Available online at www.sciencedirect.com
SCIENCE DIRECT®
Omega 33 (2005) 189–202
omega
The International Journal of Management Science
www.elsevier.com/locate/dsw

# Transfer of technologies: a cross-disciplinary taxonomy

Arnold Reisman

*Reisman and Associates, Shaker Heights, OH, USA*

Received 9 January 2004; accepted 16 April 2004

**Abstract**

Transfer of technologies (TT) takes place among various kinds of players, takes on various kinds of modalities and is done for various motivations. Its literature is very disjoint and disparate. It transcends several academic disciplines and professions. This paper presents a taxonomy defining the field in its entirety and delineating all of its facets in a manner that is parsimonious yet discriminating. Many potential uses for the taxonomy are identified. These include more effective teaching of TT subject matter.
© 2004 Elsevier Ltd. All rights reserved.

*Keywords:* Technology transfer; Web-based technology transfer; Internet transfer of technology; Illegal technology transfer; Technology transfer law; Technology transfer process; Motivations for technology transfer; Management of technology; Innovation management; Technology transfer curricula; Diffusion of technology; Barriers to transfer of technology; Research utilization; Research-technology management; R&D management; Socioeconomic development; Intellectual property; Knowledge utilization; Meta research; Taxonomy; Classification

## 1. Introduction

### 1.1. Background

*Technology transfer* (TT) is an emerging field of knowledge in which institutional interest is rapidly expanding. Using the two key words in any web-based search engine will quickly attest the fact that it is key to the development and competitiveness. Firms use it to improve their competitive advantage [1]. It is used to enhance the competitiveness of an entire industry, a region within a nation's boundaries and an entire nation-state [2]. As in the case of the Caucasus and Central Asia it can enhance development of a multi-nation geographic region. It is a means toward economic progress, social development, quality of life, and even of culture and of value systems [3].

As is often the case in an emerging area or discipline, its descriptive as well as normative theories and data available are fragmented and disjointed. There is no general theory, model or structure for the field; people merely string information and insight on an invisible thread and hope that the thread continues to hold. This is especially so because TT is of concern, to several major professions, in addition to several basic social-science disciplines. Moreover, it is of concern to policymakers in the public, private, and the not-for-profit sectors, and to decision-makers at the company or institution, community, regional, and national levels. It is also of interest to the multinational economic communities, some of which are established (e.g., *EU*), some of which are emerging (e.g., the Istanbul based, *Black Sea Economic Cooperation Business Council*), and some that have been relegated to history (e.g., the *COMECON*) [4].

Although there is at least one professional society dedicated to TT and the *Journal of Technology Transfer* [1] is now through its 28th volume year, economists, sociologists, anthropologists, engineers, and management theorists have established an interest in TT over a much longer period and yes they have contributed to TT knowledge albeit within their own disciplinary confines. Not surprisingly, the very *definition* of TT differs across the many disciplines

*E-mail address:* reismana@cs.com (A. Reisman).

[1] "The only international forum focusing purely on the transfer of technology" can be found at http://www.kluweronline.com/issn/0892-9912/current.

0305-0483/$ - see front matter © 2004 Elsevier Ltd. All rights reserved.
doi:10.1016/j.omega.2004.04.004

addressing this subject. The scope of TT has rarely been delineated or systematically analyzed. Though several (limited) taxonomies of TT have been published, currently, TT can be understood only in a limited way from a strict disciplinary framework and/or a specific aspect.

### 1.2. Previous TT taxonomies

Because of TT's multifaceted and multidisciplinary nature, a cross-disciplinary meta approach is needed to study it as a subject area. Reddy and Zhao [3] did an extensive review of TT literature as viewed from different perspectives by some disciplines. Reisman [2] offers a generic TT taxonomy base categorizing the various TT "players" e.g., the providers, or transferors and the receivers, transferees, or users. Zhao and Reisman [5] offers a synthesis of TT taxonomies transcending all the disciplinary approaches. That synthesis incorporated interdisciplinary dimensions much broader in scope and having a wider variety of potential uses/objectives than any TT taxonomy existing as of 1992. Kumar et al. [6,7] created a taxonomy of TT motivations while this paper presents a TT meta-taxonomy incorporating or subsuming all of the above.

### 1.3. Motivations and uses for this taxonomy

As will be shown in Section 3 there are no fewer than 182 fairly independent TT attributes. Thus the number of distinct and meaningful combinations of these attributes is staggering.[2] That number represents distinctly different potential TT modalities.[3] This fact alone is pregnant with meaning. Because of the enormity of this subject it is no wonder then the very mention of TT conjures different meanings to different people and different meanings at different times to a single individual.

This taxonomy offers a framework for classifying papers published in the various academic disciplines' literatures concerned with TT. Because it furthers our understanding of TT at both the conceptual and the operational levels it is intended for the researcher who chooses to study TT in an interdisciplinary manner. While the educator can use this taxonomy to present the TT subject matter in a comprehensive, comprehendible manner, the novice can grasp the wide spectrum of transactions possible in technology transfer. The seasoned worker can use it to pinpoint a market niche and the structural, operational and other characteristics of his or her involvement in TT in the context of the overall realm of possibilities. Corporate or institutional managers and/or directors can use it in developing TT strategies for growth/expansion, mergers, acquisitions, and/or divestitures. Policy makers can use it to formulate meaningful technology and/or TT policies.

The taxonomy facilitates seeing the forest while at the same time knowing the exact size, shape, color, and texture of any tree. It allows us to identify the wide spectra of TT practices and of TT related theory and findings and allows for a systematic classification of any and all papers published irrespective of the author(s)' disciplinary base. Moreover, the taxonomy can facilitate marketing of TT curricula or courses through its efficient description of the field's diversity, richness, importance, relevance, and the richness of aspects that need to be understood and managed.

