



*The International Center for Research on the  
Management of Technology*

**The Link Between Technology Complexity and  
Communication Complexity in International  
Technology Transfer**

**Eric Rebentisch**

**March 1997**

**WP # 158-97**

Sloan WP # 3947

© 1997 Massachusetts Institute of Technology

Sloan School of Management  
Massachusetts Institute of Technology  
38 Memorial Drive, E56-390  
Cambridge, MA 02139-4307

**The Link Between Technology Complexity and Communication Complexity in  
International Technology Transfer**

Eric Rebentisch  
Massachusetts Institute of Technology  
77 Massachusetts Ave., Room 33-407  
Cambridge, MA 02139  
Tel: 617-258-7773  
Fax: 617-258-7845  
E-mail: [erebenti@mit.edu](mailto:erebenti@mit.edu)

## **The Link Between Technology Complexity and Communication Complexity in International Technology Transfer**

### **Abstract:**

This paper examines the link between the complexity of a technology and the complexity of communication behaviors associated with its transfer from one location to another. The setting for the research is an international joint venture between three firms in the chemical industry. The transfers of four different categories of technology were observed in this study. They were general information, specific information, hardware, and procedures or practice. A large variety of different approaches and methods were observed to have been used in the transfers of the 208 specific technologies tracked in this research.

The transfer of general information was associated with visits to a partner's site where it was observed first-hand. Specific information also was transferred through site visits, but usually in conjunction with follow-up communication that did not require face-to-face interaction. While no clear specific communication or interaction process was associated with the transfer of physical hardware, the transfer of procedures or practices was associated with a diverse array of transfer methods and a high level of transfer effort. In general, the more complex technologies required more effort to complete their transfers than did simpler technologies. The implications of these findings are discussed.

## **Introduction**

The 1980s and early 1990s has been a time of the rapid globalization of many markets. This has given firms unprecedented access to new markets and growth opportunities. From the perspective of the firms already operating in those markets, it has brought unprecedented new competition. Simultaneous operation in a number of markets around the world can be a challenge even to large multinational corporations, especially in industries where the pace of new product development is rapid. Many firms find they must collaborate with other firms to share the risk and cost of competing globally. The challenge to collaborating firms is in actually realizing those economies of scope and scale through the integration of their efforts. This research addresses one aspect of that integration problem. This is the transfer of technologies or knowledge from one site to another. The dilemma facing any manager in a cooperative venture is first, whether the partner has something of benefit to offer, and second, if that benefit can be appropriated back to the home firm. Appropriating that benefit can be especially challenging when the technologies being transferred are part of the core functions of a firm, as often is the case with production technologies. This paper reports findings of a study of the process of harvesting the benefits of collaboration through the transfer of technology.

## **Important Questions yet Unanswered**

A reasonable question for anyone faced with the transfer of a technology from one place to another is “how should I do it?”. There is a wealth of literature addressing the transfer of

knowledge and technology that provides a cornucopia of ways in which technology is transferred from location to location (see Table 1).

**Table 1. Information Transfer Mechanisms Found in Existing Research.**

Mechanism	Examples
Communication Methods	Impersonal (policies, procedures, plans, and schedules), Personal (through supervisors or work coordinators), or Group (scheduled and unscheduled meetings; Van De Ven, Delbecq and Koenig, 1976); Face-to-face, telephone, personal documents, faxes or memos, impersonal written documents, and numeric documents (Daft, Lengal and Trevino, 1987; Daft and Lengal, 1986; Trevino, Lengal and Daft, 1987); Face-to-face, video, telephone, voice conferences, group meeting, voice messages, group gathering, chart/graphs, computer report, document/report, memos, electronic mail, facsimile, handwritten note, and letter/message (Rice, 1992; Rice and Shook, 1990); Within project group, outside group, outside R&D, outside company (Allen, 1977; Keller, 1994).
Hierarchy	Rules and programs, Joint planning, Formal information systems, Lateral relations (Galbraith, 1974; Nadler and Tushman, 1988; Tushman and Nadler, 1978; Lawrence and Lorsch, 1967).
Structural Linking Mechanisms	Standing liaisons between groups, personnel transfer to another site (Allen and Cooney, 1971; Allen, Hyman and Pinckney, 1983; Ettlue, 1990; Roberts and Frohman, 1978; Galbraith, 1974).
Formal Roles	Project or program manager (Allen, et al., 1988; Marquis and Straight, 1965).
Informal Roles	Champions or opinion leaders (Chakrabarti, 1973; Jervis, 1975; Ounjian and Carne, 1987; Rogers, 1983; Souder and Padmanabhan, 1989; Dean, 1984); Gatekeepers (Allen and Cooney, 1971; Allen, 1977); Roles oriented toward specific functions or stages in the innovation process (Jervis, 1975; Kazanjian and Drazin, 1986; Roberts and Fushfeld, 1981).
Integrating Groups	Coordinating committees, task forces, or decision-making committees (Roberts, 1979; Roberts and Frohman, 1978; Lawrence and Lorsch, 1967); Official projects, programs, or matrix structure (Larson and Gobeli, 1988; Marquis and Straight, 1965; Galbraith, 1974).
External Integrator	Consultants (Attewell, 1992); Standards (Langlois, 1992).

