souder (Sept.-Oct. 1989).

83. Ibid., Souder (1990).

84. Ibid., Souder (1989).

85. Ibid., Cutler (Feb. 1989).

86. Ibid., Cutler (Fall 1988).

87. Ibid., Heaton.

88. Ibid., Monden.

89. Ibid., Baron.

90. Ibid., Cutler (Fall 1988).

91. Ibid., Ettlie.

92. Ibid., Sagal.

93. Ibid., Souder (Sept.-Oct. 1989).

94. Ibid., Souder (1990).

95. Ibid., Souder (1989).

96. Ibid., Weijo.

97. Ibid., Souder (March-April 1989).

98. Ibid., Cutler (Feb. 1989).

99. Ibid., Cutler (Fall 1988).

100. Ibid., Heaton.

101. Ibid., Monden.

102. Ibid., Cutler (Feb. 1989).

103. Ibid., Cutler (Fall 1988).

104. Ibid., Souder (1989).

105. Ibid., Souder (Sept.-Oct. 1989).

106. Ibid., Souder (1990).

107. Ibid., Souder (1989).

108. Ibid., Samuels.

109. Ibid.

110. Ibid., Souder (Sept.-Oct. 1989).

111. Ibid., Souder (1990).

112. Ibid., Souder (1989).

113. Ibid., Souder (March-April 1989).

114. Ibid., Souder (submitted).

115. Ibid., Weijo.

116. Ibid., Souder (Sept.-Oct. 1989).

117. Ibid., Souder (1990).

118. Ibid., Souder (1989).

119. Ibid., Souder (March-April 1989).

120. Ibid., Souder (submitted).