It can be used as an organizing framework in collecting and/or collating TT related data at the company/institution, region, economic sector, and/or national levels for purposes of:

- Doing *meta* research (MR) on TT:
- Adoption of an integrative approach—an interdisciplinary approach,
- Development of new concepts.
- Describing the extent of the practice:
  - By design.
  - By diffusion.
- Pinpointing voids/weaknesses in transfer mechanisms:
  - In institutions.
  - In policies.
- Pinpointing "ports of opportunity":
  - To companies, institutions, communities, states, geographic regions and to countries.
  - To professions.
  - To scientific disciplines.
  - To individual researchers [5].

It can also serve as a vehicle for collecting data to describe the profile or mix of transfer practices in and/or by an enterprise, a community, state, or region for purposes of:

- Stating job creation and/or employment levels.
- Stating wealth generation.
- Stating dollar expenditures.
- Justifying financing.
- Setting priorities for:
  - Public fund allocations.
  - Philanthropic giving.
  - Philanthropic fundraising.
- Identifying voids in the services provided.

If such data were compiled in a uniform manner across companies/institutions in a given industry, community, and/or region, researchers, planners, policy analysts, and policymakers would have a better grounding for their efforts.

> In primary [social science] research, data are collected by asking people questions or observing their behavior. In research synthesis, data are collected by conducting a search of reports describing past studies relevant to the topic of interest, Cooper [8].

[2] It is in the order of $6.1 \times 10^{54}$.

[3] "Modalities" are to be interpreted as configurations of transactions or of contracts.

Both undergraduate and graduate OR/MS curricula do provide various methodologies for collecting "primary research" data. However, instances concerned with formal teaching of research synthesis data collection methodologies are few, Reisman [9,10]. Yet, the need for taxonomic research in any but especially in an emerging field of knowledge or practice is well documented as in Cooper [11,12], Goffman [13], Reisman [14] to mention but a few. The methodologies for doing such work are also well established e.g., Cooper [11,12], Reisman [14–16], as are some of its uses Reisman [17,18], Reisman and Buffa [19], Reisman et al. [20,21], Reisman and Xu [22,23], Taft and Reisman [24] and Gattoufi et al. [25].

## 2. Discussion

### 2.1. MR and taxonomies

It is clearly important to publish the results or findings of good research in a given field of knowledge. Having said that, it is also important to systematically review the totality of such publications on some periodic basis. The literature concerned with history and philosophy of science is replete with admonitions to that effect. Such systematic reviews represent research on research or what is sometimes called MR. MR serves many objectives, Reisman et al. [21]. At times MR is dedicated to consolidating a given knowledge domain as in Reisman [18]. There are at least two efficient and effective ways of consolidating knowledge. One of these is to create a taxonomy and the other to create a generalized framework (a general model or theory) that subsumes all existing models facts or theories within that field. The two are not mutually exclusive. In fact, they are complimentary. Taxonomies display the subject's domain in terms that are easy to understand, to communicate, to teach, to learn, and to work with. More specifically taxonomies can be used:

1. To efficiently and effectively classify any and all contributions/publications for purposes of storage, recall, sorting, and or bibliometric/statistical analyses. Because such classification results are meaningfully machine readable they, in turn, clearly enable further MR [18,26].
2. To identify voids in the literature and hence directions/specifications for research to be performed [15,16,27].

Classification of papers based on a taxonomy makes similarities and differences among studies very clear and it does so in a most efficient and effective manner. This in turn vividly displays the similarities and the differences among the various contributions, thus demonstrating the relationship of all contributions and the practical applications. It provides a framework by which all of the existing knowledge can be systematically filed and therefore efficiently and effectively recalled. Providing what amounts to an aerial view

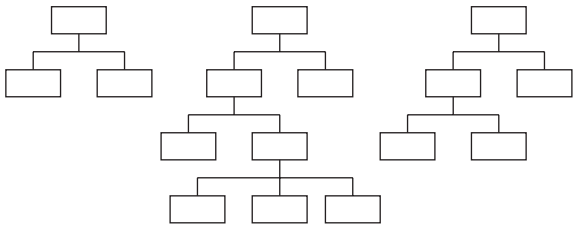

Fig. 1. Attribute vector description based taxonomy [18].

—a picture of the territory—helps to identify the voids in the literature. Stated differently:

> Knowledge consolidation is a means to various ends, and it is also an end itself. It is a means toward the end of more efficient and more effective teaching and learning of new or existing knowledge. It is a means toward the end of more efficient storage and more effective recall and/or retention of knowledge. It is a means toward a more efficient and more effective processes of research leading to the yet unknown, to the design of the yet unavailable, and it is means toward more efficient problem solving...
>
> Reisman [26, p. 29].

Moreover, the key to taxonomy effectiveness rests on criteria of comprehensiveness, parsimony and usefulness. Obviously, to be effective, a taxonomy must represent the full spectrum of the research chosen for categorization. Thus, comprehensiveness is a necessary condition for effectiveness. It is, however, not sufficient. To be further effective, a taxonomy should be parsimonious. It should not include unnecessary categories. Finally, to be considered effective, the taxonomy should be robust and generally useful. The categories should be reasonably if not mutually exclusive, i.e., non-overlapping, reasonably distinct, meaningful, commonplace, and descriptive to allow utilization by a wide variety of interested persons [27].

The current attempt to create a taxonomy for TT may have its own disadvantages but it does not suffer from ambiguity. It proceeds in an arborescent way [18] as illustrated in Fig. 1.

## 3. A meta taxonomy for technology transfer

### 3.1. Actors involved in TT

By definition TT involves at least two actors—a provider and a receiver. However each of these could represent a *scientific discipline*, a *profession*, a *company* or an *institution*, an *industry*, an *economic sector*, a *geographic region* or an entire *society* or *country*.

### 3.2. Transaction characteristics

#### 3.2.1. Duration

A single transaction may be consummated at once, (a one-time purchase of a technology) or it may be a long-term relationship between the various parties, (cases involving joint ventures). This dimension is important for TT transactions because it usually implies something about the nature of the technology exchanged, the responsibilities of each party, the strategies and capabilities of transferor and transferee, and the influence of third parties.