Unfortunately, there have been few studies that directly address how one would specifically go about transferring a specific type of technology under a given set of circumstances. There are a few exceptions, though. For instance, some studies suggest that as the complexity of the technology increases, more integrated structures or relationships with other organizations (such as the creation of special project groups) are required (Allen, Tushman and Lee, 1979; Kazanjian and Drazin, 1986; Killing, 1980). Other studies suggest that the problem-solving approaches used by an organization must be determined by the way a new technology fits into that firm's organizational structure (Tushman, 1978; Tyre, 1991). A similar group of studies imply that the firm's relative competency in a particular technical area will determine what types of technology may be transferred, and how the firm will proceed with the transfer (Attewell, 1992; Egelhoff, 1990; Hall and Johnson, 1970). Two works by Ghoshal (Ghoshal and Bartlett, 1988a; Ghoshal and Bartlett, 1988b) suggest that specific integrating mechanisms must be used to transfer technologies, depending on the firm's location in the multinational network. While these studies offer some insight that contingencies affecting technology transfer exist, they do not directly answer the question of "how should I do it?"

Part of this question is addressed by a simple, yet powerful proposition raised by Daft and Lengel in the pioneering of what has come to be known as media richness theory (Daft and Lengel, 1986). They studied the transfer of information between executives and found that, depending on the type of information being transferred, different communications media would be required to complete the task. They suggested that depending on the uncertainty and equivocality of the task situation, different types of information would have to be transferred.

Furthermore, they suggested that communication media varied in their “richness”, or capacity to carry the information to complete certain tasks. Their conclusion was that certain task situations would require specific types of information to be transferred, and depending on the type of information involved, specific communications procedures would need to be used (Daft and Lengel, 1986). Their study and others that followed measured and generally validated this notion (Daft, Lengal and Trevino, 1987; Daft and Lengel, 1986; Jones, Saunders and McLeod, 1989; Keller, 1994; Rice and Shook, 1990; Schmitz and Fulk, 1991; Trevino, et al., 1990; Trevino, Lengal and Daft, 1987; Valacich, et al., 1993).

While conceptually useful, media richness research studied only face-to-face communication, group meetings, video conferences, telephone conversations and voice conferences, E-mail, computer reports, letters, facsimile, notes, memos, special reports, and flyer bulletins (Daft and Lengel, 1986; Rice, 1992; Trevino, et al., 1990), principally during single communication episodes or events. The extent to which those results can be generalized to on-going efforts to communicate and transfer information and technology within a JV might be limited. The media richness hypothesis does provide a clear direction for needed future research, however. Specifically, to answer the question “how should I do it?” one should study both the attributes of the technology and the methods used in its transfer in tandem.

### **Research Background and Method**

The research focus for this project is a joint venture (JV) comprising three operating divisions of large multi-division, multi-product global chemical companies. The operating

divisions produce specialty shapes chemical products for the merchant markets. These divisions were each fully-functioning entities, including R&D (covering new product and process development), marketing, and production functions, as well as some raw materials production capability. Their markets were generally confined to their home regions (Europe, the U.S., and Japan, respectively), although each firm did sell some of its products in the other regions as well. The firms in the JV are Firm G GmbH, located in Germany, Firm A Corp., located in the U.S., and Firm J Co., Ltd., located in Japan<sup>1</sup>. The JV was formed in the early 1990s. Each partner owns an equal position in the joint venture company, and there is limited profit-sharing between the partners.

First contact between the researcher and research sites began almost a year prior to the official formation of the joint venture, and lasted for a period of over three years. Data were collected periodically since that time using a variety of methods, including interviews, archival data, and longitudinal survey data. The interview data were collected through telephone interviews and visits to sites in the United States, Germany, and Japan. The interviews were both open-ended and semi-structured, and lasted between one and four hours. Open-ended interviews were used to identify important areas of transfer activities and to form the basis for hypotheses, while the semi-structured interviews were used to collect data that would confirm those hypotheses. Informants are interviewed if they were involved or had been involved in the transfer of technology or information from one site to another. Managers at each of the research sites identified the informants who fit this description to participate in the study. Informants

---

1

All identifying information in this study is disguised at the request of the participating companies.

were typically asked to identify technologies or information that have been transferred to or from another site, to describe the attributes of those technologies and how they related to the organization, and to discuss any differences or similarities they had observed between their own firm and their partners while engaged in collaborative activities. Table 2 shows the total number of face-to-face interviews conducted, as well as their distribution between the JV sites. The vast majority of interviews were conducted face-to-face. Telephone interviews were used somewhat, but were not found to be very useful for addressing ambiguous or less clearly-defined issues, so they tended not to be used extensively until near the end of the research project when the objectives of the interviews were clearly defined. All interviews were conducted in English.

**Table 2. Total Number and Distribution of Interviews at Each Research Site.**

<b>Site</b>	<b>Number of Participants</b>	<b>Number of Interviews</b>
Firm A	24	58
Firm G	23	59
Firm J	27	31
<b>Total</b>	<b>74</b>	<b>148</b>

In addition to the interview notes, many participants also provided documents to help with the information gathering process. Examples of these documents include organization charts, capital improvement planning documents, R&D project planning documents, and reports of machine specifications or output. These various data were then used to construct a quantitative database describing key attributes of the technology transferred and the process used

in its transfer. A total of 208 separate technologies were identified using this approach, including the details of their transfers from one site to another.

## **Results**

For the purposes of this analysis, “technology” is divided into four categories. These categories were developed based on data collected in interviews with informants at each of the research sites. The categories were derived specifically from descriptive statements in response to the question, “when the technology was transferred to your site, what exactly was transferred?” The four categories are general information, specific information, procedures or practice, and hardware. Each category or type of technology is in essence the form in which the technology was embodied when it was transferred.