#### 3.2.2. Costs

A transaction may or may not have any direct financial ramifications or obligations. Some transactions have no monetary income whatsoever to the TT provider and zero cost to the receiver [28,29]. Such may be the case in professional exchanges at conventions, conferences, conversations, correspondence, or through journal articles. Other transactions may involve considerable amounts of monetary obligations such as sales of hardware and/or intellectual property on a onetime basis or as part of a long-time joint venture [30]. Moreover, financial considerations could include, in whole or in part, in-kind transfers of goods and/or services. If such is the case, the transaction involves the form of commerce known as barter or more broadly, countertrade [31,32].

Parenthetically it is noted that many researchers question the appropriateness of the term "transfer" as TT may or may not involve financial costs. For example, Vaitsos [33] laments its inappropriateness from a commercial perspective arguing that "transfer" connotes the free, non-commercial movement of something from one location or possessor to another. In the business world, however, technology transfer usually implies a "sale" of some technology. For this reason the term "commercialization of technology" has been argued to be generally more appropriate [34].

The significance of this dimension lies in its relevance to the issues in TT research and practice such as pricing of transfer, concentration of technology, cost of resource requirements, determinants of transfer costs, technology transfer payment, conflict and code of conduct in international technology transfer, and the effectiveness of transfer.

#### 3.2.3. Modalities

A third important characteristic describing TT transactions is the modality involved. This can be separated into seven primary categories: *External transfer* from one entity (organization) to another and *internal transfer* among separate units of an organization [35]. In external TT the transaction may be part of a joint venture, licensing or cross-licensing, cooperation agreement, sale, publication, conference, visitor and/or work-study program. In the case of internal transfer, one organizational unit may form a joint venture with another, [36] may license or cross-license one another, or may simply exchange information. Additionally, the TT modalities can be described by; *duration*, *payment requirement*, *network involved*, the *direction of TT flow*, and whether the technology is *proprietary* or not.

### 3.3. Motivations

Many motivations to participate in TT exist for parties described in Section 3.1. As will be shown, there are at least 81 fairly independent (of each other) such motivations. These are grouped into; *Economic*, *Social*, *Operational*, *Strategic*, *Global and Personal* categories.

### 3.4. Disciplines

At least four classical academic disciplines have been involved in TT over time. They are; *economics*, *anthropology*, *sociology* and *professions* such as management, engineering and more recently medicine. Each views the role of TT differently and each has a unique perspective on TT.

#### 3.4.1. Perceived role of TT

*In economics* it is economic growth.

*In anthropology* it is cultural change and advancement of society.

*In sociology* it is improvement of social life.

*In management and in engineering* it is strengthening of corporate or institutional competitiveness, including but not limited to financial, technological and other benefits.

*In medicine and related professions* it is advancement of the state of the art, enhancement of longevity and quality of life as well as economic and other benefits.

#### 3.4.2. Perspectives taken in the academic disciplines

*In economics* they are macroeconomic, nation-state, politico-economic and the flow and content of technology.

*In anthropology* they are cultural, institutional, and geographic.

*In Sociology* it is institutional and the nature of the technology.

*In management and in engineering* they are ownership, control, the nature, modality and the phase of TT.

### 3.5. The taxonomy

In what follows, TT and therefore its related literature are first classified into four basic factors. Under each factor the most discriminating attributes are listed. The full taxonomy is illustrated in Fig. 2 wherein each contribution can be given an identification code based on specified keys:

*Key* 1: *Actors* (*transferors*/*transferees*). This *key* has two domains. The first describes the provider the *transferor* and the second the receiver the *transferee* with a detailed specification for each. Thus, using Fig. 2; (1.1.1/1.2.2) means that

the transfer is made from a discipline to a profession. On the other hand, (1.1.1/1.1.2/1.2.1/1.2.2) indicates that disciplines and professions were represented on both the providing and the receiving sides.

*Key* 2: *Transaction types*. This *key* is subdivided into seven domains. The first specifies an *external transfer* and the second an *internal transfer*. The third and fourth, respectively, indicate the time duration and the need for payment, while the other three are concerned with the nature of the TT, its flow direction(s) and the extent of the network involved. Thus, using Fig. 2; (2.1.1.2/2.3.1/2.4.1/2.5.2/2.6.3), means it is a conference involving external transfers of short duration with no payment involved. However, it involves a network having more than two nodes and the exchanges are multidirectional involving non-proprietary materials.

*Key* 3: *Motivations*. This is subdivided into six domains, respectively, they specify the *Economic*, *Social*, *Operational*, *Strategic*, *Global and Personal* factors. Using Fig. 2; (3.6.1/3.6.2/3.6.4/3.6.5/3.6.8) means that all of the motivations are personal and that there is a multiplicity of these.

*Key* 4: *Disciplines*. This is subdivided into four domains, respectively, they specify Economics, Anthropology, Sociology, and Management. Thus using Fig. 2; (4.4.2/4.4.9) signifies a horizontal transfer of management technology across national boundaries.

***Key 1:*** **Actors: .**

1.1 Transferors
- 1.1.1. Scientific disciplines
- 1.1.2. Professions
- 1.1.3. Corporate or institutional entities
- 1.1.4. Industries
- 1.1.5. Economic sectors
- 1.1.6. Geographic regions
- 1.1.7. Societies/countries.

1.2. Transferees
- 1.2.1. Scientific disciplines
- 1.2.2. Professions
- 1.2.3. Corporate or institutional entities
- 1.2.4. Industries
- 1.2.5. Economic sectors
- 1.2.6. Geographic regions
- 1.2.7. Societies/countries.

***Key 2:*** **Transaction Types**

2.1 External Transfers

2.1.1. Information exchange
- 2.1.1.1 Programs: (Sabbaticals, scholarship programs such as the Fulbright awards, work- study arrangements, internships)
- 2.1.1.2 Conferences and Symposia:
- 2.1.1.3 Technical Correspondence:
- 2.1.1.4 Free Technical Services:
- 2.1.1.5 Professional-Journal Publications:
- 2.1.1.6 Software programs:
- 2.1.1.7 Internet/Web usage related exchanges:

Fig. 2. A taxonomy of technology transfer literatures (This taxonomy is intended for the legal, ethical and moral transfers of technology. Clearly there is an illegal side of TT practices and a body of the literature addressing it. A taxonomy dealing for dealing with this—the illegal TT is available in Reisman [9] and is briefly discussed later in this paper. In some cases a paper can rightfully be classified as belonging to two or more of the designations provided in any one key. In such cases each designation is shown but separated by "/". Thus (2.2.1/5.2) signifies that the paper studies a knowledge domain's historic directions. Moreover the paper defines OR/MS in general to be the knowledge domain).

2.1.2. Sales
- 2.1.2.1 Sales of Equipment and/or Intellectual Properties: (A single piece of equipment or an entire system such as a factory, turn-key projects, etc., a formula, new designs, drawings, blueprints, procedures, market surveys, demographic statistics)
- 2.1.2.2 Sales of Services: (Consulting assistance, user manuals, equipment maintenance)

2.1.3 Cooperative agreement
- 2.1.3.1 Co-production: (The GE (USA) - SNECMA (French)) collaboration in the aerospace industry
- 2.1.3.2 Co-research (the U.S. Human Genome Project, a 13-year effort coordinated by the Department of Energy and the National Institutes of Health)
- 2.1.3.3 Co-design (Arrow anti missile system (USA and Israel), The UK "Watchkeeper" unmanned spy plane project (UK, USA, Israel)

2.1.4 Arm's length licensing
- 2.1.4.1 Licensing: Conveyance of manuals, blueprints, design drawings, or data; provision of technical and managerial assistance.
- 2.1.4.2 Cross Licensing: (same as above)

2.1.5 Franchising (McDonald's hamburgers in USSR, Holiday Inn Hotels in USA).

2.1.6 Joint venture
- 2.1.6.1 Equity Joint Venture:
- 2.1.6.2 Contractual Joint Venture:

2.2 Internal Transfers

2.2.1 Internal information exchange
- 2.2.1.1 Meetings:
- 2.2.1.2 Correspondence:
- 2.2.1.3 Publications:

2.2.2 Cooperative agreement
2.2.3 Arm's length licensing
2.2.4 Internal joint venture
2.2.5 Wholly owned subsidiary

2.3 Time duration
- 2.3.1 Short term
- 2.3.2 Long term

2.4 Payment requirement
- 2.4.1 None
- 2.4.2 Required

2.5 Network
- 2.5.1 Two nodes
- 2.5.2 Multi nodal

2.6 Flow
- 2.6.1 Unidirectional

Fig. 2. (*continued*).

2.6.2 Bi-directional
2.6.3 Multidirectional
2.7 Nature of TT
2.7.1 Proprietary
2.7.2 Non-Proprietary

***Key 3*** **Motivations**

3.1 Economic Factors
3.1.1 Cost savings
3.1.2 Economic growth
3.1.3 Increased earnings in hard currency
3.1.4 Generation of foreign exchange (other than hard currency)
3.1.5 Improved balance of trade
3.1.6 Generation of exports
3.1.7 More equitable trade agreements
3.1.8 Increased tax revenues
3.1.9 Increased sales
3.1.10 Taking advantage of. tax and tariff laws
3.1.11 Increased royalties
3.1.12 Increased sales of technology
3.1.13 Improved profitability
3.1.14 Improved knowledge/database

3.2 Social Factors

3.2.1 Improved quality of life
3.2.2 Improved physical health status
3.2.3 Increased employment
3.2.4 Elevation of social or political status
3.2.5 Cultural enrichment, cultural evolution
3.2.6 Advancement of society
3.2.7 Improved environment through improved/new technology
3.2.8 Improved crime-fighting capabilities

3.3 Operational Factors

3.3.1 Changes in scale of production or service
3.3.2 Improved input material
3.3.3 Improved reliability of delivery dates
3.3.4 More efficient use of capital and labor
3.3.5 Upgraded labor skills
3.3.6 Access to alternative sources of supply
3.3.7 Increased production capacity
3.3.8 Working out trade deals under constraints
3.3.9 Reducing risk of over-demand forecast
3.3.10 Improved problem solving skills
3.3.11 Better purchasing capability

Fig. 2. (*continued*).

3.3.12 Increased mechanization/automation
3.3.13 Improved process yields
3.3.14 Changing from intermittent to mass flow processes
3.3.15 Improved communication capabilities
3.3.16 Temporal improvement: ability to do work faster
3.3.17 Moving towards standardization
3.3.18 Long-term arrangements that feed technology enhancement
3.3.19 Designing for market segments
3.3.20 Long-term arrangements that feed technology enhancements
3.3.21 Larger market for participating multinational companies
3.3.22 Improved R&D
3.3.23 Vertical and horizontal integration of an industry
3.3.24 Improved access to new technology and know-how
3.3.25 Exposure to future technical innovations
3.3.26 Improved sales opportunities
3.3.27 Gaining access to new markets
3.3.28 Accelerated introduction of a new product model
3.3.29 Opportunity to start new business
3.3.30 Productivity gains
3.3.31 Improved user satisfaction
3.3.32 Improved process innovation
3.3.33 Improved quality of conformance
3.3.34 Greater degree of computerization resulting in higher accuracy and speed
3.3.35 Improved communications (e.g., in satellite technology transfer)
3.3.36 Improved Internet or web hosting capabilities

3.4 Strategic Factors

3.4.1 Improved product and service quality of design
3.4.2 Improved product innovation
3.4.3 Entry into international market
3.4.4 Improved volume flexibility
3.4.5 Improved product/service flexibility
3.4.6 Improved managerial flexibility
3.4.7 Improved handling customer complaints/ after sales service
3.4.8 Improved agility: reduction in idea. to- market time
3.4.9 Improved product and service design
3.4.10 Improved physical properties of the product
3.4.11 Improved performance characteristics of products/services
3.4.12 Entry barrier mitigation through Internet
3.4.13 Technology management (to respond to changes)
3.4.14 Web-enabled services

3.5 Global factors

3.5.1 Improved reconnaissance capabilities
3.5.2 Improved war/defense capabilities
3.5.3 Improved space technological capabilities
3.5.4 Improved transportation capabilities
3.5.5 Improved political image

Fig. 2. (*continued*).