General information is general or conceptual knowledge about a technology, system, or method of operation. It provides an awareness of a partner’s technology, operations, or other capabilities, and typically serves as an input or an influence to a development project at the recipient site. Instances of general information transfer observed in this study typically involved cases where employees from one firm observed a technology being used at a partner’s site. The actual transfer of knowledge involved gaining insights into what type of technology was being used, how it operated, its relationship with other elements in the production system, or simply the fact that using the technology in that form or with that level of performance was possible.

Specific information is detailed or specific knowledge about the design or function of a technology. It might consist of data about production unit processing conditions, schematic

diagrams of a component or system, or materials formulations. Specific information was typically transferred as paper documentation containing data, records, or diagrams.

Procedures and Practice are behaviors used in the operation of equipment or in production. While procedures are more explicit or codified instructions for behavior, practice involves the use of tacit forms of knowledge usually acquired through apprenticeship or on-the-job training. Both prescribe the norms and behaviors people use in their work with others and with the physical forms of technology used at the production site. Procedures were typically transferred as operating manuals and/or codified lists of operating procedures that were generated on an as-needed basis. Practice was usually transferred through on-site training seminars for visiting delegations of production operators.

Hardware is technology or knowledge that is embodied in a physical form. While hardware is likely to be a piece of equipment or apparatus, it could be any physical object that is transferred intact from one location to another. Hardware was generally transferred through the shipment of a device or physical object. The shipment could originate from the partner that is the source of the technology, or perhaps from a vendor that may have been the original source.

It should be noted that there is a bit of implied hierarchy to these classifications. The transfer of hardware, for instance, almost certainly involves the transfer of general and specific information, and possibly procedures. What differentiates it as a category from the rest is that it of course involves the transfer of hardware. It is assumed for analytical clarity that each of the categories presented represents a unique category.

**Table 3. Forms in Which Knowledge was Transferred.**

<b>Knowledge Type</b>	<b>Total</b>
General information	36 (17.3%) <sup>a</sup>
Specific information	118 (56.7%)
Procedures/Practice	27 (13.0%)
Hardware, Objects	27 (13.0%)
Total	208

<sup>a</sup> The cells contain the frequency count of transfers of each knowledge type, with column percentages.

A summary of the different forms in which technology was transferred during the course of this study are shown in Table 3. Two points are worth highlighting. First, specific information is the most common form of technology transferred between the partners. Specific information was commonplace because it is the most basic form in which substantive knowledge about a technical capability can be transferred. General knowledge cannot provide the detail necessary to reproduce the capability; transferring hardware does not allow adequate flexibility for adaptation or may be too costly. Second, information in general (including both general and specific information) account for almost 75% of all “technologies” transferred during this study. Both procedures and hardware each accounted for only 13% of the total number of transfers. This suggests that technology transfer between firms in this type of collaboration is really information transfer, and that the notion that technology transfer largely involves the movement of physical objects is somewhat misleading.

Respondents were asked in interviews to describe the different methods that were used in the transfers of technologies to their site. The transfer of a given technology generally required

the use of several different methods for its completion. A total of 21 different methods were reported to have been used, and are shown in Table 4. The table shows the number of times that a specific method was used to transfer the technologies in the sample, the percentage of all technologies that were transferred using that method, the average number of times that method was used during each transfer (when it was used), and whether the method required travel off-site or not. The cells describing whether the method required travel off-site or not are shaded to aid in identification.

**Table 4. Methods Used in the Transfer of the Technologies in the Sample.**

<b>Method</b>	<b>Number of Occurrences</b>	<b>Frequency of Use</b>	<b>Average Usage</b>	<b>Location</b>
Focused technical meetings off-site	203	67.3%	1.45	off-site
Partner's visits to own site	162	46.6%	1.67	on-site
Production unit trials on-site	97	31.7%	1.47	on-site
Facsimile*	96	44.7%	1.03	on-site
Mail	54	26.0%	1.0	on-site
Video conference	47	13.9%	1.62	on-site
Telephone	38	16.8%	1.09	on-site
Own project teams on-site	28	13.5%	1.0	on-site
Other's long-term delegates on-site	28	13.5%	1.0	on-site
Partner's unit audit on-site	27	12.5%	1.04	on-site
Shipments	26	12.0%	1.04	on-site
General JV meetings	24	10.1%	1.14	off-site
Vendor or customer visits	24	5.8%	1.5	off-site
Designated transfer personnel on-site	21	10.1%	1.0	on-site
Personnel transfers	12	5.8%	1.0	off-site
Pilot production unit tests on-site	9	4.3%	1.0	on-site
Training delegations off-site	5	1.4%	1.33	off-site
Production unit audits off-site	5	2.4%	1.0	off-site
Production unit trials off-site	4	1.4%	1.33	off-site
Customer evaluations	2	1.0%	1.0	off-site
Trade or technical conferences	1	0.5%	1.0	off-site
<b>Total: 21</b>	<b>913</b>	<b>9 off-site / 12 on-site (280 off-site/913=30.7%)</b>		

\* The frequency of occurrences cited represents general usage of facsimile in a given transfer process, not the total number of facsimile transmissions required to complete that one transfer.

Since the total number of transfer method occurrences was 913 and the number of technologies transferred was only 208, it is obvious that multiple methods (or at least multiple

events) were used in the transfer of the average technology. The average number of unique methods used (ignoring repeated uses of the same method) to transfer a technology was 3.27 (standard deviation 1.62). The maximum number of unique methods used to transfer a technology was 9. The average total number of methods used to transfer a technology was 4.29 (standard deviation 2.89). The maximum total number of methods used to transfer a technology was 16.