3.5.6 Enhanced influence

3.6 Personal Factors
- 3.6.1 Benefits from learning
- 3.6.2 Gratification from teaching/sharing knowledge
- 3.6.3 *Quid pro quo* with colleagues
- 3.6.4 Enhanced status in the discipline/profession
- 3.6.5 Enhanced marketability
- 3.6.6 Increased entrepreneurship skills
- 3.6.7 Improved personal benefits-higher personal income
- 3.6.8 Enhanced travel opportunities

***Key 4*** **Disciplines and Professions**

4.1: Economics
- 4.1.1 Vertical TT
- 4.1.2 Horizontal TT
- 4.1.3 Physical item TT
- 4.1.4 Information TT
- 4.1.5 Industry– industry TT
- 4.1.6 Sector-sector TT
- 4.1.7 Region-region TT
- 4.1.8 Domestic TT
- 4.1.9 International TT
  - 4.1.9.1 West-East TT
  - 4.1.9.2 North-South TT

4.2: Anthropology Cross-cultural TT
- 4.2.1 Group program
- 4.2.2 Community program
- 4.2.3 Village program
- 4.2.4 Rural program
- 4.2.5 Urban program

4.3: Sociology
- 4.3.1 Diffusion of innovation
- 4.3.2 Adoption of Innovation
- 4.3.3 Diffusion of social technology
- 4.3.4 Diffusion of non-social technology
- 4.3.5 Centralized diffusion
- 4.3.6 Decentralized diffusion

4.4: Management, engineering and other professions
- 4.4.1 Vertical TT
- 4.4.2 Horizontal TT
- 4.4.3 Physical item TT
- 4.4.4 Information TT
- 4.4.5 Industry-industry TT
- 4.4.6 Sector-sector TT
- 4.4.7 Region-region TT
- 4.4.8 Domestic TT
- 4.4.9 International TT
- 4.4.10 Material TT
- 4.4.11 Design TT
- 4.4.12 Capacity TT
- 4.4.13 TT imparts operational capability

Fig. 2. (*continued*).

4.4.14 TT imparts duplicative capability
4.4.15 TT imparts innovative capability
4.4.16 Market level TT
4.4.17 Production level TT
4.4.18 R&D level TT
4.4.19 Inter-firm TT
4.4.20 Intra-firm TT
4.4.21 Internal TT
4.4.22 Arms-Length TT
4.4.23 TT to wholly owned subsidiary
4.4.24 TT to joint venture
4.4.25 TT to independent company
4.4.26 Web-based innovations
4.4.27 Web-based customer interactions

Fig. 2. (*continued*).

### 3.6. Classifications of previously published TT taxonomies

To classify any given TT paper requires specification of a code number in each of Fig. 2 categories e.g.,

| *Actors*: | *Transaction types*: | *Motivations*: | *Disciplines* |
|---|---|---|---|
| (../..): | (../../../..): | (../../../../../..): | (../../../..) |

As cases in point all previously published TT taxonomies attributable to this author in whole or in part, will now be shown to be special cases of Fig. 2.

A delineation of categories of the various parties known to participate in TT transactions was the starting point in this taxonomic effort overall. These are: scientific disciplines (D) professions (P) industries (I) economic sectors (S) societies/countries (C) and their pair-wise matrix is reproduced in Fig. 3, [2]. That paper can now be shown to be a very special sub-case of the Fig. 2 taxonomy. Specifically it is (1.1.1/1.1.2/1.1.4/1.1.5/1.1.6/1.1.7/1.2.1/1.2.2/1.2.4/1.2.5/1.2.6/1.2.7). All 12 entries begin with the numeral 1, e.g., that paper's taxonomy dealt only with the characteristics of the TT providers and receivers. However, there are

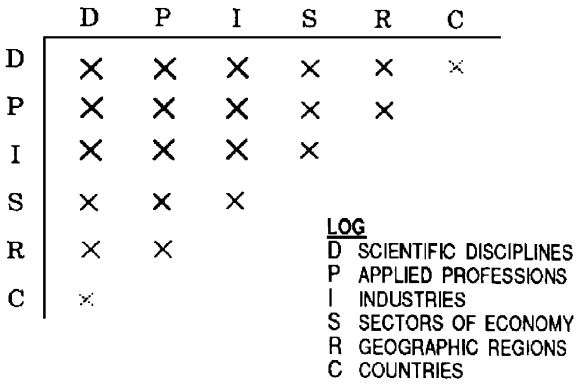


Fig. 3. Matrix of pair-wise technology transfers. From Reisman [2].

six entries with the second numeral being 1 and another six with that numeral being 2. This indicates that providers are classified separately from the receivers. It may be noted that 1.1.3. and 1.2.3. do not appear in the above classification. This reflects the fact that unlike Fig. 2, Reisman [2] did not explicitly consider *corporate or institutional entries*.

Also, it can be seen from Fig. 3, there are 21 pair-wise (transferrer/provider to transferee/receiver/beneficiary) possibilities. If three different player categories are involved in a TT transaction there are 10 distinct possibilities, six with four categories, three with four categories and one with all six categories, for a total of 40. However, if one distinguishes the transferors from the transferees, as is the case in the taxonomy of Fig. 2, the number of possibilities (combinations and permutations) increases significantly.

If classified in terms of Fig. 2, the Reisman and Zhao [4] taxonomy of TT types of transactions or modalities would be a subset of all entries starting with the numeral 2. The reason for it being a subset is the fact that included in *Key* 2 are a number of attributes as those in 2.5, 2.6 and 2.7 which were not included Reisman and Zhao [4].

A brief review of the articles that address motivations for TT indicates that Reisman et al. [31] delineated the benefits to the trading partners as a result of barter or countertrade (BC). They suggested 16 specific advantages of BC that can accrue at the macro (national) as well as at micro (enterprise) level. Significantly, most of these advantages apply to TT as well and hence they appear in Fig. 2. By culling the literature, Kumar et al. [6,7] synthesized a total of 54 advantages for TT. They went on to suggest 20 advantages which are not indicated in the existing literature. If that paper were classified using Fig. 2 it would have 54 separate entries all starting with the numeral 3.

The Zhao and Reisman [5] synthesis of taxonomies across various academic disciplines delineated several TT advantages for each discipline. These included advancement in economic growth (economics), positive cultural climate (anthropology), improvement of social life (sociology), strengthening of a firm's competitiveness, and financial and other gains (management). A Fig. 2 classification of that paper would have 49 entries all starting with the numeral 4.

Clearly this taxonomy subsumes as special cases all of the previous works (published in refereed journals) by this author on this subject.[4]

### 3.7. Some relevant literature

Elshout [37] studied the significance of reverse TT from the viewpoints of both developing and industrialized countries concluding that the developing country benefits

[4] A typical TT transaction, proposal, agreement, contract, or published paper, typically requires but a few entries from Fig. 2. The reason for the cumbersome classifications of the above illustrative papers is because each of them represents a taxonomy of a very large portion of the TT domain circumscribed by Fig. 2.

by becoming financially attractive through hard-currency earnings, technologic improvements, and development of a more skilled work force. The benefits for the industrialized country were primarily of a better purchasing power (wider choice, lower costs) and a better competitive position.

Klevorick et al. [38] listed TT benefits to production processes. These include improvement in process yields, product and service design, and the product's physical properties and performance characteristics, ability to change from intermittent to mass flow processes, design for the market, and standardization. These in turn suggested 23 specific measures of TT effectiveness from the viewpoint of sponsors, developers, and adopters. Several can be viewed as TT benefits or motivations e.g., job creation, earning of royalties, starting of new businesses, solving technical problems, generation of new products, user satisfaction, cost savings, new commercial customers and sales, market share, productivity, and competitive advantage gains, and improved return on investment.

As indicated above, several researchers have identified different sets of motivations for or benefits from TT. By grouping similar benefits, it was found that these motivations could be classified under the following five categories: economic, social, operational, strategic, and personal. These categories may well be revisited and refined in future research. Fig. 2 supports the above factors from both the transferrer and transferee viewpoints. Because these benefits come from several different sources, to maintain consistency with the structure of this paper some of the wording has been modified and some concepts regrouped. It is recognized that there may be some overlap, especially since some concepts belong to more than one category. As an example, consider the motivation of *Cost Savings*. It overlaps *More Efficient Use of Capital and Labor* in the *Operational* category of factors and *Productivity Gains* in the *Strategic* category. Moreover, they are all related to the economics for both the transferee and the transferrer but with differing connotations as suggested by their multiple classifications. Some motivations found explicit in the literature, such as *Reduced Process/Product Cost* [39], do not appear in Fig. 2 as they are subsumed in *Cost Savings*.

In addressing the *illegal* side of technology of transfer (ITT)[5] Reisman [9], makes the point that it is one of the major policy formulation, industrial management, and law enforcement issues of this decade. It includes industrial espionage, the piracy of: software, logos, databases, trade secrets, as well as reverse engineering of marketed hardware. It overlaps with issues of privacy, terrorism, and weapons of mass destruction. In the public discourse preceding year-2004 US elections it is commingled with free trade, outsourcing, and according to Fialka [40] among others, the loss of jobs and of a sustained standard of living. The Associated Press [41], reports that concerns for manufacture of counterfeit drugs and their distribution across national borders are even affecting health-care administration policy issues at national[6] state, and city levels. Like legal TT, ITT involves various kinds of players, takes on various modalities, is done for various motivations and it is of concern at corporate, national, and world-body levels. ITT's literature is also very disjoint, disparate and transcends several academic disciplines, professions and professional communities. He discusses the history of ITT, points out relevant (US) laws and international treaties and samples a number of openly practiced violations as well as indictments, judgments and pending court cases. Lastly, he offers a taxonomy for ITT's broad domain.

This paper synthesizes all of the above and adds a number of additional advantages resulting in 173 fairly independent attributes e.g., end-branches of Fig. 2. A classification of this paper would require all 173 end points of Fig. 2.

## 4. Concluding remarks

The *Periodic Table of Chemical Elements* [42], the most widely known and used taxonomic schema, currently shows 112 well described elements. Yet to-date only 92 of these have been found in nature, and only 50 or so are incorporated in the multitudes of molecules and compounds used in laboratories and in our daily life. Chemistry as we know is a very broad domain of knowledge with many sub-disciplines of its own and also as a part of a great many others. This is also true of TT. However, as shown TT has 173 very real dimensions/attributes, which in combinations, like molecules in chemistry, make up real TT possibilities. Reasoning by analogy, it is no wonder that the very mention of TT conjures up so many different meanings to different individuals. This taxonomy is a way of defining and circumscribing the field while at the same time identifying each of its many constituents. Like the *Periodic Table* this taxonomy can be used to specify TT configurations currently non-existent in the field of practice.

The literature reviews are playing an increasingly important role in social scientists' definition of knowledge [11]. Integrative reviews are clearly the most useful reviews as they show the similarities and the differences between the individual contributions [43]. More importantly they classify or "pigeon-hole" each contribution in the overall context of the field. They can be used to identify voids in a field's knowledge base [16,18,31]. A good taxonomic schema is indispensable to an effective review of the literature and especially to the efficiency of its presentation. As demonstrated in Reisman et al. [21] it offers a significantly more descriptive, more discriminating and more systematic way

[5] He broadly defines technology to include intellectual property.