Several transfer methods were used more than once during the average transfer. The average use of each method is shown in Table 4. Among those transfer methods most likely to be repeated (in occasions where they were used) were off-site technical meetings, partner's visits, on-site production unit trials, and video conferences. Transfer methods that have an average usage that is significantly greater than ones are probably particularly effective at technology transfer (and worth continued use). Off-site technical meetings, partner's visits, and on-site production unit trials were also the three most frequently used methods in the sample, so it is not surprising that they were very likely to be repeated. Since video conferences were not used for the transfer of technology nearly as frequently as were the other three methods, their high average usage *per transfer* suggests that video conferences were also deemed an effective technology transfer method.

In all, methods requiring the use of travel comprise a little over 50% of all transfer events shown in Table 4. Site visits were clearly an important mode of technology transfer. The two most-frequently used methods of technology transfer involved the use of site visits. The average number of site visits used to transfer a technology (when they were used) was 2.24 (standard

deviation 1.94). The maximum number of site visits used to transfer a given technology was 11. The remaining 48.6% of transfer events or methods did not require travel. Because they did not require travel (mostly international), they are presumed to have been less costly. Production unit trials on-site and facsimile were the most frequently used transfer methods that didn't require off-site travel.

The large number of transfer methods summarized in Table 4 prevented testing statistical correlation between transfer methods and technology types, given the existing sample size. Furthermore, it was difficult to characterize one specific transfer method for each transfer case because multiple transfer methods were used to accomplish each transfer. To remedy this problem, a hierarchical cluster analysis was performed to define basic transfer method elements and patterns. The cluster analysis algorithm defines relatively homogeneous groups based on patterns and frequency of association between different variables. In this case, the variables used in the analysis were the 21 technology transfer methods shown in Table 4, as they occurred in each of the technology transfer cases. The number of final cluster groups created by the algorithm was unconstrained so as to allow more freedom to interpret the results of the analysis. The transfer method cluster groupings created by the analysis are shown in Table 5. The transfer method groupings in the table should be interpreted as basic elements in the JV's approach to technology transfer, since the categories represent the most frequently occurring combinations of the methods used. The seven categories shown were selected because they each represent distinct groupings of transfer methods. Furthermore, a suitable number of the transfer cases are described by the categories shown since the "leftover" or indistinct methods category ("various")

is of about the same order of magnitude as the others. The next grouping of methods after the seven selected also accounted for a much smaller number of technology transferred cases than those shown in Table 5.

**Table 5. Groups of Transfer Methods Used to Transfer Technologies.**

<b>Method Grouping</b>	<b>Total</b>	<b>Mean Site Visits</b>
Various*	30 (14.4%)	1.0
Other's visit, plus various	38 (18.3%)	1.66
Own visit, plus various	32 (15.4%)	1.56
Own visit, trial, plus various	24 (11.5%)	1.63
Own visit, communication, plus various	27 (13.0%)	1.70
Exchange site visits, plus various	28 (13.5%)	3.43
Exchange site visits, trial, plus various	29 (13.9%)	4.86
<b>Total</b>	<b>208 (100.0%)</b>	<b>—</b>

\* "Various" includes collections of transfer methods that show no single predominant pattern or tendency when compared with other cluster analysis combinations.

An examination of the categories in Table 5 shows that site visits were the primary building block of most technology transfer method groupings. In fact, the three main elements of the method groupings (own visits, other's visits, and trials) are essentially the same as those most-used and most-repeated transfer methods shown in Table 4 (technical meetings off-site, other's site visits, and production trials). To clarify just what exactly is meant by own and other's visits (as opposed to exchanged visits), some explanation is in order. Own visits are visits made to partners' sites (only) by the recipient of the technology transfer. Other's visits are those visits made by a partner to the recipient (only) of the technology transfer. The average number of site visits occurring in all categories involving own or other's visits is in the range of

1.6. Exchanged visits involve at least one visit made by a partner to the recipient site, and the recipient to a partner's site. The average number of site visits involved in the two "exchanged visits" categories are 3.4 and 4.9, respectively. Both of the exchanged visits categories involve significantly more site visits than the other categories (significant at the  $p=0.05$  level). The use of exchanged visits clearly represents an increased amount of effort over simply relying on one's own or others' site visits.

**Table 6. Transfer Methods Used in the Transfer of Specific Technology Types.**

Transfer Methods	General Information	Specific Information	Procedures/ Practice	Hardware, Objects	Total
Various	1 (2.8%) <sup>a</sup>	17 (14.4%)	8 (29.6%)	4 (14.8%)	30 (14.4%)
Other's visit, plus various	4 (11.1%)	27 (22.9%)	3 (11.1%)	4 (14.8%)	38 (18.3%)
Own visit, plus various	15 (41.7%)	13 (11.0%)	3 (11.1%)	1 (3.7%)	32 (15.4%)
Own visit, Trial, plus various	4 (11.1%)	12 (10.2%)	2 (7.4%)	6 (22.2%)	24 (11.5%)
Own visit, communication, various	4 (11.1%)	20 (16.9%)	0	3 (11.1%)	27 (13.0%)
Exchanged site visits, plus various	4 (11.1%)	15 (12.7%)	3 (11.1%)	6 (22.2%)	28 (13.5%)
Exchanged site visits, trial, plus various	4 (11.1%)	14 (11.9%)	8 (29.6%)	3 (11.1%)	29 (13.9%)
Total	36 (17.3%)	118 (56.7%)	27 (13.0%)	27 (13.0%)	208

Likelihood Ratio  $\chi^2 = 45.6$ , DF = 18, Significance = 0.0003

a The shaded cells indicate significant deviations from expected occurrences of technology transfers.