[6] Study mandated by US Congress prior to drafting the new Medicare legislation prescription drug law.

to classify archival TT documents than the usual *key-words* or *subject-classification* approaches. Hence, it has the potential of significantly improving the efficiency and the effectiveness with which documents can be retrieved in response to the needs of TT practitioners and scholars alike. This is especially true for large repositories of TT documents available for public consumption as is the case with the Robert C. Byrd National Technology Transfer Center in Wheeling West Virginia.

Taxonomies have aided individual researchers in expanding the scope of information gleaned from a given literature or database and or in designing the data collection itself. Used as a checklist the taxonomy can enhance creativity in designing a mode of TT and or in writing papers on the subject. However, no taxonomy no matter how well thought out, should ever be considered as final. Rather, it should be thought of as a stepping-stone to more comprehensive, more discriminating, more parsimonious, and/or manageable classifications of the subject. It should not be treated as binding or constraining the definition and/or scope of the field of knowledge it addresses. As the subject emerges either in depth or in breadth the taxonomic work must follow. In the best of circumstances taxonomies lead to such expansions and/or extensions. There is no better example of the above admonitions then the *Periodic Table of Chemical Elements*. It has no equal as an aid to educating neophytes yet it has guided chemical research for well over a century. However, over its lifespan, it had to be periodically reviewed and revised. This process it is safe to say, is still ongoing. So it is and should be for TT.

In a systematic fashion, this paper attempts to bring together much of what we know as to why technology transfer takes place in the world of commerce, and industry; among the professions and among individual practitioners; and the role it plays in national and regional policy making. It shows the importance of TT to each type of participating entity on the providing and on the receiving ends.

Specifically, the taxonomy or classification of the various TT *actors*, their *motivations*, and the *modalities* of their transactions provided here may prove to be a useful tool for TT practitioners and for those entering the field as it puts the rationale underlying TT actions on the table. As such it provides a good baseline information for writing of proposals and/or developing more convincing arguments for consideration of TT. As a practical matter, one or more of the motivations contained in Fig. 2 should find their way into business proposals and vendors can use this taxonomy for developing marketing strategies.

Paraphrasing Cooper [43], every TT related research project, "should involve the inquirer searching out previous related investigations. Without this step, an integrated, comprehensive picture of the world cannot be built". "Yet the novice researcher has little guidance for how to conduct an integrative research review." This taxonomy attempts to fill that void. It offers a systematic, objective and user-friendly framework for doing integrative research reviews of any subject (knowledge domain) involving TT. "The intended result is a replicable review that can create a consensus among scholars and focus debate in a constructive fashion." As is the general case in the social sciences "users of this approach should finish their reviews feeling knowledgeable about the research area and confident that their future research can make a contribution to the field" Cooper [43].

Arguably, the taxonomy of Fig. 2 may be considered too detailed. No doubt it is for some applications. In those cases aggregation and/or pruning of some of the branches may be justified. If such is the case the process is relatively simple. It is certainly less demanding than having to do the reverse or expand the tree. However, when it comes to doing integrative research reviews the following admonition is in order.

> Synthesists should undertake their literature searches with the broadest possible conceptual definition in mind.... [T]he synthesist should err toward making overly inclusive decisions at least in the early stages of his or her project. Cooper [8].

TT subject matter is included in many disciplinary and professional curricula. Typically it is taught via the usual and customary *intuitive*, *subjective*, *narrative*, *didactic/expository*, approach and/or the use of *case studies*. In the rare case when quantitative methods are introduced it is done via *modelling* which at best is enriched with real-world examples. Each of these approaches has its unique virtues and shortcomings. None however provides the novice a global perspective on the subject—often not even a clue. A good taxonomy does precisely that and does not take much class-time away from what the instructor wants or is curriculum-bound to teach. And, there are many education-related uses for this taxonomy outside the classroom. Designing new or evaluating existing TT courses, curricula or programs, writing books or research papers are examples of such uses Reisman [9,10].

Lastly, mapping the universe of technology transfers would not be complete without at least mentioning the dichotomy between transfers that are legal, ethical, and moral and those that fall short in any of the above. This opens up the entire area of patent and copyright laws, international and industrial intelligence and counterintelligence, and the various caveats and admonitions addressing issues of ethics, as well as the various technologies to prevent unauthorized transfers Reisman [2]. Though very important and very current this topic cannot be meaningfully incorporated into Fig. 2 without further exploding it. Hence, it is on the author's current research agenda as is the writing of a two-volume *Handbook of Technology Transfer: Legal and Illegal*.

If but parenthetically, as a domain of knowledge and practice, TT has much in common with that of countertrade [44,46]. Both serve national and regional development processes.

## References


[1] Baughn CC, Osborne RN. Strategies for successful technological development. Technology Transfer 1989; 14(3,4):5–13.

[2] Reisman A. Technology transfer: a taxonomic view. Journal of Technology Transfer 1989b;14(3&4):31–36.

[3] Reddy M, Zhao L. International technology transfer: a review. Research Policy 1990;19(4):285–307.

[4] Reisman A, Zhao L. A taxonomy of technology transfer transactions types. Journal of Technology Transfer 1991;16(2):38–42.

[5] Zhao L, Reisman A. Toward meta research on technology transfer. IEEE Transactions on Engineering Management 1992;39(1):13–21.

[6] Kumar A, Motwani J, Reisman A. A taxonomy of motivations for the transfer of technology. In: Proceedings of the Annual Meeting of the Technology Transfer Society. 1996a. p. 469–76.

[7] Kumar A, Motwani J, Reisman A. Transfer of technologies: a classification of motivations. The Journal of Technology Transfer 1996b;21(1–2):34–42.

[8] Cooper CM. Synthesizing research. Beverley Hills, CA: Sage Publications; 1998.

[9] Reisman A. Illegal transfer of technologies: a taxonomic view. Working paper, 2004a. Available from mailto:reismana@cs.com.

[10] Reisman A. On the use of taxonomies in teaching OR/MS subject matter. Working paper, 2004b. Available from mailto:reismana@cs.com.

[11] Cooper CM. Organizing knowledge syntheses: a taxonomy of literature reviews. Knowledge in Society 1988;1:104–26.

[12] Cooper CM. Meta-analysis and the integrative research review. A paper presented at the meeting of the Operations Research Society of America/The Institute of Management Sciences, New York; 1989.

[13] Goffman W. Scientific information systems and the principle of selectivity. New York: Praeger Publishers; 1980.

[14] Reisman A. Expansion of knowledge via consolidation of knowledge. In: Proceedings of the ISMIS-87 Second International Symposium on Methodologies for Intelligent Systems. ORNL 6417, Oak Ridge National Laboratory, 1987.

[15] Reisman A. Finding researchable topics via a taxonomy of a field of knowledge. Operations Research Letters 1988;7(6):295–301.

[16] Reisman A. A systems approach to identifying knowledge voids in problem solving disciplines and professions: a focus on the management sciences. Knowledge in Society: The International Journal of Knowledge Transfer 1989a;1(4): 67–86.

[17] Reisman A. Managerial and engineering economics. Newton, MA: Allyn & Bacon Publishing Company of Boston; 1971. 530p.

[18] Reisman A. Management science knowledge: it's creation, generalization and consolidation. Westport, CT: Quorum Books Publishing Company; 1992. 495p.

[19] Reisman A, Buffa ES. A general model for investment policy. Management Science 1962;8:304–10;
Buffa ES. Models for production and operations management, New York: Wiley; 1963. p. 402–16;
Hottenstein, MP. Models and analysis for production management. Scranton, PA: International Textbook Company; 1968. p. 53–60.

[20] Reisman A, Ritchken PH, Pollack-Johnson B, Dean BV, Escueta ES, Li G. On the voids in US national education statistics. Journal of Economic and Social Measurement 1986;14(4):357–65.

[21] Reisman A, Konduk BC, Oral M. A taxonomy of meta research in OR/MS and classification of the literature. Working paper, 2003. Available from mailto:reismana@cs.com.

[22] Reisman A, Xu X. Operations research in libraries: a review of 25 years of activity. Operations Research 1994;42(1): 34–40.

[23] Reisman A, Xu X. Libraries, a chapter. In: Gass SI, Harris CM, editors. Encyclopedia of operations research and management science, Boston: Kluwer Academic Publishers; 1996. p. 340–3 [Also, in 2nd Edition].

[24] Taft M, Reisman A. The conservation equations: a systematic look. Journal of Hydrology 1965; III(3/4):161–79.

[25] Gattoufi S, Oral M, Reisman A. A taxonomy for data envelopment analysis. Socio Economic Planning Sciences 2004;38:141–58. Available from http://www.sciencedirect.com/science.

[26] Reisman A. Systems analysis in health-care delivery. Lexington, MA: Lexington Books; 1979. 311p.

[27] Vogel DR, Weterbe JC. MIS research: a profile of leading journals and universities. Data Base 1984; Fall: 3–14.

[28] Arrow K. Classificatory notes on the production and transmission of technological knowledge. American economic review 1969. Papers and Proceedings.

[29] Johnson HG. The efficiency and welfare implications of the international corporation. In: Kindle-Berger C, editor. International corporation. Cambridge, MA: MIT Press; 1970. p. p35–56.

[30] Rosenberg N, Frischtak C. Preface. In: Rosenberg N, Frischtak C, editors. International technology transfer: concepts, measures and comparisons. New York: Praeger Publishing Co.; 1985.

[31] Reisman A, Fuh DC, Li G. Achieving an advantage with countertrade. Industrial Marketing Management 1988;17: 55–63.

[32] Reisman A, Agarwal R, Fuh DC. Seeking out profitable countertrade opportunities. Industrial Marketing Management 1989;18:65–72.

[33] Vaitsos CV. The process of commercialization of technology in the Andean pact. In: Radice H, editor. International films and modern imperialism. Harmondsworth: Penguin Press; 1975.

[34] Farrell TMA. A tale of two issues: nationalization, the transfer of technology and the petroleum multinationals in Trinidad Tobago. Social and Economic Studies 1979; 234–81.

[35] Kroner M. US international transactions in royalties and fees: 1967–1978. Survey of Current Business 1980; 29–35.

[36] Shortell SM, Zajac EJ. Internal corporate joint ventures: development processes and performance outcomes. Strategic Management Journal 1988;9:527–42.

[37] Elshout J. Significance of reverse transfer of technology and experiences with its promotions in industrial countries. Technovation 1995;15(2):423–35.

[38] Klevorick A, Levin R, Nelson R, Winter S. On the sources and significance of interindustry differences in technological opportunities. Research Policy 1995;24:185–205.

[39] Madu C. Transfer technology to developing countries critical factors for success. Long Range Planning 1989;22(4): 115–24.
[40] Fialka JJ. War by other means. New York: W.W. Norton & Company; 1997.
[41] Anonymous. Associated Press. Counterfeiters worry surgeon general. April 7, 2004.
[42] Mendeleyev DI. The periodic law of the chemical elements (Faraday Lecture). Journal of the Chemical Society 1889;55:634–56; Reprinted In: Lectures delivered before the chemical society 1869–928, (Faraday Lectures, Chemical Society), London: Chemical Society.
[43] Cooper CM. The integrative research review: a systematic approach. Beverley Hills, CA: Sage Publications; 1984.
[44] Reisman A. Impact of technology transfer, barter and countertrade on the competitiveness of firms in international markets. In: Oral M, Kettani O, editors. Globalisation and competitiveness: implications for policy and strategy formulation. Ankara, Turkey: Bilkent University Press; 1997. p. 53–73.
[46] Reisman A. Barter and countertrade the well established form of trade: a new frontier for OR/MS. International Journal of Operations and Quantitative Management 1996;2(1): 35–47.