One of the questions posed in the beginning of this paper was "does the transfer method selected depend on the type of technology transferred?" A cross tabulation of the number of technologies transferred by type and by the methods used in their transfer is shown in Table 6. The percentage values found in each cell are column percentages. The shaded cells indicate

statistically significant deviations from the number of expected occurrences of technology transfers.

General Information was most likely to be transferred using one's own visit to another site, with additional various methods. Specific Information was most likely to be transferred through the use of a partner's visit, with additional various methods. The methods most likely to be used to transfer general and specific information, respectively, agree with common sense. A partner is more likely to gather insights or general information about a technology or system by seeing it firsthand during a visit to another site. On the other hand, the exchange of specific information implies some control or premeditation, as would be the case when the partner that is the source of a technology travels to the recipient site to deliver it. Procedures and Practice were most likely to be transferred when partners either exchanged visits or when they used other various methods. Hardware was most likely to be transferred when partners either exchanged visits or made their own site visit and used a production unit trial. In the cases of both procedures and hardware, the use of exchanged visits implies greater effort expended in the transfer process (recall from the previous section that exchanged visits involved from two to three times the number of site visits used in own or other's visits). Procedures differ from hardware, however, in that they were also likely to be transferred using various methods (hardware transfers were likely to be transferred using one's own visit and a trial).

The specific relationships between technology type and the transfer methods used were explored further using loglinear analysis<sup>2</sup>. The only statistically significant relationships between specific transfer methods and specific technology types interestingly involve the transfer of general information and procedures. The apparent relationship between the use of one's own visit to transfer general information is confirmed. General information is 10.1 times more likely to be transferred using one's own site visit than by using various different methods. A partner was also 9.0 times more likely to transfer general information than hardware using one's own visit. The first relationship suggests that there is nothing about general information that requires the use of a large variety of different methods. Perhaps if there is a "right" way to collect general information (because of its nature), then that way would be to travel to its location and observe it. The second relationship suggests that while one's own visit is well-suited for the transfer of general information, a more complex form of technology like hardware requires different transfer methods.

Several statistical relationships between transfer method and technology type characterize the transfer of procedures. First, procedures are one-eighth as likely as specific information to be transferred using one's own visit plus additional communication, and 8.0 times more likely than general information to be transferred using various different transfer methods. These relationships suggest that a single, fixed transfer method is probably not very useful for the transfer of procedures (recall that general information was best transferred using one's own visit).

---

2 A fully-saturated loglinear model was constructed using the transfer method groups and technology type variables, with comparative metrics being calculated from the model's interaction term coefficients. Unless otherwise noted, the level of statistical significance of the relationships cited is at the  $p=0.10$  level.

In fact, procedures are 10.7 times more likely to be transferred using various transfer methods than by using one's own visit with additional communication. They are 5.8 times more likely to be transferred using various different methods than by using exchanged visits with a production unit trial. The predominant use of various methods (as opposed to a single, set way) to transfer procedures suggests that perhaps the transfer of procedures involves a number of contingencies that cannot be planned in advance. Procedures, after all, are the interface between the physical technology and the local organization, so they are likely to be idiosyncratic in nature.

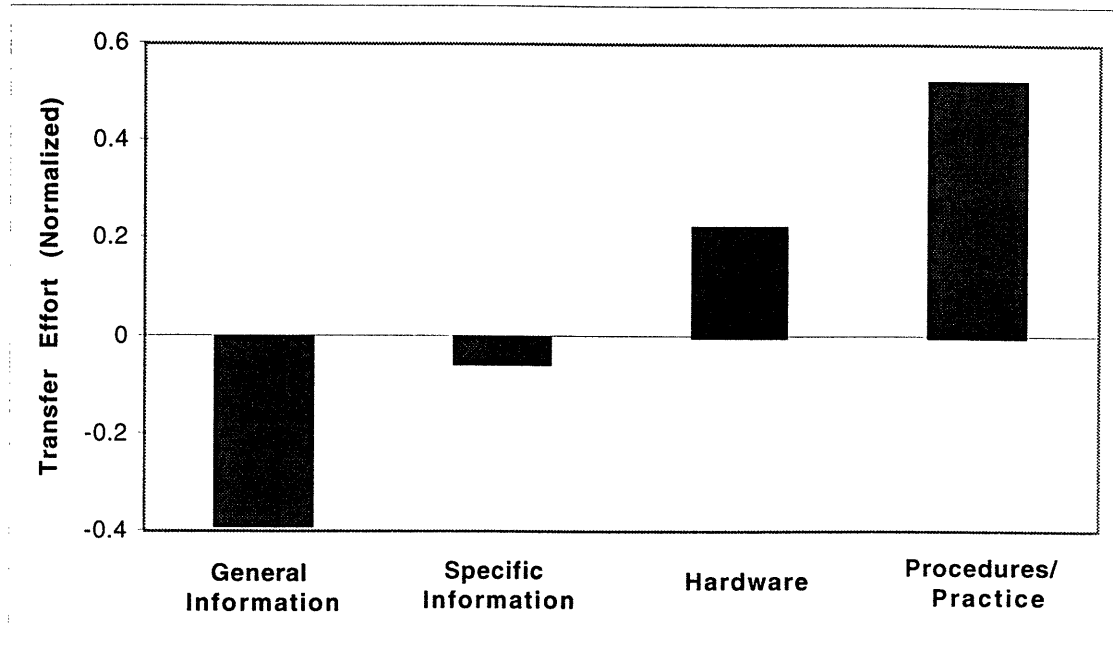
While there was some evidence that some specific transfer methods were more likely to be used than others in the cases of general information and procedures, there was no clear overall relationship between transfer method and technology type. It seems almost intuitive, however, that there should be some relationship between the complexity, information content, or even the physical form of a technology and the methods used to transfer it from one place to another. One problem with basing the analysis of such a relationship on the specific methods used in the transfer is that there is a great deal of overlap in the number of technologies transferred using a single method. For instance, at most of the technical meetings held in the JV, the topic of discussion would cover a broad variety of topics ranging from perhaps the transfer of general information through the transfer of operating procedures. In any case, the transfer of more than one technology was likely facilitated through a single event. Because this happened, the actual variance in the transfer methods used to transfer a single type of technology is probably large compared with the variance in transfer methods used to transfer different technology types. This

would result in weakened statistical power and an increased likelihood of making a Type II error (failing to identify a relationship where one actually existed).

To overcome the apparent weakness in the transfer method measure, an analysis of the relationship between the type of technology transferred and the effort expended in its transfer was performed. A multiple-indicator measure of the effort expended in technology transfer was created using factor analysis. The construct variables used in the factor analysis included the number of unique methods used (the diversity of methods used), the total number of methods used, and the number of site visits used in the transfer as inputs. One factor resulted, which accounted for 72.6% of the variance in the data and which had an internal reliability of 0.80. In the absence of other data such as cost incurred or person-hours expended, this measure was considered to be the best available of the level of effort expended in each technology transfer case. The mean values of the effort expended for each of the four technology types are shown in Figure 1.

Using this approach, the relationship between transfer effort and technology type becomes much clearer. More effort is required to complete the transfer of more complex technologies than “simple” technologies. The mean level of effort expended in the transfer of procedures and practice is significantly greater than that required to transfer both general and specific information (significant at the  $p=0.05$  level), but it is not significantly different from that required to transfer hardware. The mean level of effort expended in the transfer of hardware is significantly greater than that required to transfer general information (significant at the  $p=0.05$  level), but it is not significantly different from specific information.

**Figure 1. The Average Effort Expended in the Transfer of each Type of Technology.**



Bear in mind again the combination of factors used to calculate transfer effort: the diversity of methods used, the total number of methods used, and the number of site visits used in the transfer. This suggests that as the technology and its interdependencies with its situational context become more complex, a greater number of different methods must be used (including “on the ground” site-based observations) to identify and capture the various elements and forms of knowledge present in the technology. This finding supports the notion that the media richness hypothesis is applicable to more complex and tangible technologies than the verbal and written communications on which it was originally based.

From the evidence present in this study, there appears to be a clear relationship between the type of technology or knowledge being transferred and the methods used (or at least the effort expended) in its transfer. The lack of such a clear relationship between the technology

type and the specific methods used in its transfer undoubtedly results from the large amount of overlap in transfer efforts during the JV. This means that for every meeting (or other transfer event) held, a number of different types of technology were transferred. From the practitioner's point of view, this is a positive outcome. This means that more "mileage" or benefit was extracted from each transfer event or method than would have been the case had only one technology type been transferred. This does highlight that in actual practice, however, theory may take a back seat to pragmatism. For instance, even if the transfer of specific information might most efficiently be accomplished using facsimile transmission (according to theory), if a delegation is visiting a partner's site as part of another transfer effort, the additional cost of collecting that specific information at that time is negligible.

## **Discussion**

This paper has presented evidence from a longitudinal study of technology transfer in an international joint venture. In the process, it has attempted to identify the processes used in technology transfer (in this case), and provide insight into the question of how the type of technology being transferred affects the transfer process.

An analysis of the specific transfer methods used for the transfer of the different technology types initially showed some interesting relationships concerning specific technology types, but no compelling general relationship between the transfer methods used for the transfer of a specific technology type. A wide range of different methods were observed to have been used to transfer information and technology, depending upon the specific details of the transfer

situation. Aggregation of the different transfer methods used into a smaller number of categories shows that site visits were the primary building block of technology transfer in this international joint venture.

While this is not surprising, based on prior research and observation in the area of technology transfer, it is revealing since in this specific joint venture each of the partners had generally similar technologies at the outset. In essence, none of the technologies or concepts transferred were totally unknown or foreign to the other partner when the JV began. In fact, each partner knew generally (from prior experience and on-site observation for some time prior to the start of the JV) what the others' general technical approach and capability was. Given this context, the site visits served a number of specific functions for the JV partners.

First, site visits provided first-hand awareness of the nuances of the ways in which the common technologies used by each partner had been applied in context-specific ways. While each partner could trace the evolution of their key technologies back to common origins in the early days of their industry, over the years the selection of specific technologies and their integration into and interdependence within the overall production system had given each application of the common technologies a unique flavor. This research collectively categorized those nuances as general information, with the most likely method used in its transfer being present at the other partner's site to experience it first-hand.

Site visits also served to establish working relationships between engineers and researchers that formed communication linkages for the transfer of more detailed information through non-face-to-face interactions. Once points-of-contact or colleagues working in similar

areas had been identified through on-site meetings, would-be technology recipients could follow-up with a telephone call or facsimile message to obtain any additional needed information. This is the way that a disproportionate amount of specific or detailed information was shared in the JV.

Finally, site visits provided the opportunity for intense interaction and learning. It is easy to observe, for instance, that a partner's laboratory technicians use a different procedure for measuring a certain product characteristic, but it is a different thing to acquire the specific skills that are required to perform that procedure. As the complexity of the knowledge captured in the procedure increases, the less likely that casual observation will be able to capture its essential characteristics or details. The transfer of procedures and practices accounted for the greatest diversity of transfer methods associated with the transfer of any of the technology types. As was shown, their transfer also required the greatest amount of effort, as measured by a composite rating. Only through intense, frequent, and diverse interactions can the learning take place that is necessary to capture the full complexity of practices and other forms of social knowledge.

Now, while some statistically-significant tendencies towards using a given transfer methodology to transfer a specific technology type were found in the analysis of the data, there were by no means clear-cut singular approaches to transferring a specific type of technology. Indeed, each of the technology types was transferred using a large variety of different methods. Part of this is due to the fact that because of the expense of international site visits, the JV partners attempted to meet numerous and diverse transfer objectives during each of these events. Perhaps in a situation where the cost of face-to-face interaction is lower, the trends observed in this data would be more pronounced.

Additionally, even though the transfer of procedures required the greatest effort, they were nevertheless transferred from partner to partner with considerable success. Managers and engineers interviewed during in this research consistently stated a conviction that effective use of the best procedures and practices available in the JV would be key to successful efforts to increase their facilities' productivity. Procedures and practices are an important part of the firm's core competence and a source of competitive advantage. Evidence from this research suggests that source of competitive advantage can be transferred from one firm to another, given an appropriate level of access and effort.

This represents both good news and bad news. The good news is that an industry-trailing firm can realistically work to revitalize itself through the adoption of best practices from an industry-leading partner. The requirement is that it be given the access from a willing partner and put forth the required effort. The bad news is that a firm leading its industry can potentially lose a portion of its competitive advantage through a strategic alliance or partnership with another firm. To ensure that inter-firm alliances dependent upon technology transfer are fully successful, care should be taken to minimize the potential for current or future market competition between partners. Where potential for market competition exists between partner firms, access to key technologies and knowledge will have to be monitored and managed. Managers contemplating partnerships in such situations may realistically only be able to expect to benefit from their partners through the transfer of general or specific information, but not procedures or practices.

## References

- Allen, Thomas J. Managing the Flow of Technology. Cambridge, Mass: MIT Press, 1977.
- Allen, Thomas J., and Sean Cooney (1971) "The International Technological Gatekeeper." *Technology Review*, Vol. 73, No. 5 (March), pp. 2-9.
- Allen, Thomas J., Diane B. Hyman, and David L. Pinckney (1983) "Transferring Technology to the Small Manufacturing Firm: A Study of Technology Transfer in Three Countries." *Research Policy*, Vol. 12, , pp. 199-211.
- Allen, Thomas J., Ralph Katz, J.J. Grady, and Neil Slavin (1988) "Project Team Aging and Performance: The Roles of Project and Functional Managers." *R&D Management*, 18, 4, 295-308.
- Allen, Thomas J., Michael Tushman, and Dennis Lee (1979) "Technological Transfer as a Function of Position in the Spectrum for Research Through Development to Technical Services." *Academy of Management Journal*, Vol. 22, No. 4, pp. 694-708.
- Attewell, Paul (1992) "Technology Diffusion and Organizational Learning: The Case of Business Computing." *Organization Science*, Vol. 3, No. 1 (Feb.), pp. 1-19.
- Chakrabarti, A. K. (1973) "Some Conceptions of Technology Transfer: Adoption of Innovations in Organizational Context." *R&D Management*, Vol. 3, No. 3, pp. 111-120.
- Daft, Richard L., Robert H. Lengal, and Linda K. Trevino (1987) "Message Equivocality, Media Selection, and Manager Performance: Implications for Information Systems." *MIS Quarterly*, Vol. 11, September, pp. 334-366.
- Daft, R. L., and R. H. Lengel (1986) "Organizational Information Requirements, Media Richness and Structural Design." *Management Science*, Vol. 32, No. 5 (March), pp. 554-571.
- Dean, James W. Deciding to Innovate: How Firms Justify Advanced Technology. Cambridge, MA: Ballinger, 1984.
- Egelhoff, W. G. "The Development and Transfer of Technology in the Global Semiconductor Industry: An Exploratory Study." Presented at the Eastern Academy of Management, June 1991, at Nice, France.
- Ettlie, John E. (1990) "Intrafirm Mobility and Manufacturing Modernization." *Journal of Engineering and Technology Management*, , No. 6, pp. 281-302.

- Galbraith, J.R. (1974) "Organization Design: An Information Processing View." *Interfaces*, Vol. 4, May, pp. 28-36.
- Ghoshal, Sumantra, and Christopher A. Bartlett (1988a) "Creation, Adoption, and Diffusion of Innovations by Subsidiaries of Multinational Corporations." *Journal of International Business Studies*, , Fall, 1988, pp. 365-388.
- Ghoshal, Sumantra, and Christopher A Bartlett. "Innovation Processes in Multinational Corporations." Readings in the Management of Innovation. Ed. Michael L. Tushman and William L. Moore. 2nd ed. New York: Harper Business, 1988b. pp. 499-518.
- Hall, G. R., and R. E. Johnson. "Transfers of United States Aerospace Technology to Japan." The Technology Factor in International Trade. Ed. R. E. Vernon. New York: National Bureau of Economic Research, 1970. 305-358.
- Jervis, Paul (1975) "Innovation and Technology Transfer- The Roles and Characteristics of Individuals." *IEEE Transactions on Engineering Management*, Vol. EM-22, No. 1 (February), pp. 19-27.
- Jones, Jack W., Carol Saunders, and Raymond Jr. McLeod. "Information Media and Source Patterns Across Management Levels: A Pilot Study." *Journal of Management Information Systems* Vol. 5.No. 3 (Winter) (1989): pp. 71-84.
- Kazanjian, Robert K., and Robert Drazin (1986) "Implimenting Manufacturing Innovations: Critical Choices of Structure and Staffing Roles." *Human Resource Management*, Vol. 25, No. 3 (Fall), pp. 385-403.
- Keller, R. T. (1994) "Technology-Information Processing Fit and the Performance of R&D Project Groups: A Test of Contingency Theory." *Academy of Management Journal*, Vol. 37, No. 1 (Feb.), pp. 167-179.
- Killing, Peter (1980) "Technology Acqisition: License Agreement or Joint Venture." *Columbia Journal of World Business*, , Fall, pp. 38-46.
- Langlois, Richard N. "Capabilities and Vertical Disintegration in Process Technology: The Case of Semiconductor Fabrication Equipment." University of Connecticut Working Paper, Storrs, CT. November, 1992.
- Larson, Erik W., and David H. Gobeli (1988) "Organizing for Product Development Projects." *Journal of Product Innovation Management*, , 5, 180-190.
- Lawrence, Paul R., and Jay W. Lorsch. Organization and Environments: Managing Differentiation and Integration. Homewood, IL: Irwin, 1967.

- Marquis, Donald G., and D.L. Straight. Organizational Factors in Project Performance. MIT Sloan School of Management, 1965.
- Nadler, David A., and Michael L. Tushman. "Strategic Linking: Designing Formal Coordination Mechanisms." Readings in the Management of Innovation. Ed. Michael L. Tushman and William L. Moore. 2nd ed. New York: Harper Business, 1988. pp. 469-486.
- Ounjian, Moira L., and E. Bryan Carne (1987) "A Study of the Factors Which Effect Technology Transfer in a Multilocation Multibusiness Unit Corporation." *IEEE Transactions on Engineering Management*, Vol. EM-34, No. 3 (August), pp. 194-201.
- Rice, Ronald E. (1992) "Task Analyzability, Use of New Media, and Effectiveness: A Multi-Site Exploration of Media Richness." *Organization Science*, Vol. 3, No. 4 (November), pp. 475-500.
- Rice, Ronald E., and Douglas E. Shook (1990) "Relationships of Job Categories and Organizational Levels to Use of Communications Channels, Including Electronic Mail: A Meta-Analysis and Extension." *Journal of Management Studies*, Vol. 27, No. 2 (March), pp. 195-229.
- Roberts, Edward B., and Alan R. Fusfeld. "Staffing the Innovative Technology-Based Organization." *Sloan Management Review* (1981): 19-34.
- Roberts, Edward B. (1979) "Stimulating Technological Innovation - Organizational Approaches." *Research Management*, Vol. XXII/No. 6, November, pp.
- Roberts, Edward B., and Alan L. Frohman (1978) "Strategies for Improving Research Utilization." *Innovation/Technology Review*, Vol. 80, No. 5 (March/April), pp. 35-41.
- Rogers, E. M. Diffusion of Innovations. 3rd ed. ed. New York: The Free Press, 1983a.
- Schmitz, Joseph, and Janet Fulk. "Organizational Colleagues, Media Richness, and Electronic Mail." *Communication Research* Vol. 18.No. 4 (August) (1991): pp. 487-523.
- Souder, William E., and Venkatesh Padmanabhan (1989) "Transferring New Technologies from R&D to Manufacturing." *Research/Technology Management*, Vol. 32, No. 5 (September-October), pp. 38-43.
- Trevino, Linda K., Robert H. Lengal, and Richard L. Daft (1987) "Media Symbolism, Media Richness, and Media Choice in Organizations." *Communication Research*, Vol. 14, October, pp. 553-574.

- Trevino, Linda K., et al. "The Richness Imperative and Cognitive Style." *Management Communication Quarterly* Vol. 4.No. 2 (November) (1990): pp. 176-197.
- Tushman, Michael L. (1978) "Technical Communication in R&D Laboratories: The Impact of Project Work Characteristics." *Academy of Management Journal*, Vol. 21, No. 4, 624-645.
- Tushman, Michael L., and David A. Nadler (1978) "Information Processing as an Integrating Concept in Organizational Design." *Academy of Management Review*, , July, pp. 613-624.
- Tyre, M.J. (1991) "Managing the Introduction of New Process Technology: International Differences in a Multi-Plant Network." *Research Policy*, Vol. 22, , pp. 57-76.
- Valacich, Joseph S., et al. "Communication Concurrency and the New Media." *Communication Research* Vol. 20.April (1993): pp. 249-276.
- Van De Ven, Andrew H., Andre L. Delbecq, and Richard Jr. Koenig (1976) "Determinants of Coordination Modes Within Organizations." *American Sociological Review*, Vol. 41, April, pp. 322-338.